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Editorial Team

The *Journal* is published by the Telecommunications Association (TelSoc), a not-for-profit society registered as an incorporated association. It is the Australian telecommunication industry's oldest learned society. The *Journal* has been published (with various titles) since 1935.

Editorial

Echoes of 1935, Signals of 2025: A 90-Year Journey

Michael de Percy
Editor-in-Chief

Abstract: This editorial bridges the past and future of telecommunications and the digital economy. It highlights the third collaboration with the International Conference on Digital Economy, following its ninth conference in Morocco in 2024. The conference inspired the Special Issue section, 'Driving the Digital Economy with Cutting-Edge Technologies, Innovation, and Data Analytics,' alongside the Telecommunications articles in this March 2025 issue. These contributions signal the Journal's forward-looking vision. Meanwhile, the Biography and History sections reflect on the Journal's legacy, marking the 90th anniversary of continuous publication. The editorial concludes with gratitude to the outgoing Managing Editor for his pivotal support during the new Editor-in-Chief's inaugural issue.

Keywords: Editorial, Editor-in-Chief, Managing Editor, Digital Economy, History of Telecommunications

Introduction

As we celebrate the 90th anniversary of the *Journal of Telecommunications and the Digital Economy*, this editorial bridges the past and future of a field that has shaped modern civilisation. Since 1935, this publication has documented telecommunications' transformation from the telegraphs of its early days to the digital ecosystems driving today's global economy.

To borrow from US Admiral George Anderson, the Journal 'has both a tradition and a future – and we look with pride and confidence in both directions' (Naval History and Heritage Command, 2024). Now, as Editor-in-Chief, I am privileged to guide this legacy into a vibrant new chapter. This March 2025 issue exemplifies our legacy and our forward momentum.

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In This Issue

Our third collaboration with the 9th International Conference on Digital Economy, held in Morocco in 2024, has produced a Special Issue section, 'Driving the Digital Economy with Cutting-Edge Technologies, Innovation, and Data Analytics'. Our Guest Editors, Jallouli *et al.* (2025), provide a comprehensive outline of the current state of research into the digital economy. The articles in the Special Issue explore innovations like artificial intelligence, fintech, blockchain, and data analytics, illuminating their impact on society and the economy.

Complementing the Special Issue, our Telecommunications section addresses the challenges of choice overload for consumers of on-demand streaming video (Fisher *et al.*, 2025) and how dynamic growth of the Internet of Things is driving an exciting 6G future (Wong *et al.*, 2025). Together, they affirm the Journal's commitment to advancing knowledge in an era where learned society journals remain vital, despite challenges to their recognition by metric-driven academics and universities.

Our future is deeply rooted in a rich past, and this issue's Biography and History sections celebrate the pioneers and milestones that have shaped telecommunications. Jim Holmes (2025) pays tribute to Keith Barnes, who died on January 3, 2025, at 92, tracing his ascent from Queensland's PMG ranks to Telecom Australia's Chief Planning Engineer — a career emblematic of the post-war infrastructure boom — and his leadership in Telecom's groundbreaking Saudi Arabia project, a testament to his global impact. Simon Moorhead (2025) returns to the Journal's origins, revisiting three historical articles: two from 1938 and 1939, and the inaugural 1935 editorial by J. M. Crawford. These accounts highlight the Journal's contribution to telecommunications and the digital economy, linking its past achievements to today's advancements.

Reflections on the Journal's Legacy

As we celebrate ninety years, the Journal's archives offer a window into its storied past, including the Special Issue of the *Telecommunication Journal of Australia* from February 1962 (Volume 13, Number 3). The 1962 Special Issue focused on the construction of the Sydney-Melbourne Coaxial Cable, in a transformative period for telecommunications in Australia. I stumbled upon the 1962 Special Issue while writing a chapter for the final volume in the Robert Menzies Institute's biography series. In my chapter (de Percy, forthcoming), I reflect on Australia's communications golden age under Menzies, guided by the Postmaster General's Department. Like this Journal, the Sydney-Melbourne Coaxial Cable was a team effort, a point reflected in the many articles written by Society members who either worked on

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the project, or were involved in the project as part of the then Postmaster General's Department.

Our inaugural editor, J. M. Crawford, Chief Engineer of the Postmaster General's Department, might be surprised to learn that the journal he first edited in 1935 has suffered the fate of many Australian journals. In an effort to measure research excellence, Australian universities have followed international trends where academic success relies on an international metric (de Percy, 2025). This metric means that the publication of publicly funded Australian research is targeted towards international audiences and can leave Australian-based journals behind.

Fortunately, past editors of the Journal have adeptly tracked evolving trends, as evidenced by our sustained international collaborations, such as with the 9th International Conference on Digital Economy. Yet Australia's nineteenth century learned societies, including the precursors to the Telecommunications Association (TelSoc), laid a vital foundation, fostering and sharing knowledge for a young nation. In 1910, Dr Alexander Graham Bell, the telephone's inventor, delivered an early Society lecture in Melbourne — a moment akin to Elon Musk addressing the Society today. Inspired by this legacy and the Journal's ongoing evolution, I extend an open invitation for one of this century's foremost innovators to write for the Journal at any time.

Acknowledgements

I extend my deep gratitude to Dr Leith Campbell for his patience and guidance as I navigated the complexities of assembling my inaugural issue as Editor-in-Chief. This milestone reflects a collective effort, made possible by the dedication of authors, reviewers, copyeditors, the Board of Editors, the Editorial Advisory Board, and the TelSoc Board. Their support has made this experience both rewarding and inspiring. I am honoured to uphold the Journal's ninety-year legacy while steering its vision into a dynamic future for telecommunications and the digital economy.

References

De Percy, M. (2025, February 16). The Short-shrifting of our Academic Journals. *Quadrant*. https://quadrant.org.au/news-opinions/academia/the-short-shrifting-of-our-academic-journals/

De Percy, M. A. (forthcoming). From the Bottom of the sea to the Moon: Menzies and Australia's Communications Golden Age. In Z. Gorman (Ed.), *The Final Chapter: Purpose, endurance, and legacy 1961-66 and beyond*. Melbourne University Press.

Fisher, N. S., Lee, H., & Flansburg, G. (2025). When the Known Well May Sell: The Interaction of Familiarity and Choice Numeracy on Satisfaction with a Streaming Video on

https://doi.org/10.18080/jtde.v13n1.1240

Demand Recommendation Interface. *Journal of Telecommunications and the Digital Economy*, *13*(1), 418–438. https://doi.org/10.18080/v13n1.1011

Holmes, J. (2025). Remembering Keith Barnes and the Saudi Project: A Tribute to Keith Barnes (1932–2025) and Recollecting the Saudi Project. *Journal of Telecommunications and the Digital Economy*, *13*(1), 439–449. https://doi.org/10.18080/v13n1.1244

Jallouli, R., Bach Tobji, M. A., Sadok. H., & Lajfari, K. (2025). Guest Editorial: Driving the Digital Economy with Cutting-Edge Technologies, Innovation, and Data Analytics. *Journal of Telecommunications and the Digital Economy*, *13*(1), 1–12. https://doi.org/10.18080/v13n1.1245

Moorhead, S. (2025). Ninety Years of the Journal. *Journal of Telecommunications and the Digital Economy*, *13*(1), 450–461. https://doi.org/10.18080/v13n1.1225

Naval History and Heritage Command. (2024). Famous Navy Quotations. https://www.history.navy.mil/browse-by-topic/heritage/famous-navy-quotations.html

Wong, O. S., Gregory, M. A., & Li, S. (2025). Integration of Non-Terrestrial Network for 5G IoT and Future 6G. *Journal of Telecommunications and the Digital Economy*, *13*(1), 396–417. https://doi.org/10.18080/v13n1.1174

Journal of Telecommunications and the Digital Economy

Guest Editorial

Driving the Digital Economy with Cutting-Edge Technologies, Innovation, and Data Analytics

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Abstract: Navigating the complex terrain of digital transformation, this special issue presents a selection of studies that maps the intricate intersections of technological innovation, economic strategies, and organisational adaptation. The preamble traces the evolutionary pathways of digital transformation from its nascent stages to the current epoch of Artificial Intelligence (AI) and complex technological ecosystems. The articles selected for this special issue have been organised into three sections based on the major themes addressed in this special issue: (1) Financial technologies (Fintech) Horizons: Gamification, AI, and the Evolution of Digital Financial Ecosystems; (2) AI-Driven Strategies in Marketing and Social Media; and (3) Data Dynamics and Organisational innovation. The concluding section, 'Towards a Comprehensive Epistemological Framework of Digital Innovation in the AI Epoch,' synthesises the diverse research narratives, offering a forward-looking perspective that underscores the universal yet contextually nuanced impact of digital technologies across global economic and technological landscapes.

Keywords: Digital Transformation, Data Analytics, Digital Marketing, Fintech, Innovation, Artificial Intelligence

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Preamble

The digital economy is a key driver of global innovation and economic development, contributing significantly to the transformation of societies and economies worldwide. This transformation marks a new stage in the profound economic and social reorganisation that has been underway for several decades under the influence of technology (Mahboub & Sadok, 2022). From 1936, when Alan Turing published his article 'On Computable Numbers' and established the concept of the universal machine, to 1960, nearly a quarter of a century passed during which the computer was invented and found a market. From 1960, when the IBM 360 series mainframe computers were released, to 1984, when Apple launched the Macintosh, another quarter of a century was marked by the spread of business computing. From 1984 to the economic and financial crisis of 2008, nearly 25 years were once again marked by the computerisation of society, the deployment of the Internet, and the new economy bubble. Since 2008, we have entered a new phase, designated by a new word: digital.

At each stage, there has been talk of revolution. But with digital technology, the transformation is accelerating and becoming more radical. Three changes are occurring simultaneously (Benazzouz & Sadok, 2025):

1. The technological race is no longer led by companies or large organisations. Individuals are leading the way and constantly using new tools. They are rapidly inventing new ways of getting information, consuming, interacting, meeting, and living;
2. The impacts are becoming truly cross-cutting, with changes affecting every sector, from industry to services, from construction to agriculture, including access to knowledge, cultural expression, and health. With digital technology, new jobs are emerging and, more profoundly, the very notion of employment is transforming (Sadok *et al.*, 2024);
3. The impact of technology on the economy is becoming more diverse and complex. In addition to the structuring and growth of an increasingly powerful digital sector, at least eight effects must be taken into account. As in the previous era of computerisation, we first observe the effects of automation, with a correlative increase in factor productivity (Nobanee *et al.*, 2024): labour productivity, fixed and circulating capital, and energy and raw materials. But to this are added the effects of materialisation: the substitution of the Internet for physical networks of agencies, counters, and stores; the distortion of the traditional decreasing cost curve into a square production curve, with heavy investment in innovation and prototyping and

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> near-zero reproduction costs; the decline in transaction costs and the questioning of the scope of companies. Finally, we must take into account the effects of intermediation/disintermediation on economic models, with the new role played by individuals – producers and consumers – and with the challenge of data and the resource it represents for the optimisation and reinvention of professions.

By neglecting these critical structural transformations, contemporary policy frameworks risk fundamentally misapprehending the underlying dynamics of technological evolution. Across diverse geopolitical contexts, the paramount challenge emerges as the strategic management of technology-driven metamorphoses. Contemporary data analytics have transcended their auxiliary role, becoming a pivotal mechanism through which emergent technologies – including the Internet of Things (IoT), Artificial Intelligence (AI), collaborative digital platforms, and blockchain technologies – are comprehensively reconstructing paradigms of business innovation and marketing strategies (Jallouli & Kaabi, 2022).

The proliferation of e-commerce technologies has catalysed an unprecedented accumulation of expansive datasets, thereby engendering novel strategic opportunities for organisational ecosystems (Kaabi & Jallouli, 2019). The contemporary intellectual and managerial imperative now resides in developing sophisticated methodological approaches to deconstruct these voluminous data landscapes, with the ultimate objective of extracting nuanced, actionable insights capable of informing both strategic organisational trajectories and institutional policy frameworks (Jabado & Jallouli, 2023, 2024a, 2024b; Benslama & Jallouli, 2022, 2024; Chebil *et al.*, 2021, 2024). It is within this complex epistemological context that the present special issue of the *Journal of Telecommunications and the Digital Economy* (JTDE), thematically anchored in 'Driving the Digital Economy with Cutting-Edge Technologies, Innovation, and Data Analytics,' aspires to highlight critical dimensions of contemporary digital transformation.

In this Issue

This special issue on 'Driving the Digital Economy with Cutting-Edge Technologies, Innovation, and Data Analytics' in the *Journal of Telecommunications and the Digital Economy* (JTDE) is drawn from the 9th International Conference on Digital Economy (ICDEc) held in the Faculty of Juridical, Economic and Social Sciences (FSJES – Souissi), Mohammed V University, Rabat, Morocco, in 2024. For many years, the ICDEc conference has brought together researchers from many countries and working on divergent fields ranging from computer sciences to digital economics and marketing, discussing problematic related to technologies and digital transformation (Bach Tobji *et al.*, 2018, 2020, 2022, 2024a, 2024b; Jallouli *et al.*, 2016, 2017, 2019, 2021, 2023). The tenth edition of the ICDEc conference is scheduled to take place in Tunis from May 15-17, 2025.

This special issue marks the third collaborative effort between the *Journal of Telecommunications and the Digital Economy* (JTDE) and the ICDEc series, underscoring a commitment to advancing research in the field of digital transformation within the domains of economics, management, and business computing (Jallouli *et al.*, 2022, 2024).

Following the call for papers on Cutting-Edge Technologies, Innovation, and Data Analytics as drivers of the digital economy, this special issue attracted 48 submissions from more than ten countries, encompassing both developed and emerging economies. The rigorous peer-review process led to the acceptance of 16 papers from seven countries, resulting in a competitive selection rate of 33 per cent. This diversity of contributions aligns with the core objectives of the ICDEc community, which seeks to foster a rich and interdisciplinary debate among researchers from varied backgrounds, not only in terms of scientific domains but also across different economic and cultural contexts. By integrating diverse perspectives, this special issue contributes to a more comprehensive understanding of digital innovation, ultimately advancing the epistemological framework of the field in the era of AI.

The articles featured in this special issue are grouped into three thematic sections to reflect the key topics explored: (1) Financial Technologies (Fintech) Horizons, covering gamification, AI, and the evolution of digital financial ecosystems; (2) AI-Driven Strategies in Marketing and Social Media; and (3) Data Dynamics and Organizational Innovation. This aggregation into three sections aims to facilitate readers' exploration of the multiple facets of digital transformation addressed in this issue.

Fintech Horizons: Gamification, AI, and the Evolution of Digital Financial Ecosystems

At the intersection of technology and finance, this section unveils cutting-edge research that illuminates the dynamic mechanisms through which fintech is reconfiguring traditional economic frameworks. Hentati & Jallouli (2025) provides how gamification can improve M-Banking user engagement, satisfaction, and loyalty. In addition, Hamdi *et al.* (2025) proposes a semantic SLA model for smart contracts, enriching the traditional model with ontological descriptions. Furthermore, in the realm of digital finance, Chebbah & Mekni (2025) presents a three-tiered approach that combines traditional technical analysis, deep learning, and sentiment analysis for stock price forecasting. Likewise, Lajfari & Soumbara (2025) studies the causal relationships between key mobile money indicators and their implications for financial inclusion in Africa. Moreover, Elamine & Ben Abdallah (2025) address the relationship between reward, attitude, and intentions in a gamified application context in an emerging economy. Finally, by examining the readiness of economies for digital transformation, Laarabi *et al.* (2025) develop an index (Readiness Indicator Function, RIF), applied to the analysis of seven countries: Morocco, Tunisia, Egypt, Spain, Portugal, South Africa, and Nigeria.

This section highlights the transformative impact of fintech and the digital economy on financial services, user engagement, and economic readiness. The contributions explore a range of emerging technologies, from gamification in mobile banking to AI-driven stock market forecasting and smart contract optimisation. They also shed light on financial inclusion, digital incentives, and national preparedness for digital transformation. Collectively, these studies provide valuable insights into the evolving landscape of digital finance and its implications for businesses, policymakers, and consumers in both developed and emerging economies.

AI-Driven Strategies in Marketing and Social Media

This section covers how AI and related digital tools are applied to marketing and social media. Gadasina & Sotnichenko (2025) conducted a comparative analysis of sentiments expressed in comments on identical content published on different platforms. Following this, Jlassi *et al.* (2025) analyses how and to what extent the integration of AI via recommendation systems in online shopping can lead to a better customer experience. Similarly, Grissa (2025) explores the behaviour of micro-influencers in sharing branded digital content, focusing on business networking sites (LinkedIn, Xing). Additionally, insights from Triki *et al.* (2025) shed light on the role of AI and marketing automation in business model innovation in the Tunisian tourism sector. Furthermore, Mednini & Noubigh (2025) explores consumer hatred levels through facial emotion recognition, while the contribution by Vishnupriya & Nemat (2025) examines the influence of individual perceptions of the ethical nature of rewards.

This section delves into the growing role of AI in shaping digital marketing strategies and social media dynamics. The contributions explore key applications, from sentiment analysis across platforms to AI-driven recommendation systems enhancing customer experience. Studies also examine influencer behaviour on professional networks, the impact of AI on business model innovation, and the use of facial emotion recognition to assess consumer sentiment. Additionally, ethical considerations in digital marketing are highlighted through analyses of reward perceptions. Together, these works offer valuable insights into how AI is transforming engagement, decision-making, and business strategies in the digital era.

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Data Dynamics and Organisational innovation

At the convergence of data science and organisational dynamics, this collection of scholarly contributions illuminates the complex mechanisms through which data-driven insights are reshaping institutional innovation and strategic adaptation. To begin with, Grigorescu & Ciurea (2025) presents a systematic methodology for risk management in data-intensive systems within regulated environments, with a particular focus on European Union scenarios. Moreover, Dhaouadi & Aridhi (2025) attempt to elucidate the organisational factors facilitating the implementation of teleworking. In the same vein, Gessler *et al.* (2025) presents a conceptual framework for developing data spaces within the data economy. Lastly, in a register relating to corporate governance and digitalisation, Naselhaj & Fahmi (2025) explores researchers' perspectives on the transformative role of AI in corporate governance and suggests strategies to ensure its responsible and effective integration.

This section explores the multifaceted dimensions of digital transformation, from risk management in data-intensive systems to the organisational enablers of teleworking. It also examines the development of data spaces within the data economy and the evolving role of AI in corporate governance. Together, these studies underscore the profound impact of digitisation on business operations, regulatory frameworks, and managerial strategies. As highlighted throughout this special issue, the digital revolution is reshaping not only technological infrastructures but also the fundamental ways in which organisations manage data, collaboration, and decision-making in an increasingly interconnected world.

Towards a Comprehensive Epistemological Framework of Digital Innovation in the Artificial Intelligence Epoch

The scholarly contributions assembled in this special issue map the intricate pathways through which digital transformation, financial technologies, and AI-mediated marketing strategies are systematically recalibrating global economic landscapes and organisational dynamics. By presenting empirical research from a geographically diverse spectrum – spanning France, Germany, India, Morocco, Romania, Russia, and Tunisia – this compilation simultaneously unveils distinctive regional technological trajectories and the converging challenges inherent in navigating the contemporary digital ecosystem. The strategic interconnection of three critical research domains – fintech and the digital economy, AI-driven digital marketing strategies, and data-driven digital transformation – illuminates the complex mechanisms through which emerging technological architectures propel innovation across financial infrastructures, consumer engagement, and organisational strategies.

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A profound theoretical thread permeating these scholarly investigations is the nuanced interplay between technological advancement and organisational adaptation. The research corpus – encompassing AI-enhanced marketing methodologies, the evolutionary trajectories of mobile banking and intelligent contractual mechanisms, and the governance of digital transformation – collectively emphasises the critical necessity for a rigorously multidisciplinary and internationally contextualised approach to understanding digital technological progress. This compilation ultimately provides pivotal conceptual insights into the future of business innovation, revealing that while digital transformation manifests through contextually distinct modalities across national boundaries, its transformative impact represents a universally profound and structurally reconfiguring phenomenon. We earnestly aspire that this curated collection within the Journal of Telecommunications and the Digital Economy will substantively enrich the scholarly understanding of digital technologies' transformative implications, simultaneously serving as a catalyst for continued academic inquiry and theoretical exploration within this dynamically evolving intellectual landscape.

The guest editors, representing the International Conference on Digital Economy (ICDEc) community, extend heartfelt acknowledgment to the authors, reviewers, editorial team, and all who have contributed their intellectual and professional resources to this collective scholarly endeavour. Special recognition is due to Dr Leith Campbell, former Managing Editor of the *Journal of Telecommunications and the Digital Economy*, and Dr Michael de Percy, the Editor-in-Chief, whose strategic guidance and unwavering support have been pivotal in navigating the complex landscape of academic publishing.

References

Bach Tobji, M. A., Jallouli, R., Koubaa, Y., & Nijholt, A. (2018). *Digital Economy. Emerging Technologies and Business Innovation:* Third International Conference, ICDEc 2018, Brest France, May 3-5, Proceedings. Springer LNBIP Series, *325*. https://doi.org/10.1007/978-3-319-97749-2

Bach Tobji, M. A, Jallouli, R., Samet, A., Touzani, M., Strat, V. A., & Pocatilu, P. (2020). *Digital Economy. Emerging Technologies and Business Innovation*: 5th International Conference on Digital Economy, ICDEc 2020, Bucharest, Romania, June 11–13, 2020, Proceedings. Springer LNBIP Series, *395*. https://doi.org/10.1007/978-3-030-64642-4

Bach Tobji, M.A., Jallouli, R., Strat, V.A., Soares, A.M., & Davidescu, A.A. (2022). *Digital Economy. Emerging Technologies and Business Innovation*: 7th International Conference on Digital Economy, ICDEc 2022, Bucharest, Romania, May 9–11, 2022, Proceedings. Springer LNBIP Series, *491*. https://doi.org/10.1007/978-3-031-17037-9

Bach Tobji, M.A., Jallouli, R., Sadok, H., Lajfari, K., Mafamane, D., & Mahboub, H. (2024a). *Digital Economy. Emerging Technologies and Business Innovation*: 9th International Conference on Digital Economy, ICDEc 2024, Rabat, Morocco, May 9–11, 2024, Proceedings, Part I. Springer LNBIP Series, *530*. https://doi.org/10.1007/978-3-031-76365-6

Bach Tobji, M.A., Jallouli, R., Sadok, H., Lajfari, K., Mafamane, D., & Mahboub, H. (2024b). *Digital Economy. Emerging Technologies and Business Innovation*: 9th International Conference on Digital Economy, ICDEc 2024, Rabat, Morocco, May 9–11, 2024, Proceedings, Part II. Springer LNBIP Series, *531*. https://doi.org/10.1007/978-3-031-76368-7

Benazzouz, S., Sadok, H. (2025). Analysis of the Relationship Between Innovation, Digitalization and Economic Growth in North African Countries. In: Bach Tobji, M.A., Jallouli, R., Sadok, H., Lajfari, K., Mafamane, D., Mahboub, H. (eds) *Digital Economy. Emerging Technologies and Business Innovation*. ICDEc 2024. Lecture Notes in Business Information Processing, *531*. Springer, Cham. https://doi.org/10.1007/978-3-031-76368-7_13

Benslama, T., & Jallouli, R. (2022). Social media data analytics for marketing strategies: The path from data to value. *Journal of Telecommunications and the Digital Economy*, *10*(2), 96-110. http://doi.org/10.18080/jtde.v10n2.523

Benslama, T., & Jallouli, R. (2024). An empirical study of the impact of social media data analytics on marketing strategy: Which social media data analytics metrics to select?. *Journal of Telecommunications and the Digital Economy*, *12*(1), 575-594. https://doi.org/10.18080/jtde.v12n1.830

Chebbah, M., & Khalil Mekni, K. (2025). A Multi Headed AI approach for stock market trading. *Journal of Telecommunications and the Digital Economy*, *13*(1). https://doi.org/10.18080/jtde.v13n1.1146

Chebil, M., Jallouli, R., Bach Tobji, M.A., Ben Ncir, C.E. (2021). Topic Modeling of Marketing Scientific Papers: An Experimental Survey. In: Jallouli, R., Bach Tobji, M.A., Mcheick, H., & Piho, G. (eds.) *Digital Economy. Emerging Technologies and Business Innovation*. ICDEc 2021. Lecture Notes in Business Information Processing, *431*. Springer, Cham. https://doi.org/10.1007/978-3-030-92909-1_10

Chebil, M., Jallouli, R., & Bach Tobji, M. A. (2024). Clustering social media data for marketing strategies: Literature review using topic modelling techniques. *Journal of Telecommunications and the Digital Economy*, *12*(1), 510-537. https://doi.org/10.18080/jtde.v12n1.889

Dhaouadi, N. & Aridhi, Eya. (2025). How to Successfully Implement Telework? A conceptual framework proposition. *Journal of Telecommunications and the Digital Economy*, *13*(1). https://doi.org/10.18080/jtde.v13n1.1141

Elamine, M. & Ben Abdallah, A. (2025). Predicting Cryptocurrency Prices with a Hybrid ARIMA and LSTM Model. *Journal of Telecommunications and the Digital Economy*, *13*(1). https://doi.org/10.18080/jtde.v13n1.1052

Gadasina, L. & Sotnichenko, A. (2025). A comparative analysis of the sentiments expressed in comments posted under identical content across different social media platforms. *Journal of Telecommunications and the Digital Economy*, *13*(1). https://doi.org/10.18080/jtde.v13n1.1140

Gessler, J., Rychlik, H., & Wolfgang H. Schulz, W-H. (2025). Empowering data spaces for future mobility: Exploring organizational roles. *Journal of Telecommunications and the Digital Economy*, *13*(1). https://doi.org/10.18080/jtde.v13n1.1113

Grigorescu, P-C. & Ciurea, L-C. (2025). Modelling Inherent Risk of Data Intensive Technologies. *Journal of Telecommunications and the Digital Economy*, *13*(1). https://doi.org/10.18080/jtde.v13n1.1144

Grissa, K. (2025). Why Micro Influencers are sharing Digital Brand Content in B2B context: a social-psychological investigation using Theory of Planned Behaviour. *Journal of Telecommunications and the Digital Economy*, *13*(1). https://doi.org/10.18080/jtde.v13n1.1082

Hamdi, N., El Hog, C., Ben Djemaa, R., & Layth Sliman, L. (2025). Semantic Service Level Agreement to improve smart contract usability in Service-Based Digital Economy. *Journal of Telecommunications and the Digital Economy*, *13*(1). https://doi.org/10.18080/jtde.v13n1.1151

Hentati, A., & Jallouli,R. (2025). Gamification of Mobile Banking Applications: A Systematic Literature Review. *Journal of Telecommunications and the Digital Economy*, *13*(1). https://doi.org/10.18080/jtde.v13n1.1220

Jabado, R. & Jallouli, R. (2023). A Systematic Literature Review on CRM Critical Success Factors. In: Jallouli, R., Bach Tobji, M.A., Belkhir, M., Soares, A.M., & Casais, B. (eds.) *Digital Economy. Emerging Technologies and Business Innovation*. ICDEc 2023. Lecture Notes in Business Information Processing, *485*. Springer. https://doi.org/10.1007/978-3-031-42788-6_15

Jabado, R. & Jallouli, R. (2024). Impact of data analytics capabilities on CRM systems' effectiveness and business profitability: An empirical study in the retail industry. *Journal of Telecommunications and the Digital Economy*, *12*(1), 427-445. https://doi.org/10.18080/jtde.v12n1.845

Jabado, R. & Jallouli, R. (2024). Enhancing customer relationship management with data analytics: Insights from retail survey. *Journal of Telecommunications and the Digital Economy*, *12*(2), 76-96. https://doi.org/10.18080/jtde.v12n2.987

Jallouli, R., Nasraoui O., Bach Tobji M.A., Srarfi Tabbane R., & Rhouma R. (2016*): International Conference on Digital Economy*, ICDEc 2016, Carthage, Tunisia, April 28-30, IEEE. https://ieeexplore.ieee.org/xpl/conhome/7556633/proceeding

Jallouli, R., Zaïane, O., Bach Tobji, M., Srarfi Tabbane, R., & Nijholt, A. (2017). *Digital Economy. Emerging Technologies and Business Innovation*: Second International Conference, ICDEc 2017, Sidi Bou Said, Tunisia, May 4–6, 2017, Proceedings. Springer LNBIP Series, *290*. https://doi.org/10.1007/978-3-319-62737-3

Jallouli, R., Bach Tobji, M., Bélisle, D., Mellouli, S., Abdallah, F., & Osman, I. (2019). *Digital Economy. Emerging Technologies and Business Innovation*: 4th International

Conference, ICDEc 2019, Beirut, Lebanon, April 15–18, 2019, Proceedings. Springer LNBIP Series, *358*. https://doi.org/10.1007/978-3-030-30874-2

Jallouli, R., Bach Tobji, M.A., Mcheick, H., & Piho, G. (2021). *Digital Economy. Emerging Technologies and Business Innovation*: 6th International Conference on Digital Economy, ICDEc 2021, Tallinn, Estonia, July 15–17, 2021, Proceedings. Springer LNBIP Series, *431*. https://doi.org/10.1007/978-3-030-92909-1

Jallouli, R., Bach Tobji, M.A., Belkhir, M., Soares, A.M., & Casais, B. (2023). *Digital Economy. Emerging Technologies and Business Innovation*: 8th International Conference, ICDEc 2023, Braga, Portugal, May 2–4, 2023, Proceedings. Springer LNBIP Series, *485*. https://doi.org/10.1007/978-3-031-42788-6

Jallouli, R., Bach Tobji, M. A., Piho, G., & Mcheick, H. (2022, June 10th). Guest Editorial. *Journal of Telecommunications and the Digital Economy*, *10*(2), 1–5. https://doi.org/10.18080/jtde.v10n2.590

Jallouli, R., Bach Tobji, M. A., Soares, A. M., Casais, B., & Belkhir, M. (2024). Editorial: Emerging technologies and innovation for digital economy and transformation. *Journal of Telecommunications and the Digital Economy*, *12*(1), 113-123. https://doi.org/10.18080/jtde.v12n1.945

Jallouli, R., & Kaabi, S. (2022). Mapping top strategic e-commerce technologies in the digital marketing literature. *Journal of Telecommunications and the Digital Economy*, *10*(3), 149-164. https://doi.org/10.18080/jtde.v10n3.554

Jlassi, E., Chaabouni, A., & Triki, M. (2025). Impact of Recommendation Systems on the AI-enabled Customer Experience: Mediator role of perceived usefulness and perceived trust. *Journal of Telecommunications and the Digital Economy*, *13*(1). https://doi.org/10.18080/jtde.v13n1.1137

Kaabi, S., Jallouli, R. (2019). Overview of E-commerce Technologies, Data Analysis Capabilities and Marketing Knowledge. In: Jallouli, R., Bach Tobji, M., Bélisle, D., Mellouli, S., Abdallah, F., Osman, I. (eds) *Digital Economy. Emerging Technologies and Business Innovation*. ICDEc 2019. Lecture Notes in Business Information Processing, *358*. Springer, Cham. https://doi.org/10.1007/978-3-030-30874-2_14

Laarabi, M., Sadok, H., Maarouf, A., Chatri. A. (2025). Analysis of Countries' Maturity for a Financial Transition Towards Tokenization. *Journal of Telecommunications and the Digital Economy*, *13*(1). https://doi.org/10.18080/jtde.v13n1.1012

Lajfari, K., & Soumbara, S-A.(2025). Exploring the Dynamics of Mobile Money in Africa: Causal Links and Financial Inclusion Outcome. *Journal of Telecommunications and the* Digital Economy, *13*(1). https://doi.org/10.18080/jtde.v13n1.1062

Mahboub, H., Sadok, H. (2022). Towards a Better Digital Transformation: Learning from the Experience of a Digital Transformation Project. In: Bach Tobji, M.A., Jallouli, R., Strat, V.A., Soares, A.M., Davidescu, A.A. (eds) *Digital Economy. Emerging Technologies and Business Innovation*. ICDEc 2022. Lecture Notes in Business Information Processing, *461*. Springer, Cham. https://doi.org/10.1007/978-3-031-17037-9_15

Mednini, L., & Noubigh, Z. (2025). Deep Learning-Based Facial Emotion Recognition for Detecting Brand hate. *Journal of Telecommunications and the Digital Economy*, *13*(1). https://doi.org/10.18080/jtde.v13n1.1067

Naselhaj, S., & Fahmi, Y. (2025). Corporate governance at the Crossroads of AI: Assessing Necessity, Disruption, and Strategic Implementation. *Journal of Telecommunications and the Digital Economy*, *13*(1). https://doi.org/10.18080/jtde.v13n1.1068

Nobanee, H., El Maknouzi, M.E., Hicham Sadok, H., & Alodat, A,Y. (2024). Analysis of insurance entrepreneurship as a hedge in times of crisis: a literature review. *Sustainable Technology and Entrepreneurship*, *3*(2). https://doi.org/10.1016/j.stae.2023.100065

Sadok, H., Saadane, R., Benali, M. (2024). Artificial Intelligence and the Future of Employment: Is It an Artificial Threat?. In: Ben Ahmed, M., Boudhir, A.A., Abd Elhamid Attia, H.F., Eštoková, A., Zeleňáková, M. (eds) *Information Systems and Technological Advances for Sustainable Development*. DATA 2024. Lecture Notes in Information Systems and Organisation, *71*. Springer, Cham. https://doi.org/10.1007/978-3-031-75329-9_6

Triki, M., Ben Ghanem, I., Mednini, L., &. Chaabouni, A. (2025). How Travel Agencies Innovate their Business Models: The Role of AI and Marketing Automation. *Journal of Telecommunications and the Digital Economy*, *13*(1). https://doi.org/10.18080/jtde.v13n1.1072

Vishnupriya, O, S., & Nemat, S. (2025). The relationship between reward, attitude, and intentions in a gamified app context: Evidence from an emerging economy. *Journal of Telecommunications and the Digital Economy*, *13*(1). https://doi.org/10.18080/jtde.v13n1.1047

Gamification of Mobile Banking Applications

A Systematic Literature Review

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Abstract: Gamification has become a pivotal strategy for enhancing user experiences in digital platforms, particularly in mobile banking applications. The objective of this study is to investigate how gamification can improve engagement, satisfaction and loyalty of M-Banking (mobile banking) users. This paper presents a systematic literature review, which was refined to 16 articles after rigorous filtering of multiple academic databases. The corpus explores various gamification elements, such as rewards, leaderboards and challenges through frameworks, namely Technology Acceptance Model (TAM) and Unified Theory of Acceptance and Use of Technology 2 (UTAUT2), as well as clustering methodologies. The findings demonstrate a strong positive impact of gamification on user behaviour and adoption. Nevertheless, significant gaps persist, highlighting the need for further research and innovation in this area. This review provides valuable insights for banking professionals and offers directions for future research to further optimise gamified mobile banking applications.

Keywords: Mobile Banking, M-Banking, Banking Apps, Gamification, Systematic Literature Review

Introduction

The rapid advancement of digital technology has unlocked a wealth of innovative strategies and tools, revolutionising practices across diverse fields. Among these strategies, gamification has emerged as leveraging game-like elements to enhance engagement and user experience. In fact, gamification of mobile applications (apps) uses game-like features, such as rewards, challenges and leaderboards (other elements are explained in Appendix 1) to improve the user experience. This can make apps easier to use, and more satisfying and engaging, which helps with user retention (Widagdo *et al.*, 2024). Gamification has been shown to provide positive effects on user engagement and motivation, but its effectiveness is highly dependent on the

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context in which it is implemented and the characteristics of the users (Hamari *et al.*, 2014). Gamification is explored in relation to service marketing theory, which conceptualises the consumer as a co-producer of the service (Huotari *et al.*, 2017). Gamification has been successfully used in areas such as education (Guerrero *et al.*, 2024; Ivarson *et al.*, 2024; San Martin *et al.*, 2024; Teoh *et al.*, 2024; Widyakusuma *et al.*, 2024), health (Czerska, 2024; Malvas, 2024; Yu *et al.*, 2024), online communities and social networks, (Seaborn *et al.*, 2015), and shopping (Rabiah *et al.*, 2024; Bayır *et al.*, 2024). However, while existing research has extensively explored these areas, there is a gap in understanding how gamification could benefit the financial sector. In fact, mobile banking (M-Banking) has become increasingly popular in recent years, with studies focusing on various factors influencing its adoption and usage (Ho *et al.*, 2020). Moreover, gamification has emerged as a widely adopted strategy in M-Banking, aiming to increase user engagement, satisfaction and long-term loyalty (Rodrigues *et al.*, 2016). Gamification elements encourage users to engage more frequently with the app, adopt new features and exhibit desired financial behaviours, such as saving more effectively (Bayuk *et al.*, 2019). Additionally, by integrating game-like elements, M-Banking applications (apps) seek to create a more interactive and enjoyable user experience.

To date, there has not been a systematic literature review in this area, even though many studies are starting to focus on it. This research aims to bring together existing studies, highlight what is missing, and suggest ideas for future research. This paper aims to fill that gap by conducting a systematic literature review aimed at consolidating the existing body of research on the gamification of M-Banking. While prior reviews, including Prasetyaningrum *et al.* (2022), synthesised foundational insights, this study advances the field by critically analysing nine studies after 2022 which were unexplored in earlier reviews, conducting a geographic and time-based analysis, and proposing a framework for future work in the gamification of M-Banking apps. Through an analysis of 16 selected studies, this review explores key gamification elements and their impact on user behaviour. Moreover, by summarising the current findings, this study identifies key strategies and outcomes, highlights areas where more research is needed, and offers recommendations for future studies.

This paper is organised as follows: Section 2 presents the methodology used for the systematic literature review, including the search strategy, selection criteria and databases utilised. Section 3 outlines the results of the review, providing a summary of the selected studies and key findings related to the gamification of M-Banking. Section 4 focuses on the discussion thereof. The last section presents the proposed framework and future work for gamification of M-Banking apps, and the limitations of the study.

Method

A methodical search was carried out without regard to any start date restrictions to find pertinent items from a set of databases as of 8 December 2024. For this search, Google Scholar, Scopus, IEEE Xplore, ScienceDirect, JSTOR and ACM Digital Library were among the databases used. To target titles that specifically address mobile banking applications and gamification, search phrases were created via a two-part approach. Table 1 details the keywords used to execute the searches.

The search queries used for each database are summarised in Table 8 in Appendix 2. This table includes the name of each database alongside the corresponding queries.

Table 1. Keywords used for database searches on M-banking apps and gamification

Mobile banking	Gamification
Mobile Banking	Gamification
M-Banking	Gamified
Banking App	Game
Banking Apps	Games
Banking Application	Gaming
Banking Applications	-
Digital Banking	-

Search execution

From the initial searches, we noticed that some databases do not include any papers about our scope. Table 2 shows the results for every database searched. The only databases with papers that included our search items were Google Scholar, Scopus and IEEE Xplore.

Table 2. Number of results in each database

Database	Number of results
Google Scholar	24
Scopus	9
IEEE Xplore	2
ScienceDirect	0
JSTOR	0
ACM Digital Library	0

Selection criteria

Following the database and parameter searches that were previously specified, 35 papers were found overall, with 24 from Google Scholar, 9 from Scopus, and 2 from IEEE Xplore. The papers retrieved from IEEE Xplore are already present in the results obtained from Google Scholar. Furthermore, eight out of the nine results from Scopus are also included in the Google Scholar database.

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The first step was to combine all these entries into a single sheet and eliminate duplicated records which included 10 articles. Following the exclusion of one article that was not retrievable, 24 articles remained. By examining the papers, six articles were eliminated for not being scientific papers (for example, a thesis). The list was reduced to 17 items after one article written in a non-English language (Korean) was excluded. Following a thorough assessment, 16 publications were deemed eligible for inclusion in the study after one article was rejected for not fulfilling the eligibility requirements. Figure 1 depicts the systematic literature review process.

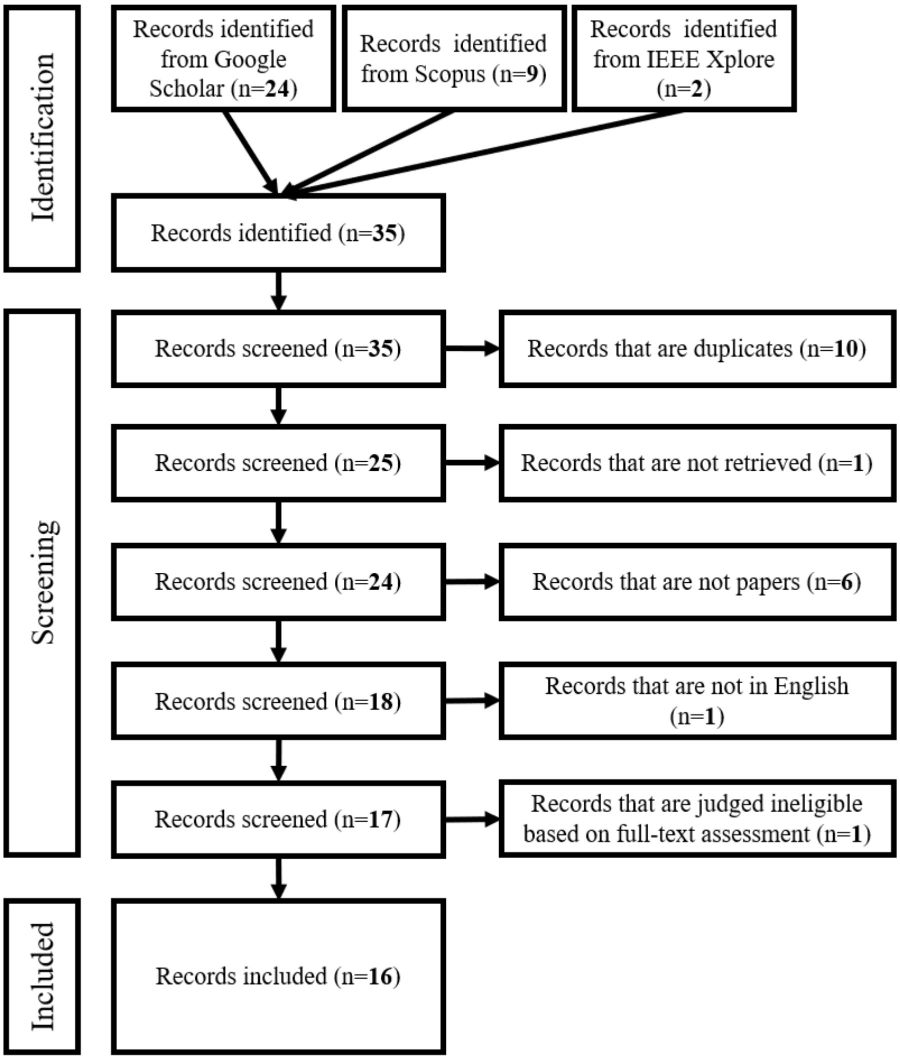

Figure 1. Procedure for choosing the articles

Results

An overview of the selected studies on gamification and M-Banking apps is shown in Table 3, which includes information on the authors, year of publication, study focus, methodology, gamification elements and key findings.

Table 3. Summary of studies on gamification and M-banking apps

Authors	**Study focus**	**Country**	**Methodology**	**Gamification elements**	**Key findings**
Prasetyaningrum *et al.* (2025)	Analysing user behaviour in gamified banking apps	Indonesia	- Survey of 451 M-Banking users in Indonesia - K-Means clustering - Machine learning classifiers (SVM, Random Forest...)	Points, rewards, rankings, badges, tasks and leaderboards	Banks may better adapt their gamification approaches, marketing initiatives, and product offerings to the varied tastes and behaviours of their users by utilising the identified user categories and the SVM classifier's predictive power. Improved user satisfaction, greater loyalty, and eventually a competitive advantage in the changing digital banking market can result from this data-driven strategy.
Prasetyaningrum *et al.* (2024)	Role of psychological drivers in gamification success	–	- Survey of 451 users - Cognitive Evaluation Theory - Analysis of user psychological needs (autonomy, competence and relatedness)	Share, score, look for offers, badge, and level	Personalised gamification that specifically addressed consumers' individual psychological demands (autonomy, competence and relatedness) increases user interaction by 35% and loyalty by 28%.
Blanchard *et al.* (2024)	Impact of gamification discontinuation on M-Banking user behaviour	Latin America	- Natural experiment - Age period cohort models	Cash rewards and module engagement	Discontinuation leads to declines in app logins (20%), bill payments (18%), and timely loan repayments via the app (31%). Effects were stronger for new users.
Hashim *et al.* (2024)	Investigates the impact of gamification and self-efficacy on	Malaysia	- Questionnaire from 384 Malaysian M-Banking users - Smart PLS	Social influence and reward	Rewards and social influence have a good impact on customer loyalty. In fact, customer

Authors	Study focus	Country	Methodology	Gamification elements	Key findings
	customer loyalty to M-Banking		analysis		loyalty is impacted by gamification, which also mediates the impact of rewards and social influence. Increasing client loyalty to M-Banking depends on how it is designed and how points are rewarded.
Viet Tam *et al.* (2024)	Extending TAM model to include gamification impacts	Vietnam	- Survey of 262 users from Vietnam - Partial least squares structural equation modelling (PLS-SEM) analysis - Extended TAM model	–	Gamification positively influences perceived value, user attitudes, and behavioural intention toward digital banking.
Rafiuddin *et al.* (2024)	Assessing gamification impact on savings behaviours	Indonesia	- 303 active M-Banking users from Indonesia - PLS-SEM analysis	Rewards, challenges, and leaderboards	Gamification elements (rewards, challenges, leaderboards) significantly increase savings rates by 15%.
Cera *et al.* (2024)	Exploring factors influencing M-Banking adoption including gamification	Western Balkans	- 731 respondents from Western Balkan countries - PLS-SEM - Mixed-model approach combining UTAUT2, DOI, and gamification frameworks	–	Technology acceptance criteria appear to be positively influenced by gamification.
Akhtar *et al.* (2023)	Identifying critical success factors for gamification in digital banking	India	- AHP (Analytic Hierarchy Process) method with input from one professional from banking industry and two academics from India	Assessment, challenge, interactivity, aesthetics, functionality, and control	Functionality (reward-based gamification) ranked highest among gamification elements, followed by interactivity (meaningful gamification). They are important for designing gamified M-Banking services to ensure customer

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Authors	Study focus	Country	Methodology	Gamification elements	Key findings
					engagement.
Aithal *et al.* (2023)	Impact of gamification elements on customer experience in digital banking	India	- Survey of 150 private-sector bank users in Kerala (India) - Descriptive and analytical approach	Badges, points, leaderboards, rewards, progress bars, trivia, opinion polls, and mini-games	Gamification factors (badges, points, leaderboards, rewards, progress bars, trivia, opinion polls and mini games) play a significant role in predicting customer experience.
Lahoti *et al.* (2022)	Impact of gamification on customer engagement in M-Banking apps	–	- Quantitative study with 303 participants	–	Gamification enhances user experience, engagement, and financial behaviour.
Prasetyaningrum *et al.* (2022)	Overview of gamification elements in banking	–	- Systematic review of 21 gamification elements and their impact	Announcements, point, reward, rank, badge, score, task, feedback, leaderboard, hunt for offers, timer, level, share, social interactivity, penalty, avatar, lottery, virtual reward, epic meaning, informing, random reward	Gamification has a big impact on improving system performance and raising customer engagement.
Rimenda *et al.* (2022)	Effect of gamified savings features on consumer-saving behaviour	Indonesia	- Questionnaire from 172 Indonesian bank customers - PLS-SEM analysis	Badges, levels, and challenges	Gamified features like badges, levels, and challenges positively influence saving habits, especially among millennials.
Anugrah *et al.* (2022)	The role of gamification and UTAUT2 in influencing behavioural intentions and use behaviour in M-Banking	Indonesia	- Quantitative analysis with 200 respondents using online questionnaires from Jakarta (Indonesia) - UTAUT2 -Descriptive statistics	–	Perceived value and habit positively influence behavioural intentions, but gamification showed no direct influence on behavioural intentions.
Çera *et al.* (2020)	Examines generational differences (Gens Y and	Albania	- PLS-SEM analysis with 380 respondents	–	Gen Z shows higher intention to use M-Banking with gamification

Authors	Study focus	Country	Methodology	Gamification elements	Key findings
	Z) in how gamification influences behavioural intentions in M-Banking		from Albania - UTAUT2		compared to Gen Y (inborn before 1996). Gamification positively influences behavioural intention for both generations.
Torres-Toukoumidis *et al.* (2017)	Examines gamification elements in M-Banking apps in Spain	Spain	- Analysis of 38 M-Banking apps using a taxonomy of game elements	The collection of rewards and application of mechanics of progression	It is necessary to consider three aspects of the gamified experience. (1) Socialisation : It has to do with customer service, commercial interactions via social networks, and transfers between users. (2) Construction is the customised configuration of products and services that alters how the customers envision and control their experiences. (3) Collection, which accounts for search and access based on reward systems.
Baptista *et al.* (2017)	Evaluates the effect of gamification on M-Banking service acceptance	Brazil	- Questionnaire of 326 Brazil M-Banking users - PLS-SEM - UTAUT2	-	Gamification and the intention to use M-Banking services are directly and strongly correlated. When gamification is applied and designed effectively, it can make banking operations more pleasurable, which will boost customer acceptance, engagement, and satisfaction.

The selected studies show that the gamification of M-Banking apps has been gaining interest in recent years across different countries. Prasetyaningrum appears to have contributed the

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most to this field, with three studies out 16 analysed. Most of the studies highlight the impact of gamification on user acceptance, engagement and experience of the M-Banking apps. Moreover, they also explore key success factors for gamification and extend models such as TAM and UTAUT2. Additionally, several studies examine generational differences in how users interact with gamified features, particularly comparing Gen Z and older users.

Time analysis

Figure 2 illustrates the evolution of the number of selected papers on gamification of M-Banking across publication years. The trend shows a notable increase in research output over time, reflecting growing interest in the topic. In 2017, only two studies met the selection criteria; the number of studies gradually increased to 16 by 2025. This upward trajectory highlights the expanding focus on gamification as a tool for enhancing user engagement and adoption in M-Banking applications. The sharp increase in recent years underscores the relevance of this area within both academic and industry contexts, emphasising the need for continued exploration and innovation.

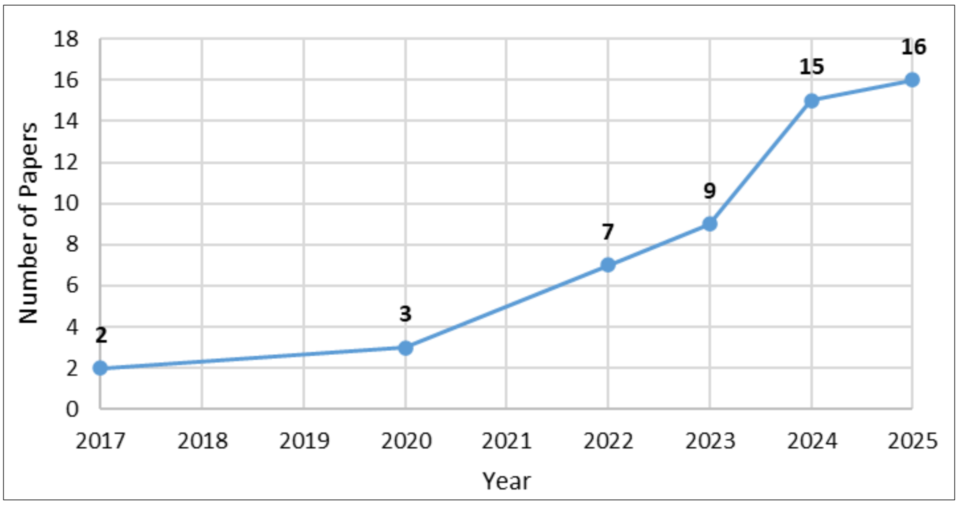

Figure 2. Evolution of papers by year: 2017–2025

Geographic analysis

This systematic literature review highlights the growing global interest in gamification within M-Banking applications. In fact, most studies on gamification of M-Banking are focused on Asia, with eight studies from countries such as Indonesia (4 studies, 2025, 2024 and 2022), India (2 studies, 2023), Malaysia (1 study, 2024) and Vietnam (1 study, 2024). This suggests that M-Banking gamification is gaining significant traction in Southeast Asia, a region where M-Banking is growing rapidly. In contrast, research from Europe is more limited, with just three studies from: Western Balkans (1 study, 2024), Albania (1 study, 2020) and Spain (1 study, 2017), pointing to less widespread attention to this topic in these regions. South America has contributed a total of two studies, one from Brazil (2017) and one from Latin

America (2024), reflecting an increasing interest in gamification of M-Banking within these regions. However, two studies (Lahoti *et al.*, 2022; Prasetyaningrum *et al.*, 2024) did not specify the country of the studied M-Banking app, which indicates some gaps in geographic detail within the research. However, the authors of the first study (Prasetyaningrum *et al.*, 2024) are affiliated with universities in Indonesia, while the second study (Lahoti *et al.*, 2022) involves authors from an Indian university. This distribution shows that while Asia is leading in the adoption and study of gamification, there are emerging trends in Europe and South America that offer promising areas for future investigations. Table 4 presents this distribution by continent and country/region. The review study by Prasetyaningrum *et al.* (2022) is not included in Table 4.

Table 4. Geographic distribution of studies on gamification of M-Banking apps

Continent	Country/Region	Number of studies
Asia (8)	Indonesia (4 studies: 2025, 2024, 2022, 2022)	4
	India (2 studies: 2023, 2023)	2
	Malaysia (1 study: 2024)	1
	Vietnam (1 study: 2024)	1
Europe (3)	Western Balkans (1 study: 2024)	1
	Albania (1 study: 2020)	1
	Spain (1 study: 2017)	1
South America (2)	Brazil (1 study: 2017)	1
	Latin America (1 study: 2024)	1
Not specified (2)	Not specified (2 studies: 2024, 2022)	2

Analysis of gamification elements in M-Banking apps

Table 5 lists the several gamification components seen in M-Banking apps along with how frequently they were mentioned in different studies. When rewards, virtual rewards and random awards are combined, they appear in seven studies, making rewards the most frequently referenced factor. This highlights how crucial it is to offer rewards to customers to interact with M-Banking apps. The badges cited in five studies and the leaderboards noted in four studies are other common components that highlight competitiveness and recognition as important motivators for users. Furthermore, three studies mentioned challenges, three mentioned levels, and three mentioned points, showing how each helps keep users engaged by providing clear pathways for progression. Additional interactive dimensions are provided by features such as hunt for offers, progress bars, ranks, scores, shares and tasks (which have been noted in two studies each). Even though other components, such as aesthetics, announcements, assessment, avatar, control, epic meaning, feedback and functionality occur less frequently, they can offer chances for deeper investigation. According to these results, a well-balanced combination of well-known components and distinctive, underutilised features may greatly improve the user experience and engagement in M-Banking apps.

Table 5. Frequency and diversity of gamification elements in M-Banking apps

No.	Gamification elements	Number of mentions	Studies
1	Reward	7	Prasetyaningrum *et al.* (2025) Rafiuddin *et al.* (2024) Hashim *et al.* (2024) Blanchard *et al.* (2024) Aithal (2023) Prasetyaningrum *et al.* (2022) Torres-Toukoumidis *et al.* (2017)
2	Badge	5	Prasetyaningrum *et al.* (2025) Prasetyaningrum *et al.* (2024) Aithal (2023) Prasetyaningrum *et al.* (2022) Rimenda *et al.* (2022)
3	Leaderboard	4	Prasetyaningrum *et al.* (2025) Rafiuddin *et al.* (2024) Aithal (2023) Prasetyaningrum *et al.* (2022)
4	Challenges	3	Rafiuddin *et al.* (2024) Akhtar *et al.* (2023) Rimenda *et al.* (2022)
5	Levels	3	Prasetyaningrum *et al.* (2024) Prasetyaningrum *et al.* (2022) Rimenda *et al.* (2022)
6	Points	3	Prasetyaningrum *et al.* (2025) Aithal (2023) Prasetyaningrum *et al.* (2022)
7	Hunt for offers	2	Prasetyaningrum *et al.* (2024) Prasetyaningrum *et al.* (2022)
8	Progress bars	2	Aithal (2023) Torres-Toukoumidis *et al.* (2017)
9	Ranks	2	Prasetyaningrum *et al.* (2025) Prasetyaningrum *et al.* (2022)
10	Score	2	Prasetyaningrum *et al.* (2024) Prasetyaningrum *et al.* (2022)
11	Share	2	Prasetyaningrum *et al.* (2024) Prasetyaningrum *et al.* (2022)
12	Task	2	Prasetyaningrum *et al.* (2025) Prasetyaningrum *et al.* (2022)
13	Aesthetics	1	Akhtar *et al.* (2023)
14	Announcements	1	Prasetyaningrum *et al.* (2022)

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15	Assessment	1	Akhtar *et al.* (2023)
16	Avatar	1	Prasetyaningrum *et al.* (2022)
17	Control	1	Akhtar *et al.* (2023)
18	Epic meaning	1	Prasetyaningrum *et al.* (2022)
19	Feedback	1	Prasetyaningrum *et al.* (2022)
20	Functionality	1	Akhtar *et al.* (2023)
21	Informing	1	Prasetyaningrum *et al.* (2022)
22	Interactivity	1	Akhtar *et al.* (2023)
23	Lottery	1	Prasetyaningrum *et al.* (2022)
24	Mini-games	1	Aithal (2023)
25	Module engagement	1	Blanchard *et al.* (2024)
26	Opinion polls	1	Aithal (2023)
27	Penalty	1	Prasetyaningrum *et al.* (2022)
28	Social influence	1	Hashim *et al.* (2024)
29	Social interactivity	1	Prasetyaningrum *et al.* (2022)
30	Timer	1	Prasetyaningrum *et al.* (2022)
31	Trivia	1	Aithal (2023)

Discussion

In this section, we focus on the 13 studies that specified their geographic foci.

Regional synthesis of studies

In Asia, studies in Indonesia, India, Malaysia and Vietnam highlight the significant influence of gamification on user satisfaction, engagement and loyalty in M-Banking (Prasetyaningrum *et al.*, 2025). Features such as rewards, challenges, badges, leaderboards, badges and levels have been particularly effective in promoting savings habits (Rimenda *et al.*, 2022; Rafiuddin *et al.*, 2024). In India, reward-based gamification ranked highest for retaining users, followed by interactive and meaningful gamification elements (Akhtar *et al.*, 2023). Predicting consumer experience is significantly influenced by gamification variables (Aithal, 2023). In Malaysia, rewards and social influence have a positive effect on customer loyalty (Hashim *et al.*, 2024). In Vietnam, gamification has a positive effect on user attitudes, behavioural intentions, and perceived value in relation to M-Banking (Viet Tam *et al.*, 2024). Notably, one study showed that gamification has no direct influence on behavioural intentions (Anugrah *et al.*, 2022).

In Europe, research in Albania, Spain and Western Balkans emphasises the regional relevance of gamification. In Western Balkans, technology acceptability seems to be positively impacted by gamification (Cera *et al.*, 2024). In Albania, younger generations (Gen Z) presented higher adoption rates for gamified M-Banking than did Gen Y (Çera *et al.*, 2020). In Spain, an analysis of 38 apps identified socialisation, construction and collection as key gamification components, stressing the importance of personalised and reward-based features (Torres-Toukoumidis *et al.*, 2017).

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In South America, studies in Brazil and Latin America have demonstrated the impact of gamification on engagement and retention. In Brazil, gamification is positively correlated with the intention to use M-Banking (Baptista *et al.*, 2017), whereas its removal in Latin America has led to a significant drop in user activity, especially among new users (Blanchard *et al.*, 2024).

This global analysis demonstrates the growing interest in gamification within M-Banking applications, highlighting its potential to increase user adoption and satisfaction across diverse regions.

Methodological approaches in the studies

The reviewed studies primarily utilise quantitative methodologies, which offer robust insights into the impact of gamification on user behaviour and M-Banking adoption. Table 6 summarises these findings. PLS-SEM seems to be the most adopted method, as it was used by six out of the 12 studies (mentioning their study's geographic location) and on all continents. In addition, the UTAUT2 model was used on three continents, which led us to recommend the exploration in future research of new approaches such as text mining and clustering of big data for marketing insights and strategies (Benslama *et al.*, 2020; Chebil *et al.*, 2024; Jallouli *et al.*, 2022; Khemiri *et al.*, 2022).

Table 6. Summary of the methods used in the studies

Continent	**Asia**				**Europe**			**South America**	
Country	**Indonesia**	**India**	**Malaysia**	**Vietnam**	**Western Balkans**	**Albania**	**Spain**	**Brazil**	**Latin America**
Survey/ Questionnaire	Prasetyaningrum *et al.* (2025); Rafiuddin *et al.* (2024); Anugrah *et al.* (2022); Rimenda *et al.* (2022)	Aithal *et al.* (2023)	Hashim *et al.* (2024)	Viet Tam *et al.* (2024)	Cera *et al.* (2024)	Çera *et al.* (2020)		Baptista *et al.* (2017)	
PLS-SEM	Rimenda *et al.* (2022); Rafiuddin *et al.* (2024)			Viet Tam *et al.* (2024)	Cera *et al.* (2024)	Çera *et al.* (2020)		Baptista *et al.* (2017)	
Smart PLS			Hashim *et al.* (2024)						
UTAUT2	Anugrah *et al.* (2022)				Cera *et al.* (2024)	Çera *et al.* (2020)		Baptista *et al.* (2017)	

Continent	**Asia**				**Europe**			**South America**	
Country	**Indonesia**	**India**	**Malaysia**	**Vietnam**	**Western Balkans**	**Albania**	**Spain**	**Brazil**	**Latin America**
TAM				Viet Tam *et al.* (2024)					
K-means clustering	Prasetyaningrum *et al.* (2025)								
Machine learning classifiers	Prasetyaningrum *et al.* (2025)								
AHP method		Akhtar *et al.* (2023)							
A taxonomy of game elements							Torres-Toukoumidis *et al.* (2017)		
Descriptive and analytical approach		Aithal *et al.* (2023)							
Natural experiment									Blanchard *et al.* (2024)
Descriptive statistics	Anugrah *et al.* (2022)								

Framework for Future Research

Figure 3 illustrates the proposed framework, summarising the current state of the literature on gamification of M-Banking and organising it into three key sections: Regions/countries, gamification elements and methods.

Future research should prioritise underrepresented regions, including the Middle East, Africa and North America, which have received limited attention in existing studies. Regarding gamification components, the findings of this systematic literature review highlight the potential of strategies such as spin-to-win and friend referral contests (Baykal, 2023), which generate excitement and encourage user sharing. Moreover, a detailed exploration of widely adopted components, such as leaderboards, badges and awards is essential to enhance user motivation and sustain engagement over time. In terms of methodology, approaches like surveys, questionnaires, PLS-SEM and UTAUT2 are recommended due to their frequent application in prior research. However, in contexts where these methods have been extensively employed, the adoption of innovative techniques may yield novel insights and address gaps overlooked by traditional approaches. Furthermore, future studies could

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incorporate bibliometric analysis using R software, techniques such as word clouds, and thematic evolution maps would provide a more nuanced exploration of the dataset and highlight key research trends.

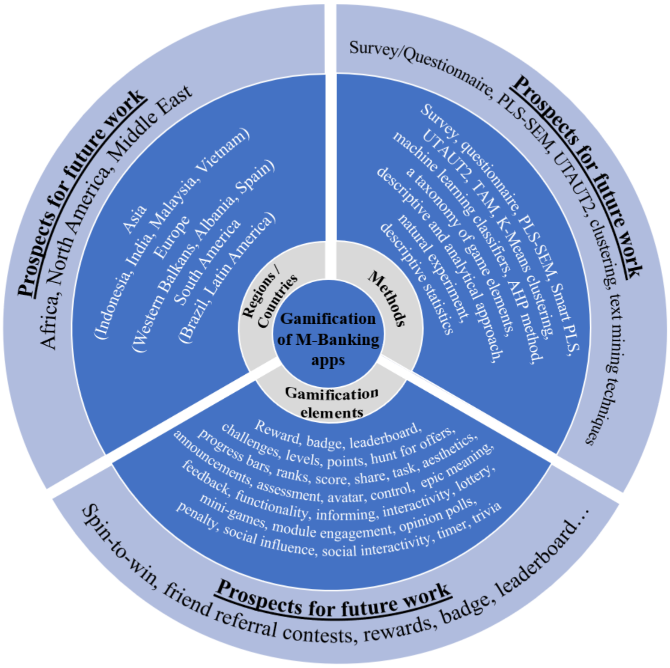

Figure 3. Gamification of M-Banking apps: Overview of literature review findings and research agenda

This review has certain limitations that warrant consideration. First, the availability of research on the gamification of M-Banking apps remains sparse, not only on a global scale but also within Asia. The limited number of studies makes it challenging to generalise findings across entire markets, as the results may reflect localised phenomena rather than broader trends.

Second, while many studies rely on surveys and quantitative methods to identify trends and measure user engagement, these approaches fall short in uncovering the deeper emotional and psychological motivations behind users' interactions with gamified components. Complementary qualitative methods, such as in-depth interviews, focus groups or ethnographic approaches could provide richer insights into user experiences and behaviours.

Third, none of the studies reviewed address the potential adverse effects of gamified features. These include concerns such as the risk of users becoming overly dependent on gamification elements or the increased likelihood of behavioural addiction. Such outcomes could undermine user well-being and lead to ethical concerns about the design and implementation of gamified M-Banking apps. Future research should prioritise exploring these risks and examine the balance between enhancing engagement and ensuring responsible gamification practices.

Finally, this review is limited by its reliance on secondary data and published studies. It is possible that valuable industry insights or unpublished findings remain inaccessible, which could limit the comprehensiveness of this analysis. Future research efforts could benefit from partnerships with financial institutions or technology providers to gain access to proprietary data and real-world use cases of gamified M-Banking applications.

Conclusion

This paper provides a systematic literature review on gamification of M-Banking applications, emphasising key trends and developments observed in recent years. The review employed a rigorous methodology, systematically analysing 16 studies to ensure a comprehensive understanding of gamification in M-Banking. It highlighted the significant role of gamification elements such as rewards, leaderboards and challenges in influencing user behaviour and driving the adoption of M-Banking services. Key outputs of this study include a framework for future research and a geographic analysis of studies across regions. The proposed framework organises findings into three key areas: regions, gamification elements and methods. However, the review also identifies important gaps in the current literature, particularly regarding the effectiveness of gamification in diverse cultural and regional contexts. These gaps present new opportunities for future research, especially in exploring the integration of emerging technologies such as artificial intelligence, text mining and clustering to enhance gamification strategies. For practitioners in the banking sector, the findings suggest that gamification should be strategically implemented not only as a feature but also as an integral part of broader user engagement and retention strategies. By aligning gamification with users' financial goals and offering personalised experiences, financial institutions can improve customer satisfaction, foster loyalty and drive greater adoption of M-Banking services. In summary, while gamification shows great promise in M-Banking, further research is needed to refine its application and explore its long-term effects across various demographic groups and geographical regions. Future studies should aim to address these gaps and offer more tailored and responsible gamification strategies to ensure that the benefits are maximised for both users and financial institutions.

References

Aithal, P. S. (2023). The influence of gamification on customer experience in digital banking practices. *International Journal of Management, Technology and Social Sciences 8*(3), 280–293. https://doi.org/10.47992/IJMTS.2581.6012.0303

Akhtar, A., Chauhan, S., Kaushik, M., & Zaheer, A. (2023). The Critical Factors of Success of Gamification in Digital Banking Services: Using Analytic Hierarchy Process (AHP) Approach. In *International Conference on Science, Engineering Management and*

Information Technology (pp. 56–70). Cham: Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-72284-4_4

Anugrah, K., Pasaribu, J. P. P., & Astuti, C. D. (2022). Implementation of the UTAUT2 model with gamification and its influence on behavioral intentions and behavior of use of m-banking. *Budapest International Research and Critics Institute – Journal*, *5*(3). https://doi.org/10.33258/birci.v5i3.6602

Baptista, G. & Oliveira, T. (2017*). Why so serious? Gamification impact in the acceptance of mobile banking services. Internet Research, 27*(1), 118–139. https://doi.org/10.1108/IntR-10-2015-0295

Bayır, T. & Akel, G. (2024). Gamification in mobile shopping applications: A review in terms of technology acceptance model. *Multimedia Tools and Applications, 83*(16), 47247–47268. https://doi.org/10.1007/s11042-023-16823-7

Baykal, B. (2023). Brands on play: Harnessing the power of gamification for success. Fettahlıoğlu, H. S. & Bilginer Ozsaatcı, F. G. (Eds.), *Featured Topics in Digital Marketing and Applied Studies.* Özgür Publications. https://doi.org/10.58830/ozgur.pub311.c1365

Bayuk, J. & Aurora Altobello, S. (2019). Can gamification improve financial behavior? The moderating role of app expertise. *International Journal of Bank Marketing*, *37*(4), 951–975. https://doi.org/10.1108/IJBM-04-2018-0086

Benslama, T. & Jallouli, R. (2020). Clustering of social media data and marketing decisions. In *Digital Economy. Emerging Technologies and Business Innovation: 5th International Conference on Digital Economy, ICDEc 2020, Bucharest, Romania, June 11–13, 2020, Proceedings 5* (pp. 53–65). Springer International Publishing. https://doi.org/10.1007/978-3-030-64642-4_5

Blanchard, S. J. & Palazzolo, M. (2024). Game over? Assessing the impact of gamification discontinuation on mobile banking behaviors. *Marketing Science* 0(0), Articles in Advance, pp. 1-20. https://doi.org/10.1287/mksc.2023.0345

Cera, G. & Khan, K. A. (2024). Mobile banking intention: Nexus between innovation, tech adoption, and gamification. *Journal of East-West Business*, 1–27. https://doi.org/10.1080/10669868.2024.2347165

Çera, G., Pagria, I., Khan, K. A., & Muaremi, L. (2020). Mobile banking usage and gamification: the moderating effect of generational cohorts. *Journal of Systems and Information Technology, 22*(3), 243–263. https://doi.org/10.1108/JSIT-01-2020-0005

Chebil, M., Jallouli, R., & Bach Tobji, M. A. (2024). Clustering social media data for marketing strategies: Literature review using topic modelling techniques. *Journal of Telecommunications and the Digital Economy, 12*(1), 510–537. http://doi.org/10.18080/jtde.v12n1.889

Czerska, I. (2024). Gamification in health promotion in the context of creating the concept of health 2.0–a comparative analysis of selected health mobile applications. *European Research Studies Journal, 27*(4), 985–1007. https://doi.org/10.35808/ersj/3641

Guerrero, J. E. M., Manzaba, J. B. P., Sánchez, K. W. G., Salazar, P. A. C., Robles, L. C. S., Jiménez, K. A. S., Escobar, J. E. F., Palacios, C. E. C., & Meza, D. V. L. (2024).

Integration of gamification and mobile applications to promote inclusive education: A techno pedagogical approach. *Revista de Gestão Social e Ambiental, 18*(11), e09584–e09584. https://doi.org/10.24857/rgsa.v18n11-004

Hamari, J., Koivisto, J., & Sarsa, H. (2014). Does gamification work? A literature review of empirical studies on gamification. In *2014 47th Hawaii International Conference On System Sciences* (pp. 3025–3034). IEEE. https://doi.org/10.1109/HICSS.2014.377

Hashim, M. A. A. & Hassan, Z. B. (2024). The mediating role of self-efficacy and gamification in influencing the customer's loyalty toward mobile banking in Malaysia. *Nanotechnology Perceptions, 20*(S5). https://doi.org/10.62441/nano-ntp.v20is5.52

Ho, J. C., Wu, C. G., Lee, C. S., & Pham, T. T. T. (2020). Factors affecting the behavioral intention to adopt mobile banking: An international comparison. *Technology in Society, 63*, 101360. https://doi.org/10.1016/j.techsoc.2020.101360

Huotari, K. & Hamari, J. (2017). A definition for gamification: anchoring gamification in the service marketing literature. *Electronic markets, 27*(1), 21–31. https://doi.org/10.1007/s12525-015-0212-z

Ivarson, E., Erlandsson, V., Faraon, M., & Khatib, S. (2024). Augmented reality and gamification in higher education: Designing mobile interaction to enhance students' motivation and learning. *E-Learning and Digital Media*. https://doi.org/10.1177/20427530241239981

Jallouli, R., & Kaabi, S. (2022). Mapping top strategic e-commerce technologies in the digital marketing literature. *Journal of Telecommunications and the Digital Economy, 10*(3), 149–164. http://doi.org/10.18080/jtde.v10n3.554

Khemiri, M., & Jallouli, R. (2022). Technology-enabled personalization for mobile banking services: Literature review and theoretical framework. *Journal of Telecommunications and the Digital Economy, 10*(2), 173–194. http://doi.org /10.18080/jtde.v10n2.545

Lahoti, Y. (2022). Gamification in mobile banking apps to enhance customer experience and engagement. *NeuroQuantology, 20*(2), 693. https://doi.org/10.48047/nq.2022.20.2.NQ22368

Malvas, G. (2024). The need to 'git gud': A review of potential and pitfalls in mobile gamification of paediatric health education. *Medical Research Archives, 12*(3). https://doi.org/10.18103/mra.v12i3.5263

Prasetyaningrum, P. T., Purwanto, P., & Rochim, A. F. (2025). Consumer behavior analysis in gamified mobile banking: clustering and classifier evaluation. *Journal of System and Management Sciences 15*(2), 290–308. https://doi.org/10.33168/JSMS.2025.0218

Prasetyaningrum, P. T., Purwanto, P., & Rochim, A. F. (2024). Enhancing user engagement in mobile banking through personalized gamification: A cognitive evaluation theory approach. *International Journal of Intelligent Engineering & Systems, 17*(4). https://doi.org/10.22266/ijies2024.0831.60

Prasetyaningrum, P. T., Purwanto, P., & Rochim, A. F. (2022). Gamification On Mobile Banking Application: A Literature Review. In *2022 1st International Conference on Information System & Information Technology* (pp. 222–227). IEEE. https://doi.org/10.1109/ICISIT54091.2022.9873034

Rabiah, A. S., Setiawan, M., & Rohman, F. (2024). Assess the impact of hedonic motivation, social influence, gamification, and education level on behavioral intention to adopt mobile shopping in Jakarta, Indonesia. *Revista de Gestão Social e Ambiental, 18*(7), e05024–e05024. https://doi.org/10.24857/rgsa.v18n7-008

Rafiuddin, T. W., Lutfiani, N., Rizky, A., & Cesna, G. P. (2024). Evaluating the Effectiveness of Gamification in Mobile Banking to Increase Savings Rates. In *2024 2nd International Conference on Technology Innovation and Its Applications* (pp. 1–6). IEEE. https://doi.org/10.1109/ICTIIA61827.2024.10761169

Rimenda, T., Aulia, M. R., Listiawati, R., & Marbun, J. (2022). Gamification: Saving in digital banking is like playing a game. *ASEAN Marketing Journal, 14*(2), 5. https://doi.org/10.21002/amj.v14i2.1206

Rodrigues, L. F., Costa, C. J., & Oliveira, A. (2016). Gamification: A framework for designing software in e-banking. *Computers in Human Behavior, 62*, 620–634. https://doi.org/10.1016/j.chb.2016.04.035

San Martin, J., Castillo–Sequera, J. L., & Wong, L. (2024). Talki: A mobile application to improve English learning of high school students in Peru utilizing virtual reality and gamification. *Engineering, Technology & Applied Science Research, 14*(5), 17472–17481. https://doi.org/10.48084/etasr.8223

Seaborn, K., & Fels, D. I. (2015). Gamification in theory and action: A survey. International *Journal of human-computer studies, 74*, 14–31. http://dx.doi.org/10.1016/j.ijhcs.2014.09.006

Teoh, W. T., & Wahid, N. (2024). Development of a mobile learning application for form 5 mathematics with a gamification approach. *Applied Information Technology And Computer Science, 5*(1), 335–354.

Torres-Toukoumidis, Á., & Marín-Mateos, P. (2017). Gamification in mobile applications for banking services in Spain. RETOS. *Revista de Ciencias de la Administración y Economía, 7*(13), 43–57. https://doi.org/10.17163/ret.n13.2017.02

Viet Tam, T., Tien, N. H., & Banka, M. (2024). Identifying gamification factors for digital banking service users in Vietnam: Extending TAM model with gamification and perceived value. *Cogent Business & Management, 11*(1), 2398730. https://doi.org/10.1080/23311975.2024.2398730

Widagdo, P., Wibawanto, W., & Sugiarto, E. (2024). The impact of gamification in user interfaces on user experience and retention: An empirical study. Catharsis, 13(1), 1–8.

Widyakusuma, A., & Sudibyo, A. S. R. (2024). The future of education: How mobile learning, microlearning, and gamification are revolutionizing architecture learning. *Jurnal Syntax Transformation, 5*(11), 1284–1300. https://doi.org/10.46799/jst.v5i11.1025

Yu, T., Parry, M., Yu, T., Xu, L., Wu, Y., Zeng, T., ... & Li, F. (2024). Effectiveness of mobile health-based gamification interventions for improving physical activity in people with cardiovascular diseases: a systematic review and meta-analysis of randomized controlled trials. *JMIR Serious Games 2025, 13*(e64410). https://doi.org/10.2196/preprints.64410

Appendix 1

Table 7. Summary and description of some gamification elements – Prasetyaningrum *et al.* (2022)

Gamification element	Description
Announcements	Notifications or menus introducing gameplay and providing initial hints about the game's objectives.
Avatar	Use of personalised avatars representing customers in their profiles.
Badge	Visual markers (badges or medals) awarded to achievements to superior users as symbols of achievements or group membership.
Epic meaning	Encouraging users to feel part of a larger, meaningful purpose or goal beyond personal benefit.
Feedback	Mechanisms allowing users and banks to exchange feedback to better understand and meet customer needs.
Hunt for offers	Users are hunting for promotional deals or discounts.
Informing	Providing customers with useful insights to maximise their banking benefits.
Leaderboard	Displays all consumers performance to foster competition and collaboration.
Level	Progressive levels with customised rewards for customers based on their performance at each step.
Lottery	Random draws (lotteries) among customers with rewards for winners.
Penalty	Restrictions or reduced service offerings as consequences for poor performance.
Point	Points earned based on user performance or achievements, which can be converted into coins or specific rewards.
Random reward	Unpredictable and surprise gifts offered to customers.
Rank	A system to display user rankings.
Reward	Rewards offered to users upon successfully completing challenges.
Score	Displays scores achieved in different sections to motivate users to improve their overall performance.
Share	Incentives for users to share information, encouraging collaboration and knowledge exchange among participants.
Social interactivity	Opportunities for customers to interact with others through electronic platforms.
Task	A menu outlining specific banking-related activities for users to complete.
Timer	Timed elements included in gameplay.
Virtual reward	Virtual gifts, such as virtual money, that customers can use within the banking system or collect.

Appendix 2

Table 8. Summary of database queries

Database	Queries
Google Scholar	allintitle: (Gamification OR Gamified OR Game OR Games OR Gaming) ("Mobile Banking" OR "M Banking" OR "Banking App" OR "Banking Apps" OR "Banking Application" OR "Banking Applications" OR "Digital Banking")
Scopus	TITLE ((Gamification OR Gamified OR Game OR Games OR Gaming) AND ("Mobile Banking" OR "M-Banking" OR "Banking App" OR "Banking Apps" OR "Banking Application" OR "Banking Applications" OR "Digital Banking"))
IEEE Xplore	("Document Title":"Mobile Banking" OR "Document Title":"M-Banking" OR "Document Title":"Banking App" OR "Document Title":"Banking Apps" OR "Document Title":"Banking Application" OR "Document Title":"Banking Applications" OR "Document Title":"Digital Banking") AND ("Document

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Database	**Queries**
	Title":"Gamification" OR "Document Title":"Gamified" OR "Document Title":"Game" OR "Document Title":"Games" OR "Document Title":"Gaming")
ScienceDirect	As ScienceDirect imposes a limit on the length of search queries, we divided the search into seven separate queries to ensure that the scope was fully covered. ("Mobile Banking" OR "M-Banking" OR "Banking App" OR "Banking Apps" OR "Banking Application" OR "Banking Applications") AND (Gamification) ("Mobile Banking" OR "M-Banking" OR "Banking App" OR "Banking Apps" OR "Banking Application" OR "Banking Applications") AND (Gamified) ("Mobile Banking" OR "M-Banking" OR "Banking App" OR "Banking Apps" OR "Banking Application" OR "Banking Applications") AND (Game) ("Mobile Banking" OR "M-Banking" OR "Banking App" OR "Banking Apps" OR "Banking Application" OR "Banking Applications") AND (Games) ("Mobile Banking" OR "M-Banking" OR "Banking App" OR "Banking Apps" OR "Banking Application" OR "Banking Applications") AND (Gaming) ("Mobile Banking" OR "M-Banking" OR "Banking App" OR "Banking Apps" OR "Banking Application" OR "Banking Applications") AND (Gaming) ("Digital Banking") AND (Gamification OR Gamified OR Game OR Games OR Gaming)
JSTOR	((ti:"Gamification OR Gamified OR Game OR Games OR Gaming") AND (ti:""Mobile Banking" OR "M-Banking" OR "Banking App" OR "Banking Apps" OR "Banking Application" OR "Banking Applications" OR "Digital Banking"))
ACM Digital Library	Title:(Gamification OR Gamified OR Game OR Games OR Gaming) AND Title:("Mobile Banking" OR "M-Banking" OR "Banking App" OR "Banking Apps" OR "Banking Application" OR "Banking Applications" OR "Digital Banking")

Semantic Service Level Agreements

Improving Smart Contract Usability in the Service-Based Digital Economy

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Abstract: Service Level Agreements (SLAs) are formal contracts that define the expected level of service between a provider and a consumer. They are utilised in various domains, including cloud computing and IoT. With the advent of blockchain technology, SLAs have been integrated into smart contracts – self-executing contracts with terms directly written into code. However, unlike traditional cloud and IoT services, the functions of smart contracts on the blockchain are typically not monitored through SLAs, leaving potential violations undetected during execution. In a digital economy context, where efficiency, transparency, and trust are paramount, this gap poses significant challenges. Existing SLAs often lack semantic depth, being simple documents without enrichment or flexibility. This paper proposes a semantic SLA for smart contracts, enhancing the traditional SLA with ontological descriptions. This work aims to provide a more robust and flexible SLA model (SC-SLA) for monitoring smart contracts, ultimately enhancing trust and performance in blockchain-based systems. By addressing these issues, the proposed model contributes to the broader goal of optimising service delivery and reliability in the digital economy. The paper evaluates the quality of the ontology, validates the effectiveness of this approach through a detailed ontology, and demonstrates its application with a specific use case.

Keywords: SLA, Ontology, Service-based Digital Economy, Smart Contract, Blockchain

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Introduction

A Service Level Agreement (SLA) is a contractual method established between two or more parties, typically outlining the rights and obligations related to the agreed-upon Service Level Objectives (SLOs) (Alzubaidi *et al.*, 2020). SLAs typically define the minimum Quality of Service (QoS) levels that must be maintained, as well as the penalties and remedies that will be implemented in the event of a violation. Although SLAs are designed to ensure that the rights of all parties are protected, they often fall short of their purpose. Common issues include the difficulty of proving that a violation has occurred, as well as the tedious processes that customers face when filing complaints. Additionally, providers might contest these complaints, leading to significant friction between contractual parties, introducing inefficiencies, and being prone to errors.

In the context of the digital economy, where agility, trust, and transparency are critical, these challenges can undermine service delivery and customer satisfaction. In recent years, the emergence of smart contracts has been proposed as an automated solution to guarantee the enforcement of agreed terms in SLAs. A smart contract is a self-executing computer program deployed on a blockchain, designed to automatically execute pre-defined actions when certain conditions are met. Researchers have begun exploring the integration of smart contracts with SLAs, particularly within domains like cloud computing (Labidi *et al.*, 2018). This integration promises to enhance the security and immutability of SLA terms by leveraging blockchain's decentralised nature, which is increasingly vital in the digital economy. However, despite these advancements, the integration of SLAs within pure blockchain-based smart contracts remains an emerging area of research with significant challenges.

Previous studies have introduced various frameworks that incorporate SLAs into blockchain ecosystems. For example, some frameworks convert traditional SLA documents into smart contracts deployed on the blockchain (Uriarte *et al.*, 2018). However, these frameworks often rely on basic, static SLA documents without any semantic enrichment or flexibility. Additionally, while ontologies have been widely used to represent domain-specific rules in various technologies, such as cloud computing and IoT, their integration into blockchain and smart contracts is limited. Ontologies offer a formal way to describe domain knowledge, providing structured representations of concepts and relationships. Some studies have explored the potential of using ontologies in blockchain environments. For instance, researchers have developed ontologies to represent the Solidity smart contract language or to automatically generate smart contracts based on encoded constraints (Choudhury *et al.*, 2018). However, these efforts have primarily focused on the blockchain ecosystem or the smart contract language itself, rather than on the SLAs that govern these contracts. Despite advances

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in SLA management and smart contract automation, no existing research has specifically addressed semantic SLA ontology for blockchain-based smart contracts. This gap in the literature motivates our research to harness the benefits of ontologies to develop semantic SLAs for smart contracts. Therefore, this work enhances smart contract flexibility, ensures automated SLA monitoring, and enables real-time detection of SLA violations. By integrating a structured ontology, it provides a more comprehensive, intelligent, and enforceable SLA framework for smart contracts.

Our goal is to enrich SLAs for smart contracts with semantic notions, making them more flexible and capable of capturing customer expectations in a structured, machine-readable format. This research paper contributes to the field by proposing and evaluating an ontology-based SLA model (SC-SLA) for smart contracts, thereby enhancing service delivery and trust in the digital economy. We also present a practical use case to demonstrate the effectiveness of this approach in modelling and managing SLAs within blockchain environments.

The rest of this paper is organised as follows: Section 2 presents the background dealing with blockchain, smart contracts, and ontologies. Section 3 summarises some related works. Section 4 presents an overview of the proposed approach and its evaluation. Section 5 presents the monitoring rules for a use case study. Section 6 compares the proposed approach with existing works. Finally, Section 7 concludes the paper and gives future work directions.

Background

This section provides definitions and explanations of key concepts, terms, or theories that are essential for understanding this paper topic.

Service Level Agreement

A Service Level Agreement (SLA) is the main document that guarantees the QoS. It is defined as the contract between two or more parties generally a service consumer and a service provider. The SLA includes Service Level Objectives (SLOs), specifies the quantitative values of QoS metrics. An SLO ensures that an SLA parameter will be delivered within a certain amount of time. It also defines the objectives to be fulfilled and penalties if expected QoS metrics are not met by the service provider (Khan *et al.*, 2022). The details of an SLA document differ from one another depending on the use case. Nonetheless, there are essential components that every SLA should contain such as the Contracting Parties, Services Definition and Obligations (Binu & Gangadhar, 2014).

Blockchain and smart contract

The first appearance of the blockchain was in 2008 with Satoshi Nakamoto. Blockchain is a decentralised and immutable ledger (Matulevicius *et al.*, 2022). It is grouped as a peer-to-peer computer network. It can sustain confidence in a distributed system. Blockchain is based on the consensus mechanisms to validate each transaction. For each blockchain transaction an immutable record is generated, based on cryptographic hash functions (Ranchal & Choudhury, 2020). Thus, the blockchain forms a chain of blocks, each block is linked to the previous one via a unique cryptographic hash. In 1997, Szabo proposed the concept of smart contract. It is known as pieces of computer code stored in the blockchain that is autonomously enforced without the intervention of a trusted third party. Smart contract operates by executing statement (if/when…then). The blockchain nodes are charged to execute the specific tasks or operations when the conditions are verified (Souei *et al.*, 2021).

Ontology and semantic rules

An ontology serves as a structured representation of concepts and relationships within a specific domain (Uriarte *et al.*, 2018). It is a conceptualisation and representation of domain knowledge to be a machine-readable format (Tartir *et al.*, 2010). It encompasses the formal naming, definition, and categorisation of various entities, properties and data as well as the different relationships between these concepts. Consequently, ontologies do not only facilitate the creation of a common and reusable knowledge representation but also contribute to expanding knowledge within the domain. Ontologies have many advantages such as first, ontology reuse sharing knowledge and data validation.

There are several ways to express ontologies, but the Web Ontology Language (OWL) is the most used. OWL is a language of the semantic web. It is based on the Description Logic (DL) to form a complex and rich knowledge pertaining to various entities such as concepts, a set of entities and their interconnections. The OWL is based on a Resource Descriptive Framework (RDF) to establish a metadata model, thereby enabling the construction of a coherent and intelligible semantic infrastructure (Matulevicius *et al.*, 2022). The OWL offers a rather large collection of class constructors, but among its shortcoming is its lack of expressiveness. It could not describe composite properties' relationships (Tartir *et al.*, 2010). To overcome this limit, a rule language was designed which is the Semantic Web Rule Language (SWRL). SWRL is a rule language designed to expand the expressiveness of OWL. Its strength lies in the ability to deduce rules from OWL concepts (Choudhury *et al.*, 2018). An SWRL rule contains two main parts: the antecedent and the consequent. The antecedent specifies the requirements that must be satisfied through the combination of one or more atoms. The consequent, on the other hand, indicates the fact that may occur if the antecedent criteria are me. When SWRL rules are combined with an OWL ontology (Tartir *et al.*, 2010), a knowledge base is created that may be utilised for reasoning or inference.

Ontology evaluation tools

The evaluation of an ontology is an important step to ensure its quality, relevance, and effectiveness in different contexts. For instance, throughout the process of developing an ontology, the evaluation is crucial to ensure that what is created satisfies the application needs (Tartir *et al.*, 2010). With the increase in the number of ontologies, there have been efforts to examine the various methods and tools used for its evaluation. Many methods to evaluate ontologies were described in Gomez & Perez (2004) and McDaniel *et al.* (2018). They are used to check if there are structural errors in the ontology. Among ontology evaluation efforts is the use of tools, which are automated and available such as OOPS! and Protégé. For Protégé there is an extension module or plugin used to check the ontology correctness. The most known Reasoner are Hermit, PELLET and Fact++ (Zorgati *et al.*, 2020). In OWL ontology, when two objects are identified as distinct from one another (owl: differentFrom) the ontology cannot assert that they are identical (owl: sameAs). On the other hand, when two classes are considered disjoint (owl: disjointWith) in an ontology, it means that the ontology cannot contain statements indicating that an instance belongs to both classes.

Related works

Blockchain is a relatively new technology that has quickly gained significant traction and widespread adoption. Due to the novelty of this technology, there is still a significant amount of work to be done before it reaches full maturity (Hamdi *et al.*, 2022). While recent works have addressed several aspects of this technology, our paper concentrates specifically on research related to SLA management and examines the utilisation of ontologies in blockchain. Therefore, the related works of this paper is divided into two subsections. The first part gives an overview of SLA management using blockchain-based smart contracts. The second part provides a description of recent research pertaining to the application of ontology in blockchain and smart contracts.

Within the existing literature, several works have focused on SLA management across various domains. They exploit blockchain technology and smart contracts to enhance SLA management process. In the work (Alzubaidi *et al.*, 2020) a decentralised blockchain-based solution was suggested to determine SLA compliance and enforce penalties in cloud-based Internet of Things (IoT) applications. The authors (Kochovski *et al.*, 2020) proposed a novel approach for SLA management using smart contract in the federated Edge-to-Cloud computing environments. This solution enables the control of the QoS criteria specified in the SLA. The authors have implemented a system called Markov Decision Process (MDP) used for automating the decision-making and based on the likelihood of reaching a high QoS. Aryal *et al.* (2024), proposed a blockchain-based solution for managing the SLA lifecycle in cellular networks. This approach automates SLA negotiation, violation monitoring and compensation mechanism using smart contracts and oracles. Javed & Mangues-Bafalluy (2024) proposed a blockchain based solution to manage SLAs across multiple providers to lease and sell resources in 6G networks. The proposed solution uses Chainlink and smart contracts to monitor SLAs and calculate penalty. The solution was deployed on Ethereum and Polygon blockchains. Booth *et al.* (2024) used blockchain technology and smart contract to monitor IoT systems. The authors developed a Java library to convert an end-to-end IoT SLA into smart contract. This smart contract is deployed on Hyper ledger Fabric consortium to detect any SLA violation.

This study eliminated third trust parties and highlighted the advantages of blockchain's distributed nature and immutability. However, none of the approaches that have been provided offer a formal description of the SLA, which is essential for automation and reasoning. The common idea within these different research works was the design and the implementation of an SLA management prototype using blockchain based smart contract. After the negotiation phase, the SLA is converted into a smart contract. Then it is deployed in the blockchain. The SLA compliance level is ensured by monitoring solution to perform the automatic compensation of the consumer by the smart contract in case of SLA violation. Now, this topic is still under research and the state of the art in this field suffers from some limitations. We have noticed that for each solution, only one criterion of QoS is studied. Moreover, the most tested criterion is availability. Furthermore, the proposed approaches were studied as a simulation and no evaluation has been carried out. All current research has focused on using blockchain and smart contracts to manage services in other domains, such as cloud computing and IoT. However, there is no research that describes service level agreements (SLAs) specifically for smart contracts themselves.

There is, indeed, limited research on the integration and advancement of semantics in blockchain and smart contracts. Iqbal *et al.* (2024) proposed two models for security risk management in traditional and blockchain-based applications. The first is a blockchain-based reference model to identify and organise security threats. The second is an ontology-driven reference framework to represent and structure security risks, for better understanding and semantic interoperability between different blockchains. This approach was evaluated through expert opinions and Colored Petri Nets simulations to check its practical use.

Cano-Benito *et al.* (2021) developed an ontology for the Solidity smart contract language, aligning it with standard ontologies like Besancon *et al.* (2022). The goal of this ontology is to fully characterise the Solidity language to facilitate interoperability and take advantages of semantic web technologies. The ontology was evaluated by analysing the published contracts in Ethereum, verifying coverage of language characteristics and accuracy.

The paper used two main tools to evaluate the ontology: OOPS! for finding pitfalls and the Hermit Reasoner for verifying validity. By identifying pitfalls like disjoint elements and missing domain/range in properties, OOPS! helped to improve the ontology. The Hermit Reasoner confirmed the ontology's consistency with no errors found, ensuring its quality and correctness. Baqa *et al.* (2019) presented a Semantic Smart Contracts, which utilised Semantic Web technologies to improve the search functionality of decentralised IoT services and applications running on Blockchain platforms. Through the integration of RESTful, semantic web technologies and the expansion of the OWL-S service ontology with domain-specific terms. The suggested approach facilitates the browsing, indexing, and annotation of Smart Contracts to enhance resource discovery within Blockchain operations. Besancon *et al.* (2022) proposed an ontology using the Decentralized Blockchain Applications terminology. The goal of this ontology is to formalise DApps in order to avoid ambiguities between these applications and decentralised applications that do not integrate the blockchain technology.

Some related studies utilised ontology to describe the blockchain ecosystem, and others focused on auto generating, describing, representing, indexing, and annotation of Smart Contracts. Based on literature, ontologies are used to semantically define the various concepts required within a given domain. On the other hand, due to the attractive characteristics of blockchain, previous studies were carried out to facilitate SLA management using blockchain-based smart contracts. However, for all related works presented above there are some limitations. The presented solutions entirely focused on describing SLA management in other fields (i.e. IoT, cloud) and there was no research on pure blockchain. In addition, the authors have utilised a basic static SLA document without incorporating any additional enhancement or enrichment to its core content. There was a lack of clear presentation regarding the SLA document. The integration of semantics using ontologies in blockchain and smart contracts is restricted to describing blockchain (Besancon *et al.*, 2022) or solidity SC (Cano-Benito *et al.*, 2021). None of them has addressed the notion of smart contract SLA and smart contract QoS. As far as we know, no previous research has investigated the ontology to describe SLA for smart contracts. A new approach is necessary to address these gaps in the literature. Driven by the benefits that ontologies offer in describing a domain through semantic representations, as well as the benefits and features of SLAs, our approach involves merging these two concepts to create a semantic SLA for smart contracts. This paper highlights the importance of using ontology to describe an SLA for smart contracts (SC-SLA) deployed on the blockchain. To show the effectiveness of the proposed approach, we present a use case study.

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SLA ontology model for smart contract (SC-SLA)

As outlined in Section 2, Ontologies play a crucial role in describing the knowledge within a specific domain, consisting of a collection of concepts and their relationships (Choudhury *et al.*, 2018). An ontology can be created using the Web Ontology Language (OWL). After identifying the concepts or entities within a specific domain, they are then defined as OWL classes. The relationship between entities (two individuals) is represented as ObjectProperty, while the relationship between individual (instance of class) and literals (data value) is represented as DataProperty (Choudhury *et al.*, 2018). In this paper, we define an ontology to model SLA for smart contract (SC-SLA). We followed the guidelines outlined by MethOntology (Fernandez *et al.*, 1997). It is recognised as a leading methodology in the creation of ontologies. It revolves around four key stages: specification, conceptualisation, formalisation, and validation.

SC-SLA specification

In order to generate an ontology specification document, we conducted various sub-activities. This phase included defining the scope of the ontology, conducting domain analysis, identifying key concepts, searching for existing ontologies, and acquiring knowledge (Labidi *et al.*, 2016). Our contribution in this paper is to define a comprehensive SLA ontology model for smart contracts (SC-SLA). We want to enhance the representation of SC-SLA with the semantic depth of ontology, to create a comprehensible and readable model for both machine and smart contract parties despite their varying levels of knowledge. Furthermore, we aimed to monitor the agreed-upon SLOs in the SC-SLA and to detect any violations through the utilisation of reasoning techniques and the inference rules outlined in the ontology. Thus, customers and providers can protect their rights and seek compensation from each other in case of any detected violations. We studied the efficiency of the ontology in modelling SLA terms to make it more understandable. According to Labidi *et al.* (2018) a basic SLA document should contain 'Terms' and 'Parties', but in Schweizer (2019) this document is composed of 'Parties', 'Service Definition', and 'Obligations'. In the work presented by Labidi *et al.* (2016) an SLACloud is linked to three concepts 'Terms', 'Parties', and 'Context'. At present, there is no universally accepted ontological SLA format available (Peoples *et al.*, 2021).

SC-SLA conceptualisation and Formalisation

The initial phase involves the establishment of the fundamental concepts within our ontology. We are based on the available documents in the literature to design our model called SC-SLA. Specifically, the proposed ontology SC-SLA encompasses essential concepts that are crucial for both defining and monitoring objectives. Based on the existing ontology proposed in Labidi *et al.* (2016), we define our SC-SLA ontology for representing the SLA that controls smart contracts. We use most of the concepts proposed by Labidi *et al.* (2016) with the customisation of the model to be suitable for the smart contract. Through our SC-SLA ontology, we describe the necessary concepts and properties for the representation of SLA for smart contract. The SC-SLA concept was defined as the root of this model. It is composed of three parts: Parties, Terms and Obligations as illustrated by the Figure 1 below:

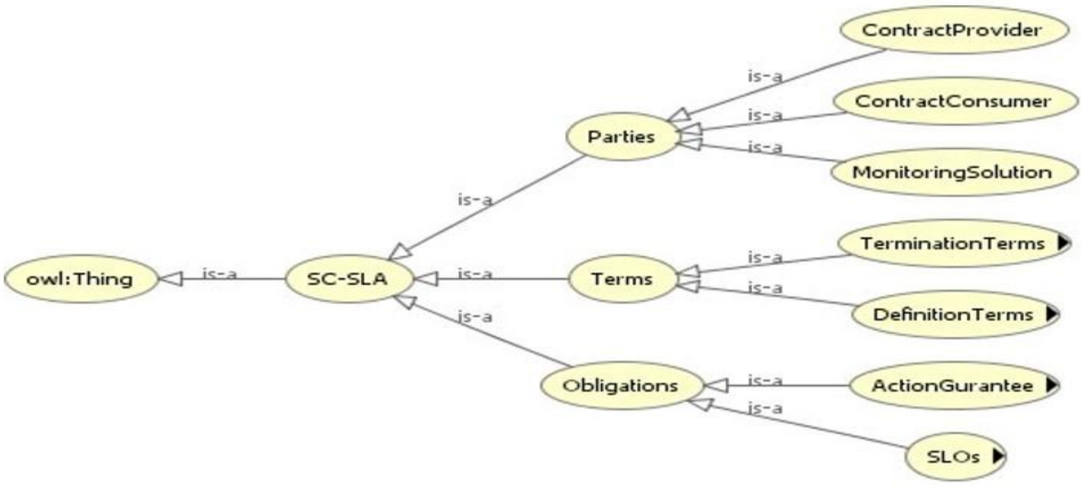

Figure 1: Visual representation of SC-SLA ontology

Parties represent the signed members, which include the ContractProvider, the ContractConsumer, and the MonitoringSolution. Terms contains 'Definition and Termination Terms' (Labidi et al, 2018). 'Definition Terms' contains a list of smart contract parameters such as Functions, ApplicationDomain, and validityPeriod. 'Termination Terms' shows how a SC-SLA is terminated. Firstly, termination occurs when the SC-SLA validity expires which means that the reservation date for the SC-SLA is ended. Secondly, termination may happen when the number of violations exceeds the predefined threshold. Obligations are divided into two main sub-classes, which are SLOs and Action Guarantee. SLOs define the measurable QoS metrics that should be maintained during the period of the contract (Labidi *et al.*, 2018). While Action Guarantee describes penalty specifications in case of violation.

A smart contract is considered as a middleware component responsible for providing a service with certain QoS (Molina-Jimenez, 2018). The QoS in smart contracts may vary based on the use case, the particular application and its requirements. However, there are certain standard metrics used for evaluating QoS in smart contracts which include throughput, latency, response time and cost (Molina-Jimenez, 2018). The throughput represents the number of transactions or operations that are verified by a smart contract per second. The latency represents the duration required for a transaction to be verified and processed. The response

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time represents the duration required to deliver a decision or to answer a request. And the cost represents the financial charges that the involved parties incur for the processing of each operation within the smart contract. There exist additional qualitative aspects of QoS in smart contract that cannot be quantified, such as Security, reliability, scalability and compliance. In the proposed ontology SC-SLA, the QoS of the smart contract are described in the SLOs concept. To make the SLOs more flexible allowing users to adjust them based on their needs, they are improved semantically by classifying QoS into two main sub-classes: Global_SLOs and Specific_SLOs (See Figure 2).

Global _SLOs represent the acceptable level of QoS for any smart contract. While Specific_0SLOs are, the specific QoS applied in a specific domain. Depending on the type of smart contract, the Specific_SLOs must be customised. This sub-class of SLOs will be detailed in the next section. To build the ontology we used Protégé 5.5 (Knublauch, 2004) which is the most popular knowledge-based framework and ontology editor. The formalisation of this ontology was accomplished through the utilisation of the W3C Web Ontology Language (OWL2). The OntoGraf plugin assists in the automatic organisation of the ontology's structure, showcasing all the relationships defined through the object properties. The next section will focus on the instantiation of the ontology.

Figure 2: Visual representation of SLOs branch

SC-SLA validation

In this section, we are interested in the validation of the ontology of the SC-SLA. The aim is to check whether the ontology is correctly constructed or not, and whether it effectively represents real-world scenarios. For this purpose, we used the Reasoner Pellet in Protégé 5.5

as shown in Figure 3. When the Reasoner is running, and no error or warning is displayed, this result reflects the coherence of our ontology. Furthermore, for the validation of the ontology and the assessment of its quality, we used the logical and rule-based approaches. We apply rules to detect conflicts. These rules are built in the ontology languages to determine the completeness of reasoning and inference. There are also several other kinds of ontology evaluation techniques that can be categorised into four approaches: Golden standard, Application based, Human assessment, and Data driven (Sekandar, 2018). After reviewing the various ontology evaluation approaches, we focus on Data driven ontology evaluation which uses a recent approach that measures the ontology quality based on the theory of semiotics (McDaniel *et al.*, 2018).

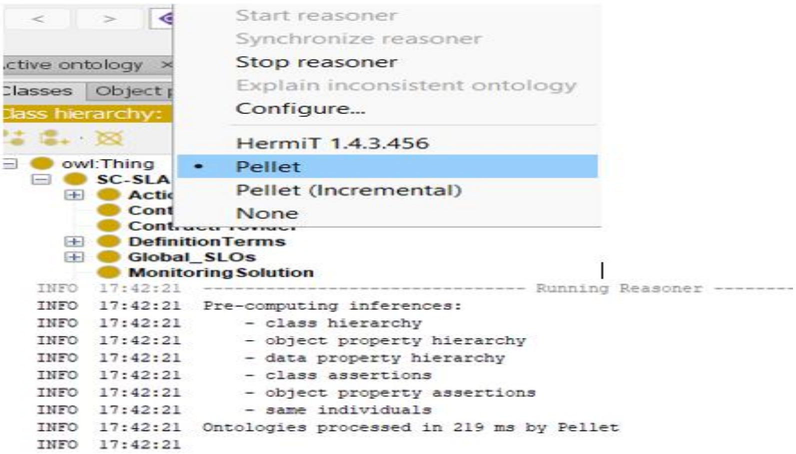

Figure 3: Pellet Reasoner validation result

This theory represents the study of meaning-making and sign process. This evaluation technique is organised into three layers: syntactic, semantic, and pragmatic. We present in the Table 1 below some of the ontology metrics from Protégé that will be used to evaluate the SC-SLA ontology.

Table 1: Ontology metrics from Protégé

Metrics	Axiom	Logical axiom	Declaration axiom	Object property	Class count	Data property	Individual count	Class Assertion
Value	436	313	83	16	33	11	24	60

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Syntactic layer

The Syntactic layer (S) is used to measure the ontology's quality based on its formulation and structure (Burton *et al.*, 2004). Two specific metrics are used: Lawfulness and Richness

- **Lawfulness**: is the degree to which an ontology languages rules have been complied. To calculate Lawfulness (SL) (see equation (a)): we consider X as the total syntactical rules, Xb as the total violated rules and NS as the statements number in the ontology.

Then $SL = \frac{Xb}{NS}$ (a)

Where $SN = Logicalaxiomcount + Declarationaxiomscount$ (b)

Based on the result displayed by the Reasoner Pellet, there is no syntactic violations or inconsistencies; it indicates that the ontology completely complies with the syntactic rules established by the ontology language. So $Xb = 0$

$$SL = \frac{0}{396} = 0$$

- **Richness**: is the extent of the use of ontology language features in an ontology (e.g., whether it includes only terms or both terms and axioms). To calculate Richness (SR)

We consider Y as the total syntactical features available in ontology language, and Z as the total syntactical features used in this ontology.

In Protégé, there are $Y = 46$ syntactical features. We used $Z = 42$ syntactical features

Then $SR = \frac{Z}{Y} = \frac{42}{46} = 0{,}913$

The obtained value of SR is 0,913 means that 90 per cent of the syntactic features in OWL available have been used. This result shows a relatively rich use of syntactic constructs.

The overall Syntactic layer quality is given by following equation:

$S = bs1 * SL + bs2 * SR = (0.5 * 0) + (0.5 * 0.913) = 0{,}4565$ (c)

Semantic layer

The Semantic layer (E) is used to evaluate the terms meaning in the ontology library (Burton-Jones, 2005). Three specific metrics are used: interpretability, consistency, and clarity.

- **Interpretability** *(EI)*: represents the terms meaning (see equation (d)). We consider C as the total number of used terms to define properties and classes in the ontology, and W as the number of terms that have a sense listed in WordNet. With our ontology we verified about W=55 words in the WordNet (WordNet Online).

Then $EI = \frac{W}{C}$ (d)

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Where $C = ClassCount + ObjectPropertyCount + DataPropertyCount$ (e)

$C = 33 + 16 + 11 = 60 \rightarrow EI = \frac{55}{60} = 0{,}916$

- **Consistency** *(EC):* we consider I as the number of inconsistent meaning terms in the ontology, and C is calculated in the equation (e). In this ontology, $I = 0$

  Therefore $EC = \frac{I}{C}$ (f) $\rightarrow$ $EC = 0$

This result indicates that all terms are used consistently within this ontology.

- **Clarity** *(EA)* is used to evaluate the degree of ambiguity in the ontology. It is given by equation (g).

EA= $\frac{A}{C}$ (g)

Where A is the number of senses used for all terms in the ontology. For each term we count the number of word senses in WordNet. We found that about 20 terms with one sense for each and about 35 terms with two senses.

$$EA = \frac{90}{60} = 1{,}5$$

This result shows that each term has only one clear meaning, on average. This indicates that the ontology has low ambiguity, so it has a high clarity.

The Semantic quality is given by the equation (h).

$E = be1 * EI + be2 * EA + be3 * EC = (0{,}5 * 0{,}916) + (0{,}3 * 1{,}5) = 0{,}908$ (h)

Pragmatic layer

The pragmatic layer (P) refers to the use of ontology by users (Burton *et al.*, 2004). It highlights the meaning-making practical aspects in real word. Three metrics are used

- **Comprehensiveness** *(PO)* is given by equation (i), where C is the total number of classes and properties in ontology and V is the average value for C in the entire library.
- **Accuracy** *(PU)* is given by equation (j), where F is the false statements number and NS is the number of statements.
- **Relevance** *(PR)* is given by equation (k), NS is the number of statements and R is the number of syntax pertinent for a user within NS (it depends on the goal of the ontology).

$PO = \frac{C}{V} = \frac{60}{100} = 0{,}6$ (i) , $PU = \frac{F}{NS} = \frac{12}{436} = 0{,}0275$ (j) , $PR = \frac{R}{NS} = \frac{230}{436} = 0{,}527$ (k)

To calculate the Pragmatic quality we use equation (k), where: for comprehensiveness (bp1=0.5)/ for accuracy (bp2=0.2) / for relevance (bp3=0.3)

$$P = bp1 * PO + bp2 * PU + bp3 * PR = (0{,}6 * 0{,}5) + (0{,}0275 * 0{,}2) + (0{,}527 * 0{,}3) = \mathit{0.4636} \text{ (l)}$$

Result of the ontology semiotic evaluation

We present in this section the result of the different measurements obtained based on the semiotic theory of the SC-SLA ontology

$$OntologyQuality = \frac{S + E + P}{3} = \frac{0{,}4565 + 0{,}908 + 0.4636}{3} = 0{,}6094$$

According to Burton *et al.* (2004), the lowest value of ontology quality is 0.02, the mean value is 0.56 and the highest value is 0.90. Based on the found result 0, 6094, our ontology quality is in the range of a moderate to good quality of ontology.

Monitoring Rules in the SC-SLA of a car rent example

During our monitoring process, we leverage the power of inference, known as one of the ontology's most potent features, for its effectiveness and efficiency. Based on the inferential reasoning we can identify violations. To fulfil this purpose, we use the Semantic Web Rule Language (SWRL) in combination with the inference engine. This language enables the SC-SLA monitoring process and decision making in case of violations. SWRL rules are formulated to express obligations outlined in the SC-SLA. In this section, we present an SC-SLA instantiation rules example of a car rent between two parties. For the sake of simplicity, we address only one scenario where the consumer commits violations and we present in this example, only two QoS to monitor the smart contract. First, the smart contract must respond in a maximum response time less than 3 seconds. The maximum speed allowed should be less than 120 km/h. Figure 4 presents an extract of the proposed SC-SLA ontology instantiation example.

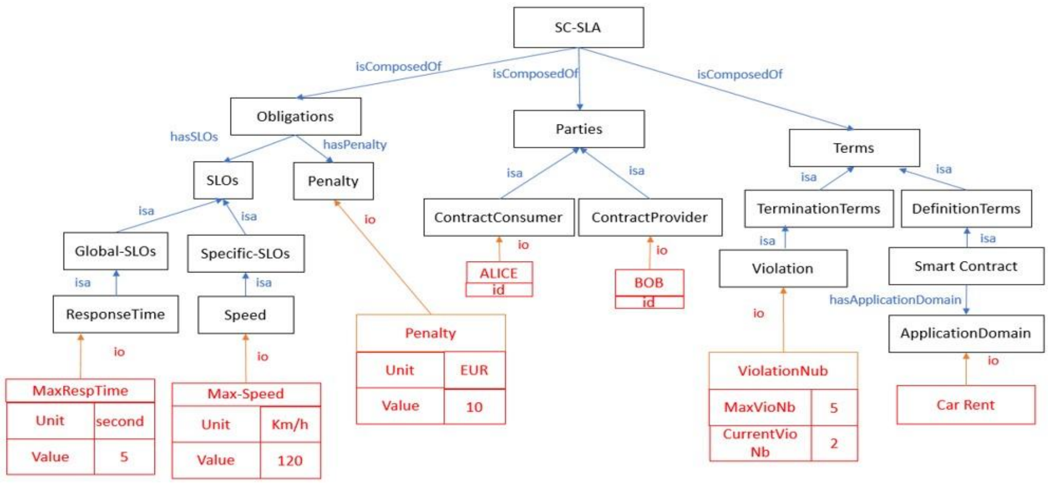

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Figure 4: SC-SLA rules instantiation example

For better understanding of the rules in the SC-SLA instantiation example, we present in Figure 5 a flow diagram for the car rent. We describe in the flow diagram three rules of Specific-SLOs predefined in the SC-SLA document. First, when the contract consumer start using the car, we apply the monitoring rules agreed in the SC-SLA. The aim of checking SLOs is to verify whether any violations have occurred. Each unmet SLO is considered a violation. The number of violations is then compared to the maximum number allowed under the SC-SLA. This step determines whether a penalty should be applied. For example, we detail the rule of speed written in SWRL within Protégé.

Rule 1: Detecting Speed violations and triggering guarantee actions for ContractProvider.

Speed(?D) ∧ SpValue(?D, ?y)∧ swrlb : greaterThan(?y, ?MaxSpV alue)→actions:notifyViolation("SpValue", "not respected", ?c, ?z, ?PenaltyV alue) ∧ sqwrl:select(?PenaltyV alue)

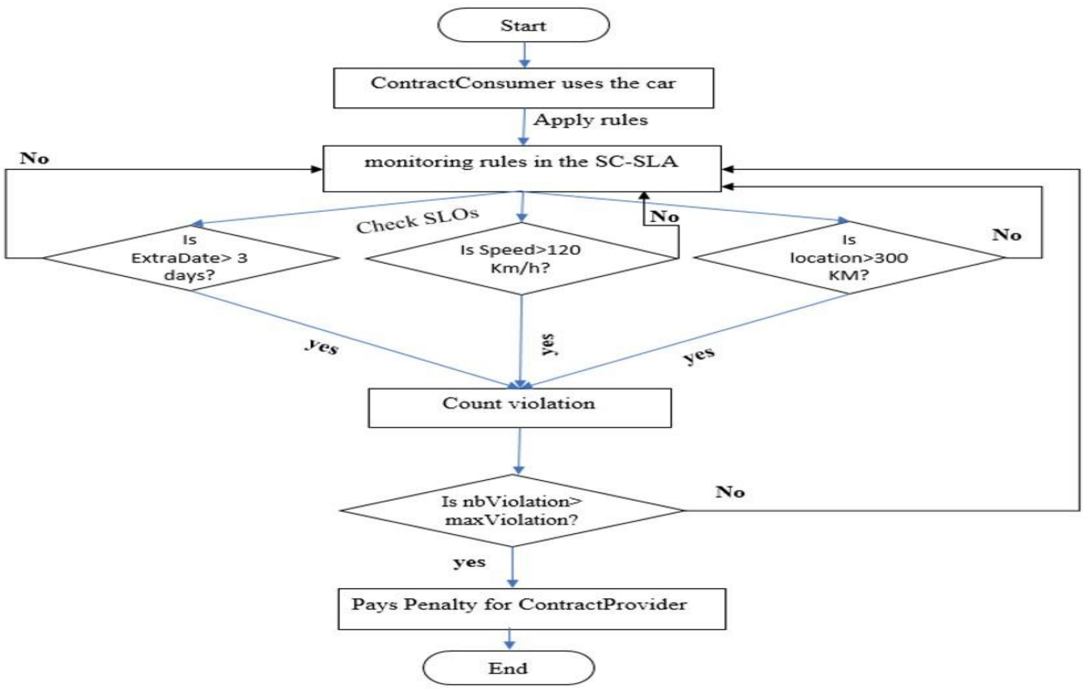

Figure 5: Flow diagram of car rent instance

In this example, car renter must respect the SLOs mentioned above. However, the car owner should monitor the SC-SLA by detecting violations. The SC-SLA ontology is used as a knowledge base to facilitate the monitoring task. Therefore, our ontology is implemented through the Jena API. We first load the SC-SLA.OWL model with Apache Jena in the Eclipse environment. Then we apply OWL reasoning, provided by Jena Reasoner. Once we have applied reasoning, we can query the model using SPARQL. A SPARQL query is defined to query the triples in the inferred model, which includes the inferences based on SWRL rules. The query is executed on the inferred model, and the results are displayed. The results of the

SPARQL query can be examined to verify if the SWRL rules have been applied correctly. In this example, we instantiate the first SWRL rule, we check if the value of the maximum speed is greater than or equal to 120 km/h. Following the execution of this rule through the inference engine, a violation is detected once we give a speed value greater than 120 km/h. Therefore, our SC-SLA monitoring prototype instantly sends a notification to the involved parties containing details about this violation. This message, illustrated in Figure 6, indicates the maximum speed value causing the violation.

Figure 6: Notification for violation detection

Once the SC-SLA is deployed on the Ethereum blockchain, the monitoring of the predefined rules is initiated. If a violation is detected through SWRL reasoning, an event is triggered to automatically enforce penalties. In this case, when the renter exceeds the agreed speed limit, the smart contract can automatically calculate and deduct a fine from the renter deposit. The penalty value calculation is explicitly defined in the SC-SLA based on well-structured SWRL rules. Figure 7 shows an extract of the Solidity SC-SLA smart contract that calls the function applyPenalty(). This function first deducts a fine from the renter`s deposit and then emits an event called PenaltyApplied(). In the case of a severe violation, it may lead to a contract termination by calling terminateContract().

```
function applyPenalty(uint speedLimit, uint actualSpeed) external onlyOwner {    infinite gas
    require(isActive, "Contract is not active");

    if (actualSpeed > speedLimit) {
        uint penalty = (actualSpeed - speedLimit) * 10; // Example: $10 per km/h over the limit
        require(deposit >= penalty, "Not enough deposit to cover penalty");

        deposit -= penalty;
        payable(owner).transfer(penalty);

        emit PenaltyApplied(renter, penalty, "Speed limit exceeded");

        // If severe violation, terminate contract
        if (actualSpeed > speedLimit + 50) { // Example threshold
            terminateContract("Severe violation detected");
```

Figure 7: Extract from the solidity SC for the function applyPenalty()

Comparing existing works and our approach

We detail in this section a comparison study between our proposed approach and the different existing solutions. Table 2 presents a comparison with existing SLA management approaches. To have an accurate comparison we define the following criteria: The domain of application. The SLA type which represents the structure of the SLA and how it is managed. SLA management automation which describes the automation level (partial, fully automated). Metadata Richness refers to level of SLA data description. Violation Detection refers to the mechanism or tools used to detect a violation. Penalty Enforcement indicates whether the solution gives details about penalty mechanisms or not. The methods discussed in the related work section have been analysed against several criteria to highlight their limitations and position the proposed contribution within this context. The type of SLA is a fundamental criterion. Most approaches, rely on static SLAs with fixed parameters, which limits their adaptability to evolving requirements or user-specific needs. The metadata richness also highlights a limited descriptive metadata without semantic annotations. All the studied papers focus on the SLA management mechanisms using blockchain for transparency, smart contracts for automation and enforcement. They are concerned with how the SLA is handled, not the precise format of the SLA document itself. A key innovation of our work is the use of ontologies to enrich SLAs.

Table 2: Comparison with existing SLA management approaches

Ref	**Domain**	**SLA Type**	**SLA management automation**	**Metadata Richness**	**Violation detection**	**Penalty Enforcement**
(Alzubaidi *et al.*, 2020)	Cloud based IoT	Static	Partial	Low	Monitoring Agent	Yes
(Kochovski *et al.*, 2020)	Edge to cloud	Static	Fully automated	Low	Monitoring System	No
(Booth *et al.*, 2024)	IoT systems	Static	Partial	Low	Smart contract	No
(Aryal *et al.*, 2024)	Cellular networks	Static	Fully automated	Low	Oracle based on the requests	yes
(Javed Mangues Bafalluy, 2024)	6G networks	Static	Fully automated	Low	Chainlink with smart contract	yes
Proposed approach	Pure blockchain	Semantic	Fully automated	High	Rule based /Smart contract	yes

The proposed SC-SLA offers the benefits of semantic richness, clarity, flexibility, interoperability, and machine-readability. The violation detection method is another key aspect. While some works, including Booth *et al.* (2024), and Alzubaidi *et al.* (2020), employ automated mechanisms, these are often limited to predefined scenarios and lack advanced capabilities to handle complex violations. The proposed contribution addresses this by employing formal rule-based detection (SWRL) integrated with ontology, enabling accurate and dynamic violation identification and penalty enforcement.

Table 3 presents a comparison study between our proposed approach and the different existing works based on ontology. To make an accurate comparison, we define three criteria: Ontology methodology that represents the followed methodology to create the ontology model, Ontology validation/ evaluation describes the tools or methods used for evaluation, and testing method which indicates the ontology evaluation/testing method. Three criteria were used to analyse existing ontology-based solutions, highlighting their limitations. The methodology followed to create any ontology is an important criterion. Most approaches such as Iqbal *et al.* (2024) and Besancon *et al.* (2022) did not address how they created their ontology however, the proposed approach used the guidelines outlined by MethOntology to build ontologies systematically. This guideline provides a structured framework for the ontologies design, development, and maintenance ensuring consistency, maintainability and re-usability. Another key criterion is the evaluation and validation of the ontology.

Table 3: Comparison with existing works based ontology

Ref	**Ontology creation methodology**	**Ontology validation/ evaluation**	**Testing method**
(Iqbal *et al.*, 2024)	Not addressed	Pellet/ Petri Nets	Use case
(Besancon *et al.*, 2022)	Not addressed	Not addressed	Use case
(Cano_Benito *et al.*, 2021)	Linked Open Terms	OOPS!	Use case
(Baqa *et al.*, 2019)	Not addressed	Not addressed	Use case
Proposed approach	MethOntology	Pellet /Semiotic theory	Use case

Approaches by Baqa *et al.* (2019) and Besancon *et al.* (2022) did not address these two concepts. Thus, without proper validation, an ontology may contain inconsistencies or errors, which lead to incorrect reasoning or misinterpretation. However, the proposed solution evaluated and validated the designed ontology to ensure that it is consistent and accurate.

Conclusions

This paper has addressed the significant gap in the integration of Service Level Agreements (SLAs) with blockchain-based smart contracts by proposing a novel approach: the development of a semantic SLA (SC-SLA) model. Using ontologies, we have enriched traditional SLAs, making them more flexible, dynamic, and capable of capturing customer expectations in a structured, machine-readable format. The research highlights the critical role of ontologies in enhancing the description and management of SLAs within the context of smart contracts. The formal structure of ontology has enabled the negotiation and enforcement of SLAs as well as the automatic monitoring and violation detection. This advancement addresses the shortcomings of current SLA management practices, which often lack semantic depth and flexibility, especially within blockchain technology. Our proposed SC-SLA model has been evaluated through a specific use case, demonstrating its effectiveness in real-world applications.

This approach strengthens the reliability and transparency of smart contracts as well the overall trust between providers and consumers. Despite the progress made, this research opens several avenues for future work. Further research could develop more comprehensive ontologies with rich relationships to describe a wider range of SLA parameters and integrate advanced reasoning techniques, such as Hermit, to further automate SLA management. Additionally, extending the SC-SLA model to support multi-party contracts and more complex service arrangements could significantly broaden its applicability. Furthermore, in the digital economy, scalability issues like query execution times and reasoning efficiency regarding large-scale SLAs need to implement optimised storage and efficient reasoning mechanisms. For protecting sensitive data during the negotiation and enforcement, SLA privacy must be guaranteed by the integration of homomorphic encryption. This encryption mechanism enhances the protection of sensitive SLA clauses while enabling verifiable execution on the blockchain.

References

Alzubaidi, A., Mitra, K., Patel, P., & Solaiman, E. (2020). A blockchain-based approach for assessing compliance with SLA-guaranteed IoT services. IEEE International Conference on Smart Internet of Things (SmartIoT), 213–220. https://doi.org/10.1109/smartiot49966.2020.00039

Aryal, N., Ghaffari, F., Bertin, E., & Crespi, N. (2024). A blockchain-based approach for service level agreement management in cellular network. 15th International Conference on Network of the Future (NoF), 186–194. https://doi.org/10.1109/nof62948.2024.10741405

Baqa, H., Truong, N. B., Crespi, N., Lee, G. M., & Gall, F. L. (2019). Semantic smart contracts for blockchain-based services in the Internet of Things. IEEE 18th International Symposium on Network Computing and Applications (NCA), 1–5. https://doi.org/10.1109/nca.2019.8935016

Besancon, L., Da Silva, C. F., Ghodous, P., & Gelas, J. (2022). A blockchain ontology for DApps development. IEEE Access, 10, 49905–49933. https://doi.org/10.1109/access.2022.3173313

Binu, V., & Gangadhar, N. D. (2014). A cloud computing service level agreement framework with negotiation and secure monitoring. IEEE International Conference on Cloud Computing in Emerging Markets (CCEM), 1–8. https://doi.org/10.1109/ccem.2014.7015474

Booth, A., Alqahtani, A., & Solaiman, E. (2024). IoT monitoring with blockchain: Generating smart contracts from service level agreements. *arXiv* preprint arXiv:2408.15016. https://doi.org/10.1049/PBPC027E_ch7

Burton-Jones, A., Storey, V. C., Sugumaran, V., & Ahluwalia, P. (2004). A semiotic metrics suite for assessing the quality of ontologies. *Data & Knowledge Engineering*, *55*(1), 84–102. https://doi.org/10.1016/j.datak.2004.11.010

Cano-Benito, J., Cimmino, A., & Garcia-Castro, R. (2021). Toward the ontological modeling of smart contracts: A solidity use case. IEEE Access, 9, 140156–140172. https://doi.org/10.1109/access.2021.3115577

Chenchev, I. (2024). Service-to-SLA lifecycle model with blockchain management. AIP Conference Proceedings, 3001, 030013. https://doi.org/10.1063/5.0196325

Choudhury, O., Rudolph, N., Sylla, I., Fairoza, N., & Das, A. (2018). Auto-generation of smart contracts from domain-specific ontologies and semantic rules. IEEE International Conference on Internet of Things (iThings) and IEEE Green Computing and Communications (GreenCom) and IEEE Cyber, Physical and Social Computing (CPSCom) and IEEE Smart Data (SmartData), 963–970. https://doi.org/10.1109/cybermatics_2018.2018.00183

Fernández-López, M., Gómez-Pérez, A., & Juristo, N. (1997). Methontology: From ontological art towards ontological engineering. National Conference on Artificial Intelligence. http://oa.upm.es/5484/

Gómez-Pérez, A. (2004). *Ontology evaluation*. In Springer eBooks (pp. 251–273). Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-540-24750-0_13

Hamdi, N., Hog, C. E., Djemaa, R. B., & Sliman, L. (2022). A survey on SLA management using blockchain based smart contracts. In Lecture notes in networks and systems (pp. 1425–1433). https://doi.org/10.1007/978-3-030-96308-8_132

Iqbal, M., Kormiltsyn, A., Dwivedi, V., & Matulevičius, R. (2024). Blockchain-based ontology driven reference framework for security risk management. *Data & Knowledge Engineering*, *149*, 102257. https://doi.org/10.1016/j.datak.2023.102257

Javed, F., & Mangues-Bafalluy, J. (2024). Blockchain-based SLA management for 6G networks. *Internet Technology Letters*, *7*(3). https://doi.org/10.1002/itl2.472

Khan, K. M., Arshad, J., Iqbal, W., Abdullah, S., & Zaib, H. (2022). Blockchain-enabled real-time SLA monitoring for cloud-hosted services. *Cluster Computing*, *25*(1), 537–559. https://doi.org/10.1007/s10586-021-03416-y

Knublauch, H., Fergerson, R. W., Noy, N. F., & Musen, M. A. (2004). The Protégé OWL plugin: An open development environment for semantic web applications. In Lecture notes in computer science (pp. 229–243). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-540-30475-3_17

Kochovski, P., Stankovski, V., Gec, S., Faticanti, F., Savi, M., Siracusa, D., & Kum, S. (2020). Smart contracts for service-level agreements in edge-to-cloud computing. *Journal of Grid Computing*, *18*(4), 673–690. https://doi.org/10.1007/s10723-020-09534-y

Labidi, T., Mtibaa, A., & Gargouri, F. (2018). Cloud SLA terms analysis based on ontology. *Procedia Computer Science*, *126*, 292–301. https://doi.org/10.1016/j.procs.2018.07.263

Labidi, T., Mtibaa, A., & Brabra, H. (2016). CSLAONTO: A comprehensive ontological SLA model in cloud computing. *Journal on Data Semantics*, *5*(3), 179–193. https://doi.org/10.1007/s13740-016-0070-7

Matulevičius, R., Iqbal, M., Elhadjamor, E. A., Ghannouchi, S. A., Bakhtina, M., & Ghannouchi, S. (2022). Ontological representation of healthcare application security using blockchain technology. *Informatica*, 365–397. https://doi.org/10.15388/22-infor486

McDaniel, M., Storey, V. C., & Sugumaran, V. (2018). Assessing the quality of domain ontologies: Metrics and an automated ranking system. *Data & Knowledge Engineering*, *115*, 32–47. https://doi.org/10.1016/j.datak.2018.02.001

Molina-Jimenez, C., Sfyrakis, I., Solaiman, E., Ng, I., Wong, M. W., Chun, A., & Crowcroft, J. (2018). Implementation of smart contracts using hybrid architectures with on and off–blockchain components. 2018 IEEE 8th International Symposium on Cloud and Service Computing (SC2), 83–90. https://doi.org/10.1109/sc2.2018.00018

Neidhardt, N., Köhler, C., & Nüttgens, M. (2018). Cloud service billing and service level agreement monitoring based on blockchain. EMISA Forum, 38, 46–50. http://ceur-ws.org/Vol-2097/paper11.pdf

Peoples, C., Abu-Tair, M., Wang, B., Rabbani, K., Moore, A., Morrow, P., Rafferty, J., McClean, S., Zoualfaghari, M., Cui, Z., & Kulkarni, P. (2021). A multi-level ontology to manage service level agreements in smart cities. In Lecture notes in intelligent transportation and infrastructure (pp. 135–157). https://doi.org/10.1007/978-3-030-60922-1_7

Ranchal, R., & Choudhury, O. (2020). SLAM: A framework for SLA management in multicloud ecosystem using blockchain. 2020 IEEE Cloud Summit, 33–38. https://doi.org/10.1109/ieeecloudsummit48914.2020.00011

Schweizer, C. (2019). SLAMer: A blockchain-based SLA management system. In Communication Systems Group, University of Zurich. https://capuana.ifi.uzh.ch/publications/PDFs/18551_BA-Thesis-Carlos-Schweizer.pdf

Sekandar, K. (2018). A quality measure for automatic ontology evaluation and improvement. http://dspace.library.uu.nl/handle/1874/365954

Souei, W. B. S., Hog, C. E., Sliman, L., Djemaa, R. B., & Amor, I. a. B. (2021). Towards a uniform description language for smart contract. 2021 IEEE 30th International Conference on Enabling Technologies: Infrastructure for Collaborative Enterprises (WETICE), 57–62. https://doi.org/10.1109/wetice53228.2021.00022

Tartir, S., Arpinar, I. B., & Sheth, A. P. (2010). *Ontological evaluation and validation*. In Springer eBooks (pp. 115–130). https://doi.org/10.1007/978-90-481-8847-5_5

Uriarte, R. B., De Nicola, R., & Kritikos, K. (2018). Towards distributed SLA management with smart contracts and blockchain. 2018 IEEE International Conference on Cloud Computing Technology and Science (CloudCom), 266–271. https://doi.org/10.1109/cloudcom2018.2018.00059

Zorgati, H., Djemaa, R. B., Amor, I. a. B., & Sedes, F. (2020). QoC enhanced semantic IoT model. 24th International Database Engineering & Applications Symposium, 13, 1–7. https://doi.org/10.1145/3410566.3410610

A Multi Headed Artificial Intelligence Approach for Stock Market Trading

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Abstract: Stock market prediction remains a challenging task due to market volatility and the complex interplay of multiple factors affecting price movements. While traditional technical analysis and modern machine learning/deep learning approaches have shown promise, they often fall short when used in isolation. This paper presents a novel three-layer approach that combines traditional technical analysis, deep learning, and sentiment analysis for more accurate stock price prediction. The first layer employs technical indicators to capture price trends from historical data. The second layer utilises deep learning models to process comprehensive market data and identify complex patterns. In this second layer, predicted prices are also plotted with historical data, and the buy or sell decision is based on the chart classification. The third layer incorporates real-time sentiment analysis of news and social media to capture market sentiment impact. We evaluate our approach using historical data from major stock exchanges spanning three years (2021-2023). Results demonstrate that our integrated approach significantly outperforms existing methods, achieving lower Mean Absolute Error (MAE) and Mean Squared Error (MSE) scores while maintaining a higher R^2. These findings suggest that combining multiple analytical perspectives through a layered architecture can provide more reliable stock market predictions than single-method approaches.

Keywords: Stock Market Analysis, Deep Learning, Ensemble Model, Sentiment Analysis, Algorithmic Trading

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Introduction

The stock market exchange serves as a fundamental platform in the global financial system, facilitating the trading of securities between various participants, from individual investors to large financial institutions. This marketplace not only enhances capital movement and economic growth but also acts as a crucial mechanism for price regulation and economic indication (Dhankar, 2019). Beyond its practical function, the stock exchange represents a complex institution that reflects social relationships, historical contexts, and technological advancements, deeply intertwined with the narratives and ideologies of modern finance (Roscoe, 2023).

Traditionally, stock market trading decisions have relied heavily on human judgment and analysis. Investors typically analyse fundamental factors, such as company earnings and growth potential, alongside technical indicators like price trends and trading volume. These traditional techniques encompass various analytical methods, including Technical Analysis, where analysts study historical price charts to identify predictive patterns and statistical approaches like the Integrated Moving Average (ARIMA) for capturing temporal dependencies in stock prices. However, this human-centric approach often suffers from emotional biases such as overconfidence, fear, and greed, which can cloud judgment and lead to inconsistent trading decisions. Moreover, these traditional methods frequently struggle with the inherent unpredictability of stock markets, highlighting the need for more sophisticated approaches (Cabrera *et al.*, 2018).

The emergence of algorithmic trading has fundamentally transformed this landscape by introducing data-driven, automated decision-making processes. These systems leverage advanced mathematical models to execute trades at unprecedented speeds and frequencies, analysing vast amounts of market data to identify profitable opportunities while minimising costs and emotional bias. While algorithmic trading has increased market efficiency and reduced transaction costs, it has also introduced new challenges related to technical reliability and regulatory compliance.

Recent research has pushed the boundaries of stock market prediction even further, exploring increasingly sophisticated approaches. Studies have demonstrated promising results using advanced machine learning techniques (Idowu, 2024), deep learning architectures (Paul & Das, 2023), and hybrid approaches combining deep learning with natural language processing (Awad *et al.*, 2023). A comprehensive review by (Sahu *et al.*, 2023) highlights the applications of various learning paradigms in quantitative finance and outlines promising future research directions.

Building upon these advances, we propose a novel three-layer approach that integrates complementary prediction techniques: (1) a traditional technical analysis layer for trend prediction based on technical indicators, (2) a deep learning layer and chart classification that processes comprehensive historical market data, and (3) a sentiment analysis layer that incorporates real-time news and market sentiment. This integrated approach aims to address the limitations of existing methods while leveraging the strengths of both traditional and modern prediction techniques. Experimental results demonstrate the superiority of our approach, achieving significantly lower Mean Absolute Error (MAE) and Mean Squared Error (MSE) scores, along with higher R^2 values compared to existing state-of-the-art methods. These improvements in prediction accuracy validate the effectiveness of our multi-layered integration strategy and its potential for real-world applications in stock market prediction.

The remainder of this paper is structured as follows: Section 2 presents a comprehensive review of related works, covering traditional approaches, machine learning methods, and recent hybrid models in stock market prediction. Section 3 details our proposed three-layer architecture, describing the technical analysis component, deep learning framework, and sentiment analysis integration. Section 4 presents extensive experimental results, including performance comparisons with state-of-the-art methods. Finally, in Section 5 conclusions are drawn.

Related Works

The use of advanced machine learning techniques, particularly deep learning, has revolutionised the stock market prediction field. Recent methodologies, including CNN-LSTM and hybrid models combining various deep learning architectures, have demonstrated significant improvements in prediction accuracy (Fan & Zhang, 2024). Furthermore, the integration of technical indicators with sentiment analysis has led to more comprehensive models that leverage both quantitative and qualitative data for better forecasting (Kurniawan & Yusuf, 2024).

As the financial landscape becomes increasingly complex, incorporating novel approaches, such as image classification techniques for stock pattern detection, alongside traditional methods, provides a promising direction for future research and practical applications in trading strategies (Cohen *et al.*, 2020).

Machine learning and deep learning have become essential for stock price forecasting, with models like Long Short-Term Memory (LSTM), Random Forest, and XGBoost leading the field. These models are particularly effective for capturing complex relationships in large datasets and providing accurate, real-time predictions (Singh *et al.*, 2023).

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A study by (Siva *et al.*, 2024) introduced an ensemble learning approach, combining LSTM with RNN and CNN, to predict stock prices. This hybrid model outperformed single models in both short- and long-term forecasting tasks.

Similarly, Liapis *et al.* (2023) demonstrated that combining deep learning with sentiment analysis improved the prediction of stock market trends. The use of ensemble learning allows for the strengths of different algorithms to be leveraged, reducing the error margins associated with stock market predictions.

The Deep Reinforcement Learning based approach proposed by Awad *et al.* (2023) and detailed in Figure 1 models the stock market as a dynamic environment where the agent learns by interacting with it. While this approach adapts to changing market conditions, it does not explicitly account for the underlying temporal dynamics in the same way as Neural ODEs.

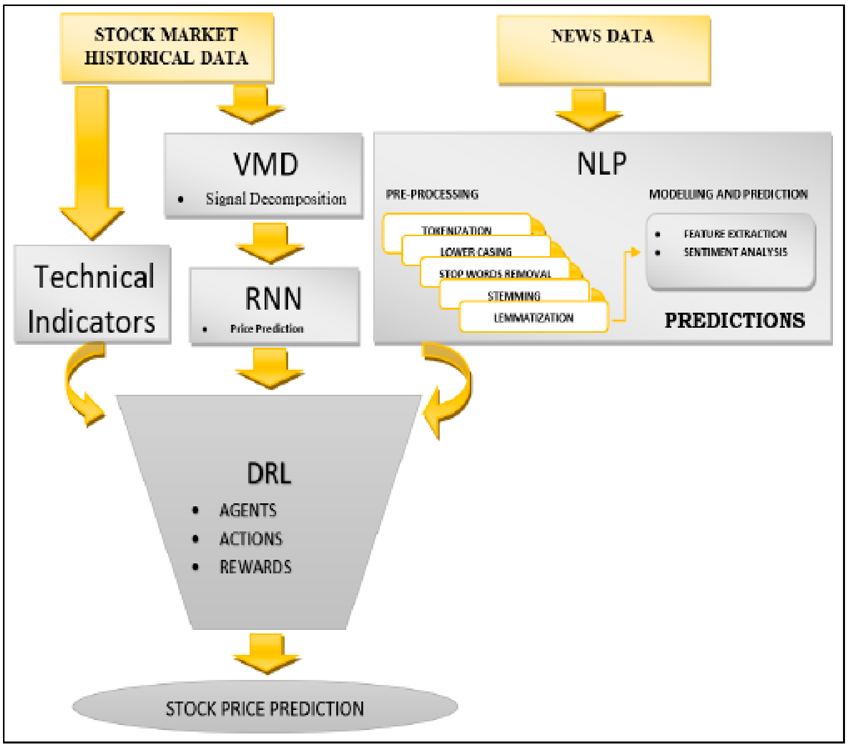

Figure 1: Deep Reinforcement Based Approach (Awad *et al.*, 2023)

The 1D-CapsNet-LSTM model proposed by Zhang *et al.* (2024) integrates Capsule Networks with LSTM layers for multi-step stock index forecasting. The Capsule Networks, shown in Figure 2, capture hierarchical spatial features, while LSTM layers address temporal dependencies. The architecture is effective in multi-step forecasting but does not utilise a physics-inspired approach for modelling temporal dynamics.

Our model differs in that it employs Neural ODE layers to naturally model continuous-time dynamics, combined with an Attention mechanism that focuses on significant patterns in the data.

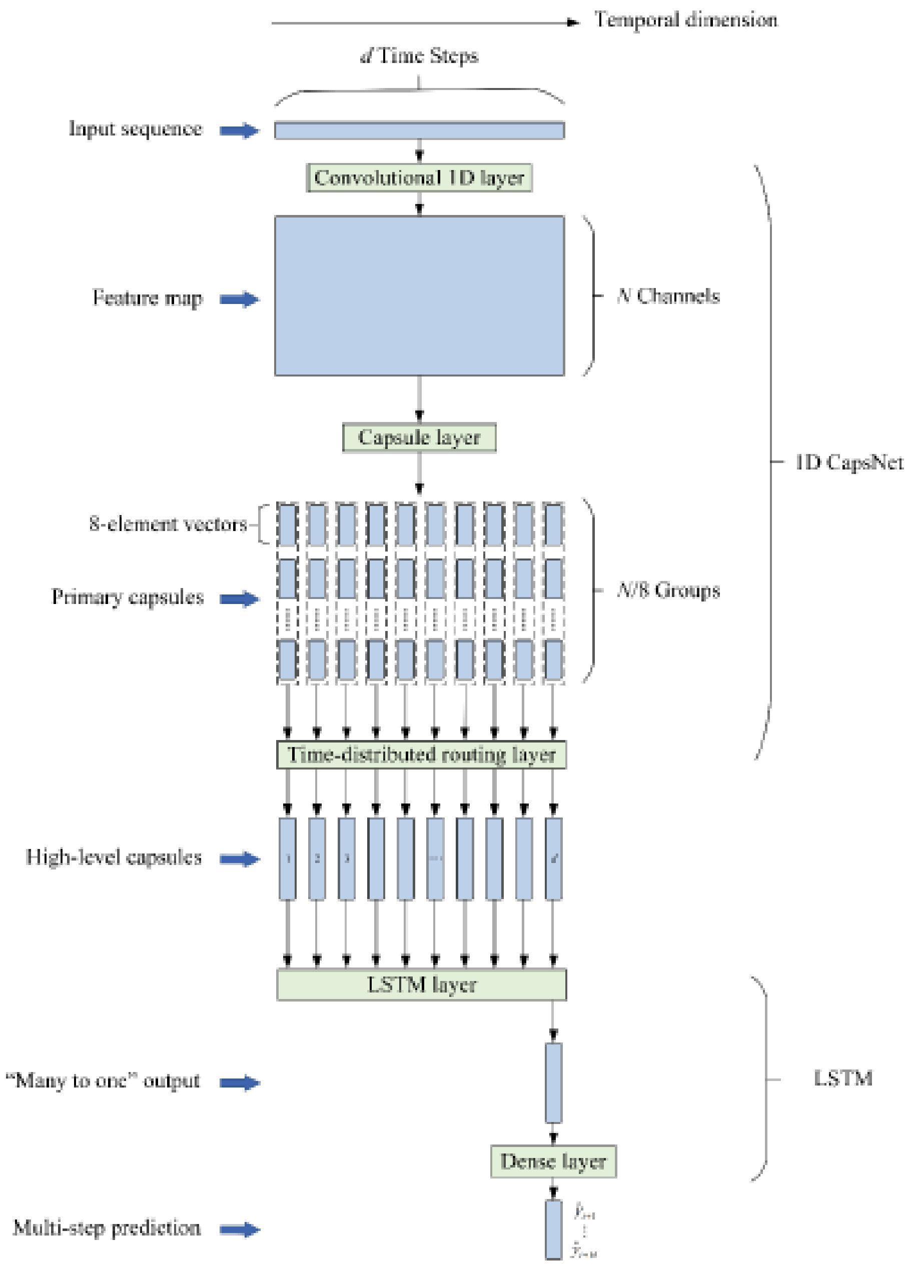

Figure 2: 1D-CapsNet-LSTM Architecture ([Zhang *et al.*, 2024](#))

The DRAGAN-based model proposed by Nejad & Ebadzadeh (2024) utilises Generative Adversarial Networks (GANs) to generate synthetic data and match the features to enhance stock market prediction. The approach detailed in Figure 3 improves performance by generating more representative data distributions, but it lacks the explicit modelling of continuous dynamics found in Neural ODEs.

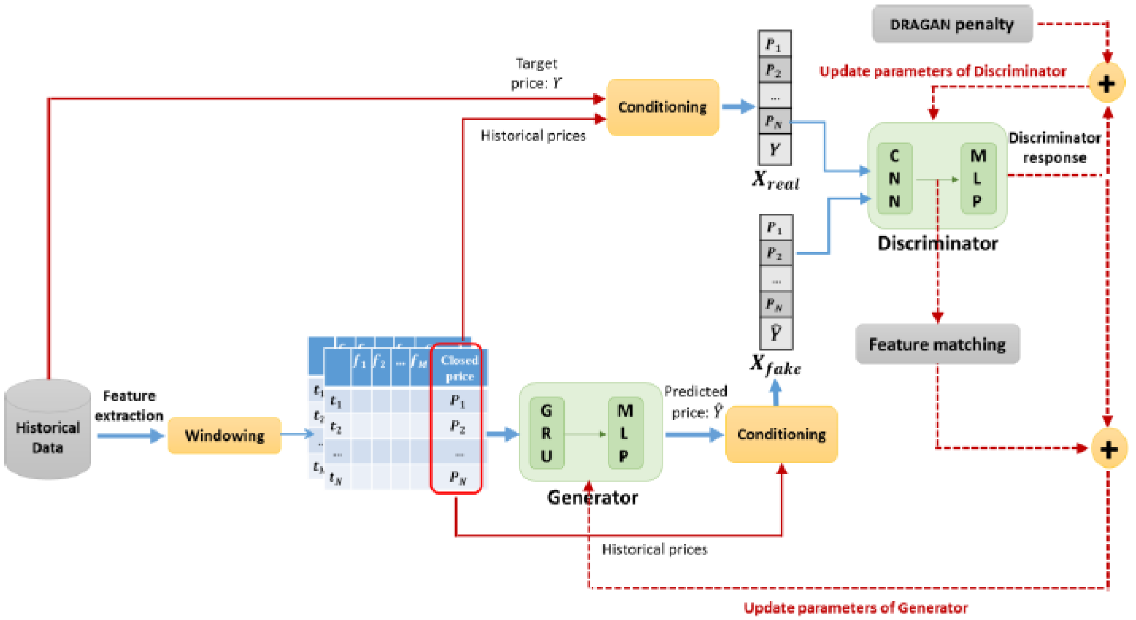

Figure 3: DRAGAN with Feature Matching Architecture ([Nejad & Ebadzadeh, 2024](#))

Proposed Approach

The stock market represents one of the most complex and dynamic financial systems, attracting significant research attention due to its challenging predictive nature. Recent breakthroughs in artificial intelligence have revolutionised our understanding of market behaviour and created new opportunities for sophisticated market analysis. Building upon these advances, we present a novel multi-layer AI framework that seamlessly integrates four essential components: technical indicator analysis, price prediction modelling, financial sentiment analysis, and automated chart pattern recognition.

Our approach is distinguished by its efficient data utilisation, requiring only two complementary data streams:

Historical Market Data: This dataset includes comprehensive OHLCV (Open, High, Low, Close, Volume) time series data at various granularities (e.g. daily, weekly, or min-by-min intervals). This fundamental dataset serves multiple purposes:

- Technical pattern identification and trend analysis.
- Price movement prediction.
- Market volatility assessment.
- Trading volume behaviour modelling.

Financial News Data: This encompasses real-time financial news and market updates, including:

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- Corporate announcements and earnings reports.
- Macroeconomic indicators and policy changes.
- Industry-specific developments.
- Market sentiment indicators.

The strategic integration of these data sources through our multi-layer AI framework enables robust market analysis and more informed trading decisions. By leveraging the synergies between historical price patterns and real-time market sentiment, our system achieves enhanced predictive accuracy while maintaining computational efficiency. This balanced approach demonstrates the power of combining traditional market indicators with advanced AI methodologies for real-time trading applications.

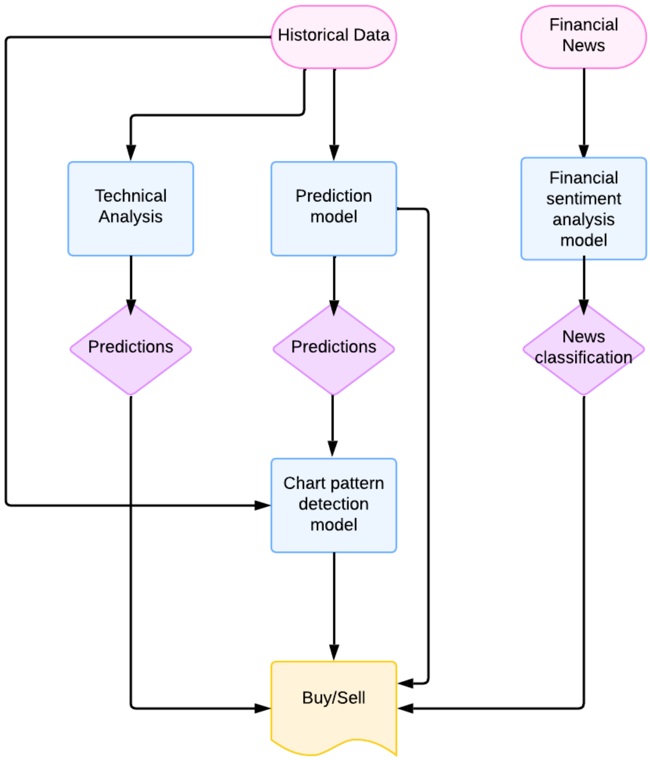

Figure 4: The decision-making process

Our proposed multi-layer architecture for stock trading decision-making is illustrated in Figure 4. The system operates through three parallel processing layers, each analysing distinct aspects of market behaviour while drawing from two primary data streams: historical market data and financial news from authenticated sources. Our approach begins by scrapping stock market historical data and financial news from reliable sources. Then, in the first layer, the technical analysis is done on historical data to classify if the stock is overbought or oversold in a bearish or bullish situation. In the second layer, the prediction model also gets historical data and predicts the stock price for the coming 30 mins. Predicted stock prices will be added to historical data to have a predicted trend graph that will be classified with a chart pattern detection model to guide a second buy or sell decision. At the same time, in the third layer, the financial sentiment analysis model scraps data from financial news and classifies the stock news with a sentiment analysis approach.

Finally, the decision of selling or buying a stock will be made based on the output of the three layers.

Technical Analysis

Technical analysis forms a cornerstone of market prediction through its systematic application of mathematical indicators derived from key market metrics: price movements, trading volume, and open interest. These quantitative tools transform raw market data into actionable trading signals, enabling traders to anticipate future price trajectories. These indicators, such as Moving Averages, Relative Strength Index (RSI), and Bollinger Bands are used to identify trends, reversals, and market volatility. By analysing historical price patterns and market behaviour, traders can make decisions about entry and exit points, risk management, and overall trading strategies, enhancing their chances of success in the stock market (Murphy, 1999).

In our approach, we used a combination of these indicators for the following reasons:

- The Relative Strength Index (RSI) is a momentum oscillator that measures the speed and change of price movements to assess overbought or oversold conditions in a market. Ranging from 0 to 100, RSI values above 70 indicate that an asset may be overbought, while values below 30 suggest it may be oversold. Traders often use RSI to identify potential reversal points and trends in stock prices, allowing them to make more informed trading decisions by evaluating the strength of a price movement relative to its historical performance (Wilder, 1978).
- The MACD is a trend-following momentum indicator that shows the relationship between two Moving Averages of a security's price. It is calculated by subtracting the 26-period Exponential Moving Average (EMA) from the 12-period EMA. The resulting value is the MACD line, which is typically plotted alongside a 9-period EMA of the MACD, known as the signal line. Traders use the MACD to identify potential buy and sell signals based on crossovers and divergences, making it a popular tool for analysing market trends (Appel, 2005).
- The Average Directional Index (ADX), introduced by Wilder (1978), serves as a crucial technical indicator for measuring trend strength in financial markets. Operating on a scale of 0-100, the ADX synthesises market momentum through the analysis of

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smoothed moving averages derived from directional movement indicators (DMI). Values below 20 signal weak market trends suitable for range-trading strategies, while readings above 25 indicate strong directional movements optimal for trend-following approaches. By quantifying trend strength independently of price direction, the ADX provides traders with an objective metric for strategy selection and position timing. This indicator's particular value lies in its ability to distinguish between trending and non-trending market phases, enabling more precise implementation of directional trading strategies.

- The Stochastic Oscillator is a momentum indicator that compares a security's closing price to its price range over a specific period, typically 14 days. Ranging from 0 to 100, values above 80 indicate overbought conditions, while values below 20 suggest oversold conditions. The indicator consists of two lines: the *%K* line and the *%D* line (a moving average of the *%K*). Traders use the Stochastic Oscillator to identify potential reversal points and confirm trends, making it a key tool for timing entry and exit points in trading (Lane, 1984).
- Bollinger Bands are a volatility indicator that consists of a middle band (the simple moving average) and two outer bands (standard deviations above and below the moving average). The distance between the bands adjusts based on market volatility: narrower bands indicate low volatility, and wider bands indicate high volatility. Traders use Bollinger Bands to identify potential overbought or oversold conditions, as well as to gauge price volatility and potential price reversals, aiding in decision-making for entries and exits (Bollinger, 2002).

By combining these technical indicators, each one checks on the other one. For example, a buy signal from the MACD can be confirmed by a corresponding bullish signal from the RSI or Stochastic Oscillator, while the ADX indicates strong trend conditions. This reduces the likelihood of false signals. Combining indicators also improves risk management strategies. Bollinger Bands can help determine stop-loss levels by indicating price volatility, while the ADX helps identify when to enter or exit trades based on trend strength.

In addition, each indicator may work better under different market conditions. For instance, RSI and Stochastic Oscillator may be more effective in sideways markets, while MACD and ADX may shine in trending markets. Using a combination allows traders to adapt their strategies accordingly.

Finally, using multiple indicators allows for more precise entry and exit points. Traders might enter a position when the Stochastic Oscillator indicates oversold conditions, confirm strength with the MACD and RSI, and observe volatility through Bollinger Bands.

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By using MACD, ADX, Stochastic Oscillator, Bollinger Bands, and RSI together, we can enhance the robustness of our trading strategies, leading to better decisions in the stock market.

Prediction Model

In our approach, the prediction model uses historical data that are denoised, normalised, and formatted. The pre-processing steps are shown in Figure 5. In the prediction model, which is the last step of Figure 5, we are introducing a new multi-layer model that combines Convolutional Neural Networks (CNN), Neural Ordinary Differential Equations (Neural ODE), and an Attention Mechanism. This innovative architecture leverages the strengths of each component, resulting in outstanding performance in time series analysis and forecasting. By integrating these advanced techniques, our model effectively captures complex patterns, adapts to dynamic changes, and focuses on the most relevant data points, enhancing both accuracy and interpretability.

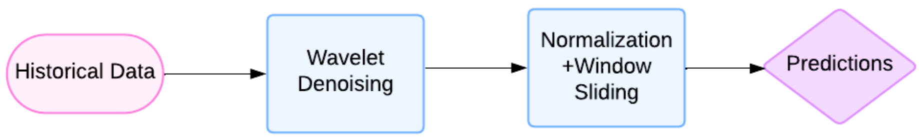


Figure 5: Prediction Process

Multiple layers, shown is Figure 8, are used in the predictions step. The convolutional Neural Networks (CNNs) excel at capturing spatial and temporal patterns in data through their specialised convolutional filters. These filters automatically learn local patterns, making them particularly effective for time series analysis (Borovykh *et al.*, 2017). When applied to time series forecasting, CNNs demonstrate remarkable capability in detecting short-term dependencies, patterns, and trends by focusing on nearby values in sequences. Their strength in feature extraction makes them valuable components in hybrid architectures, where they often work alongside GRU or LSTM layers to model both local and long-range dependencies.

Neural Ordinary Differential Equations (Neural ODEs) represent a revolutionary approach to modelling continuous-time dynamics in data (Chen *et al.*, 2018). Unlike traditional discrete models, Neural ODEs define a hidden state that evolves according to differential equations, enabling adaptive time-stepping and computational efficiency. This framework particularly shines in learning patterns across varying time intervals, making it ideal for capturing dynamic changes in time series data.

The attention mechanism introduced by (Vaswani *et al.*, 2017) revolutionised how neural networks processes sequential information. By dynamically weighing different time steps, attention allows models to focus on the most relevant parts of input data while making predictions. This selective focus proves especially valuable in time series analysis, where capturing long-range dependencies and complex patterns is crucial for accurate forecasting and classification.

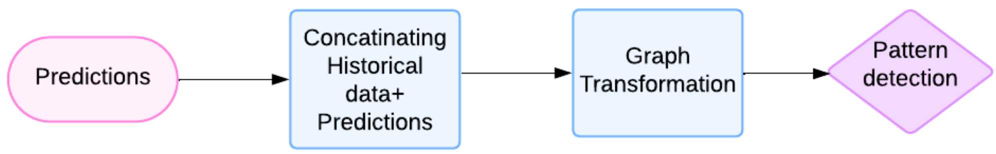
The ReduceSum layer serves as a fundamental building block in neural network architectures by computing element sums across specified tensor dimensions (Abadi *et al.*, 2016). In time series analysis, this aggregation capability helps models identify global trends by summarising local variations. This dimensional reduction simplifies the learning of sequential patterns, ultimately enhancing performance in various time series tasks.

The synergy between these architectural components creates a powerful framework for stock price prediction. The process begins with CNN layers extracting crucial local dependencies and patterns from the time series data. This processed information then flows into the Neural ODE layer, which models the continuous dynamics of stock prices with greater flexibility than traditional discrete approaches. The attention mechanism then acts as a selective filter, weighing historical data points based on their relevance to the current prediction task. This sophisticated combination enables the model to capture both fine-grained patterns and broader market trends, leading to more accurate and robust predictions.

Chart Pattern Detection

For identifying stock market patterns, predicted data are concatenated with historical data to have a coherent predicted graph modelling the time series from past stock market exchanges and the predicted upcoming stock market prices to have historical price charts. The obtained graph is then used to identify patterns that may predict future movements, as shown in Figure 6. We used the YOLOv8 (Jia *et al.*, 2024) stock market pattern detection model. This model, sourced from Hugging Face, is optimised to detect classic stock chart patterns like head and shoulders, double tops, and triangles, which can indicate future price movements.

Figure 6: Chart pattern Detection model Process



Financial Sentiment Analysis

We incorporated a financial sentiment analysis model based on FinBERT (Araci, 2019), a specialised version of BERT fine-tuned for financial text analysis. Figure 7 shows that in our approach, data are scraped from financial news and then used for sentiment analysis using

FinBERT. This model analyses financial news and reports to derive sentiments (positive, negative, or neutral) related to the stock being studied, which can serve as an additional indicator of market sentiment.

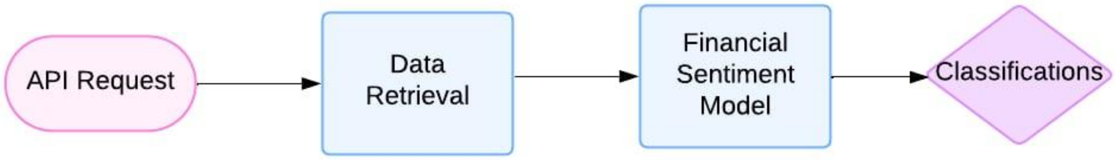


Figure 7: Financial Sentiment analysis classification process

Experiments

The dataset used for the prediction model was obtained from Kaggle, containing historical OHLC (Open, High, Low, Close) stock price data. In our experiments, a sliding window technique was applied with a window size of 5, meaning the model considers the last 5 timesteps for each prediction. This approach captures short-term patterns in the stock data, allowing the model to learn from recent market trends. Along with this, a denoising method using wavelet denoising was implemented to reduce noise in the data, improving the model's performance. Additionally, MinMax scaling was applied to normalise the data, ensuring that all features contribute equally to the learning process and enhancing the model's ability to make accurate predictions.

Architecture of the Prediction Model

The core of our predictive model is a deep learning architecture designed to analyse the time series data from the stock market. Figure 8 describes the architecture of the prediction model with the following parameter tuning:

Input Layer: The input shape is `(None, 5, 4)`, where 5 refers to the sliding window size, and 4 refers to the OHLC values.

Conv1D Layer: A 1D convolutional layer with 64 filters extracts local patterns from the time series data.

MaxPooling1D Layer: This layer reduces the dimensionality, retaining only the most salient features while preserving the temporal dependencies.

Dropout Layer: Introduced to prevent overfitting by randomly setting a fraction of input units to zero during training.

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Neural ODE Layer: A Neural ODE (Ordinary Differential Equation) layer, with 64 units, is used to model the continuous evolution of stock prices. Neural ODEs are particularly effective for time-dependent problems, offering flexibility in capturing complex dynamics.

Attention Mechanism: This layer helps focus the model on the most important features in the input sequence, emphasising the timesteps that carry the most predictive power.

ReduceSum Layer: It aggregates information across timesteps, simplifying the model output for final predictions.

Dense Layers: Series of fully connected layers refine the features. The output passes through several Dense layers: first 32 units, then 16 units, and finally a layer with 4 units corresponding to the OHLC prediction.

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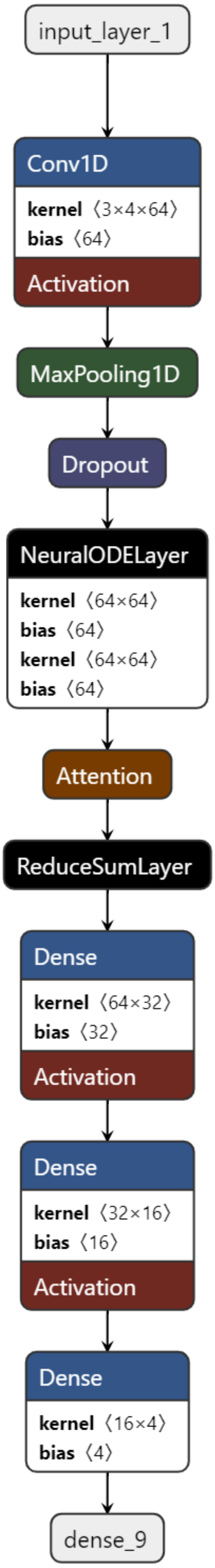

Figure 8: CNN NEURALODE ATTENTION Architecture

Training and Evaluation

The model was trained using mean squared error (MSE) as the loss function, optimised with the Adam optimiser. A 5-fold Cross-validation was used to prevent overfitting, and the performance was evaluated using key metrics such as the Mean Squared Error (MSE), Mean Absolute Error (MAE) and R^2 score.

Integrating stock market patterns and sentiment analysis helped create a holistic prediction framework, capturing technical and fundamental market indicators.

The model was trained on the three different Datasets detailed in Table 1 with three different time intervals.

Table 1: Data Partitioning Summary

	Stocks	Interval	Period	Train Size	Test Size	Validation Size
Datasets	Google	1 min	2021-2023	1,400,000	47,000	47,000
	Nasdaq	5 min	2021-2023	195,000	6,231	6,231
	Gold	1 day	2000-2021	4,850	150	150
	VCB (Vietnam)*	1 day	2012-2023	3,689	97	97
	Zimplats Holdings Ltd (Zimbabwe)	1 day	2009-2025	2,645	70	70

* Joint Commercial Bank for Foreign Trade of Vietnam

Stock market data is a time series; thus, time series cross-validation is used to evaluate the model performance on sequential data. Unlike traditional cross-validation, it respects the temporal ordering of data by splitting data on training and testing sets that simulate real-world forecasting conditions, where past data is used to predict future outcomes. This approach helps to ensure that the model is evaluated on unseen periods, providing a more reliable assessment of its predictive capabilities.

To rigorously evaluate our multi-layer approach, we implemented a time series cross-validation methodology with K=5 folds, ensuring robust assessment of the model's predictive capabilities across different market conditions. Each fold underwent comprehensive training for 400 epochs, maintaining consistency across experimental iterations. Table 2 presents the detailed cross-validation results, highlighting the model's performance across multiple financial instruments.

The cross-validation results, detailed in Table 2, demonstrate good predictive performance across three distinct financial instruments, with each showing unique characteristics.

Google stock prediction performance has the lowest MAE and an extremely low MSE. The R^2 score is a near-perfect fit. The model shows outstanding prediction accuracy for Google stock, with the highest R^2 score and lowest error metrics, suggesting highly reliable predictions for this technology stock.

We extended our analysis to emerging markets by testing the model on VCB and Zimplats Holdings. While both stocks demonstrated satisfactory predictive performance with R^2 scores above 0.80, they fell short of the exceptional accuracy achieved for established market securities like Google (R^2=0.99) and Nasdaq100 (R^2=0.98). Interestingly, despite Zimplats exhibiting higher absolute prediction errors (MAE=0.035 vs 0.016), it achieved a marginally superior overall fit (R^2=0.85 vs 0.83). Both securities displayed identical mean squared errors (MSE=0.006), suggesting similar prediction variance. These relatively lower performance metrics likely reflect the inherent challenges of emerging markets, including higher market volatility, limited trading volumes, and potential information asymmetries.

NASDAQ-100 stock prediction performance shows a very low MAE and a MSE. The R^2 score is an excellent fit. Thus, performance on the NASDAQ-100 index is remarkably strong, with error metrics nearly as good as Google's, indicating robust prediction capability for market index movements.

Finally, Gold stock prediction performance shows the highest among the three MAE, but still low. The R^2 score is a good fit, though lower than others. While showing good performance, the model's predictions for Gold show slightly higher variability, possibly due to the commodity's unique market dynamics.

These results are particularly impressive because all R^2 scores are above 0.85, indicating excellent predictive power. The extremely low MAE and MSE values suggest high precision in predictions compared to baseline models. The model performs well across different asset classes (stocks, indices, and commodities). Finally, the results demonstrate consistent performance across multiple validation folds.

Table 2: Our approach 5-fold cross-validation results

		Cross Validation Metrics		
		Average MAE	**Average MSE**	**Average R^2Score**
Datasets	Google	0.005	3.64*e^-5	0.99
	Gold	0.021	0.0009	0.86
	Nasdaq100	0.006	0.0003	0.98
	VCB (Vietnam)	0.016	0.006	0.83
	Zimplats Holdings Ltd (Zimbabwe)	0.035	0.006	0.85

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After training, our model was put to test several different datasets:

- NIFTY 100_min: stock index of India's top 100 companies, representing large-cap stocks.
- NIFTY 200_min: stock index with the top 200 companies, providing broader market exposure.
- NIFTY 500_min: stock index covering India's top 500 companies, spanning diverse industries.
- NIFTY 50_min: key stock index for India's economy, featuring 50 prominent large-cap stocks.
- NIFTY ALPHA 50_min: stock index focused on high-alpha stocks, showcasing market-leading returns.
- NIFTY AUTO_min: stock index for the auto sector, including major vehicle and component stocks.
- S&P 500: the S&P 500 is a stock market index that measures the performance of 500 of the largest publicly traded companies in the United States.

The sizes of these datasets are detailed in Table 3.

Table 3: Testing Datasets sizes

Dataset	Size (number of rows)	Interval
Apple validation set	47 000	1 min
Nifty 100 min	898 331	1 min
Nifty 200 min	898 332	1 min
Nifty 500 min	486 092	1 min
Nifty 50 min	898 755	1 min
Nifty Alpha 50 min	485 765	1 min
Nifty Auto min	898 331	1 min
S&P500	2070834	1 min

To visually assess our model's accuracy, we plotted in Figures 9, 10, 11, 12, 13, 14, 15, and 16 the predicted Open, High, Low, and Close (OHLC) values alongside the original data. The dual representation allows for a comprehensive comparison of the model's predictions against actual market movements. By visualising the predicted OHLC data simultaneously, we can effectively identify how closely our model tracks the true market behaviour over time. This plotting not only highlights the model's strengths and weaknesses in predicting each component of the OHLC data but also reveals any significant discrepancies that may arise during periods of volatility or market shifts. Such visualisations are crucial for understanding

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the model's performance, facilitating informed adjustments, and enhancing overall predictive accuracy.

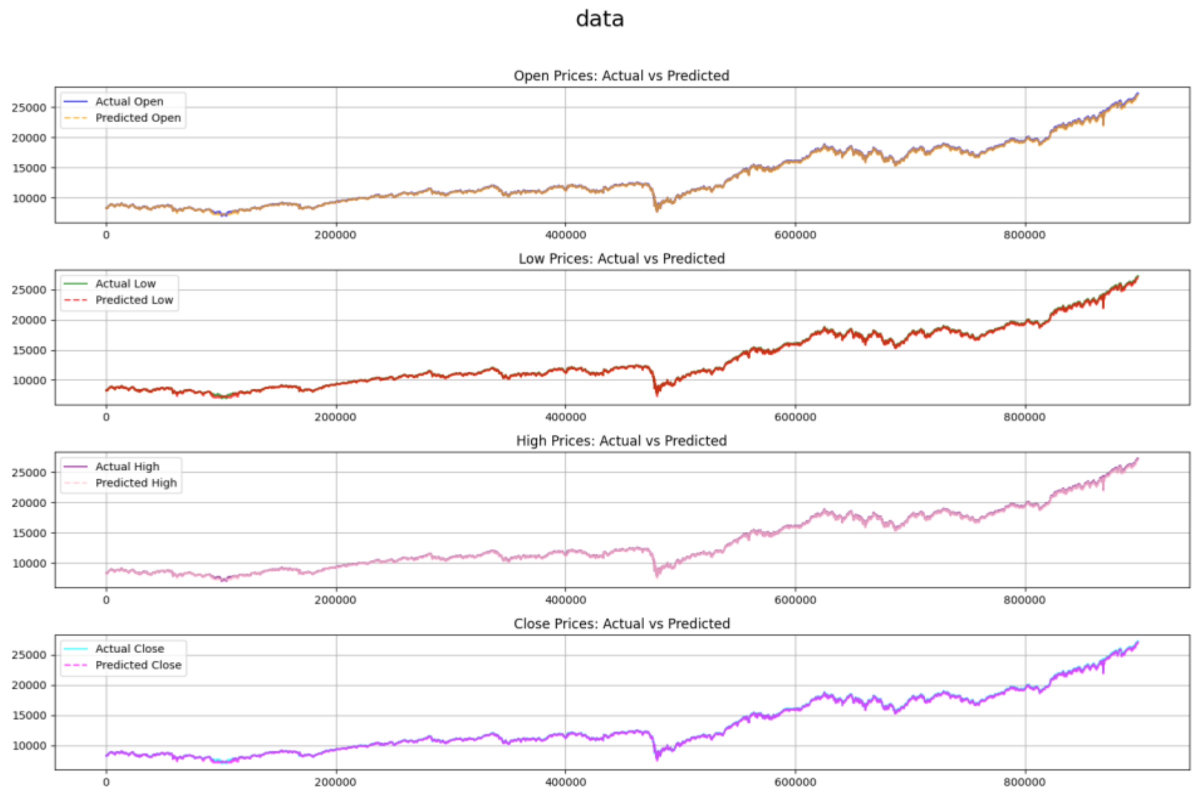

Figure 9: Predictions vs Actual data Apple Validation data

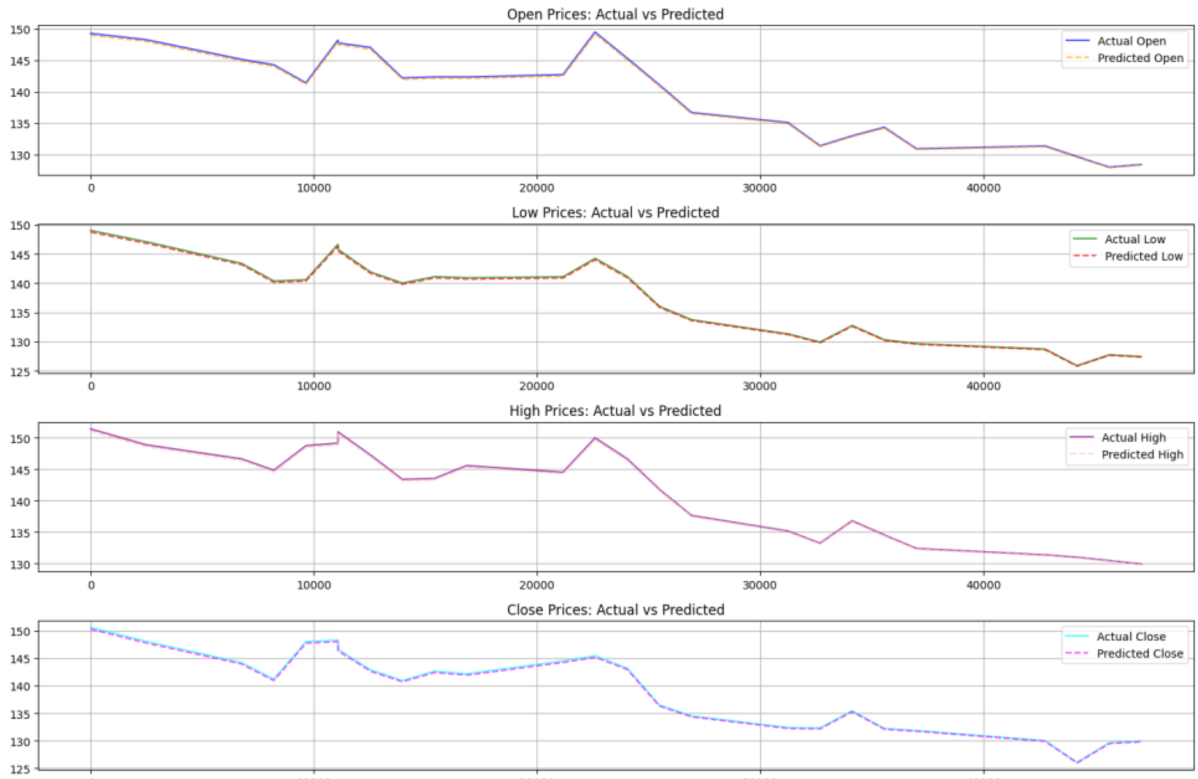

Figure 10: Predictions vs Actual data Nifty 100 min

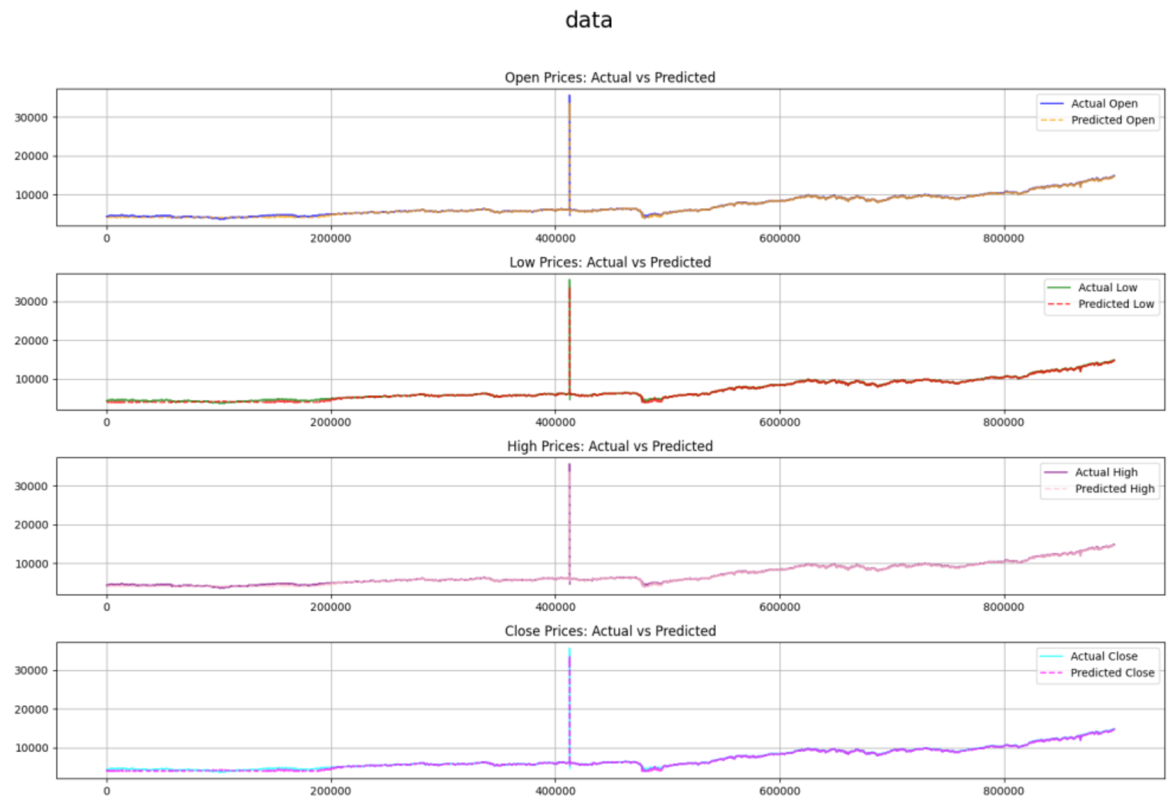

Figure 11: Predictions vs Actual data Nifty 200 min

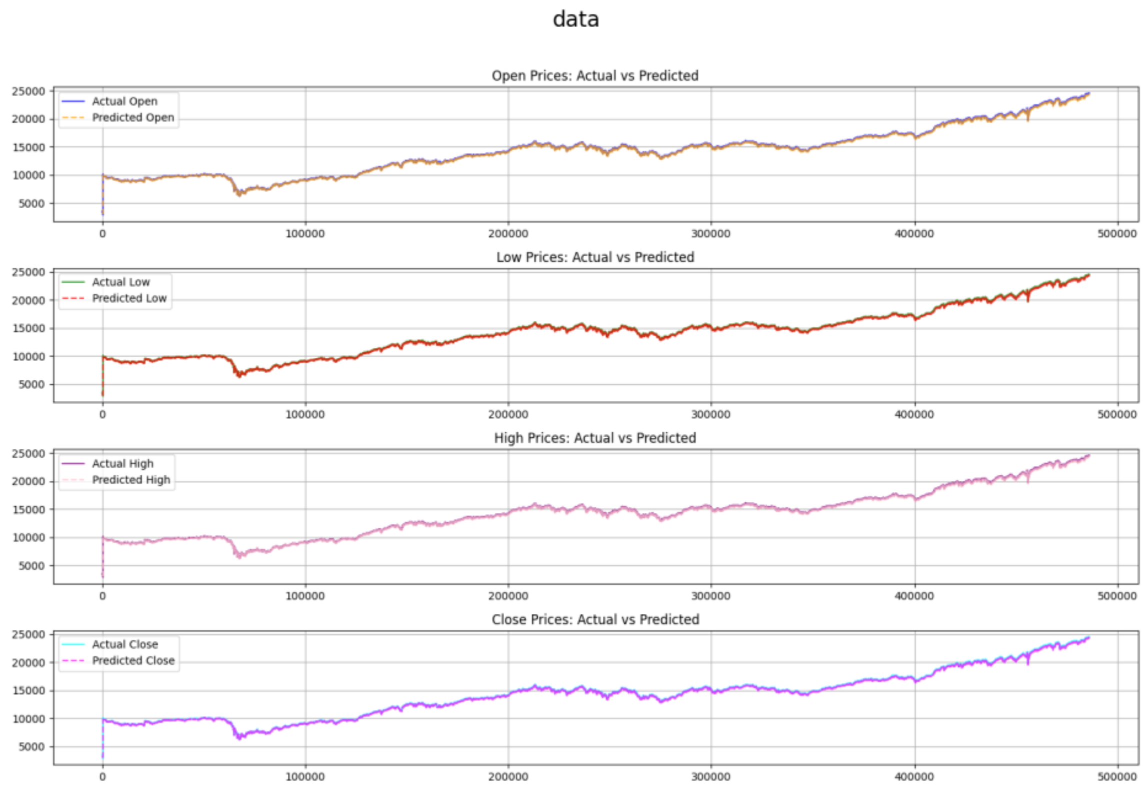

Figure 12: Predictions vs Actual data Nifty 500 min

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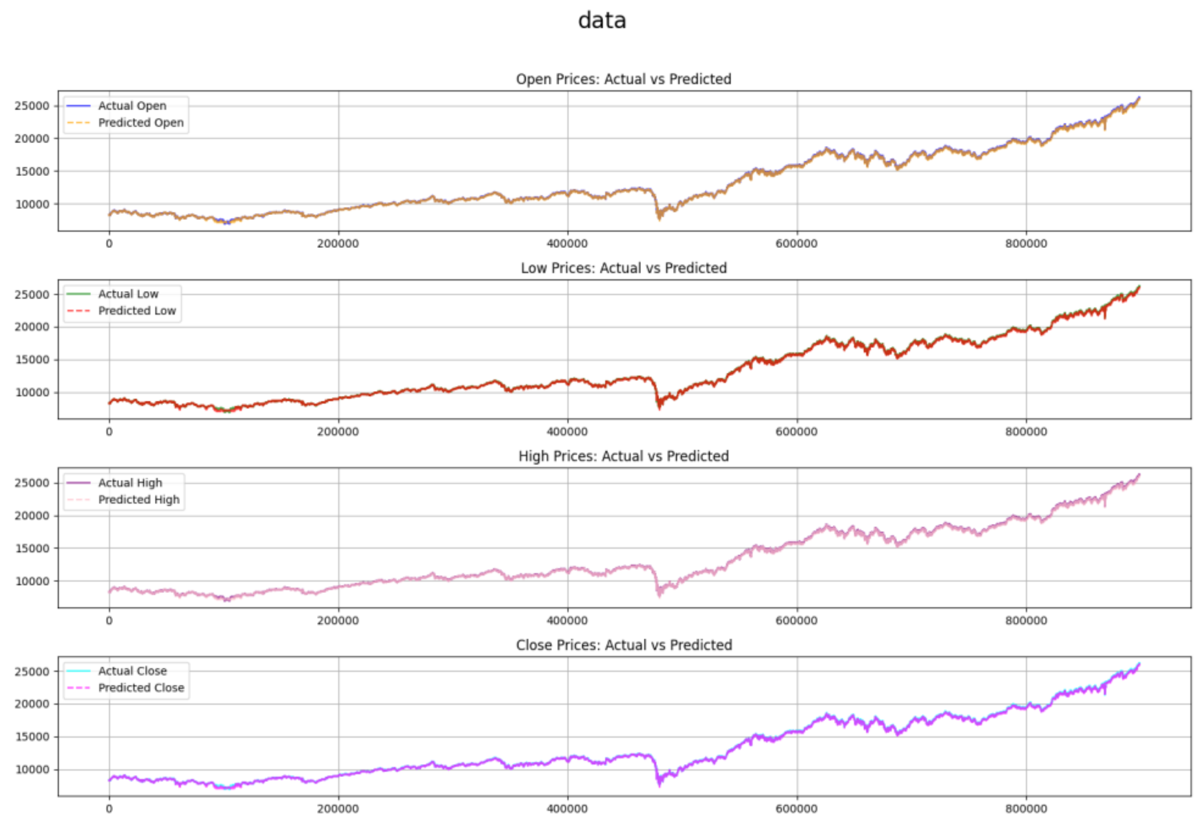

Figure 13: Predictions vs Actual data Nifty 50 min

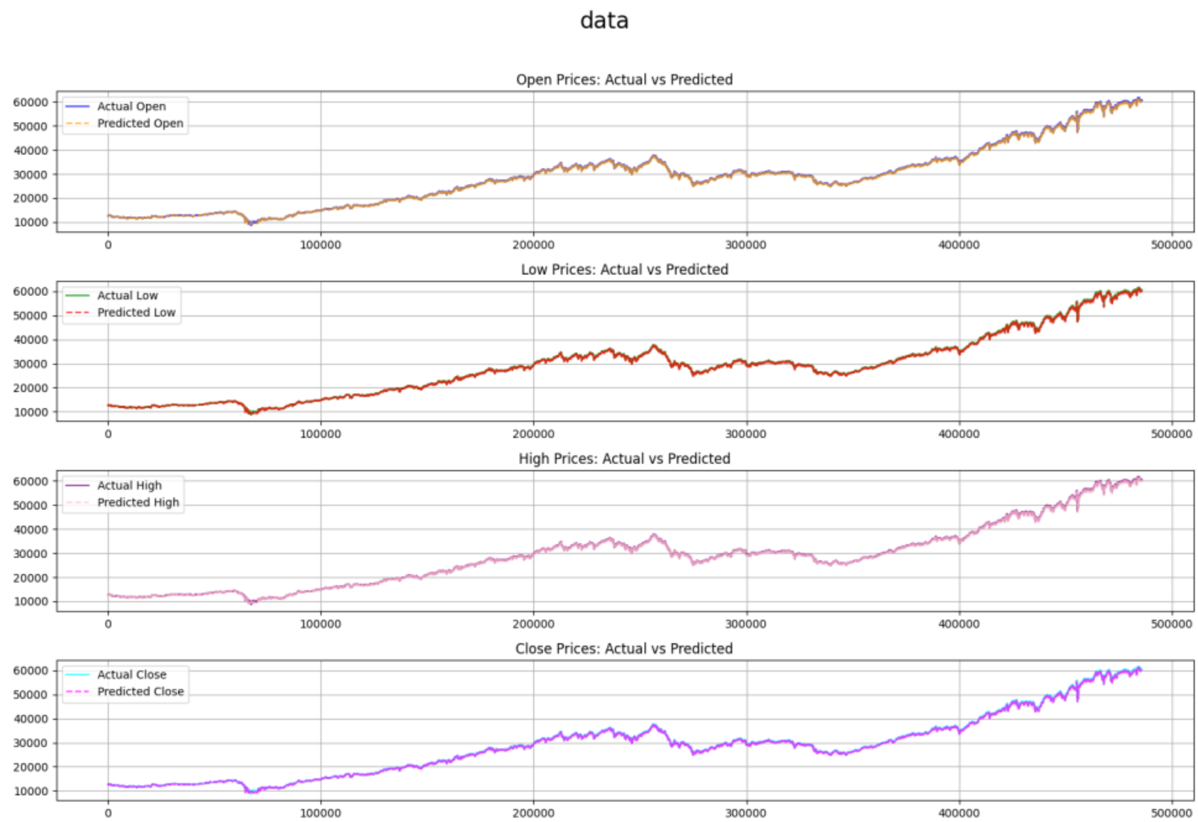

Figure 14: Predictions vs Actual data Nifty_Alpha 50 min

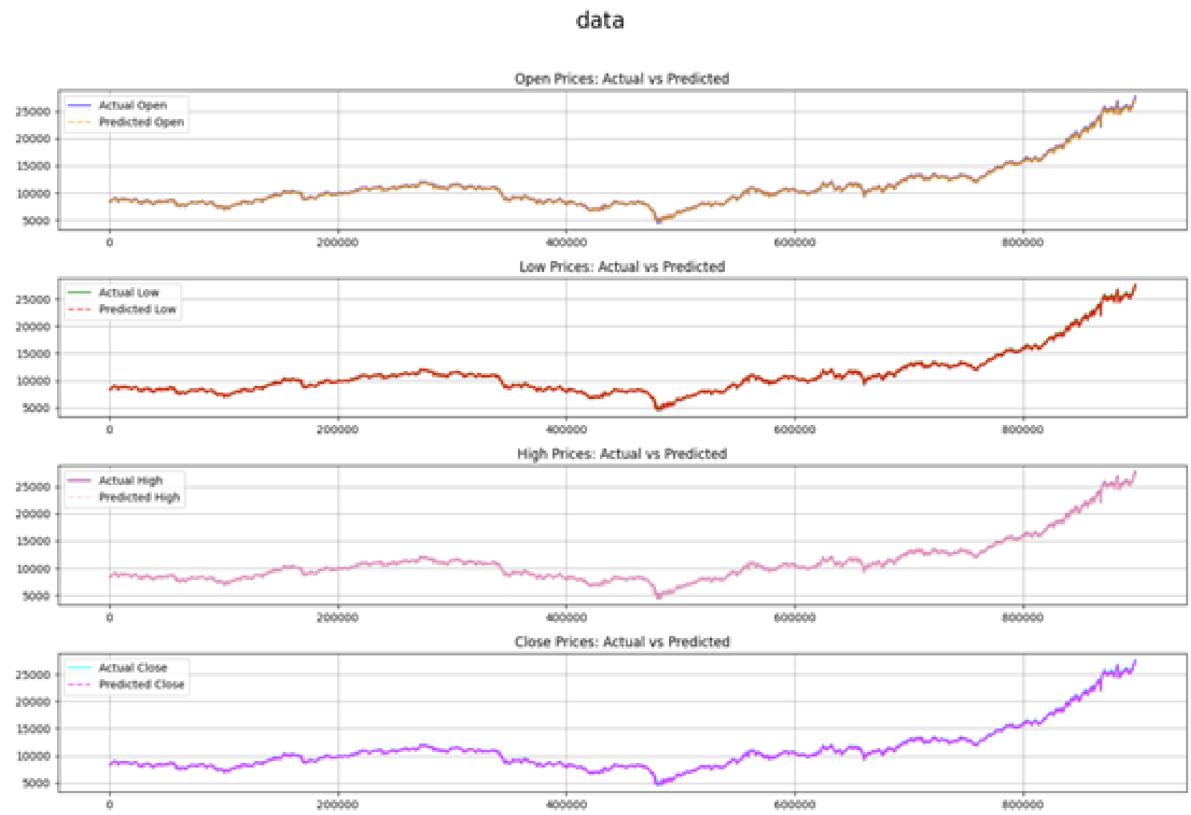

Figure 15: Predictions vs Actual data Nifty_auto 50 min

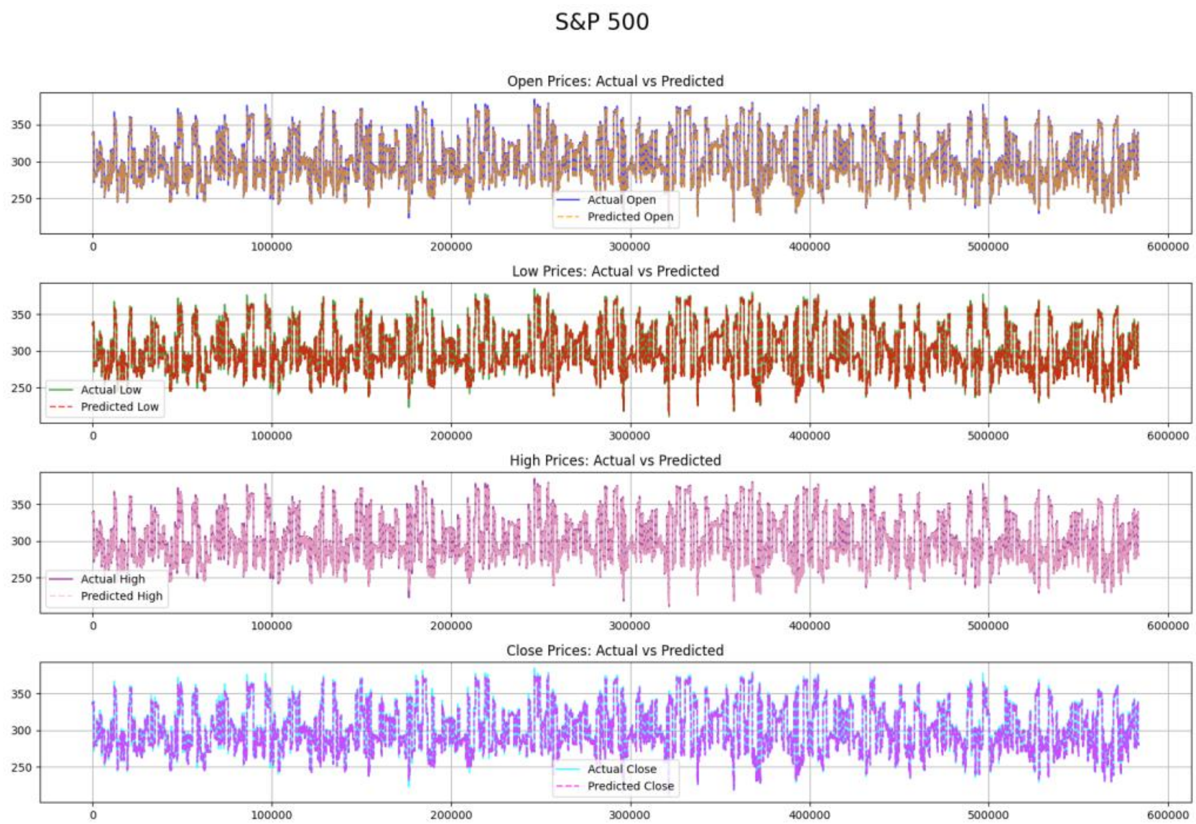

Figure 16: Predictions vs Actual data S&P500

Finally, we compare our model's performance with several other stock market forecasting models. The comparison is based on metrics such as Mean Absolute Error (MAE), Mean Squared Error (MSE), R^2 score, and Mean Absolute Percentage Error (MAPE), as well as the datasets used and architectural differences. Table 4 shows that our model outperforms the 1D-Capsnet LSTM (Zhang *et al.*, 2024) by a large margin across all three-error metrics, with improvements ranging from 80-95%. The most dramatic improvement is in RMSE, suggesting that our model is particularly good at minimising large prediction errors. The low MAPE of 0.36% indicates very high accuracy relative to the actual values being predicted.

Table 4: Comparison of Our Model with 1D-CapsNet-LSTM

Model	Dataset	RMSE	MAE	MAPE
1D-Capsnet LSTM	S&P 500	64.11	54.11	1.83%
Our Model		3.137	9.84	0.36%

Table 5 shows a comparison of our approach to DRAGAN (Nejad & Ebadzadeh, 2024) on the Apple stock dataset, revealing substantial improvements in prediction accuracy and model stability. Our model demonstrates superior performance with significantly lower RMSE values in both training (0.15 vs 0.458) and testing (0.2 vs 1.047) phases, representing improvements of 67.2% and 80.9%, respectively. The minimal gap between our model's training and testing errors (0.05) compared to DRAGAN's larger discrepancy (0.589) indicates better generalisation capabilities and more robust prediction performance, suggesting our approach is more reliable for real-world stock price forecasting applications.

Table 5: Comparison of Our Model with DRAGAN and Feature Matching

		RMSE	
Model	**Dataset**	**Train**	**Test**
DRAGAN	APPLE	0.458	1.047
Our Model		0.15	0.2

Table 6 compares our model's performance with LSTM (Awad *et al.*, 2023) on the Commodities dataset and demonstrates a remarkable improvement in prediction accuracy across all metrics. Our model achieved substantially lower error rates with an MSE of 0.0009 (compared to LSTM's 26.11), MAE of 0.21 (versus 3.64), and MAPE of 0.09% (versus 0.29%). This represents improvements of 99.99% in MSE, 94.2% in MAE, and 69% in MAPE. The exceptionally low MSE value indicates that our model effectively minimises prediction errors and handles price volatility in commodities trading much more accurately than the traditional LSTM approach, making it a more reliable tool for commodities price forecasting.

Table 6: Comparison of Our Model with Deep Reinforcement Learning

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Model	Dataset	MSE	MAE	MAPE
LSTM	Commodities	26.11	3.64	0.29%
Our Model		0.0009	0.21	0.09%

To evaluate our model's computational complexity, we conducted extensive testing across 28 stocks spanning 17 diverse industries, including Biotechnology, Software, Airlines, and others. As illustrated in Figure 17, the model's performance in predicting these 28 stocks demonstrates remarkable consistency across iterations, with processing times typically ranging from 900 to 1,100 seconds. The execution period varies from a minimum of 247.93 seconds (approximately 4 mins) to a maximum of 1291.68 seconds (approximately 21 mins), with an average processing time of around 19 mins. This timing aligns perfectly with our automated 20-min launch cycle, ensuring prediction results are consistently delivered within the expected timeframe. On a per-stock basis, the processing time ranges from 8.85 to 46.13 seconds, indicating efficient scalability across different securities. This computational efficiency demonstrates that our model can handle real-time predictions for a diverse portfolio while maintaining reliable performance within operational constraints.

It is important to note that these computational complexity results were obtained using relatively modest hardware specifications: an Intel Core i7 6th Generation processor running at 2.5 GHz, 12GB DDR3L RAM, and a 10Mb/s WiFi connection. The model's performance could be significantly enhanced with modern hardware configurations and a better WiFi connection.

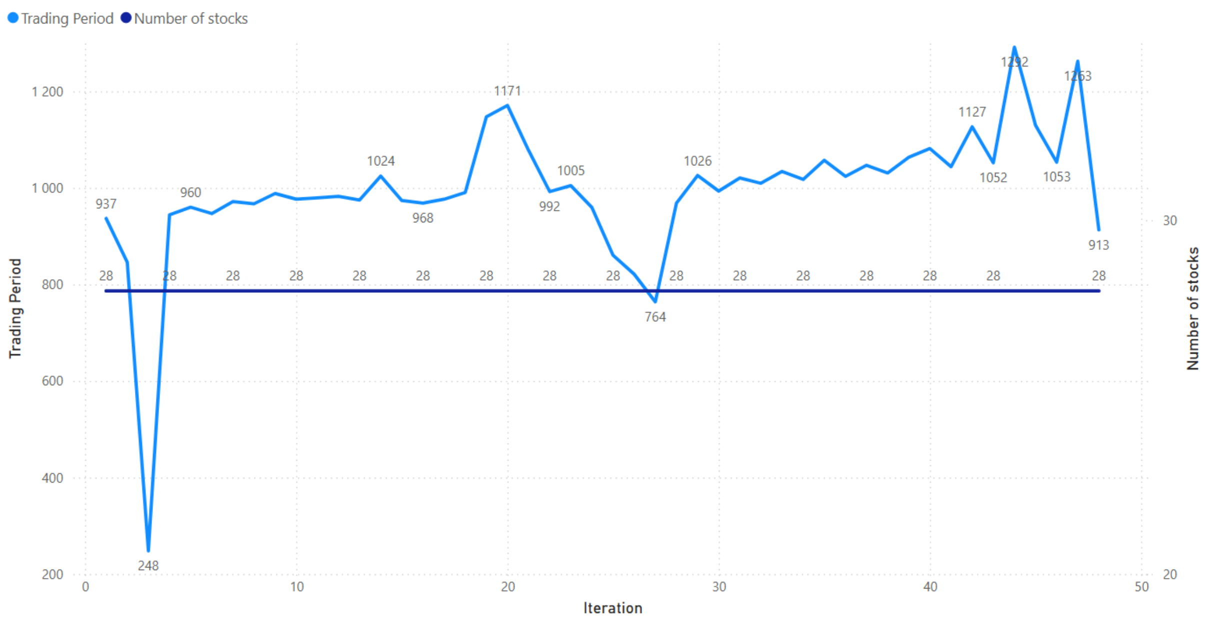

Figure 17: Computational Complexity Analysis of our Multi-Stock Prediction Model on 28 stocks

Conclusion

This paper presents a novel three-layer approach for stock market prediction that effectively combines traditional technical analysis, deep learning, chart classification, and sentiment analysis. Our research addresses the inherent limitations of conventional single method approaches by integrating multiple analytical perspectives into a cohesive framework. The experimental results demonstrate the superiority of our proposed architecture across multiple evaluation metrics.

The technical analysis layer successfully captures market trends and patterns through established indicators, while the deep learning component processes comprehensive historical data to identify complex market behaviours. The sentiment analysis layer adds a crucial dimension by incorporating real-time market sentiment from financial news, enabling our system to respond to emerging market dynamics. This multi-modal approach achieved significant improvements over existing methods, with lower Mean Absolute Error (MAE) and Mean Squared Error (MSE) scores, while maintaining a robust R^2 score.

Our findings suggest that the integration of traditional technical analysis with advanced machine learning techniques and sentiment analysis provides a more robust framework for stock market prediction than any single approach alone and other ensemble approaches. The success of our three-layer architecture demonstrates that combining different analytical perspectives can effectively capture the complex interplay of factors affecting stock market movements.

Future research directions could explore the integration of additional data sources, such as social media sentiment and macroeconomic indicators, as well as the application of more sophisticated deep learning architectures. Additionally, investigating the system's performance across different market conditions and time horizons could provide valuable insights for further improvements. As algorithmic trading continues to evolve, our approach provides a foundation for developing more sophisticated and reliable prediction systems that can adapt to changing market dynamics.

References

Abadi, M., Barham, P., Chen, J., Chen, Z., Davis, A., Dean, J., Devin, M., Ghemawat, S., Irving, G., Isard, M., Kudlur, M., Levenberg, J., Monga, R., Moore, S., Murray, D. G., Steiner, B., Tucker, P., Vasudevan, V., Warden, P., Wicke, M., Yu, Y., & Zheng, X. (2016). TensorFlow: A system for large-scale machine learning. In 12th USENIX Symposium on Operating Systems Design and Implementation (OSDI 16) (pp. 265–283). USENIX Association. https://www.usenix.org/conference/osdi16/technical-sessions/presentation/abadi

https://doi.org/10.18080/jtde.v13n1.1146

Appel, G. (2005). *Technical analysis: Power tools for active investors*. FT Press. https://dl.acm.org/doi/abs/10.5555/1408581

Araci, D. (2019). FinBERT: Financial sentiment analysis with pre-trained language models. *arXiv*. https://arxiv.org/abs/1908.10063

Awad, A. L., Elkaffas, S. M., & Fakhr, M. W. (2023). Stock market prediction using deep reinforcement learning. *Applied System Innovation*, *6*(6), 106. https://doi.org/10.3390/asi6060106

Bollinger, J. (2002). *Bollinger on Bollinger Bands*. McGraw-Hill. https://www.mencap.org.uk/sites/default/files/2021-06/pdf-bollinger-on-bollinger-bands-john-bollinger-pdf-download-free-book-547b394.pdf

Borovykh, A., Bohte, S., & Oosterlee, C. W. (2017). Conditional time series forecasting with convolutional neural networks. *arXiv*. https://doi.org/10.48550/arXiv.1703.04691

Cabrera, D., Cubillos, C., Cubillos, A., Urra, E., & Mellado, R. (2018). Affective algorithm for controlling emotional fluctuation of artificial investors in stock markets. *IEEE Access*, *6*, 7610–7624. https://doi.org/10.1109/ACCESS.2018.2802781

Chen, R. T., Rubanova, Y., Bettencourt, J., & Duvenaud, D. K. (2018). Neural ordinary differential equations. *Advances in Neural Information Processing Systems*, *31*. https://proceedings.neurips.cc/paper/2018/hash/69386f6bb1dfed68692a24c8686939b9-Abstract.html

Cohen, N., Balch, T., & Veloso, M. (2020). Trading via image classification. In Proceedings of the First ACM International Conference on AI in Finance (pp. 1–6). ACM. https://dl.acm.org/doi/abs/10.1145/3383455.3422544

Dhankar, R. S. (2019). Stock market operations and long-run reversal effect. In *Capital markets and investment decision making* (pp. 41–58). Springer. https://doi.org/10.1007/978-81-322-3748-8_3

Fan, C., & Zhang, X. (2024). Stock price nowcasting and forecasting with deep learning. *Journal of Intelligent Information Systems*. https://doi.org/10.1007/s10844-024-00908-2

Idowu, E. (2024). Advancements in financial market predictions using machine learning techniques. Preprints. https://doi.org/10.20944/preprints202407.1075.v1

Jia, C., Wang, D., Liu, J., & Deng, W. (2024). Performance optimization and application research of YOLOv8 model in object detection. *Academic Journal of Science and Technology*, *10*(1), 325–329. https://doi.org/10.54097/p9w3ax47

Kurniawan, A., & Yusuf, M. (2024). Stock price prediction using technical data and sentiment score. In 2024 IEEE International Conference on Industry 4.0, Artificial Intelligence, and Communications Technology (IAICT) (pp. 360–366). IEEE. https://doi.org/10.1109/IAICT62357.2024.10617768

Lane, G. C. (1984). Lane's stochastics. *Technical Analysis of Stocks and Commodities*, *2*(3), 80.

Liapis, C. M., Karanikola, A., & Kotsiantis, S. (2023). Investigating deep stock market forecasting with sentiment analysis. *Entropy*, *25*(2), 219. https://doi.org/10.3390/e25020219

Murphy, J. J. (1999). *Technical analysis of the financial markets: A comprehensive guide to trading methods and applications*. New York: New York Institute of Finance.

Nejad, F. S., & Ebadzadeh, M. M. (2024). Stock market forecasting using DRAGAN and feature matching. *Expert Systems with Applications*, *244*, 122952. https://doi.org/10.1016/j.eswa.2023.122952

Paul, M. K., & Das, P. (2023). A comparative study of deep learning algorithms for forecasting Indian stock market trends. *International Journal of Advanced Computer Science and Applications*, *14*(10), 889–897. http://doi.org/10.14569/IJACSA.2023.0141098

Roscoe, P. (2023). *How to build a stock exchange: The past, present and future of finance*. Policy Press. https://doi.org/10.1332/policypress/9781529224313.001.0001

Sahu, S., Mokhade, A., & Bokde, N. (2023). An overview of machine learning, deep learning, and reinforcement learning-based techniques in quantitative finance: Recent progress and challenges. *Applied Sciences*, *13*(3), 1956. https://doi.org/10.3390/app13031956

Singh, A., Afsar, M. M., Sharm, A., Rao, T., Kodip, A., & Rohini, B. R. (2023). Harnessing ML and DL for stock market analysis: A Tableau forecasting perspective. In 2023 4th IEEE Global Conference for Advancement in Technology (GCAT) (pp. 1–5). IEEE. https://doi.org/10.1109/GCAT59970.2023.10353264

Siva, N., Sivaiah, B. V., Nikkam, P. V., Volliboina, V., Sai, D. H., & Pushpalatha, K. (2024). Improving predictions of stock price with ensemble learning. In International Conference on Computational Innovations and Emerging Trends (ICCIET-2024) (pp. 548–558). Atlantis Press. https://doi.org/10.2991/978-94-6463-471-6_53

Vaswani, A., Shazeer, N., Parmar, N., Uszkoreit, J., Jones, L., Gomez, A. N., Kaiser, Ł., & Polosukhin, I. (2017). Attention is all you need. *Advances in Neural Information Processing Systems*, *30*. https://proceedings.neurips.cc/paper/2017/hash/3f5ee243547dee91fbd053c1c4a845aa-Abstract.html

Wilder, J. W. (1978). *New concepts in technical trading systems*. Trend Research.

Zhang, C., Sjarif, N. N. A., & Ibrahim, R. (2024). 1D-CapsNet-LSTM: A deep learning-based model for multi-step stock index forecasting. *Journal of King Saud University - Computer and Information Sciences*, *36*(2), 101959. https://doi.org/10.1016/j.jksuci.2024.101959

Exploring the Dynamics of Mobile Money in Africa

Causal Links and Financial Inclusion Outcome

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Abstract: This study investigates the causal relationships between key mobile money indicators and their implications for financial inclusion in Africa. Using macro-level data from the Global Mobile Money Dataset covering the period 2011–2023, we apply the Toda-Yamamoto causality approach to analyse interactions between registered accounts, active accounts, registered agents, and global transactions. Our results reveal a bidirectional causal relationship between registered accounts and global transactions, highlighting a reinforcing cycle that strengthens mobile money adoption. Additionally, registered agents play a crucial role in facilitating transactions, yet no direct causality is found between agent expansion and new account registrations, suggesting that factors such as trust and awareness are critical drivers of adoption. These findings emphasise the need for targeted policy interventions beyond agent network expansion, including financial literacy programs and user engagement initiatives. This study contributes to the growing literature on mobile money by providing empirical evidence on its role in financial inclusion and offering policy-relevant insights. Future research could explore the long-term integration of mobile money with traditional financial systems and its broader economic implications across diverse regulatory environments.

Keywords: Mobile Money, Financial Inclusion, Causality Analysis

Introduction

Financial inclusion, defined as the accessibility of individuals and businesses to affordable and useful financial services, is recognised as a critical driver of economic growth and development (World Bank, 2025). Despite the global push towards inclusivity, globally, about 1.4 billion adults are still unbanked according to the 2021 Global Findex Database (World Bank, 2025). highlighting the significant barriers that persist in accessing financial services. In this context,

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mobile money has emerged as a transformative financial technology (fintech) that has the potential to bridge the gap between the unbanked population and essential financial services. By facilitating transactions such as cash deposits, savings, money transfers, and payments for goods and services, mobile money systems offer enhanced convenience, speed, and reduced transaction costs (Senyo & Osabutey, 2020).

The definition of financial inclusion has been a debate subject (Zhang & Valle-Sison, 2014). Early studies focused primarily on access to financial services as the key determinant (Kempson *et al.*, 2000), while recent research (Central Bank of Kenya, 2024) highlights multiple dimensions such as access, usage, quality, and affordability of services.

Technology and mobile phone penetration have been shown to positively impact financial inclusion. Unlike mobile banking, which links to bank accounts, mobile money operates independently, with funds managed by mobile network operators. Since their introduction in 2004 in South Africa, mobile money services have rapidly expanded across Africa, outpacing bank-based mobile services. M-Pesa, launched in 2007 by Safaricom in Kenya and Vodacom in Tanzania, is a notable success. In Kenya, mobile money broadened access to services like health insurance and payments, becoming a vital alternative to traditional banking for the unbanked population.

Despite the promising benefits, the literature reveals a need for deeper investigation into the causal relationships between various mobile money indicators and financial inclusion outcomes. While previous studies have primarily focused on the adoption and usage patterns of mobile money (Lepoutre & Oguntoye, 2018; Malinga & Maiga, 2019; Rahman *et al.*, 2017) there remains a significant gap in understanding how these indicators interact to enhance financial inclusion effectively. Furthermore, the impact of mobile money on financial access varies across different demographics, necessitating a nuanced exploration of user behaviors and preferences costs (Senyo & Osabutey, 2020).

A more recent body of literature focuses on technology and financial inclusion, ranging from the role of blockchain technology in resolving the problems of financial inclusion in developing countries (Prisco *et al.*, 2022) and (Mavilia & Pisani, 2020), to the potential impact of metaverse on banks and the improvement of financial inclusion (Lyoussi & Kouchih, 2023).

The current study aims to add to the existing literature by analysing the causal linkages between mobile money indicators and their contributions to financial inclusion. The rest of the paper is structured as follows: Section 2 presents a literature review on the linkage between mobile money and financial inclusion. Section 3 outlines the methodology employed for the causality analysis Section 4 discusses the data sources, results, and their implications, while Section 5 offers conclusions, highlighting the findings' significance and proposing avenues for

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future research. We aim to provide insights into the pathways through which mobile money can be leveraged to enhance financial inclusion across diverse contexts in Africa.

Literature review

This section reviews the literature on financial inclusion and explores how technological advancements have accelerated its development. It focuses specifically on mobile money and summarises the consensus in the literature regarding its positive impact on financial inclusion.

Financial inclusion and technology advancements

Financial inclusion plays a pivotal role in promoting economic growth by ensuring access to financial services. The concept has evolved significantly, with early literature primarily focusing on accessibility as the sole determinant. However, more recent studies highlight that financial inclusion is a multidimensional concept, encompassing not only access but also usage and other factors that contribute to broader financial engagement (Adamo *et al.*, 2024). Access and usage remain the most widely used metrics to evaluate financial inclusion levels (Espinosa-Vega *et al.*, 2020; IMF, 2020), although additional elements, such as quality and affordability, are increasingly recognised as influential.

According to the G20, financial inclusion is defined through three core dimensions: (i) access to financial services, (ii) usage of these services, and (iii) the quality of both the products and the service delivery. The World Bank (2018) expands on this by emphasising that financial products and services should meet the needs of individuals and businesses, ensuring affordability, sustainability, and responsible delivery. These include services like transactions, payments, savings, credit, and insurance.

Further advancing this idea, the Global Financial Inclusion Index identifies three key pillars: government support for promoting financial inclusion, the financial system's role in providing essential services, and employer support for employee financial well-being. Affordability, in particular, is acknowledged as a critical dimension in reducing poverty, especially in developing countries (Dev, 2006; Lashitew *et al.*, 2019; N'dri & Kakinaka, 2020; Djahini-Afawoubo *et al.*, 2023). Some scholars also highlight the importance of ensuring that financial services are both useful and tailored to meet the practical needs of users (Dev, 2006; Lashitew *et al.*, 2019; N'dri & Kakinaka, 2020; Djahini-Afawoubo *et al.*, 2023).

Technological advancements, particularly the proliferation of mobile phones, have played a significant role in expanding access to financial services, thus promoting financial inclusion. The increasing penetration of mobile technology enhances the provision and accessibility of financial services, particularly in regions where traditional banking infrastructure is lacking (Demirgüç-Kunt *et al.*, 2008; Agyekum *et al.*, 2016). Fintech innovations have further facilitated this shift by allowing non-bank institutions to offer financial services, fostering greater inclusion across a broad spectrum of the population (Gai *et al.*, 2018; Avom *et al.*, 2023; Demirgüç-Kunt *et al.*, 2018).

Mobile transactions have become a powerful tool for integrating previously unbanked individuals into formal financial systems. In Ghana, for example, the rise of digital financial services through mobile phones and the internet has proven successful in providing cost-effective financial solutions to a broader segment of the population (Agyekum *et al.*, 2016). Mobile banking has also helped to address infrastructural challenges, improving financial access across Africa (Allen *et al.*, 2014). The impact of mobile technology on financial inclusion has been linked to broader economic development, as it reduces transaction costs and facilitates greater participation in financial markets (Aker & Mbiti, 2010).

As noted by the World Bank, the advantages of digital payments extend beyond mere convenience. When delivered efficiently, they can transform the financial lives of individuals and communities by enhancing access to essential financial services (The World Bank, 2018).

Mobile Money and financial inclusion

Mobile money, as defined by the World Bank, refers to the provision of financial services via a mobile device. While this definition is broad and could lead to confusion with mobile banking, there are critical distinctions between the two. Both mobile money and mobile banking involve the use of mobile phones to access financial services, but mobile money operates through funds managed by mobile network operators rather than traditional banking institutions. Unlike mobile banking, which is directly linked to bank accounts and is run by banks or financial institutions, mobile money is independent of banking systems and is supported by the infrastructure of telecom companies (Aker & Mbiti, 2010).

The regulatory frameworks for these services further underscore their differences. Mobile banking is regulated within existing banking frameworks, while mobile money is typically governed by company law and overseen by telecommunications regulators. However, the distinction between these services is not always clear-cut. In countries like Uganda, for example, formal partnerships between mobile network operators and banks blur the lines between mobile banking and mobile money (Aron, 2018).

Mobile money services were first introduced in South Africa in 2004, but the most notable success story is M-Pesa, launched by Safaricom in Kenya and Vodacom in Tanzania in 2007. These services, partly owned by Vodafone, have revolutionised financial access in many parts of Africa. ”M” stands for mobile, while “pesa” means money in Swahili. M-Pesa’s success has become an inspiration for many developing nations, showcasing the rapid expansion of mobile

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network operators' services compared to traditional bank-based mobile offerings (Masha, 2016).

The role of mobile money in advancing financial inclusion has been a significant topic of discussion in recent literature (Asongu & Le Roux, 2023; Avom *et al*., 2023; Djahini-Afawoubo *et al*., 2023; Johnen *et al*., 2023; Nguyen & Mogaji, 2022). Mobile money has been shown to facilitate financial inclusion by broadening access to financial services, particularly in regions with high mobile phone penetration. In Kenya, as in many African countries, the widespread adoption of mobile money has allowed individuals to access services such as health insurance, remittances, and payments, thereby expanding the scope of financial inclusion (Geng *et al*., 2018). The success of platforms like M-Pesa has highlighted mobile money's role in enhancing banking services, increasing the volume of financial transactions, and improving individual financial outcomes through expanded access to formal financial systems (Mbiti & Weil, 2015; Della Peruta, 2018).

Access to financial services through mobile phones has also been linked to poverty reduction. Studies indicate that mobile money users increasingly engage in transactions for credit and insurance purposes, which supports broader financial inclusion and economic resilience (Jack & Suri, 2014). Mobile money is considered one of the most promising tools for expanding financial access in developing economies (Donovan, 2012), with numerous studies demonstrating its positive impact on financial inclusion (Munyegera & Matsumoto, 2016; Mothobi & Grzybowski, 2017; Geng *et al*., 2018; Tyce, 2020). However, some scholars have pointed out that the poorest segments of the population do not always fully benefit from this financial revolution (Ozili, 2021; Prahalad, 2005; Balasubramanian *et al*., 2023).

From a business perspective, mobile money offers tangible benefits by reducing transaction and cash management costs, thereby improving customer service and increasing profitability for enterprises that adopt it (Ahmad *et al*., 2020). In Kenya, mobile money has demonstrated its capacity to reduce transaction costs and help users better withstand financial shocks without sacrificing household consumption. In a study of 16 Sub-Saharan African economies, mobile money usage was positively correlated with increased investment by women owned small and medium-sized enterprises (SMEs), highlighting its importance for economic empowerment and business growth (Islam & Muzi, 2022).

From a consumer perspective, mobile money also plays a crucial role in facilitating remittances, particularly during periods of economic shocks such as the COVID-19 pandemic. By enhancing remittance flows, mobile money helps reduce poverty and vulnerability in rural areas, where many urban workers send money to support their families (Koomson *et al*., 2021; Munyegera & Matsumoto, 2016; N'dri & Kakinaka, 2020). The use of mobile money has proven to be a fast, convenient, and cost-effective means of improving the financial situations of the rural poor (Geng *et al.*, 2018; Senyo & Osabutey, 2020; Batista & Vicente, 2020; Suri & Jack, 2016). Its benefits extend across all income groups (David-West *et al.*, 2019, N'dri & Kakinaka, 2020, Senyo & Osabutey, 2020), with advantages such as reduced transaction costs and increased security for remittances (Ahmad *et al.*, 2020).

Mobile money further enhances financial inclusion by facilitating various payments, such as utility bills and fund transfers, and by creating transaction histories that can improve credit scores and transparency for users (Aron, 2018; Demirgüç-Kunt et al., 2018). These developments help integrate users into formal financial systems and improve their access to loans (Comninos *et al.*, 2009; Demirgüç-Kunt *et al.*, 2018; Gosavi, 2018). Additionally, in countries like Mauritius, the adoption of mobile money for tax payments has been linked to a significant increase in tax receipts, further showcasing its broader societal benefits (Scharwat, 2014).

Finally, mobile money's liquidity and privacy provide users, particularly women, with opportunities for financial independence. As a liquid asset, mobile money can serve as an alternative to traditional savings methods, while its privacy features allow users, such as housewives, to maintain secret savings and achieve greater financial autonomy (Demirgüç-Kunt *et al.*, 2018).

Overall, the literature on mobile money underscores its significant role in advancing financial inclusion, particularly in Africa, by expanding access to financial services through mobile technology. Studies consistently highlight its positive effects on poverty reduction, remittance facilitation, and enhanced business operations, particularly for underserved populations. However, the uneven distribution of benefits, especially among poorer communities, suggests a need for further investigation into the dynamics of mobile money usage. Thus, understanding the causality and direction of relationships between key mobile money indicators offers critical insights into its economic impact. This is particularly relevant in Africa, where mobile money's rapid adoption has had significant implications for both financial inclusion and economic development, making the exploration of causal linkages an essential aspect of empirical analysis.

Methodology

Model

To investigate the causality between different indicators of mobile money in Africa and determine the direction of causality, we applied the Toda and Yamamoto causality test (Toda & Yamamoto, 1995). This method is well-suited to address some of the limitations of the

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traditional Granger causality test (Granger, 1969). While the Granger test requires the time series data to be stationary or integrated of the same order, the Toda and Yamamoto approach allows for the possibility of causality between series that are integrated of different orders. One advantage of this method is that it does not rely on the cointegration properties of the series, meaning that the test can be performed regardless of whether the variables are cointegrated. In the Toda and Yamamoto approach, a standard vector autoregressive (VAR) model is constructed using the variables in their levels, irrespective of their integration order. The order of the VAR model is then artificially increased by adding the maximum integration order, d_{max}, to the actual lag length of the model, k. However, the coefficients of these additional terms are not taken into account when testing for causality. The Toda-Yamamoto causality test allows us to assess the causal relationships between mobile money indicators such as global transactions, active accounts, registered accounts, and registered agents, while accommodating potential differences in their integration orders. The model used for this analysis is represented by the following equations:

$$X_t = \alpha_0 + \sum_{i=1}^{k+d_{max}} \alpha_{2i} X_{t-i} + \sum_{i=1}^{k+d_{max}} \alpha_{3i} Y_{t-i} + \mu_{1t} \tag{1}$$

$$Y_t = \beta_0 + \sum_{i=1}^{k+d_{max}} \beta_{2i} X_{t-i} + \sum_{i=1}^{k+d_{max}} \beta_{3i} Y_{t-i} + \mu_{2t} \tag{2}$$

The Toda and Yamamoto causality test is performed with the help of modified Wald using above equations. In the equations, X_t and Y_t represent the variables examined. In the models, each variable is regressed on each other with a number of delays from 1 to $k + d_{max}$. μ_{1t} and μ_{2t} expresses error terms in equations. k shows the maximum number of delays and d the degree of integration of the variables.

Data

The data for this analysis is sourced from the Global Mobile Money Dataset, a comprehensive collection of industry metrics curated by the GSMA Mobile Money program (GSMA, 2023). The dataset spans from January 2011 to December 2023, providing extensive coverage of mobile money trends across Africa. The variables, along with their notations and sources, are detailed in Table 1.

Table 1 Variables notation and sources

Variables	Notation	Source
Active accounts for 90 Days	A_t	(GSMA, 2023)
Global transactions	G_t	(GSMA, 2023)
Registered accounts	R_t	(GSMA, 2023)

Registered agents	RA_t	(GSMA, 2023)

Variables

Our study examines four key indicators of mobile money in Africa: Active Accounts for 90 Days, Global Transactions, Registered Accounts, and Registered Agents. Each variable offers insights into the availability and usage of mobile money services across the continent.

- **Active Accounts for 90 Days** measure the number of mobile money accounts that have been active within the last three months. This variable reflects user engagement and ongoing utilisation of mobile money services. In Africa, where many individuals rely on mobile money for daily transactions, the number of active accounts is crucial for understanding adoption and sustained usage (N'dri & Kakinaka, 2020; Demirgüç-Kunt & Singer, 2017).
- **Global Transactions** represent the total number of mobile money transactions over a given period. This metric serves as a direct indicator of system functionality and demand. Prior research suggests that rising transaction volumes signal increasing trust in mobile money platforms, which is vital for economic growth in regions with limited banking infrastructure (Gai *et al.*, 2018; N'dri & Kakinaka, 2020).
- **Registered Accounts** capture the total number of mobile money accounts created, indicating the extent of mobile money reach. While high registration numbers suggest expanding financial inclusion, the challenge lies in converting registered users into active users. Addressing this gap is essential for enhancing financial participation in Africa (Demirgüç-Kunt & Singer, 2017; Gai *et al.*, 2018).
- **Registered Agents** form the backbone of the mobile money ecosystem, facilitating cash-in and cash-out operations. The number of registered agents reflects service availability, particularly in rural and underserved areas. A broader agent network enhances accessibility, mitigating geographic and infrastructural barriers to financial services (Gai *et al.*, 2018; N'dri & Kakinaka, 2020).

These indicators collectively capture both the availability and usage of mobile money services. Analysing them provides valuable insights into the health of the mobile money ecosystem in Africa and its role in financial inclusion.

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Results and Discussion

This section presents the empirical results of our analysis on the causal relationships between mobile money indicators. First, we examine the level of integration of the variables. Finally, we analyse the causality between the variables using the Toda-Yamamoto approach.

Unit root and causality analysis

The results of the unit root test are displayed in Table 2. After determining the integration order of the variables, we applied the Toda-Yamamoto causality test, as outlined in the previous section, to explore the causal relationships among the selected mobile money indicators in Africa.

Table 2 ADF unit root test results

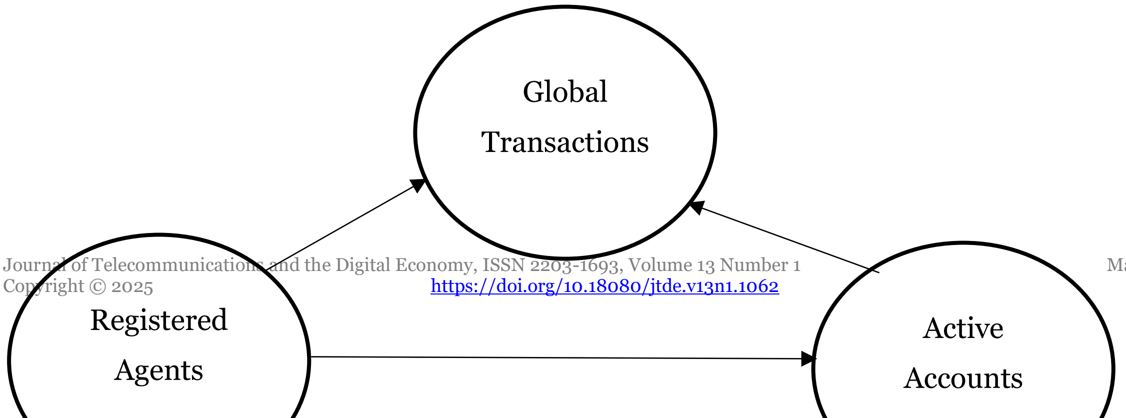
Variable	Level		First Difference	
	Statistic	p-value	Statistic	p-value
A_t	0.88	0.99	-6.603***	0.00
G_t	1.23	0.99	-4.038***	0.01
R_t	0.81	0.99	-5.79***	0.00
RA_t	5.12	1.00	-10.081***	0.00

*Note: ** and *** indicate significance levels at 5% and 1% respectively*. Source: Author's calculations

Table 3 Toda-Yamamoto causality test

	Statistic	p-value
$A_t \to G_t$	13.523***	0.009
$A_t \to RA_t$	9.001*	0.061
$A_t \to R_t$	5.972	0.201
$G_t \to A_t$	5.493	0.240
$G_t \to RA_t$	8.780*	0.066
$G_t \to R_t$	5.773	0.16
$RA_t \to A_t$	0.824	0.935
$RA_t \to G_t$	9.758**	0.044
$RA_t \to R_t$	0.981	0.912
$R_t \to A_t$	10.773**	0.029
$R_t \to G_t$	12.526**	0.013
$R_t \to RA_t$	8.091	0.088

*Note: ** and *** indicate significance levels at 5% and 1% respectively*. Source: Author's calculations



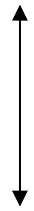


Figure 1 Causality direction between mobile money indicators. Source: Author's calculations

The objective of this study is to examine the causal relationships between key components of mobile money adoption, particularly registered accounts, global transactions, and registered agents. By analysing these interdependencies, the study seeks to uncover the mechanisms that drive mobile money growth and sustainability. Understanding these relationships is crucial for designing policies and strategies that enhance financial inclusion and the efficiency of digital financial services.

The results, as presented in Table 3 and Figure 1, indicate a bidirectional causality between registered accounts and global transactions, highlighting a reinforcing feedback mechanism. An increase in registered accounts expands the user base, leading to higher transaction volumes, while the growth in transactions encourages further account registrations by enhancing trust and accessibility. This interplay illustrates the dynamic nature of mobile money adoption, where both supply (account registration) and demand (transactions) evolve together, strengthening the ecosystem (N'dri & Kakinaka, 2020).

Table 3 also reveals a causal link between registered agents and global transactions, emphasising the pivotal role of agents in driving transaction volumes. The expansion of the agent network enhances the ease and frequency of transactions by providing users with localised financial services, particularly in rural and underserved areas. Agents reduce the friction associated with mobile money usage, reinforcing a cycle of increased engagement and value creation (Gai *et al.*, 2018; Demirgüç-Kunt & Singer, 2017).

Additionally, the causality from registered agents to active accounts underscores their role in maintaining user participation. As agent networks grow, more registered accounts transition from inactive to active status, increasing transaction volumes and reinforcing the sustainability of mobile money platforms. However, an unexpected finding is the absence of causality between registered agents and registered accounts. Given the common assumption that agent expansion directly leads to new registrations, this result challenges traditional perspectives on mobile money adoption. Several factors may explain this outcome. First, it is possible that other determinants, such as awareness campaigns, social influence, or trust in the platform, play a more decisive role in driving initial registrations (Ozili, 2021). Second, in markets where mobile money is already well-established, the presence of agents may not be a key motivator for new users. Finally, regional disparities may account for variations in user behavior, as urban areas with access to traditional banking services may not rely on mobile money agents as heavily as rural areas.

One limitation of this study is the potential influence of unobserved factors affecting mobile money adoption. The lack of causality between registered agents and registered accounts suggests that agent expansion alone may not be sufficient to increase user registrations, particularly in mature markets where alternative financial services exist. Additionally, the study does not account for regional variations in mobile money adoption patterns, which may impact the generalisability of the findings. Future research could incorporate qualitative analyses or survey data to better understand the motivations behind user registrations and transaction behaviors. Another potential gap is the assumption that all registered accounts represent unique users, which may overlook multiple accounts held by the same individual. Despite these limitations, the study successfully demonstrates the interdependencies between key elements of the mobile money ecosystem.

The identification of bidirectional causality between registered accounts and global transactions confirms the self-reinforcing nature of mobile money adoption. The findings also underscore the significance of active accounts in sustaining transaction volumes, reinforcing the value of continuous user engagement. Comparing different causal pathways, the study reveals that while agent expansion is crucial for maintaining transaction flow, it is not a primary driver of account registration. This distinction is essential for policymakers and mobile money operators, as it suggests that strategies should focus not only on expanding agent networks but also on increasing awareness and trust among potential users. These results align with prior research (Suri & Jack, 2016; Demirgüç-Kunt & Singer, 2017), which emphasises the importance of user activity in driving mobile money success. Future studies could build on these insights by exploring the role of digital literacy and financial incentives in enhancing adoption rates.

Conclusions

Our study aims to contribute to the understanding of mobile money adoption by analysing the causal relationships among four key indicators and their impact on financial inclusion in

Africa using the Toda-Yamamoto causality approach. Our findings highlight a reinforcing feedback loop between registered accounts and global transactions, demonstrating that mobile money systems play a crucial role in fostering financial inclusion. Additionally, the study underscores the essential role of registered agents in sustaining mobile money ecosystems by facilitating transactions and building user trust, particularly in underserved regions.

Despite the evident benefits of mobile money in expanding financial access, the absence of direct causality between registered agents and new account registrations suggests that increasing agent networks alone is insufficient for driving broader adoption. Instead, awareness, trust, and perceived reliability of mobile money platforms appear to be key determinants. This insight calls for policymakers and mobile money operators to implement integrated strategies, including targeted awareness campaigns, financial literacy programs, and user incentives, to drive sustainable adoption and engagement.

Furthermore, as active accounts play a vital role in driving transaction volumes, ensuring continuous user participation is critical. Future research should explore additional factors influencing mobile money usage, such as regulatory environments, socio-economic conditions, and technological advancements. Expanding the scope to include cross-country comparisons or panel data analysis could provide deeper insights into the broader implications of mobile money on economic development. By advancing knowledge in this field, this study lays the groundwork for informed policy decisions and strategic initiatives that maximise the potential of mobile money to drive financial inclusion and economic growth across Africa.

References

Adamo, R., Federico, D., Notte, A. (2024). Financial Inclusion Literature Review: Definition, Measurement, and Challenges. In João Jungo, Mara Madaleno, Anabela Botelho, and Eyup Dogan (Eds.) *The Role of Financial Inclusion for Reaching Sustainable Development Goals*, 28–46. https://doi.org/10.4018/979-8-3693-0522-5.ch003

Agyekum, F., Locke, S., & Hewa-Wellalage, N. (2016). Financial inclusion and digital financial services: Empirical evidence from Ghana. MPRA Paper No. 82885. https://mpra.ub.uni-muenchen.de/82885/

Ahmad, A. H., Green, C., & Jiang, F. (2020). Mobile money, financial inclusion and development: A review with reference to African experience. *Journal of Economic Surveys, 34*, 753–792. https://doi.org/10.1111/joes.12372

Aker, J. C., & Mbiti, I. M. (2010). Mobile phones and economic development in Africa. *Journal of Economic Perspectives, 24*, 207–232. https://doi.org/10.2139/ssrn.1629321

https://doi.org/10.18080/jtde.v13n1.1062

Allen, F., Carletti, E., Cull, R., Qian, J., Senbet, L., & Valenzuela, P. (2014). The African financial development and financial inclusion gaps. *Journal of African Economies, 23*, 614–642. https://doi.org/10.1093/jae/eju015

Aron, J. (2018). Mobile money and the economy: A review of the evidence. *The World Bank Research Observer, 33*, 135–188. https://doi.org/10.1093/wbro/lky001

Asongu, S. A., & Le Roux, S. (2023). The role of mobile money innovations in transforming unemployed women to self-employed women in sub-Saharan Africa. *Technological Forecasting and Social Change, 191*, 122548. https://doi.org/10.1016/j.techfore.2023.122548

Avom, D., Bangaké, C., & Ndoya, H. (2023). Do financial innovations improve financial inclusion? Evidence from mobile money adoption in Africa. *Technological Forecasting and Social Change, 190*, 122451. https://doi.org/10.1016/j.techfore.2023.122451

Balasubramanian, K., Drake, D. F., & Urrea, G. (2023). The impact of poverty on base of the pyramid operations: Evidence from mobile money in Africa. *Journal of Operations Management, 69*, 616–642. https://doi.org/10.1002/joom.1227

Bateman, M., Duvendack, M., & Loubere, N. (2019). Is fin-tech the new panacea for poverty alleviation and local development? Contesting Suri and Jack's M-Pesa findings published in *Science*. *Review of African Political Economy, 46*, 480–495. https://www.jstor.org/stable/48547696

Batista, C., & Vicente, P. C. (2020). Improving access to savings through mobile money: Experimental evidence from African smallholder farmers. *World Development, 129*, 104905. https://doi.org/10.1016/j.worlddev.2020.104905

Beck, T., Demirgüç-Kunt, A., & Levine, R. (2007). Finance, inequality and the poor. *Journal of economic growth, 12*, 27–49. https://doi.org/10.1007/s10887-007-9010-6

Central Bank of Kenya. (2024). *FinAccess Household Survey Report*. Central Bank of Kenya. https://www.centralbank.go.ke/2024/12/13/10960/

Comninos, A. C., Esselaar, S., Ndiwalana, A., & Stork, C. S. (2009). Airtime to cash: unlocking the potential of Africa's mobile phones for banking the unbanked. In *IST-Africa 2009 Conference Proceedings*, Paul Cunningham & Miriam Cunningham (Eds.), Ireland: International Information Management Corporation Limited, 2009.

David-West, O., Iheanachor, N., & Umukoro, I. O. (2019). Mobile money as a frugal innovation for the bottom of the pyramid–Cases of selected African countries. *Africa Journal of Management, 5*, 274–302. https://doi.org/10.1080/23322373.2019.1652023

Della Peruta, M. (2018). Adoption of mobile money and financial inclusion: a macroeconomic approach through cluster analysis. *Economics of Innovation and New Technology, 27*, 154–173. https://doi.org/10.1080/10438599.2017.1322234

Demirgüç-Kunt, A., & Singer, D. (2017). Financial inclusion and inclusive growth: A review of recent empirical evidence. Policy Research Working Paper, 8040. Washington, DC: World Bank. https://hdl.handle.net/10986/26479

Demirgüç-Kunt, A., Beck, T. H., & Honohan, P. (2008). *Finance for all? Policies and pitfalls in expanding access*. World Bank Policy Research Report. Washington, DC: World Bank. http://hdl.handle.net/10986/6905

Demirgüç-Kunt, A., Klapper, L., Singer, D., & Ansar, S. (2018). *The Global Findex Database 2017: Measuring Financial Inclusion and the Fintech Revolution*. Washington, DC: World Bank. http://hdl.handle.net/10986/29510

Demirgüç-Kunt A., Klapper L., Singer D., & Ansar S. (2021). *The Global Findex Database 2021: Financial Inclusion, Digital Payments, and Resilience in the Age of COVID-19*. Washington, DC: World Bank. https://openknowledge.worldbank.org/bitstream/handle/10986/37578/9781464818974.pdf

Dev, S. M. (2006). Financial inclusion: Issues and challenges. *Economic and Political Weekly*, 4310–4313. http://www.jstor.org/stable/4418799

Diniz, E., Birochi, R., & Pozzebon, M. (2012). Triggers and barriers to financial inclusion: The use of ICT-based branchless banking in an Amazon county. *Electronic Commerce Research and Applications, 11*, 484–494. https://doi.org/10.1016/j.elerap.2011.07.006

Djahini-Afawoubo, D. M., Couchoro, M. K., & Atchi, F. K. (2023). Does mobile money contribute to reducing multidimensional poverty? *Technological Forecasting and Social Change, 187*, 122194. https://doi.org/10.1016/j.techfore.2022.122194

Donovan, K. (2012). Mobile money for financial inclusion. *Information and Communications for development, 61*, 61–73. https://doi.org/10.1596/9780821389911_ch04

Espinosa-Vega, M. A., Shirono, M. K., Villanova, M. H., Chhabra, M., Das, M. B., & Fan, M. Y. (2020). *Measuring financial access: 10 years of the IMF financial access survey*. Washington, DC: International Monetary Fund. https://www.imf.org/en/Publications/Departmental-Papers-Policy-Papers/Issues/2020/05/12/Measuring-Financial-Access-10-Years-of-the-IMF-Financial-Access-Survey-49298

Gai, K., Qiu, M., & Sun, X. (2018). A survey on FinTech. *Journal of Network and Computer Applications, 103*, 262–273. https://doi.org/10.1016/j.jnca.2017.10.011

Geng, X., Janssens, W., Kramer, B., & van der List, M. (2018). Health insurance, a friend in need? Impacts of formal insurance and crowding out of informal insurance. *World Development, 111*, 196–210. https://doi.org/10.1016/j.worlddev.2018.07.004

Gosavi, A. (2018). Can mobile money help firms mitigate the problem of access to finance in Eastern sub-Saharan Africa? *Journal of African Business, 19*, 343–360. https://doi.org/10.1080/15228916.2017.1396791

Granger, C. W. (1969, August). Investigating Causal Relations by Econometric Models and Cross-spectral Methods. *Econometrica, 37*, 424. https://doi.org/10.2307/1912791

GSMA. (2023). Global Mobile Money Dataset. *Global Mobile Money Dataset*. https://www.gsma.com/solutions-and-impact/connectivity-for-good/mobile-for-development/gsma_resources/global-mobile-money-dataset/

International Monetary Fund (IMF). (2020). *Financial Access Survey*. Washington, DC: IMF.

Islam, A. M., & Muzi, S. (2022). Does mobile money enable women-owned businesses to invest? Firm-level evidence from Sub-Saharan Africa. *Small Business Economics, 59*, 1245–1271. https://doi.org/10.1007/s11187-021-00562-w

Jack, W., & Suri, T. (2011). *Mobile Money: The Economics of M-PESA, Working Paper 16721*. Cambridge, MA: National Bureau of Economic Research. http://www.nber.org/papers/w16721

Jack, W., Ray, A., & Suri, T. (2013). Transaction networks: Evidence from mobile money in Kenya. *American Economic Review, 103*, 356–361. https://doi.org/10.1257/aer.103.3.356

Jack, W. & Suri, T. (2014). Risk sharing and transactions costs: Evidence from Kenya's mobile money revolution. *American Economic Review, 104*, 183–223. https://doi.org/10.1257/aer.104.1.183

Johnen, C., Parlasca, M., & Mußhoff, O. (2023). Mobile money adoption in Kenya: The role of mobile money agents. *Technological Forecasting and Social Change, 191*, 122503. https://doi.org/10.1016/j.techfore.2023.122503

Kempson, E., Whyley, C., Caskey, J., & Collard, S. (2000). *In or Out? Financial Exclusion: A Literature and Research Review*. London: Financial Services Authority.

Klapper, L. & Singer, D. (2014). *The Opportunities of Digitizing Payments*. Washington, DC: World Bank.

Koomson, I., Bukari, C., & Villano, R. A. (2021). Mobile money adoption and response to idiosyncratic shocks: Empirics from five selected countries in sub-Saharan Africa. *Technological Forecasting and Social Change, 167*, 120728. https://doi.org/10.2139/ssrn.3802345

Lashitew, A. A., Van Tulder, R., & Liasse, Y. (2019). Mobile phones for financial inclusion: What explains the diffusion of mobile money innovations? *Research Policy, 48*, 1201–1215. https://doi.org/10.1016/j.respol.2018.12.010

Lepoutre, J., & Oguntoye, A. (2018, June). The (non-)emergence of mobile money systems in Sub-Saharan Africa: A comparative multilevel perspective of Kenya and Nigeria. *Technological Forecasting and Social Change, 131*, 262–275. https://doi.org/10.1016/j.techfore.2017.11.010

Lyoussi, D., & Kouchih, A. (2023). Metaverse and financial inclusion opportunities and risks for the banking ecosystem. In Rohit Bansal, Sikandar Ali Qalati, and Aziza Chakir (Eds.), *Advances in Marketing, Customer Relationship Management, and E-Services*, 205–224. IGI Global. https://doi.org/10.4018/978-1-6684-8898-0.ch013

Malinga, R. B. & Maiga, G. (2019). A model for mobile money services adoption by traders in Uganda. *The Electronic Journal of Information Systems in Developing Countries*, 86. https://doi.org/10.1002/isd2.12117

Masha, I. (2016). Macroeconomic impact of mobile payment services: A survey of research evidence. Presentation to the International Growth Centre and the London School of Economics Regional Workshop, Freetown, Sierra Leone. https://www.theigc.org/sites/default/files/2016/03/2.-Iyabo-Masha.pdf

Mavilia, R., & Pisani, R. (2020). Blockchain and catching-up in developing countries: The case of financial inclusion in Africa. African Journal of Science, Technology, Innovation and Development, *12*(2), 151–163. https://doi.org/10.1080/20421338.2019.1624009

Mbiti, I., & Weil, D. N. (2015). Mobile banking: The impact of M-Pesa in Kenya. In Sebastian Edwards, Simon Johnson, and David N. Weil (Eds.), *African Successes, Volume III: Modernization and Development* (pp. 247–293). Chicago: University of Chicago Press.

Mothobi, O., & Grzybowski, L. (2017). Infrastructure deficiencies and adoption of mobile money in Sub-Saharan Africa. *Information Economics and Policy, 40*, 71–79. https://doi.org/10.1016/j.infoecopol.2017.05.003

Munyegera, G. K., & Matsumoto, T. (2016). Mobile money, remittances, and household welfare: Panel evidence from rural Uganda. *World Development, 79*, 127–137. https://doi.org/10.1016/j.worlddev.2015.11.006

N'dri, L. M., & Kakinaka, M. (2020). Financial inclusion, mobile money, and individual welfare: The case of Burkina Faso. *Telecommunications Policy, 44*(3). https://doi.org/10.1016/j.telpol.2020.101926

Nguyen, N. P. & Mogaji, E. (2022). #BankFromHome: Using Advertisement Campaigns to Change Banking Behaviour During the COVID-19 Pandemic in an Emerging Economy. In *Marketing Communications and Brand Development in Emerging Markets Volume II Insights for a Changing World* (83-108). Springer. https://doi.org/10.1007/978-3-030-95581-6_4

Ozili, P. K. (2021). Financial inclusion: globally important determinants. *Financial Internet Quarterly, 17*, 1–11. https://doi.org/10.2478/fiqf-2021-0023

Prahalad, C. K. (2005). *The Fortune at the Bottom of the Pyramid.* London: Financial Times/Prentice Hall.

Prisco, A., Abdallah, Y. O., Morande, S., & Gheith, M. H. (2022). Factors affecting blockchain adoption in Italian companies: The moderating role of firm size. Technology Analysis and Strategic Management, 1–14. https://doi.org/10.1080/09537325.2022.2155511

Rahman, S. A., Taghizadeh, S. K., Ramayah, T., & Alam, M. M. (2017, May). Technology acceptance among micro-entrepreneurs in marginalized social strata: The case of social innovation in Bangladesh. *Technological Forecasting and Social Change, 118*, 236–245. https://doi.org/10.1016/j.techfore.2017.01.027

Scharwat, C. P. (2014). Paying taxes through mobile money: Initial insights into P2G and B2G payments. *Paying taxes through mobile money: Initial insights into P2G and B2G payments*. London: GSMA.

Senyo, P. K. & Osabutey, E. L. (2020, December). Unearthing antecedents to financial inclusion through FinTech innovations. *Technovation, 98*, 102155. https://doi.org/10.1016/j.technovation.2020.102155

Suri, T. & Jack, W. (2016). The long-run poverty and gender impacts of mobile money. *Science, 354*, 1288–1292. https://doi.org/10.1126/science.aah5309

The World Bank. (2018). Financial inclusion on the rise, but gaps remain. *Financial inclusion on the rise, but gaps remain*. Washington, DC: World Bank.

The World Bank. (2025) Financial inclusion is a key enabler to reducing poverty and boosting prosperity. *Financial inclusion is a key enabler to reducing poverty and boosting prosperity*. Washington, DC: World Bank.

Toda, H. Y. & Yamamoto, T. (1995). Statistical inference in vector autoregressions with possibly integrated processes. *Journal of econometrics, 66*, 225–250. https://doi.org/10.1016/0304-4076(94)01616-8

Tyce, M. (2020). Beyond the neoliberal-statist divide on the drivers of innovation: A political settlements reading of Kenya's M-Pesa success story. *World Development, 125*, 104621. https://doi.org/10.1016/j.worlddev.2019.104621

Zhang, Q. & Valle-Sison, J. B. (2014). Financial inclusion and regulatory implications. In Iwan J. Azis & Hyun S. Shin (Eds.), *Global Shock, Risks, and Asian Financial Reform*. Cheltenham, UK: Edward Elgar Publishing.

Predicting Cryptocurrency Prices with a Hybrid ARIMA and LSTM Model

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Abstract: Cryptocurrencies have attracted significant attention from investors, regulators and the media since their emergence. In a world where digital advancements are increasingly included in everyday relations, studying the behaviour of cryptocurrencies and their impact on financial markets becomes a necessity. This paper introduces a comparative analysis towards a hybrid model combining classical and modern methods for predicting cryptocurrency prices. This study deals with everyday recordings of 10 cryptocurrencies that represent different technological innovations and use cases. Studying these cryptocurrencies can help understand volatility, volumes and price movements. We aim to develop a time series statistical model and to study the effectiveness of deep learning (DL) models, specifically long short-term memory (LSTM) model and the autoregressive integrated moving average (ARIMA) model, for predicting cryptocurrency prices accurately and forecasting stationary data. Combining ARIMA and LSTM, we managed to obtain a high value of R^2 for Binance Coin (BNB) cryptocurrency (0.936) with an average R^2 for all evaluated cryptocurrencies of 0.6555.

Keywords: Cryptocurrency, Price Prediction, Deep Learning, Digital Investment, Blockchain

Introduction

Cryptocurrencies have garnered substantial attention from investors, regulators and researchers since their inception (Corbet *et al.*, 2019). The unprecedented growth of the cryptocurrency sector, fuelled by Bitcoin's launch in 2009, has driven innovation across various fields, including finance, technology and economics. Blockchain technology, the foundation of Bitcoin, has paved the way for a new wave of digital currencies (Urquhart & Yarovaya, 2023), leading to the exponential expansion of the cryptocurrency market over the last decade (Jaquart *et al.*, 2022). In an era where digital transformation is reshaping financial

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systems, understanding cryptocurrency behaviour and its implications for financial markets has become imperative (Jalan *et al.*, 2023).

While traditional financial ecosystems rely on centralised institutions and policies to ensure stability, efficiency and cost reduction (Bose *et al.*, 2019), cryptocurrencies have emerged as decentralised alternatives that aim to address systemic flaws, such as inflation and high transaction costs (Chaum, 1983; Wu *et al.*, 2024). Consequently, cryptocurrency price prediction has become a key research area, offering valuable insights for market participants, regulators and investors.

Existing studies on cryptocurrency price prediction have explored various modelling approaches. Statistical models, such as the autoregressive integrated moving average (ARIMA) (Zhang *et al.*, 2020) and generalised autoregressive conditional heteroskedasticity (GARCH) (Raza & Riaz, 2020), have been widely used but often struggle with scalability when applied to large datasets. Machine learning (ML) models, such as those proposed by Orte *et al.* (2023) and Omar & Soliman (2023) have shown promise in handling complex datasets, though they are sometimes limited in capturing temporal dependencies. Deep learning (DL) approaches, including convolutional neural networks (CNN) and bidirectional long short-term memory (BI-LSTM) networks (Ramakrishnan *et al.*, 2022a), have demonstrated strong generalisation capabilities and predictive accuracy. More recently, transformer-based models have been explored for their potential to improve predictions (Chen & Wang, 2024; Koo & Kim, 2024).

Despite these advancements, there remains a gap in understanding how classical statistical models and advanced DL approaches compare in terms of effectiveness for cryptocurrency price prediction. Motivated by this gap, this paper aims to address the question:

> How can advanced ML models, such as LSTM, and statistical models, like ARIMA, enhance the accuracy of cryptocurrency price predictions in a rapidly evolving digital financial landscape?

In this study, we propose a hybrid approach that combines the strengths of LSTM, a DL model designed to capture temporal dependencies, and ARIMA, a statistical model known for its stationary analysis and retrospective forecasting capabilities. The analysis is conducted on a comprehensive dataset comprising over 20,000 daily recordings of 10 cryptocurrencies, including Bitcoin (BTC), Ethereum (ETH), Solana (SOL) and others, spanning from 2014 to 2024. In fact, our study focuses on these 10 cryptocurrencies as we selected them for their market capitalisation, trading volume, public interest and unique characteristics. Besides, the chosen cryptocurrencies present diverse blockchain platforms enabling us to provide a comprehensive market view. The selection of these 10 cryptocurrencies was based on their significant market capitalisation, liquidity and diverse blockchain technologies. They provide long-term transactional data suitable for time series analysis, making them ideal for predicting price trends using ARIMA and detecting patterns with LSTM models. Their widespread adoption and relevance in the cryptocurrency market further support their inclusion in this study.

The findings of this study have significant implications for academia. They provide a methodological framework for researchers and practical insights for investors and policymakers navigating the complexities of the cryptocurrency market. Using a DL model implementing LSTM, we managed to obtain promising results; a root mean square error (RMSE) of 1360.13, a mean absolute error (MAE) of 513.03 and an R squared (R^2) of 0.992. However, what we managed to achieve using ARIMA's implementation in Python was not as good; 2137.454, 1850.549 and -8.506 for RMSE, MAE and R^2, respectively. Despite its lower performance, the ARIMA model demonstrated potential, particularly in its ability to conduct stationary analysis through the deployment of an autocorrelation function and perform retrospective forecasts (backtests) by comparing forecasted data against actual data in the test set. Recognising the strengths of both methods, we developed a hybrid ARIMA–LSTM model to leverage the advantages of each approach, aiming to achieve improved predictive accuracy and robustness. The robustness of our model enhances its ability to accurately analyse historical cryptocurrency price patterns. However, the study does not extend to predicting values beyond the analysed period, and the scope is limited to historical data evaluation for better understanding of price dynamics. As a matter of fact, combining ARIMA and LSTM, we managed to obtain an average R^2 for all evaluated cryptocurrencies of 0.6555.

The remainder of this paper is structured as follows: Section 2 discusses the related work linked to cryptocurrency price prediction. Section 3 presents the data and proposed model. Section 4 discusses the experiments and results. Section 5 concludes with remarks on the study's contributions and future research directions.

Related Work

Over the past few decades, ML and DL have become crucial in the field of financial forecasting, including predicting cryptocurrency prices (Zhang *et al.*, 2021; Mohammadabadi *et al.*, 2023). ML models use historical pricing data to predict future trends, effectively capturing complex nonlinear patterns in the data. DL is an advanced branch of ML that uses multi-layer neural networks (McCarthy *et al.*, 2021). These models are particularly tractable in time series data such as cryptocurrency prices by identifying complex patterns and modelling interdependencies in the data.

In the initial stage, the most recognised model was ARIMA (Zhang *et al.*, 2020). Subsequently, (Raza & Riaz, 2020) used the GARCH model to predict cryptocurrency market data. Other works by Moussa & Faye (2021), Nguyen & Vo (2021) and Patel & Thakur (2024) used a combination of ARIMA and GARCH models.

In the studies of Jiang & Zhang (2020) and Omar & Soliman (2023), ML methods such as support vector machine (SVM), decision trees, naive Bayes, and random forests are used for classification and prediction tasks, each offering different strengths, from handling complex datasets (SVM, random forests) to making probabilistic predictions (naive Bayes) and creating interpretable models (decision trees). Similarly, Cortez *et al.* (2020) developed a feature-weighted SVM and k-nearest neighbors (KNN) algorithm to predict the cryptocurrency market index. Their experimental results demonstrated robust predictive capabilities across short-term, medium-term and long-term horizons, supported by findings from Hossain & Muhammad (2023), who explored hybrid ML techniques, and Fahad & Awan (2022), who examined the integration of various ML methods for financial forecasting. Additionally, Karami & Khatami (2021) provided a comprehensive review of ML models for cryptocurrency price prediction, while Liu & Zhang (2023) focused on feature selection and model ensemble techniques to enhance prediction accuracy.

In recent years, DL techniques have been increasingly employed to predict cryptocurrency prices, reducing the dependency on expert knowledge (Safari *et al.*, 2022). As a result, these methods have become a prominent focus of scholarly research in the field of cryptocurrency prediction. DL approaches include gated recurrent unit (GRU), recurrent neural network (RNN), convolutional neural network (CNN), LSTM, and BI-LSTM (Wegayehu & Muluneh, 2022; Omran *et al.*, 2021; Patel & Kumar, 2023). Additionally, Ramakrishnan *et al.* (2022b) conducted predictive research on global cryptocurrency indices using BI-LSTM, demonstrating its exceptional predictive accuracy and robust generalisation capabilities. Recent studies also highlight the use of transformers in financial time series forecasting, further enhancing prediction accuracy (Chen & Wang, 2024; Koo & Kim, 2024).

Researchers have developed various adaptations of the transformer architecture to enhance its suitability for time series data. Sridhar & Sanagavarapu (2023) presented a novel approach for predicting Dogecoin prices using a multi-head self-attention transformer. Furthermore, Son *et al.* (2022) explored cryptocurrency price prediction by analysing trends on social media, while You *et al.* (2023) introduced a spatiotemporal transformer aimed at predicting high-dimensional short-term time series data. This model utilises a spatiotemporal information transformation equation along with a continuous attention mechanism to enhance prediction accuracy. In a comprehensive study, Yunsi *et al.* (2024a) investigated the application of transformer neural networks for predicting cryptocurrency prices, while Du *et*

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al. (2024) proposed a novel method leveraging a self-attention mechanism that incorporates two diagonally-masked self-attention blocks, effectively learning missing values through a weighted combination of temporal and feature dependencies.

Upon reviewing the existing literature, it is clear that LSTM networks have shown significant promise in modelling complex time series data, particularly in the context of cryptocurrency price prediction. By exploring LSTM's ability to learn complex patterns from extensive historical data with ARIMA's robustness in handling autocorrelation, we enhance predictive accuracy and refine forecasts. This innovative approach not only improves reliability in price predictions but also provides greater interpretability, making it a valuable asset for investors and analysts in the volatile cryptocurrency market.

Data Analysis and Model Creation

Data analysis

This study is based on a comprehensive dataset comprising over 20,000 daily trading records for various cryptocurrencies. The dataset spans different timeframes, with some records dating back to 2014, while others cover a shorter period (for example, four or seven years). The data was sourced from Lamali (2024), ensuring access to a wide range of historical trading activity. Our data is based on daily recordings, thus it can be challenging to infer informative price movements. For this reason, we experimented with different time periods and decided to use semi-annual data analysis to achieve a better understanding of our data. Table 1 provides an overview of the cryptocurrencies included in our study, specifying their mean, minimum, maximum and StD values, respectively. The semi-annual analysis over the studied period is shown in Figure 1. It is worth noting that we used the semi-annual analysis solely to get a better understanding of our data distribution.

Table 1. Data statistics

Cryptocurrency	Mean Price (USD)	Min Price (USD)	Max Price (USD)	StD
ADA	0.4697	0.0239	2.9682	0.5692
AVAX	30.7032	2.9061	134.5310	27.7525
BNB	169.9576	1.5103	675.6840	173.4134
BTC	14998.1535	178.1029	67566.8281	14984.5618
DOGE	0.06368	0.00131	0.68477	0.0893
ETH	1266.2312	84.30829	4812.0874	1119.9970
SOL	47.28201	0.51527	258.9343	54.0358
TRX	0.05186	0.00198	0.2205	0.03170
USDT	1.00131	0.96664	1.0778	0.0052
XRP	0.52411	0.13963	3.37781	0.3326

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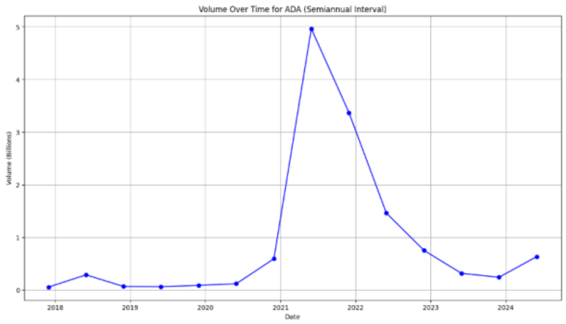
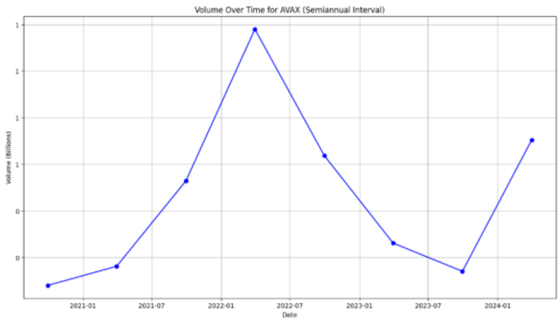
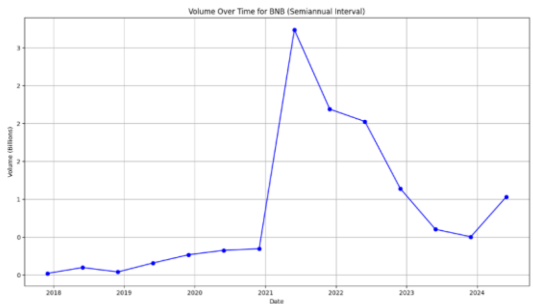


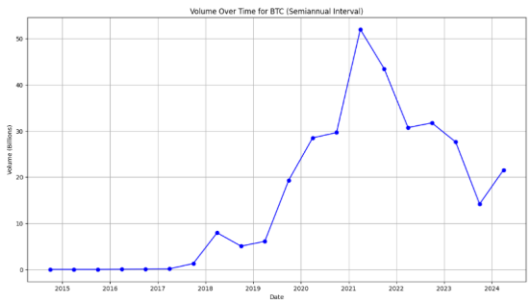
(a) ADA Semi-annual visualisation of traded volume



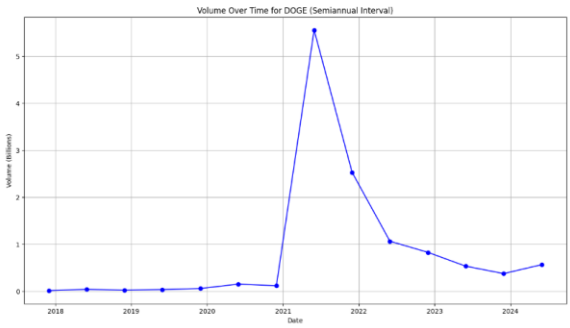
(b) AVAX Semi-annual visualisation of traded volume



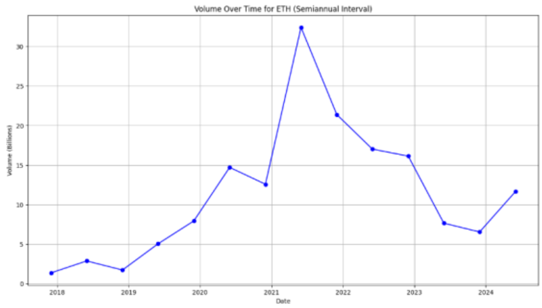
(c) BNB Semi-annual visualisation of traded volume



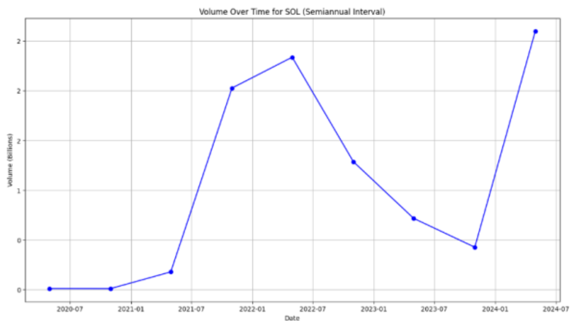
(d) BTC Semi-annual visualisation of traded volume



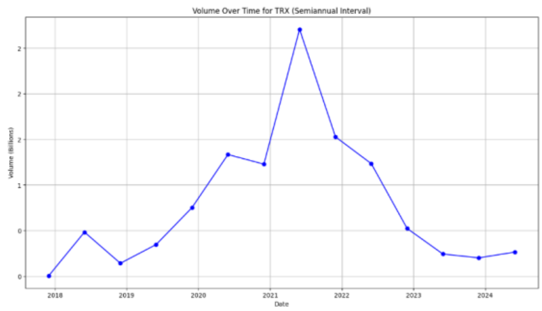
(e) DOGE Semi-annual visualisation of traded volume



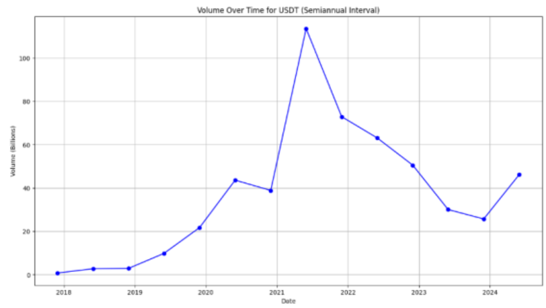
(f) ETH Semi-annual visualisation of traded volume



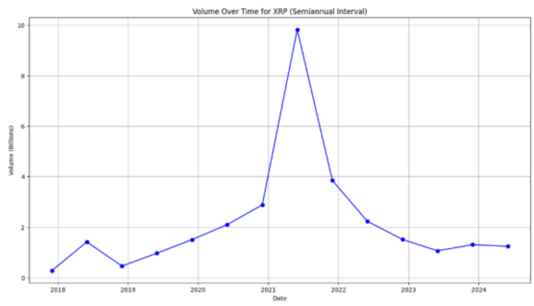
(g) SOL Semi-annual visualisation of traded volume



(h) TRX Semi-annual visualisation of traded volume



(i) USDT Semi-annual visualisation of traded volume



(j) XRP Semi-annual visualisation of traded volume

Figure 1. Semi-annual visualisation of traded volume over time for each studied cryptocurrency

Feature description

Originally, our data comprised eight features: Date, Currency, Open, Close, Low, High, Adj Close and Volume; however, upon closer inspection, we did not observe a significant difference between the features 'Close' and 'Adj Close' that reflect the last price at which a cryptocurrency is traded at the end of the day and the adjusted price, respectively. Consequently, we removed it from our dataset and continued our experiments with the remaining seven.

Model creation

We tested and compared different types of predictive models, including the statistical model ARIMA and DL model LSTM. After thorough tests and configuration, we employed LSTM on a data split of (80:20) a sequence length of 90, three layers, two LSTM and one dense, 20 epochs and a batch size of 32 (Figure 2). In fact, dense layers are often used to transform the high-dimensional output from the LSTM layers into the desired output shape. Moreover, they help in learning complex non-linear relationships in the data, enhancing the model's ability to make accurate predictions (Brownlee, 2019). As for the ARIMA model, after data resampling and data splitting of (80:20), we trained our model then forecasted the data to make our predictions and evaluated our model on the corresponding test dataset.

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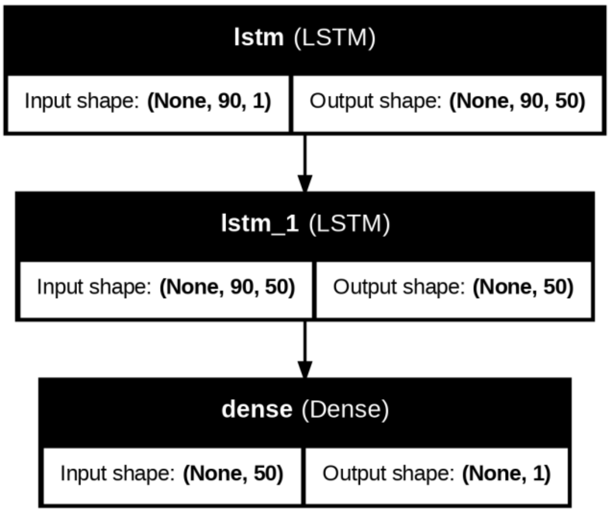


Figure 2. Architecture of the implemented LSTM model

Experiments and Results

The proposed approach, ARIMA (p,d,q), is a statistical model used to forecast time series. It was introduced by Box & Pierce (1970) and developed by Brockwell & Davis (2016). The formula is as follows:

$$\nabla^d x_t = c + \sum_{t=1}^{p} \phi_t \nabla^d x_{t-1} + \sum_{t=0}^{q} \theta_t \, \epsilon_{t-1}$$

where ∇^d is a differential factor, introducing a difference of order d, aiming to remove the non-stationarity of the time series x_t.

The values for p (autoregressive term) and q (moving average term) can be determined by analysing the autocorrelation function (ACF), partial autocorrelation function (PACF), and extended autocorrelation function (EACF). The ACF helps determine the appropriate MA (q) order by examining how current values are correlated with past values. The PACF is used to identify the AR (p) order, as it measures the direct relationship between observations while controlling for intermediate lags.

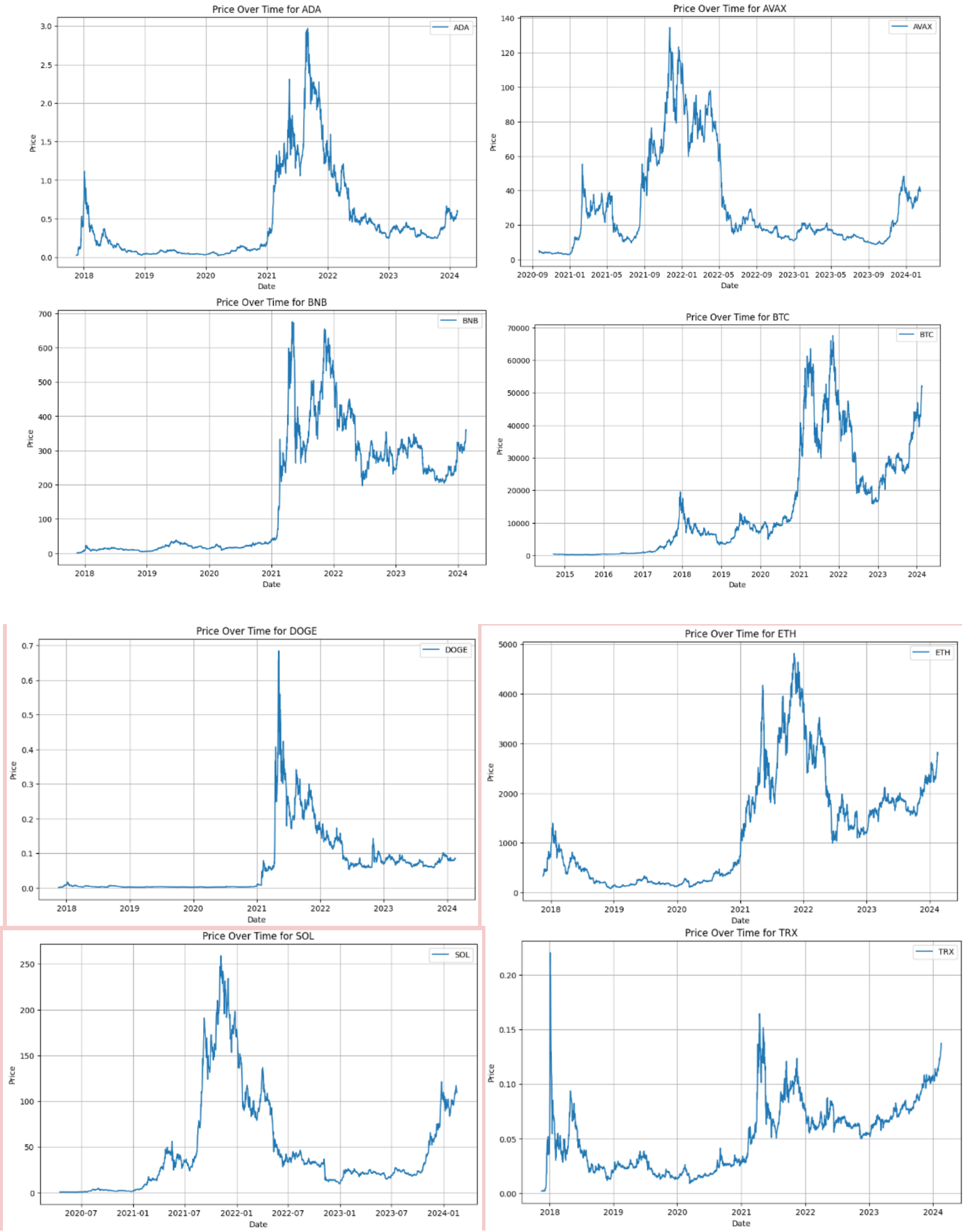
Stationarity

Stationarity can be tested using the Augmented Dickey-Fuller (ADF) test. The null hypothesis suggests that the series is stationary, while the alternative suggests non-stationarity. If the ADF test statistic is lower than the critical value (5%), the series is stationary, otherwise, it is non-stationary. According to the stationarity table below (Table 2), all variables are non-stationary except for USDT and XRP. This suggests that the time series for these two cryptocurrencies do not require differentiating, as they already exhibit a constant mean and variance over time, which is a key requirement for modelling in time series analysis.

Table 2. Stationarity values with ADF test

Cryptocurrency	ADA	AVAX	BNB	BTC	DOGE	ETH	SOL	TRX	USDT	XRP
ADF-statistics	-1.98	-2.09	-1.63	-0.91	-2.74	-1.26	-1.89	-2.39	-5.84	-4.20
p-value	0.29	0.24	0.46	0.78	0.06	0.64	0.33	0.14	0.00	0.00

A p-value above 0.05 in a stationarity test, such as the ADF test, indicates that the time series is non-stationary. Since stationarity is crucial for ARIMA models, the data must be different to remove trends and seasonality and to achieve stationarity. Figure 3 illustrates price distribution over time for each studied cryptocurrency.



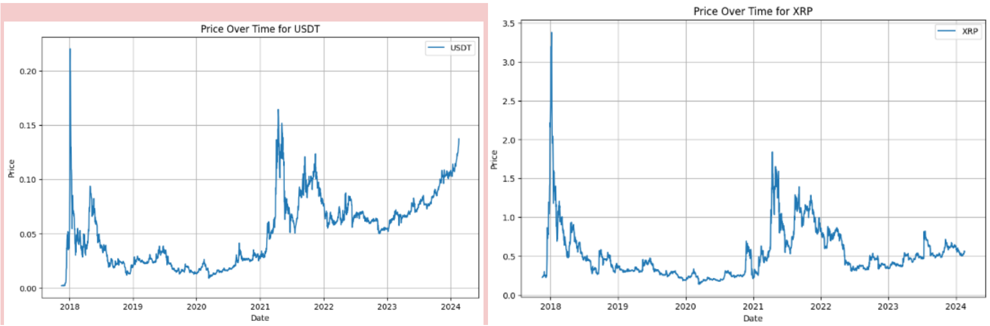
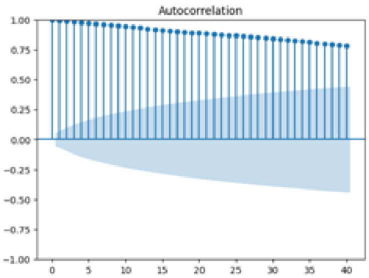
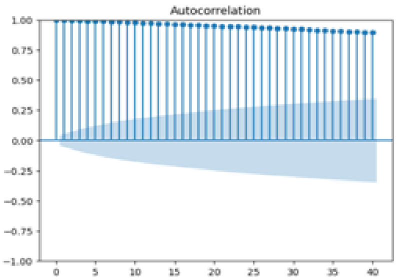


Figure 3. Price distributions indicating the price of each cryptocurrency over time

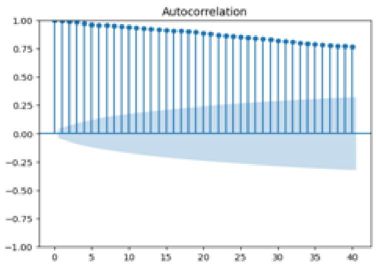
After checking the stationarity, we can use the ACF and PACF plots to find the ARIMA parameters. Figure 4 presents the ACF plot of the dataset used in this study, helping to identify the lag structures in the series.



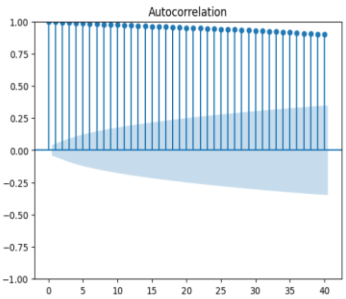
(a) ADA – Autocorrelation



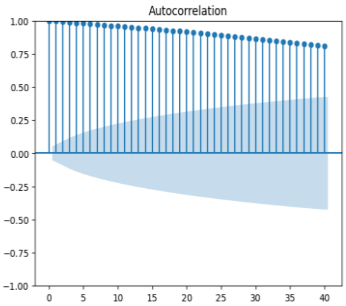
(b) AVAX – Autocorrelation



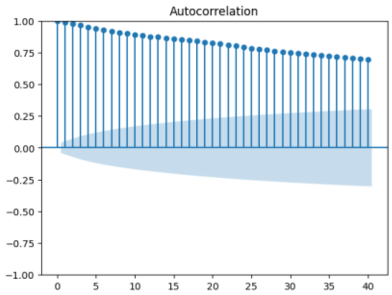
(c) BNB – Autocorrelation



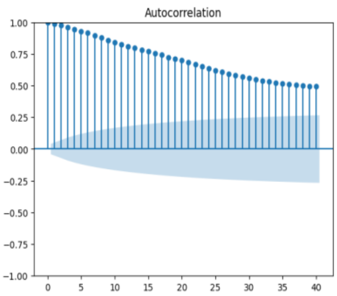
(d) BTC – Autocorrelation



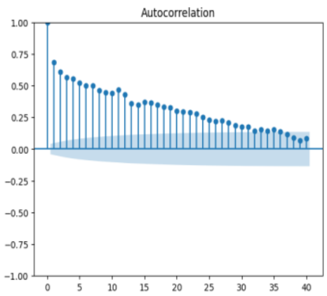
(e) DOGE – Autocorrelation



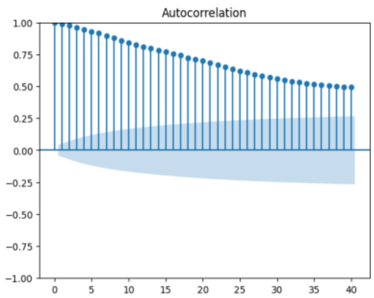
(f) ETH – Autocorrelation



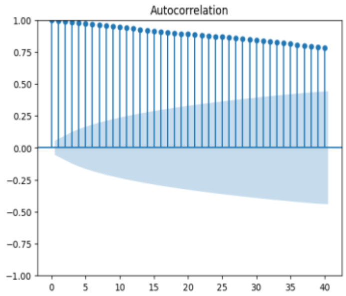
(g) SOL – Autocorrelation



(h) TRX – Autocorrelation



(i) USDT – Autocorrelation

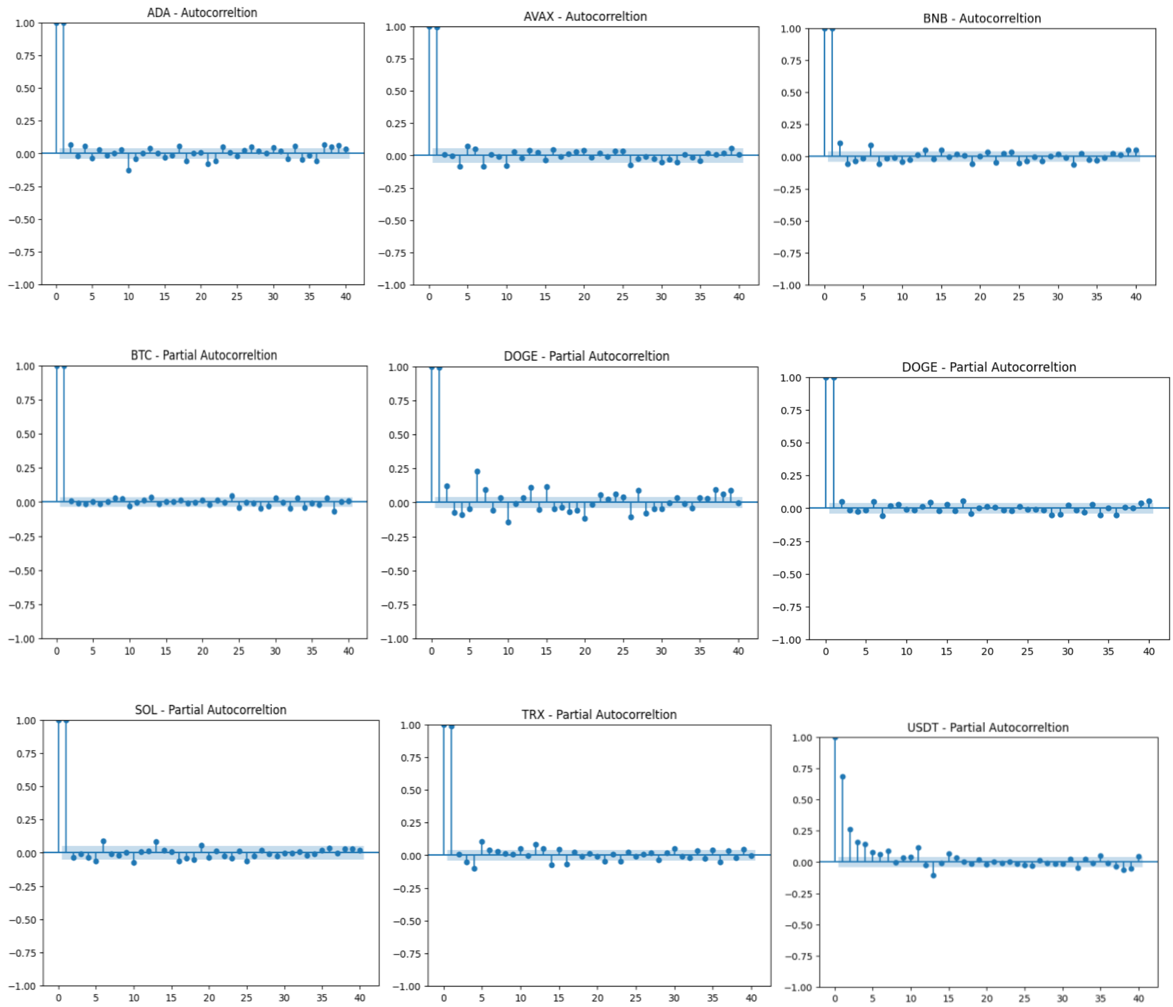


(j) XRP – Autocorrelation

Figure 4. Autocorrelation function (ACF) plot for each cryptocurrency

The ACF measures the correlation of a time series with its lagged values, providing insight into the relationship between the data points over time. These plots suggest that an ARIMA (5, 1, 2) model may be a good starting point.

The partial autocorrelation function (PACF) measures the direct correlation between a time series and its lagged values, after accounting for the correlations from intervening lags. Figure 5 shows the PACF plot of the dataset used in this research.



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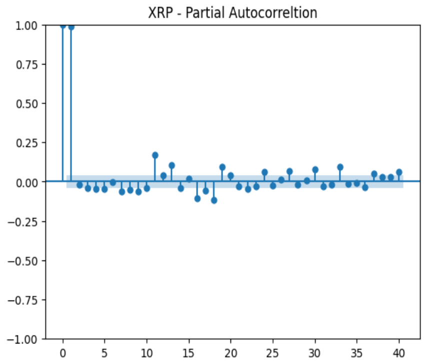

Figure 5. Partial autocorrelation function (PACF) plot for each cryptocurrency

After confirming stationarity, checking for seasonality is important to improve forecast accuracy; however, we deduce that it is absent in this time series, indicating that a seasonal ARIMA model is unnecessary for this analysis.

Training and forecasting

We train the model using the available data, and then proceed the forecasting to make predictions. Such projections can be derived from various forecasting models, including ARIMA and ML algorithms, which analyse past price behaviours to estimate future values. By visualising these trends, investors can make more informed decisions regarding buying, selling or holding their assets.

Comparative analysis of the tested models

During our study, we performed multiple experiments testing multiple models. Specifically, we tested GARCH and ARIMA for the classical models and LSTM for the modern ones. Compared to ARIMA, GARCH did not report good results, according to Tables 3 and 4. ARIMA, on the other hand, compared to LSTM did not manage to achieve much; however, in spite of its lower performance, we chose to keep it for its potential, particularly in its ability to conduct stationary analysis. Thus, we combined both models and opted for a hybrid model. Table 4 presents a comparative analysis of the tested models.

Table 3. Estimation results for GARCH and ARIMA models

GARCH model (α)	Mean model (mu)	Volatility (ω)	ARIMA model (β)
0.100 (0.818)	0.389 (0.312)	827.3269 (827.326)	0.500 (0.112)

According to Table 3, we observe that the mean return is not significantly ($p>0.05$) different from zero, and, the base level of volatility is not statistically significant. For the GARCH model, the past shocks have no significant effect on current volatility, while for the ARIMA model, the past volatility does not significantly influence current volatility.

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Table 4. Model performance comparison

Measure Model	RMSE	MAE	R^2
GARCH	40.6775	8197.5858	0.000
ARIMA	2137.454	1850.549	-8.506
LSTM	136101.130	513.030	0.992
ARIMA – LSTM	0.0205	0.0143	0.6555

The retrospective forecast (backtest) evaluates the model by comparing the forecasted values to the actual data in the test set, yielding a root mean squared error (RMSE) of approximately 2137.454. The RMSE serves as an indicator of forecast accuracy, with lower values reflecting a better model fit. Whether this level of error is deemed acceptable depends on the specific application of the model.

Combining ARIMA and LSTM, we managed to achieve an average R^2 of 0.6555. In fact, the best achieved R^2 was for BNB cryptocurrency with a value of 0.936. The reported R^2 results were as follows: 0.886 for ADA, 0.007 for AVAX, 0.936 for BNB, 0.758 for BTC, 0.731 for Doge, 0.718 for ETH, 0.606 for SOL, 0.86 for TRX, 0.303 for USDT and 0.75 for XRP.

The GARCH model struggles with nonlinear and volatile data, such as cryptocurrency prices, which aligns with prior findings (Fang *et al.*, 2023). Similarly, ARIMA models, while effective for linear time series, are inadequate for capturing the inherent nonlinearity in financial market data (Zhang *et al.*, 2020). In contrast, LSTM demonstrates superior performance by effectively modelling long-term dependencies and identifying complex patterns in time series data (Ramakrishnan *et al.*, 2022b; Patel & Kumar, 2023). Furthermore, hybrid approaches that combine ARIMA (5,1,2)'s strength in short-term predictions with LSTM's ability to model long-term dependencies have shown remarkable improvements in predictive performance, particularly in volatile markets like cryptocurrencies (Yunsi *et al.*, 2024b; Tanwar & Kumar, 2023).

A recent study by Zhang & Xie (2021) have confirmed the limitations of traditional models like ARIMA and GARCH in capturing the volatility and nonlinearity of cryptocurrency prices. These findings support the superiority of LSTM networks in handling such complexities, particularly when combined with hybrid approaches for improved predictive accuracy in volatile markets.

The accompanying plots display our obtained results with ARIMA and LSTM combined predictions for each studied cryptocurrency (Figure 6), actual test values (in blue), and forecasted values (in orange).

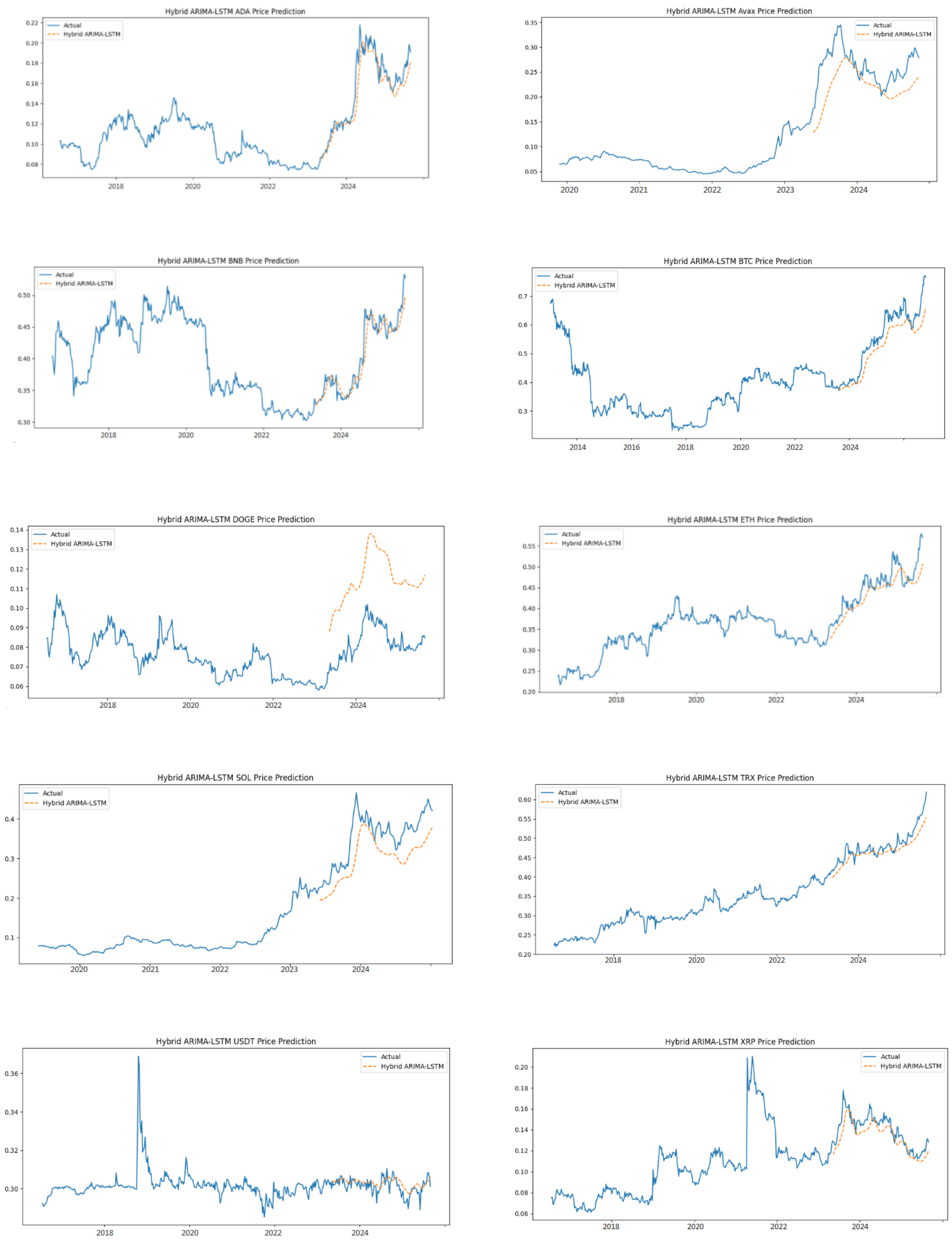

Figure 6. ARIMA-LSTM model evaluation for each studied cryptocurrency

According to Figure 7, the histogram illustrates the distribution of the residuals (differences between actual and predicted values). A symmetric, bell-shaped histogram suggests that our model does not systematically over- and under-predict.

The same figure yields an identical R-squared value, indicating that the model accounts for most of the variance. If the ACF reveals no significant autocorrelations, it suggests that the remaining errors are random, reinforcing the model's robustness. However, the presence of large, standardised residuals might highlight periods where the model struggles to predict highly volatile or nonlinear market movements, while smaller residuals closer to zero would suggest a better fit

Given the obtained R-squared, the model fits the data well. However, the Q-Q plot shows significant deviation from normality, which may suggest that cryptocurrency prices jumps are not fully accounted for by the model.

Our findings are consistent with those of Hua (2020), who highlighted the effectiveness of LSTM models in capturing the dynamic and nonlinear nature of financial time series. In fact, they employed LSTM models for Bitcoin price prediction, achieving mean squared error values comparable to the RMSE values we obtained. This suggests that while LSTM models can be highly accurate in forecasting, they remain susceptible to significant errors due to inherent market volatility. From similar results, Omran *et al.* (2021) emphasised that despite high-prediction accuracy, LSTM models can struggle with strong market changes and occasionally produce large residuals, as shown in the data below, with RMSE higher than MAE.

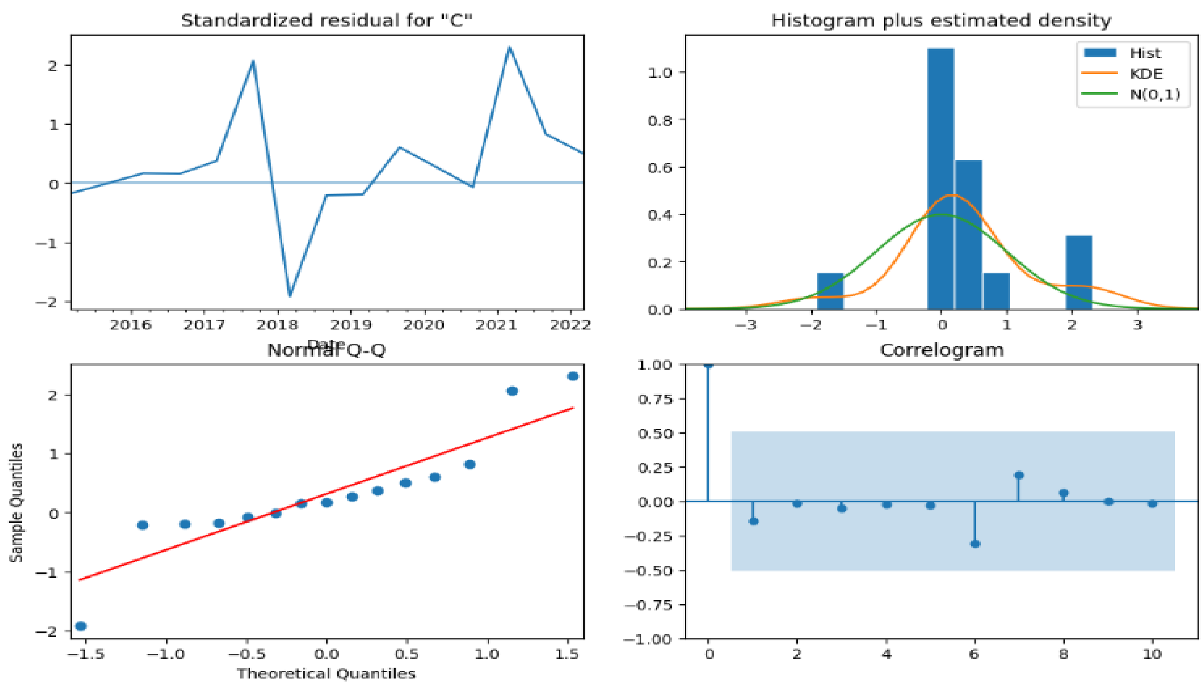

Figure 7. Forecasted data

Robustness check

To ensure robustness and validity in model comparisons, we applied forecast accuracy tests, including Hansen's (2005) and Romano & Wolf's (2005), as recommended in the literature. The obtained results did not yield much since our dataset and the market conditions introduce variability that make it difficult to establish clear superiority.

Conclusion

In this paper, we proposed a method for cryptocurrency price prediction. This study was performed on data of 10 cryptocurrencies that represent different technological innovations and use cases. Studying these cryptocurrencies can help understand volatility, volumes and price movements. Our goal was to study the effectiveness of traditional and modern algorithms in this task. In fact, our aim was to assess traditional and modern models in predicting cryptocurrency prices; however, after many experiments including various models such as GARCH, ARIMA and LSTM, we combined ARIMA's forecasts with LSTM's prediction and experimented with a hybrid model. Indeed, by combining ARIMA and LSTM we managed to obtain an average R^2 for all evaluated cryptocurrencies of 0.6555, with a high value of R^2 for BNB cryptocurrency equal to 0.936.

For future work directions, we aspire to experiment with more models, specifically transformers, in this particular task since many authors have experimented with this technique and reported good results. In addition, the implementation of the gradient descent model (XGBoost model) can be used to predict the prices of longer time series of complex multivariate time series models.

References

Bose, S., Dong, G., Simpson, A., Bose, S., Dong, G., & Simpson, A. (2019). The Financial Ecosystem. In *Palgrave Studies in Impact Finance*, 19–46. Palgrave Macmillan. https://10.1007/978-3-030-05624-7_2

Box, G.E., & Pierce, D.A. (1970). Distribution of Residual Autocorrelations in Autoregressive-Integrated Moving Average Time Series Models. *Journal of the American Statistical Association*, *65* (332), 1509–1526. https://doi.org/10.1080/01621459.1970.10481180

Brockwell, P.J., & Davis, R.A. (2016). Nonstationary and seasonal time series models. In *Introduction to Time series and Forecasting*, 157–193. Springer.

Brownlee, J. (2019). Stacked Long Short-Term Memory Networks. Machine Learning Mastery. https://machinelearningmastery.com/stacked-long-short-term-memory-networks/

Chaum, D. (1983). Blind signatures for untraceable payments. In *Advances in Cryptology: Proceedings of Crypto 82,* 199–203. Boston, MA: Springer.

https://doi.org/10.18080/jtde.v13n1.1052

Chen, Y., & Wang, J. (2024). Transformers for time series forecasting: A comprehensive survey. *IEEE Transactions on Neural Networks and Learning Systems, 35*(4), 789–805. https://doi.org/10.1109/TNNLS.2023.3287512

Corbet, S., Lucey, B., Urquhart, A., & Yarovaya, L. (2019). Cryptocurrencies as a financial asset: A systematic analysis. *International Review of Financial Analysis, 62,* 182–199. https://doi.org/10.1016/j.irfa.2018.09.003

Cortez, K., Rodríguez-García, M. D. P., & Mongrut, S. (2020). Exchange market liquidity prediction with the k-nearest neighbor approach: Crypto vs. fiat currencies. *Mathematics, 9*(1), 56. https://doi.org/10.3390/math9010056

Du, Y., Côté, B., & Liu, F. (2024). A self-attention mechanism for learning missing values in time series forecasting. *Journal of Time Series Analysis, 45*(1), 78–95. https://doi.org/10.1111/jtsa.12678

Fahad, S., & Awan, I. (2022). Combining machine learning techniques for financial forecasting: An application in cryptocurrency. *Expert Systems with Applications, 190,* 116077. https://doi.org/10.1016/j.eswa.2021.116077

Fang, X., Zhao, L., & Li, Q. (2023). Modeling cryptocurrency volatility: A comparative study of GARCH and hybrid machine learning approaches, *45*(2), 123–138.

Greff, K., Srivastava, R. K., Koutník, J., Steunebrink, B. R., & Schmidhuber, J. (2017). LSTM: A search space odyssey. *IEEE Transactions on Neural Networks and Learning Systems, 28*(10), 2222–2232. https://doi.org/10.1109/TNNLS.2016.2582924

Hansen, P. R. (2005). A test for superior predictive ability. *Journal of Business & Economic Statistics, 23*(4), 365–380. http://www.jstor.org/stable/27638834

Hochreiter, S., & Schmidhuber, J. (1997). Long short-term memory. *Neural Computation, 9*(8), 1735–1780. https://doi.org/10.1162/neco.1997.9.8.1735

Hossain, M. S., & Muhammad, A. (2023). Hybrid machine learning techniques for cryptocurrency price prediction: A comprehensive study. *Journal of Computational Science, 63,* 101678. https://doi.org/10.1016/j.jocs.2023.101678

Hua, W. (2020). Bitcoin price prediction using long short-term memory (LSTM) neural networks. P*roceedings of the 2020 IEEE International Conference on Computational Intelligence and Virtual Systems (CIVS),* 143–150. https://ieeexplore.ieee.org/document/8637486

Jalan, A., Matkovskyy, R., Urquhart, A., & Yarovaya, L. (2023). The role of interpersonal trust in cryptocurrency adoption. *Journal of International Financial Markets, Institutions and Money, 83,* 101715. https://doi.org/10.1016/j.intfin.2022.101715

Jamali, A. (2024). Cryptocurrencies Prices. Kaggle. https://www.kaggle.com/datasets/ahmadalijamali/cryptocurrencies-prices

Jaquart, P., Köpke, S. & Weinhardt, C. (2022). Machine learning for cryptocurrency market prediction and trading. *The Journal of Finance and Data Science, 8,* 331–352. https://doi.org/10.1016/j.jfds.2022.12.001

Jiang, X., & Zhang, H. (2020). A comparative study of machine learning algorithms for financial time series prediction. *Journal of Computational and Theoretical Nanoscience, 17*(12), 1–8. https://doi.org/10.1166/jctn.2020.10000

Karami, A., & Khatami, S. (2021). Forecasting cryptocurrency prices using machine learning models: A review. *International Journal of Financial Studies, 9*(2), 27. https://doi.org/10.3390/ijfs9020027

Kim, D., Park, J., & Lee, H. (2023). Integrating CNNs and attention mechanisms for enhanced cryptocurrency price prediction. *Journal of Computational Finance, 27*(1), 15–30. https://doi.org/10.21314/JCF.2023.365

Koo, H. Y., & Kim, D. H. (2024). Enhancing financial time series prediction with transformer networks. *Journal of Forecasting, 43*(3), 456–472. https://doi.org/10.1002/for.2973

Liu, Y., & Zhang, J. (2023). Feature selection and model ensemble for cryptocurrency price prediction. *Journal of Economic Dynamics and Control, 133,* 104047. https://doi.org/10.1016/j.jedc.2022.104047

McCarthy, P.X., Gong, X., Eghbal, S., Falster, D.S., & Rizoiu, M.A. (2021). Evolution of diversity and dominance of companies in online activity. *PLOS one, 16*(4), e0249993. https://doi.org/10.1371/journal.pone.0249993

Mohammadabadi, S. M. S., Zawad, S., Yan, F., & Yang, L. (2023). Speed up federated learning in heterogeneous environment: A dynamic tiering approach. *arXiv* preprint arXiv:2312.05642. https://doi.org/10.48550/arXiv.2312.05642

Moussa, A., & Faye, I. (2021). ARIMA-GARCH Approach to cryptocurrency volatility prediction. *Financial Innovation, 7*(1), 1–15. https://doi.org/10.1186/s40854-021-00257-5

Nguyen, D. K., & Vo, X. V. (2021). A combined ARIMA-GARCH model for predicting cryptocurrency prices. *Mathematics, 9*(2), 234. https://doi.org/10.3390/math9020234

Omar, A. F., & Soliman, A. (2023). Predicting stock prices using machine learning techniques: A study of SVM, decision trees, and random forest. *Applied Sciences, 13*(6), 2980. https://doi.org/10.3390/app13062980

Omran, N. F., Abd-el Ghany, S. F., Saleh, H., Ali, A. A., Gumaei, A., & Al-Rakhami, M. (2021). Applying deep learning methods on time series data for forecasting COVID19 in Egypt, Kuwait, and Saudi Arabia. *Complexity,* 6686745. https://doi.org/10.1155/2021/6686745

Orte, D., Pastor, J. A., & Mora, A. M. (2023). A machine learning approach to cryptocurrency portfolio management. *Expert Systems with Applications, 213,* 118933. https://doi.org/10.1016/j.eswa.2022.118933

Patel, H., & Kumar, A. (2023). Deep learning models for cryptocurrency price forecasting: A review. *Journal of Financial Stability, 65,* 100972. https://doi.org/10.1016/j.jfs.2023.100972

Patel, R., & Thakur, M. (2024). Utilizing ARIMA and GARCH models for predictive analytics in cryptocurrencies. *International Journal of Financial Studies, 12*(1), 55–75. https://doi.org/10.3390/ijfs12010055

Patel, R., Gupta, K., & Mehta, S. (2023). Improving time series forecasting for cryptocurrency markets using deep learning techniques. *Journal of Computational Finance, 18*(1), 101–119.

https://doi.org/10.18080/jtde.v13n1.1052

Ramakrishnan, S., Menon, V., & Shah, P. (2022a). Cryptocurrency price prediction using LSTM and attention mechanisms: A deep learning approach. *IEEE Access, 10,* 55643–55654.

Ramakrishnan, R., Vadakedath, A., Bhaskar, A., Sachin Kumar, S., & Soman, K. P. (2022b). Data-Driven volatile cryptocurrency price forecasting via variational mode decomposition and BiLSTM. In *International Conference on Innovative Computing and Communications: Proceedings of ICICC 2022, 1*, 651–663.

Raza, S. A., & Riaz, S. (2020). Modeling and forecasting bitcoin returns Using GARCH models: Evidence from Pakistan. *Journal of Risk and Financial Management, 13*(11), 267. https://doi.org/10.3390/jrfm13110267

Romano, J.P. & Wolf, M. (2005). Stepwise multiple testing as formalized data snooping. *Econometrica, 73,* 1237–1282. https://doi.org/10.1111/j.1468-0262.2005.00615.x

Safari, K., Khalfalla, S., & Imani, F. (2022, October). Dependency evaluation of defective formation and printing location in additive manufacturing. In *ASME International Mechanical Engineering Congress and Exposition,* Vol. 86632, p. V02AT02A016. American Society of Mechanical Engineers. https://doi.org/10.1115/IMECE2022-95145

Son, H., Lee, J., & Kim, M. (2022). Predicting cryptocurrency prices by analyzing social media trends. *Journal of Financial Technology, 1*(2), 34–50. https://doi.org/10.1016/j.jft.2022.05.002

Sridhar, A., & Sanagavarapu, P. (2023). Multi-head self-attention transformer for cryptocurrency price prediction. *International Journal of Financial Studies, 11*(3), 45–58. https://doi.org/10.3390/ijfs11030045

Tanwar, A., & Kumar, S. (2023). Integrating ARIMA and LSTM models for improved cryptocurrency forecasting: Applications in Bitcoin and Ethereum markets. *Financial Innovation, 9*(2), 345–366. https://doi.org/10.1186/s40854-023-00429-8

Urquhart, A., & Yarovaya., L, (2023). Cryptocurrency research: future directions. *The European Journal of Finance. 30*(16), 1849–1854. https://doi.org/10.1080/1351847X.2023.2284186

Wegayehu, E. B., & Muluneh, F. B. (2022). Short-term daily univariate streamflow forecasting using deep learning models. *Advances in Meteorology*. https://doi.org/10.1155/2022/1860460

Wu, J., Zhang, X., Huang, F., Zhou, H., & Chandra, R. (2024). Review of deep learning models for crypto price prediction: implementation and evaluation. *arXiv* preprint arXiv:2405.11431. https://doi.org/10.48550/arXiv.2405.11431

You, H., Xu, Z., & Li, T. (2023). Spatiotemporal transformer for short-term time-series data prediction. *IEEE Transactions on Neural Networks and Learning Systems, 35*(2), 512–526. https://doi.org/10.1109/TNNLS.2023.3287547

Yunsi, S., Lahcen, A., & Azzouz Mohamed, A. (2024a). Transformer neural networks for cryptocurrency price prediction. *Journal of Financial Stability, 70,* 101029. https://doi.org/10.1016/j.jfs.2023.101029

https://doi.org/10.18080/jtde.v13n1.1052

Yunsi, H., Lahcen, A., & Mohamed, A. (2024b). Hybrid ARIMA-LSTM models for cryptocurrency price forecasting: A novel approach for volatile markets. *Computational Economics, 62*(3), 789–810. https://doi.org/10.1007/s10614-023-10125-9

Zhang, W., Wang, P., Li, X., & Shen, D. (2020). Forecasting cryptocurrency prices with ARIMA and hybrid models: Evidence from Bitcoin and Ethereum. *Economic Modelling, 91,* 340–355. https://doi.org/10.1016/j.econmod.2020.01.025.

Zhang, Y., & Wang, S. (2020). Cryptocurrency price prediction using time series analysis: an ARIMA approach. *Journal of Applied Statistics, 47*(1), 45–61. https://doi.org/10.1080/02664763.2019.1610860

Zhang, Y., & Xie, T. (2021). Comparative analysis of time series models for cryptocurrency price prediction: ARIMA, GARCH, and machine learning approaches. *Journal of Computational Finance, 27*(3), 15–38.

Zhang, Z., Dai, H. N., Zhou, J., Mondal, S. K., García, M. M., & Wang, H. (2021). Forecasting cryptocurrency price using convolutional neural networks with weighted and attentive memory channels. *Expert Systems with Applications, 183,* 115378. https://doi.org/10.1016/j.eswa.2021.115378

Analysis of Countries' Maturity for a Financial Transition Towards Tokenization

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Abstract: A silent revolution is taking place in the world of finance. Approved by regulators, blockchain technology is gradually becoming established in the issuance of new "tokenized" financial securities, which allow financiers to make significant progress in overcoming the constraints imposed by transaction cost theory (TCT). In this era of financial transition towards the tokenization process, our research aims to examine the state of readiness for this digital transformation through the development of an index (Readiness Indicator Function, RIF), which will be applied to the analysis of seven countries, namely Morocco, Tunisia, Egypt, Spain, Portugal, South Africa and Nigeria. Using Principal Component Analysis (PCA), we examine 16 crucial economic and technological factors to provide a comprehensive framework to assess the capacity of each country to integrate tokenization into its markets and financial institutions. Despite low Gross Domestic Product (GDP) per capita, analysis of RIF criteria data shows that the sample countries have potential for implementing digital financial transformation through tokenization. This study provides policy makers, economic actors and financial institutions with grounded insights into critical areas for strategic investments and regulatory reform to implement tokenization.

Keywords: Digital Finance, Blockchain, Tokenization, Transaction Costs

Introduction

Tokenization emerges as a revolutionary force that has the potential to redefine the fundamental structure of economic transactions in an era where digital transformation is reshaping the global financial landscape (Harvey *et al.*, 2020; Sadok *et al.*, 2023). This

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innovative technology, which is based on blockchain, is expected to bring about previously unheard-of levels of efficiency, transparency and liquidity in global financial systems (Zohar, 2015). The "token" is currently shaking up the world of innovation by positioning itself as an alternative to traditional financing systems. It makes it possible to value and materialise real assets in the digital world. By registering an asset and its rights directly on a token, tokenization facilitates management and exchange with a peer, instantly and securely.

A token is a digital item that can be owned and transferred. Broadly speaking, there are two types of tokens: fungible tokens and non-fungible tokens (NFTs). The term "fungible" refers to an object that can be interchanged with the same object. For example, one bitcoin (BTC) has the same value as another BTC. There is no unique distinction or added value to one BTC over another. Conversely, the term "non-fungible" means that an object is unique and cannot be exchanged for the same. For example, a work by Leonardo Da Vinci cannot be strictly exchanged for a work by Claude Monet, because each work is unique. Thus, by tokenizing a physical good as a financial asset, it is possible to create a unique NFT on a blockchain representing ownership of that good. This NFT then becomes a digital certificate of ownership. The person who holds this token in their digital wallet can then claim ownership of the tokenized object (Mahboub *et al.*, 2023).

Tokenization is transforming the way assets are managed and traded, offering many advantages that make them more competitive than traditional forms, such as: global access to financial markets; reduced transaction costs; fractionalisation of assets making them more accessible to small investors; accessibility and financial inclusion for populations with limited access to banking services; transparency and traceability; improved security; operational efficiency; integration with smart contracts and regulatory compliance with proper configuration and a user identity verification process (Know Your Customer Checks, KYC), particularly in the fight against money laundering (Li & Wang, 2017).

However, the path to widespread adoption is far from straightforward, as different countries are at different levels of readiness due to a complex interplay of economic and technological regulatory factors (Hughes *et al.*, 2019). In an attempt to understand the prerequisites for tokenization, our study focuses on analysing seven different countries to determine their level of readiness for this digital transition to tokenization. The countries in our sample are Morocco, Tunisia, Egypt, Spain, Portugal, South Africa, and Nigeria. We thus present a nuanced and data-driven analysis of each country's potential to integrate tokenization into its financial ecosystems. For this purpose, we use the Readiness Indicator Function (RIF) index, developed from principal component analysis (PCA), which is based on a wide range of economic and technological indicators.

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The purpose of this article is therefore to assess the state of readiness, which also allows for identifying gaps in the infrastructure and guiding targeted improvements (Cong & He, 2019). This study aims to assess this degree of readiness for the deployment of tokenization in the seven countries mentioned above. To achieve this objective, this article is organised as follows. We describe the theoretical and practical advances of tokenization through a study of the literature. Then, we present the methodology for the development of the readiness indicator function (RIF), as well as the data used for the evaluation of the seven countries of the study. We then proceed to the principal component analysis (PCA). The results of this analysis are presented in the last section, allowing us to deduce the implications for policy makers, as well as research perspectives on this topic.

The Challenges of Tokenization: Literature Review

According to a recent study by Binance Research, real-world asset (RWA) tokenization is on track to reach a value of $16 trillion by 2030 (Nobanee *et al.*, 2024). To give some perspective, in 2022 the sector was already valued at $310 billion, which represented 0.4% of global Gross Domestic Product (GDP). The study predicts that, by 2030, asset tokenization could even constitute 10% of global GDP. Furthermore, the number of addresses holding RWA tokens on the Ethereum blockchain has doubled in just one year, from 17,900 to over 43,000. By opting for asset tokenization, banking and government institutions could significantly increase the efficiency of their transfer and custody systems. This approach has many advantages, including increased accessibility, ease of exchange, simplified authentication, reduced administrative procedures and, above all, a smaller energy footprint compared to traditional methods (Watsky *et al.*, 2024).

However, while tokenization offers many contractual advantages, it seems to address the problem posed by the transaction cost theory (TCT), first presented by Coase (1937) and then developed by Williamson (2010). This author categorised these costs in relation to the central notion of time, which leads from the simple, instantaneous exchange on a market (spot) to the transaction, which requires several steps, such as search and information costs, creating trust, negotiating, decisions costs, concluding the contract by legal form, law enforcement and policing costs. Thus, the need for recourse to a contract by relevant professionals is imposed, in order to establish the obligations already outlined during the negotiation phase, itself producing costs. At this first stage, the risk of deliberate withholding of information (biased or not), known as adverse selection, may already appear.

In addition to the difficulty of determining the behaviour of certain agents, there is the complexity of the environment, which makes it difficult to predict all possible occurrences, such as knowledge of the factors that condition the future. This creates a level of uncertainty that cannot be removed by the incompleteness of contracts, due to the cost of drafting multiple clauses that are too specific and contingent (Sadok & El Maknouzi, 2021). Protecting against the vagaries of the actors' behaviour then involves using specialists, experts, and consultants to initiate control mechanisms by any trusted third party. They will be responsible for removing these constraints of uncertainty and unverifiability (Juan *et al.*, 2023; Mouline & Sadok, 2021).

Furthermore, a fundamental dimension of transaction cost economics is, according to Williamson (2010), the specificity of assets. The more the asset is engaged in a particular transaction, the less it can be reallocated to another transaction without a substantial increase in costs. In this area, where the interdependence of the actors is strong, the risk of opportunism is all the more detrimental and will require increased control, and, consequently, all these elements will generate an immeasurable cost. It is in this context that blockchain emerges as a revolution in financial intermediation, allowing a gain for economic agents to the detriment of middlemen and trusted third parties (Al-Dhlan *et al.*, 2022).

Sadok (2023) highlights that the introduction of tokenization creates a new type of asset specificity that allows for new forms of organisation to emerge in the digital economy. Allen *et al.* (2020) further incorporate tokenization into TCT, suggesting that it creates a new governance structure called token-based organisation that, in some situations, can be more efficient than conventional market or hierarchical structures. Thus, a new approach to transaction cost theory applied to the field of financial asset transactions (tokenization) made possible by blockchain technology offers new perspectives for reducing token transaction costs. Networking and verification, two essential elements of token transaction costs, could be significantly reduced thanks to blockchain (Davidson *et al.*, 2018). Radziwill (2018) argues that the transparency and immutable ledger of blockchain technologies can significantly reduce the cost of information searches. By providing a single source of truth for asset ownership and transaction history, tokenization eliminates the need for extensive due diligence. According to Chen & Bellavitis (2020), information asymmetry in fundraising has decreased through initial coin offerings (ICOs) and security token offerings (STOs), which has reduced the costs associated with search and information for issuers and investors.

Also, the reduction in transaction costs and token trading has substantially decreased since the emergence of smart contracts (Mahboub & Sadok, 2023), and subsequently executed via blockchain technology. Smart contracts eliminate the need for intermediaries and reduce the cost of trading (Cong & He, 2019), while Davidson *et al.* (2018) argue that tokenization enables new forms of governance, such as decentralised autonomous organisations (DAOs) that use distributed consensus techniques to reduce the cost of decision-making.

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Although tokenization has strong theoretical advantages for advancing TCT, Adhami *et al.* (2018) argue that, compared to conventional techniques, tokenization can significantly reduce early-stage financing costs. However, Momtaz (2020) warns that the risks of regulatory uncertainty in token-based systems must be considered alongside their benefit of reducing transaction costs. Regulatory uncertainty is therefore a major obstacle to the widespread adoption of tokenization (Fenwick & Vermeulen, 2018).

This exploratory review of the elements of the token economy anchored in blockchain technology reveals a variety of combinations of these elements used to facilitate new forms of value circulation. However, there is a tension between the aspiration to introduce transformative systems and the need to ensure the stability of the economic framework. The highly experimental nature of these initiatives requires continued monitoring of their emergence and development. To fully benefit from the advantages of tokenization in terms of reducing transaction costs, the implementation of a new regulatory paradigm is essential.

Materials and Methodology

Method design

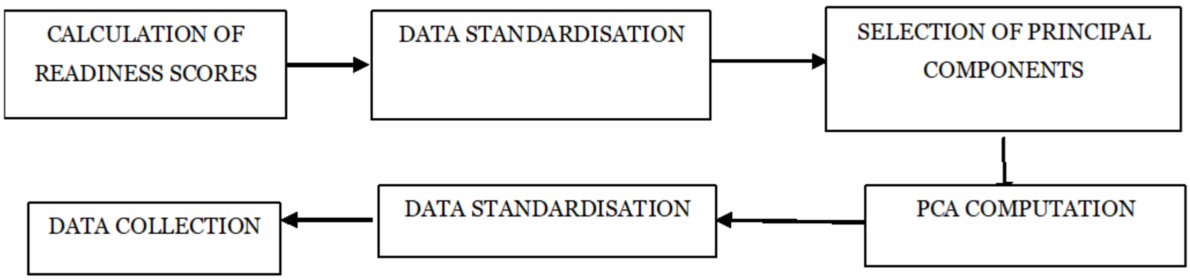

Figure 1. Methodology diagram

To quantify the readiness for tokenization adoption in the seven countries studied, we used a method combining the PCA principal components and their associated factor loadings to produce a readiness indicator function (RIF). The principal components are first extracted, then each is weighted, and then the readiness indicator for each nation is created as a weighted total of its principal component scores. Finally, the standardised data are transformed using the principal component loadings. Figure 1 summarises the description of the methodology.

The use of PCA as a statistical technique in this work aims to reduce the dimensionality of a dataset while preserving the majority of the variation collected. It allows us to identify key variables affecting tokenization adoption readiness by simplifying our dataset, which consists of 16 variables from seven different countries. By reducing the dimensionality, we can focus on the essential elements that contribute the most to the variance. This approach improves the understanding of the factors influencing tokenization adoption readiness and allows for more meaningful cross-country comparisons (see Figure 1).

Figure 2 summarises the approach adopted to respond to our problem.

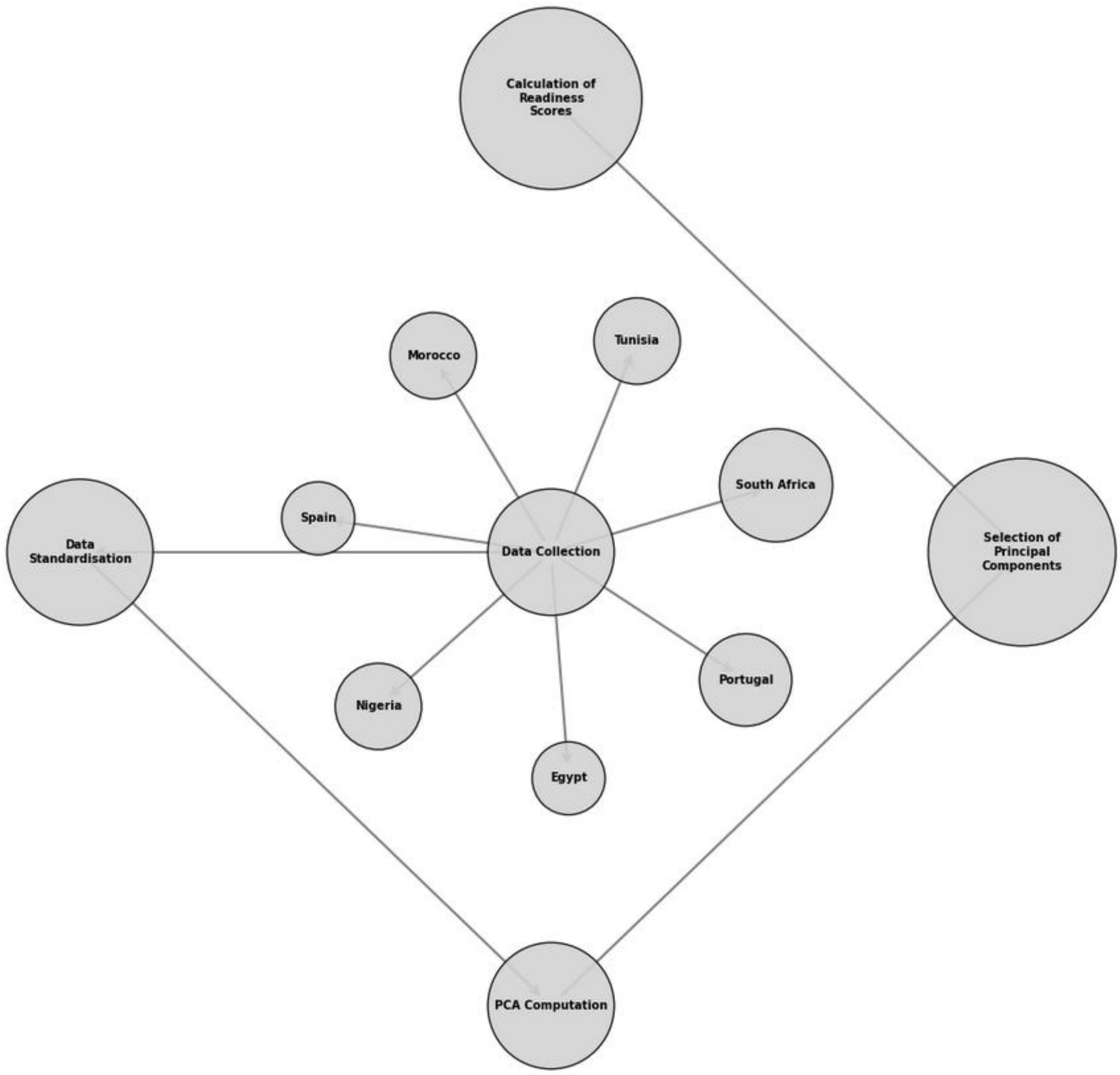

Figure 2. Methodology diagram

Data collection

The data collection procedure for this study included obtaining economic and technological data from Morocco, Tunisia, Egypt, Spain, Portugal, South Africa and Nigeria, to assess the capacity of each country to implement tokenization.

The choice of these seven benchmark countries was motivated by two reasons: first, the five African countries (Tunisia, Morocco, Egypt, Nigeria and South Africa) are considered the most equipped countries in Africa with digital and regulatory infrastructures allowing the transition to tokenization; then, the two countries of Southern Europe (Spain and Portugal) were added to this panel to highlight the path to be taken, and the differences in trends in the variables between these five African countries and the other two of Southern Europe. Thus, the latter can serve as a model, especially since they are the closest to the others geographically and especially in terms of the path taken for development.

The variables chosen to assess the predisposition and state of maturity of these countries for tokenization include GDP per capita, financial market size, Foreign Direct Investment (FDI) inflows, economic stability indicators, Internet penetration, mobile phone penetration, blockchain adoption, technological infrastructure, regulatory environment, legal framework for digital assets, Anti-Money Laundering (AML) compliance, government support for innovation, financial literacy rate, trust in financial systems, digital payments adoption rate, and socio-economic inequalities.

Table 1. Data sources

Variable	Data Source
GDP per Capita	World Bank
Financial Market Size	IMF and World Bank
FDI Inflows	UN Trade & Development (UNCTAD)
Economic Stability Indicators	IMF and World Bank
Internet Penetration Rate	International Telecommunication Union (ITU)
Mobile Phone Penetration Rate	ITU
Blockchain Adoption Rate	Global Blockchain Business Council (GBBC) and industry reports
Technological Infrastructure	World Economic Forum (WEF) Global Competitiveness Report
Regulatory Environment	World Bank and national regulatory bodies
Legal Framework for Digital Assets	Various national legal databases and reports
AML Compliance	Financial Action Task Force (FATF)
Government Support for Innovation	WEF Global Competitiveness Report and national innovation indices
Financial Literacy Rate	Standard & Poor's Global Financial Literacy Survey
Trust in Financial Systems	Edelman Trust Barometer
Adoption Rate of Digital Payments	Global Findex Database by the World Bank
Socioeconomic Inequality	World Bank and national statistics

The data for each variable was collected from data sources as shown in Table 1.

The sixteen variables (see Table 1) specified for the RIF are selected to represent the key factors impacting tokenization readiness. Each variable addresses a crucial element propelling the adoption of tokenized systems based on, on the one hand, the country's economic maturity, such as wealth, investment potential, liquidity, and macroeconomic resilience, and, on the other hand, the country's digital infrastructure, such as Internet prevalence, mobile phone usage, blockchain acceptance rates, institutional landscape, security, and compliance through regulatory and legal factors.

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These sixteen variables fully capture the interplay between societal acceptance, technological infrastructure, economic capacity, and regulatory clarity. This multidimensional design ensures that the RIF is sufficiently representative to help stakeholders detect gaps in the readiness of strategic levers for this digital transformation (Sadok & Assadi, 2023).

Table 2 presents the 16 descriptive statistical variables of the seven countries in our sample.

Table 2. Dataset for the selected countries

Variable	Morocco	Tunisia	Egypt	Spain	Portugal	South Africa	Nigeria
GDP per Capita (USD)	3672.1	3667.3	4177.61	31811.3	26278.4	6267.3	2085.1
Financial Market Size (Index)	45	40	50	85	75	55	35
FDI Inflows (USD Billion)	3.0	2.5	6.0	35.0	20.0	5.0	8.0
Economic Stability (Index)	60	55	50	80	75	45	40
Internet Penetration (%)	74	66	72	94	83	70	38
Mobile Phone Penetration (%)	130	120	105	115	110	145	140
Blockchain Adoption (Index)	20	18	25	60	55	30	15
Tech Infrastructure (Index)	55	50	60	85	80	65	40
Regulatory Environment (Index)	50	48	55	78	70	60	45
Legal Framework for Digital Assets (Index)	45	40	50	75	70	55	35
AML Compliance (Index)	60	55	65	85	80	70	50
Gov. Support for Innovation (Index)	50	48	55	75	70	65	40
Financial Literacy Rate (%)	70	65	60	85	80	68	55
Trust in Financial Systems (Index)	55	52	58	80	75	65	50

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Variable	Morocco	Tunisia	Egypt	Spain	Portugal	South Africa	Nigeria
Digital Payments Adoption (%)	65	62	70	85	80	75	60
Socioeconomic Inequality (Gini)	39.5	35.0	31.8	32.5	33.5	63.0	43.0

Standardising the data

To allow comparison between the different scales of variables obtained in the seven different countries, the data in Table 2 will be standardised. Each variable is transformed to have a mean of 0 and a standard deviation of 1 to make the data standardised and amenable to comparison (D'Agostino *et al.*, 2017). This procedure ensures that each variable makes a proportional contribution to the PCA (see Table 4).

Thus, the standardised values for each variable are listed in Table 3.

Table 3. Standardised data

Country	Morocco	Tunisia	Egypt	Spain	Portugal	South Africa	Nigeria
GDP per Capita (USD)	-0.59	-0.60	-0.56	1.67	1.22	-0.39	-0.72
Financial Market Size (Index)	-0.54	-0.81	-0.26	1.62	1.08	-	-1.08
FDI Inflows (USD Billion)	-0.70	-0.74	-0.45	1.97	0.72	-0.53	-0.28
Economic Stability (Index)	0.14	-0.19	-0.53	1.48	1.15	-0.86	-1.19
Internet Penetration (%)	0.17	-0.29	0.06	1.34	0.69	-0.06	-1.91
Mobile Phone Penetration (%)	0.42	-0.25	-1.22	-0.56	0.89	1.41	1.08
Blockchain Adoption (Index)	-0.65	-0.76	-0.38	1.54	1.27	-0.10	-0.92
Tech Infrastructure (Index)	-0.45	-0.76	-0.13	1.43	1.11	0.18	-1.38
Regulatory Environment (Index)	-0.66	-0.82	-0.25	1.64	0.99	0.16	-1.07
Legal Framework for Digital Assets (Index)	-0.53	-0.86	-0.19	1.48	1.15	0.14	-1.19
AML Compliance (Index)	-0.50	-0.89	-0.11	1.45	1.07	0.28	-1.28
Gov. Support for Innovation (Index)	-0.59	-0.75	-0.20	1.37	0.97	0.58	-1.38
Financial Literacy Rate (%)	0.09	-0.38	-0.85	1.51	1.04	-0.09	-1.32
Trust in Financial Systems (Index)	-0.61	-0.87	-0.36	1.54	1.11	0.25	-1.04

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Country	Morocco	Tunisia	Egypt	Spain	Portugal	South Africa	Nigeria
Digital Payments Adoption (%)	-0.64	-0.96	-0.11	1.49	0.96	0.42	-1.17
Socioeconomic Inequality (Gini)	-0.02	-0.43	-0.72	-0.66	-0.57	2.11	0.29

Principal Component Analysis

This section presents the results of our principal component analysis (PCA) used to assess the readiness of Morocco, Tunisia, Egypt, Spain, Portugal, South Africa, and Nigeria to adopt tokenization. The data for this analysis is in Table 3.

The PCA results revealed the eigenvalues and explained variance for the principal components as shown in Table 4.

Table 2. Eigenvalues and explained variance for the principal components

Principal Component	Eigenvalue	Explained Variance (%)	Cumulative Explained Variance (%)
PC1	12.94	80.88%	80.88%
PC2	1.79	11.19%	92.07%
PC3	0.65	4.06%	96.13%

Three principal components were found by PCA and these components collectively account for a sizable amount of the variance in the data. The influence of technological infrastructure, Internet penetration, financial market size, and economic stability on tokenization readiness is captured by the first principal component (PC1), which accounts for 80.88% of the total variance. The significance of government support and regulations, along with the negative impacts of socioeconomic inequality, are underscored by the second principal component (PC2), which explains 11.19% of the variance. The third principal component (PC3), which accounts for 4.06% of the variation, is concerned with digital payment adoption, financial literacy and trust in financial systems. Figure 3 summarises the variance explained by the three principal components of the PCA.

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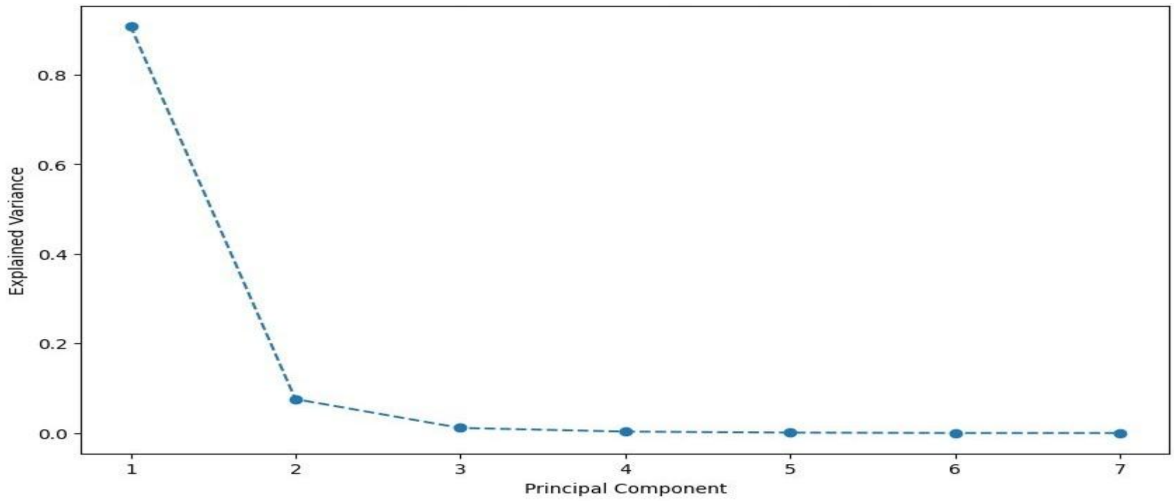

Figure 3. Scree plot of the variance PCA

The loadings of each variable on the principal components are synthesised in Table 5. The loadings of these variables show how each one contributes to the main components (Laarabi et al., 2022). These results demonstrate that inclusive policies, regulatory frameworks that support them, and a strong technological and economic foundation are necessary to improve tokenization readiness.

Table 3. The loadings of each variable on the principal components

Variable	PC1	PC2	PC3
GDP per capita	0.2664	-0.0366	0.3293
Financial market size	0.2766	0.0254	0.0242
FDI inflows	0.2452	-0.0836	0.4084
Economic stability	0.2464	-0.2248	0.2157
Internet penetration rate	0.2458	-0.1275	-0.4326
Mobile phone penetration rate	-0.0449	0.6161	0.4950
Blockchain adoption rate	0.2738	0.0300	0.1609
Technological infrastructure	0.2748	0.0456	-0.1549
Regulatory environment	0.2754	0.0640	-0.0192
Legal framework for digital assets	0.2759	0.0608	-0.0545
AML compliance	0.2736	0.0831	-0.1507
Government support for innovation	0.2659	0.1555	-0.2436
Financial literacy rate	0.2601	0.0165	0.0859
Trust in financial systems	0.2741	0.1142	0.0161
Adoption rate of digital payments	0.2699	0.1269	-0.1556
Socioeconomic inequality	-0.0748	0.6880	-0.2798

Pairwise relationship analysis reveals many significant relationships between variables (Figure 4). For example, there is a strong positive correlation between financial market size and economic stability, highlighting the importance of a healthy financial sector for tokenization. The correlation between Internet penetration rates and technological infrastructure is also significant, suggesting that both are essential to foster an enabling environment for blockchain adoption. Proactive policies and supportive frameworks are needed, as evidenced by the positive correlation between regulatory environment and government support. On the other hand, financial literacy and socioeconomic inequality are inversely correlated, which may hinder the widespread adoption of tokenization technologies.

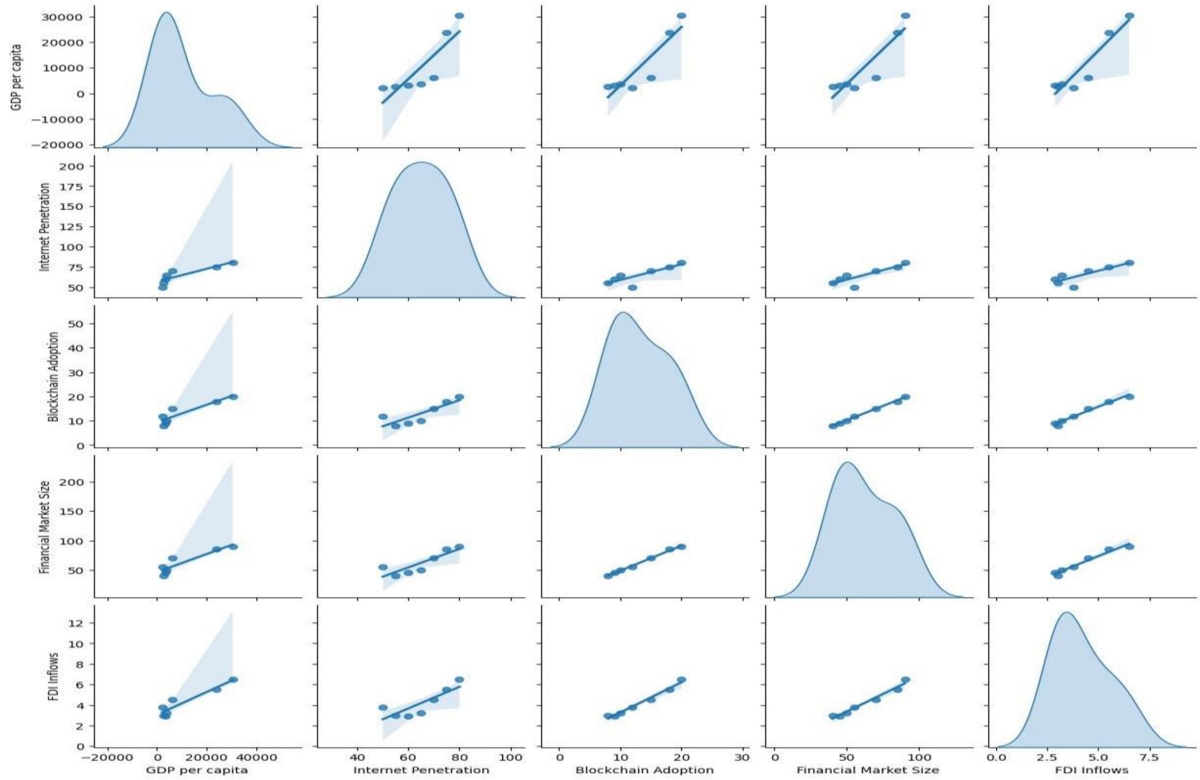

Figure 4. Pair plot with KDE diagonals for pairwise relationships

Readiness Indicator Function

To quantify the readiness for tokenization adoption in the seven countries studied, we prepared the PCA principal components and their associated factor loadings to produce a Readiness Indicator Function (RIF). We will highlight the steps in developing this index in order to apply it to the seven countries in our study sample.

The principal components will be put together and weighted based on the percentage of variance that each principal component accounts for. This yields the indication. The principal components are extracted first, then each is weighted, and then the readiness indicator for each nation is created as a weighted total of its principal component scores. Finally, the standardised data is transformed using principal component loadings.

From the PCA, we extract the principal components:

$PC_1, PC_2, PC_3, \ldots, PC_k$ and their corresponding eigenvalues $\lambda_1, \lambda_2, \lambda_3, \ldots, \lambda_k$.

Then, each principal component's weight is determined by dividing the total variance explained by the component by its respective weight. These ratios are provided by:

$$w_k = \frac{\lambda_k}{\sum_{i=1}^{k} \lambda_i}$$

The readiness indicator for a country i is represented as the weighted total of its principal component scores:

$$RIF_i = \sum_{k=1}^{m} w_k \cdot PC_{ik}$$

where PC_{ik} is the score of country i on the kth component.

Then, the scores on the principal components (PC_{ik}) are derived from the standardised variables (Z_{ij}) through the principal component loadings (V_{jk}) :

$$PC_{ik} = \sum_{j=1}^{n} Z_{ij} \cdot V_{jk}$$

where (Z_{ij}) is the standardised value of variable j of country i and (V_{jk}) is the loading of variable j on the kth principal component. Therefore, the readiness indicator function's final mathematical model is produced by combining these steps:

$$RIF_i = \sum_{k=1}^{m} \left(\frac{\lambda_k}{\sum_{=1}^{k} \lambda_i} \right) \left(\sum_{j=1}^{n} Z_{ij} \cdot V_{jk} \right).$$

λ_k : The variance explained by each principal component is represented by its corresponding eigenvalue.

PC_{ik} : Principal component scores for country i.

Z_{ij} : Standardised values of the original variables.

V_{jk} : The contribution of each original variable to the principal components is displayed by principal component loadings.

Results and Discussion

The PCA results provide a comprehensive understanding of the factors influencing tokenization adoption in each of the seven countries studied. Key findings include the following.

As measured by their weight on the first principal component (PC1), financial market size and economic stability are important parameters that define tokenization readiness. Tokenization technologies are more advantageous for use in countries with stable economies and highly developed financial markets. Economic stability, closely linked to the strength of financial institutions and investor confidence, is a prerequisite for widespread adoption of blockchain-

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based tokenization. Larger financial markets are better suited to the adoption of such innovations because they have the infrastructure and liquidity to support token issuance and trading.

The variables of technological infrastructure and Internet penetration exhibit noteworthy loadings on both PC1 and PC2, highlighting the criticality of a resilient technological infrastructure and elevated rates of Internet penetration for the adoption of tokenization.

The significance of governmental assistance and a supportive regulatory framework is emphasised in the second principal component (PC2). Tokenization projects are more likely to be successful in nations with proactive governments and well-defined legal frameworks for digital assets.

As shown by its negative loading on the principal components, inequality in socioeconomic status can lead to unequal access to digital infrastructure and financial literacy, both of which are necessary for the use of tokenized systems.

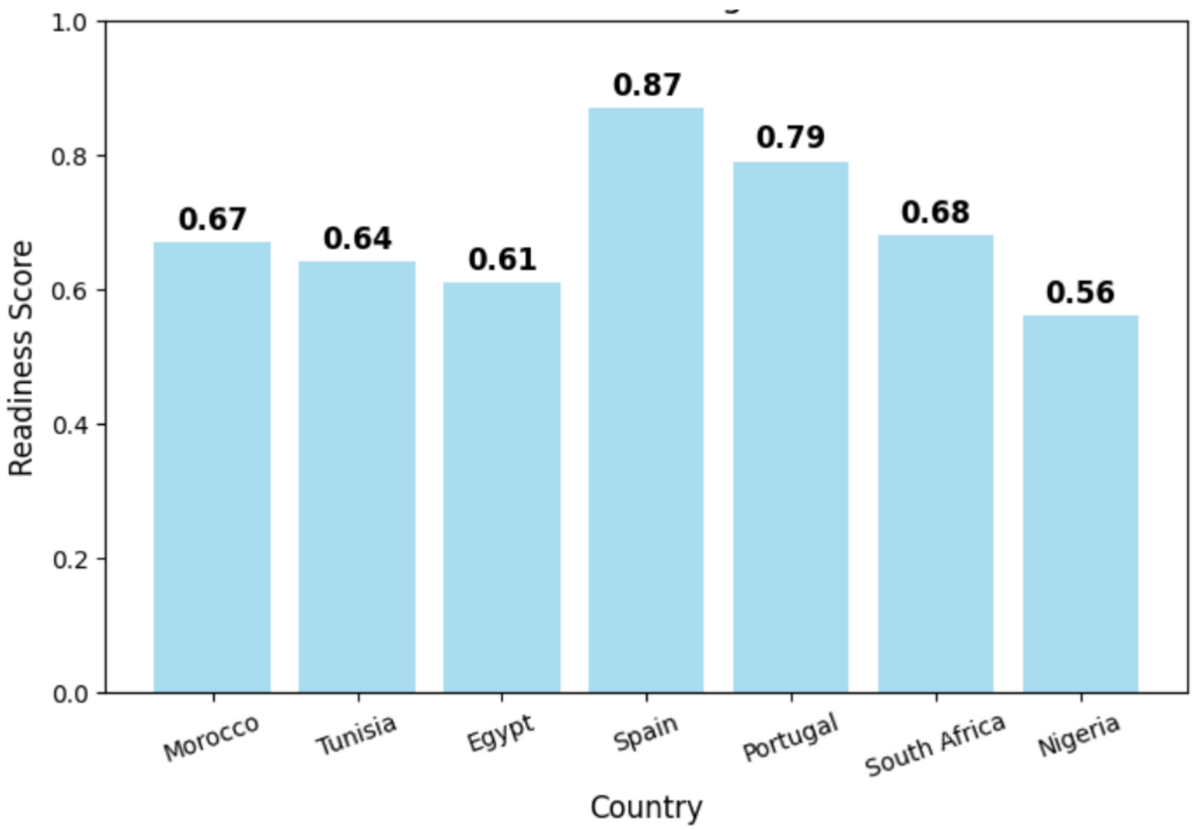

Figure 5. Readiness scores for tokenization adoption

Thus, by exploiting these principal components of the PCA and their associated factor loadings for the establishment of the RIF, it turns out that the score of the seven countries in our study varies between 0.56 for Nigeria, for the lowest score, and 0.87 for Spain as the country most prepared for the transition to tokenization. Figure 5 reveals the Readiness Indicator Function (RIF) for each country in our study.

However, and to better analyse the RIF of each country studied, it is necessary to distinguish the contribution of each variable to this score. This step is crucial for policymakers to determine which variables require more attention or investment among the 16 variables that make up the index. Figure 6 shows the scores of each variable factor contributing to the formulation of the RIF for each country.

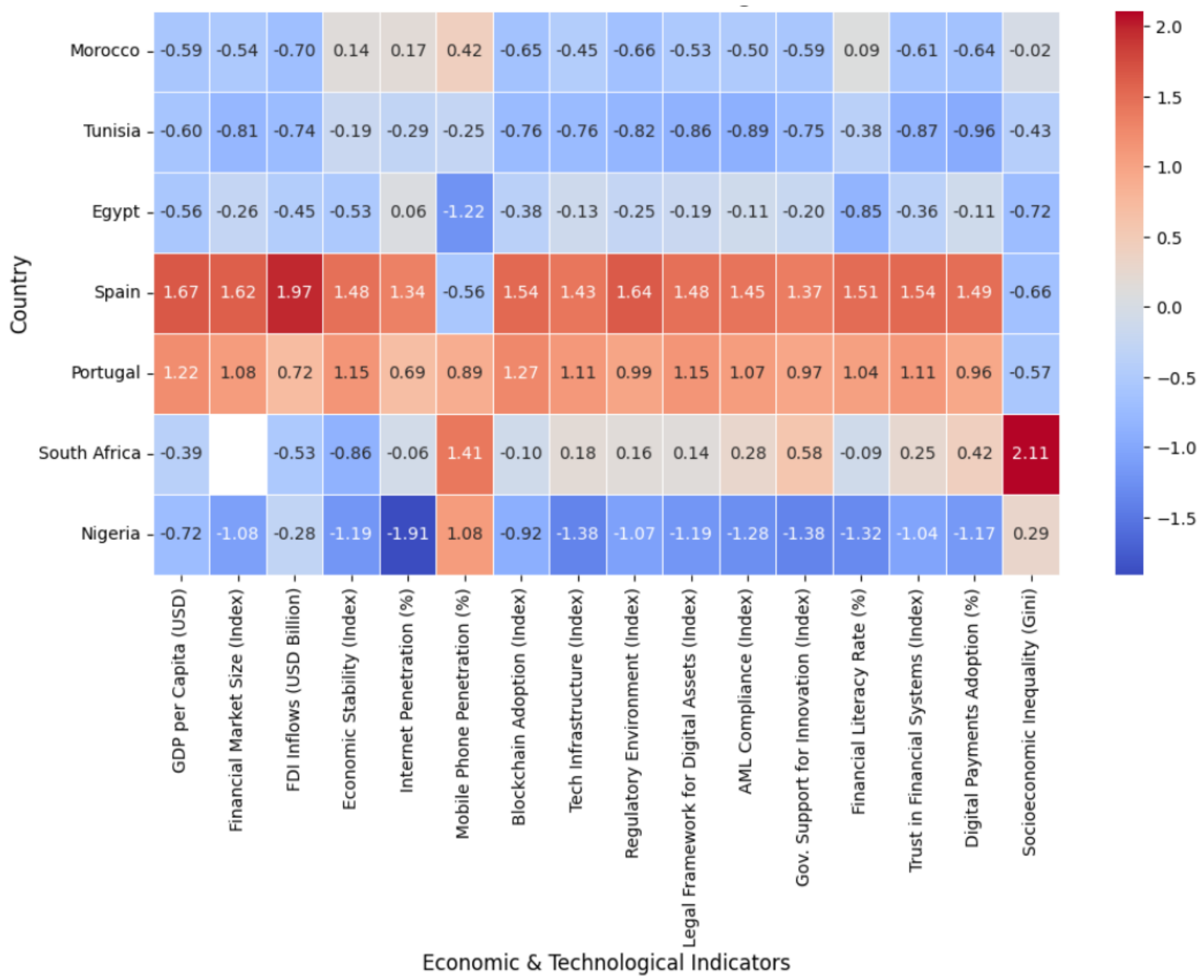

Figure 6. Normalised scores for factors contributing to readiness

The analysis of the matrix in Figure 6 confirms that the score reflecting a high level of readiness for tokenization for Spain and Portugal is due to their robust economic stability, their advanced technological infrastructure and their benevolent regulatory frameworks. Their high scores for most of the other criteria prove their maturity for the implementation of tokenization.

South Africa, for its part, has a score that suggests there is still room for improvement in terms of technological infrastructure and regulatory framework. As such, its level of readiness for tokenization remains moderate, despite the existence of a large and relatively stable financial market.

As for the three North African countries, Morocco, Tunisia and Egypt, they share roughly the same characteristics that allow for a relatively low score to be obtained in preparing for tokenization. Efforts should mainly be made to strengthen economic stability, the development of a technological infrastructure and the creation of a favourable regulatory framework. These findings confirm the work of Mahboub & Sadok (2024).

Regarding Nigeria, it has the lowest RIF due to its inadequate technological infrastructure, extreme socio-economic disparities and inadequate legal framework and institutional system.

Our findings enhance the knowledge of tokenization readiness and are consistent with the results of Juan *et al.* (2023). It illuminates how significant blockchain adoption rates and technology infrastructure are to the evolution of the digital market.

Our findings also support these conclusions while going beyond them by offering a multifaceted framework that considers factors such as societal, economic, and technical aspects and the use of mobile phone penetration as a variable, therefore emphasising the importance of a mobile network as a solution in areas with inadequate Internet infrastructure, a very important detail that Kewell *et al.* (2017) did not thoroughly examine.

In a similar vein, Watsky *et al.* (2024) stated that legislative certainty is critical for enhancing tokenization ecosystems, especially in industries like renewable energy. Our analysis proposes a comparative perspective across the selection of the seven different economies by inspecting regulatory regimes at the national level, whereas their research concentrated on sector-specific implications.

Conclusion

As the global economy continues its inevitable march towards digitalisation, our work attempts to lay the foundations of a model to measure tokenization readiness globally, which could lead to more informed policy decisions and targeted investments in digital infrastructure. Our study first attempts to deepen the reflection on the interest and challenges of tokenization for cost reduction by renewing the contributions of transaction cost theory; then it sets up an index to measure the degree of preparation for this digital transformation applied to the field of financial assets.

Thus, our study contributes to the development of the field of digital finance by establishing a quantitative criterion of readiness for tokenization, providing regulators and investors with a useful decision-making tool. The multidimensional methodology we used illustrates the complex interplay of factors that influence the ability of the seven countries studied to implement tokenized assets in their financial ecosystem.

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The results show marked gaps between the countries studied in terms of equipment for tokenization, the importance of economic stability, and adequate laws and regulations, particularly for Nigeria and the three North African countries, while Portugal and Spain display digital maturity for a smooth transition to tokenization, and consequently to financial inclusion.

These findings have important policy ramifications for promoting tokenization preparedness. To close technological gaps and facilitate broad adoption, governments should place a high priority on investing in digital infrastructure, such as by increasing access to the Internet and blockchain. As for token markets and in order to remain secure, clear and flexible regulatory frameworks are necessary to attract investment. Thirdly, to guarantee fair access to tokenization, especially in marginalised groups, it is imperative to address socioeconomic inequities and improve financial literacy. Fourth, by testing and evaluating tokenized initiatives, both public and private collaborations, they may serve as drivers of innovation, demonstrating their ability to foster both social and economic progress.

In order to modify legislation and take advantage of new possibilities, policymakers must also continue to be more flexible with technology advancements and the rapid evolution of innovation, as it is concluded at the end of many works that a more flexible jurisdictional system provides a better response to changes. By addressing these propositions, countries can take advantage of the solutions they offer and also position themselves at the forefront of the global tokenization revolution, discovering the innovation part and also enhancing financial inclusion and economic growth.

Limitations and future research

Although this study offers a strong framework for evaluating tokenization preparedness, it is important to recognise some shortcomings in order to direct future investigations and improve the relevance of related studies. Initially, the examination is limited to seven nations chosen for their geographic and economic variety. Although this guarantees a wide viewpoint, the results could not adequately convey the complexities of tokenization preparedness in areas with unique socioeconomic or regulatory traits. It would be possible to create a more globally applicable and generic framework by broadening the scope to include more nations or regional blocs.

Second, the Readiness Indicator Function's (RIF) 16 variables were carefully selected to reflect important aspects of preparedness. However, because of data limitations, several qualitative factors—like cultural attitudes toward technology or geopolitical influences—were left out, leaving space for future research to improve the framework by adding these components.

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Third, the field of tokenization is still developing quickly due to ongoing legal and technological developments. This study's cross-sectional design leaves out temporal changes that might have a big influence on preparedness measurements. Longitudinal studies would offer important new perspectives on how tokenization preparedness changes over time.

Fourth, although Principal Component Analysis (PCA) is a powerful technique for reducing dimensionality, complicated, non-linear interactions between variables may be missed due to its linearity assumption. Using cutting-edge techniques like machine learning might improve the framework's ability to forecast outcomes and adjust to complex data patterns.

Lastly, the study is still mostly quantitative, even if the Technology Acceptance Model (TAM) integration covers certain behavioural aspects. Incorporating qualitative methods, such case studies or stakeholder interviews, might enhance comprehension of the human-centric elements of tokenization adoption.

Future study should investigate cross-country comparative studies, including qualitative factors like political and cultural effects, and create longitudinal datasets to monitor changes over time in order to overcome these constraints. Evaluations of preparedness might be improved by sophisticated analytical methods like machine learning; and sector-specific studies could shed light on the contextual application of tokenization in industries like healthcare and energy. The RIF framework's usefulness for a wider variety of applications is expected to be expanded and improved by these directions

References

Adhami, S., Giudici, G., & Martinazzi, S. (2018). Why do businesses go crypto? An empirical analysis of initial coin offerings. *Journal of Economics and Business*, *100*, 64–75. https://doi.org/10.1016/j.jeconbus.2018.04.001

Al-Dhlan, K. A., Alreshidi, H. A., Pervez, S., Paraveen, Z., Zeki, A. M., Sid Ahmed, N. M. O., Alshammari, E. J., & Lingamuthu, V. (2022). Customizable Encryption Algorithms to Manage Data Assets Based on Blockchain Technology in Smart City. *Mathematical Problems in Engineering*, *2022*, 1–8. https://doi.org/10.1155/2022/8996629

Allen, D. W. E., Berg, C., Markey-Towler, B., Novak, M., & Potts, J. (2020). Blockchain and the evolution of institutional technologies: Implications for innovation policy. *Research Policy*, *49*(1), 103865. https://doi.org/10.1016/j.respol.2019.103865

Chen, Y., & Bellavitis, C. (2020). Blockchain disruption and decentralized finance: The rise of decentralized business models. *Journal of Business Venturing Insights*, *13*, e00151. https://doi.org/10.1016/j.jbvi.2019.e00151

Coase, R. H. (1937). The Nature of the Firm. *Economica*, *4*(16), 386–405. https://doi.org/10.1111/j.1468-0335.1937.tb00002.x

Cong, L. W., & He, Z. (2019). Blockchain Disruption and Smart Contracts. *The Review of Financial Studies*, *32*(5), 1754–1797. https://doi.org/10.1093/rfs/hhz007

https://doi.org/10.18080/jtde.v13n1.1012

D'Agostino, M., Dardanoni, V., & Ricci, R. G. (2017). How to standardize (if you must). *Scientometrics*, *113*, 825–843. https://doi.org/10.1007/s11192-017-2495-7

Davidson, S., De Filippi, P., & Potts, J. (2018). Blockchains and the economic institutions of capitalism. *Journal of Institutional Economics*, *14*(4), 639–658. https://doi.org/10.1017/S1744137417000200

Fenwick, M., & Vermeulen, E. P. M. (2018). Technology and Corporate Governance: Blockchain, Crypto, and Artificial Intelligence. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3263222

Harvey, C. R., Ramachandran, A., & Santoro, J. (2020). DeFi and the Future of Finance. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3711777

Hughes, A., Park, A., Kietzmann, J., & Archer-Brown, C. (2019). Beyond Bitcoin: What blockchain and distributed ledger technologies mean for firms. *Business Horizons*, *62*(3), 273–281. https://doi.org/10.1016/j.bushor.2019.01.002

Juan, A. A., Perez-Bernabeu, E., Li, Y., Martin, X. A., Ammouriova, M., & Barrios, B. B. (2023). Tokenized Markets Using Blockchain Technology: Exploring Recent Developments and Opportunities. *Information*, *14*(6), 347. https://doi.org/10.3390/info14060347

Kewell, B., Adams, R., & Parry, G. (2017). Blockchain for good? *Strategic Change*, *26*(5), 429–437. https://doi.org/10.1002/jsc.2143

Laarabi, M., Chegri, B., Mohammadia, A. M., & Lafriouni, K. (2022). Smart Contracts Applications in Real Estate: A Systematic Mapping Study. 2022 2nd International Conference on Innovative Research in Applied Science, Engineering and Technology (IRASET), 1–8. https://doi.org/10.1109/IRASET52964.2022.9737796

Li, X., & Wang, C. A. (2017). The technology and economic determinants of cryptocurrency exchange rates: The case of Bitcoin. *Decision Support Systems*, *95*, 49–60. https://doi.org/10.1016/j.dss.2016.12.001

Mahboub, H., & Sadok, H. (2023). Contribution to a Better Digital Transformation Implementation: An Integrative Approach. In J.-L. Kim (Ed.), *Frontiers in Artificial Intelligence and Applications*. IOS Press. https://doi.org/10.3233/FAIA230773

Mahboub, H., & Sadok, H. (2024). Barriers to Digital Transformation: The Case of Moroccan Companies. *Journal of Telecommunications and the Digital Economy*, *12*(1), 261–277. https://doi.org/10.18080/jtde.v12n1.814

Mahboub, H., Sadok, H., Chehri, A., & Saadane, R. (2023). Measuring the Digital Transformation: A Key Performance Indicators Literature Review. *Procedia Computer Science*, *225*, 4570–4579. https://doi.org/10.1016/j.procs.2023.10.455

Momtaz, P. P. (2020). Initial Coin Offerings. *PLOS One*, *15*(5), e0233018. https://doi.org/10.1371/journal.pone.0233018

Mouline, B., & Sadok, H. (2021). Determinants of corporate cash holdings: Evidence from the Moroccan market. *Accounting*, *7*(6), 1231–1240. https://doi.org/10.5267/j.ac.2021.4.017

Nobanee, H., El Hadi El Maknouzi, M., Sadok, H., & Alodat, A. Y. (2024). Analysis of insurance entrepreneurship as a hedge in times of crisis: A literature review. *Sustainable*

Technology and Entrepreneurship, *3*(2), 100065. https://doi.org/10.1016/j.stae.2023.100065

Radziwill, N. (2018). [Book Review] Blockchain Revolution: How the Technology Behind Bitcoin is Changing Money, Business, and the World.: 2016. Dan Tapscott and Alex Tapscott. New York: Penguin Random House. 348 pages. *Quality Management Journal*, *25*(1), 64–65. https://doi.org/10.1080/10686967.2018.1404373

Sadok, H. (2023). The Initial Coin Offering: Is It a Profitable Tool for Investment? In R. Jallouli, M. A. Bach Tobji, M. Belkhir, A. M. Soares, & B. Casais (Eds), *Digital Economy. Emerging Technologies and Business Innovation* (Vol. 485, pp. 185–194). Springer International Publishing. https://doi.org/10.1007/978-3-031-42788-6_12

Sadok, H., & Assadi, D. (2023). The Contribution of AI-Based Analysis and Rating Models to Financial Inclusion. In R. Gera, D. Assadi, & M. Starnawska, *Artificial Intelligence, Fintech, and Financial Inclusion* (1st ed., pp. 11–25). CRC Press. https://doi.org/10.1201/9781003125204-2

Sadok, H., & El Maknouzi, M. E. H. (2021). The regulation of virtual currencies in comparative perspective: New private money or niche technological innovation? *Journal of Money Laundering Control*, *24*(4), 712–724. https://doi.org/10.1108/JMLC-09-2020-0101

Sadok, H., Mahboub, H., Chaibi, H., Saadane, R., & Wahbi, M. (2023). Applications of Artificial Intelligence in Finance: Prospects, Limits and Risks. 2023 International Conference on Digital Age & Technological Advances for Sustainable Development (ICDATA), 145–149. https://doi.org/10.1109/ICDATA58816.2023.00034

Watsky, C., Liu, M., Ly, N., Orr, K., Seira, A., Vida, Z., & Wu, L. (2024). Tokenized Assets on Public Blockchains: How Transparent is the Blockchain? *FEDS Notes*, April 3, 2024. Board of Governors of the Federal Reserve System [US]. https://doi.org/10.17016/2380-7172.3444

Williamson, O. E. (2010). Transaction Cost Economics: The Natural Progression. *American Economic Review*, *100*(3), 673–690. https://doi.org/10.1257/aer.100.3.673

Zohar, A. (2015). Bitcoin: Under the hood. *Communications of the ACM*, *58*(9), 104–113. https://doi.org/10.1145/2701411

A Comparative Analysis of the Sentiments Expressed in Comments Posted under Identical Content across Different Social Media Platforms

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Abstract: Currently, there is a wide range of platforms available for video content and communication. Bloggers attract different audiences on various platforms, who view the content and provide feedback in the form of comments. The accessibility of similar tools, particularly the ability to post short videos, has encouraged bloggers to share the same content across multiple platforms. This has allowed for a comparative analysis of the sentiments expressed in comments on identical content posted on different platforms. For the purpose of this study, short videos by Russian-language bloggers producing content related to art were chosen for analysis. This field was selected as it is relatively neutral in terms of social and political perspectives. The ruBERT model was employed to classify comments based on their emotional tone. The findings support the hypothesis that the comments' sentiment under identical videos related to art, posted on various platforms, differs.

Keywords: Comments Sentiment, Russian-Language Comments, Social Media Platforms, ruBERT, Painting and Handcrafts Bloggers

Introduction

The social network, built on the basis of comparisons of their social tools, can be categorised into the following groups (Păvăloaia *et al.*, 2019): social communities, such as Facebook, LinkedIn, and Twitter, which are widely used for communication and information exchange; blogs and microblogs, including Twitter, Tumblr, and Yandex Zen, where users can share their thoughts and ideas; picture-sharing platforms like Pinterest, Instagram, and Flickr, which allow users to showcase their visual content; audio-sharing services like Spotify, iTunes, and

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Podcast.com; video-sharing platforms such as YouTube, Vimeo, and TikTok, where users can upload and share videos; online games like World of Warcraft; and RSS services such as Google, FeedBurner, and Elfeed.

Until recently, the content on different types of social media platforms varied significantly. However, the rise of short video content on TikTok (Cheng & Li, 2024) has led to other social media platforms incorporating similar features into their offerings. For instance, YouTube and VKontakte now offer the ability to share short videos. This development prompted bloggers to begin publishing identical content across multiple platforms in an effort to broaden their audience.

Traditionally, the analysis of user attitudes towards a particular type of phenomenon or product was conducted through the examination of the findings of surveys (Felix *et al.*, 2017), comments (Fang *et al.*, 2020), or reviews (Nie *et al.*, 2020). However, comments represent an immediate response to a post or video, requiring no special effort on the part of the user to generate separate new content on their own page or dedicated review platforms. The sentiment of comments beneath a post or video offers a wealth of opportunities for delving into the analysis of published material.

The existing research in the field of sentiment analysis of comments and reviews typically concentrates on examining the audience of a single social media platform (for example, Aly & van der Haar, 2020 and Alrumaih *et al.*, 2020) or on analysing posts and reviews pertaining to a specific topic that are collected from various social media platforms without considering any differences based on the source (Păvăloaia *et al.*, 2019).

However, the presence of identical content across multiple platforms provides an opportunity for a comparative examination of the sentiments expressed on different social media networks. The objective of this investigation is to undertake a comparative analysis of the sentiment of comments associated with the same video content across various platforms.

We limit our research by analysing the comments from an audience of Russian-language bloggers whose content focuses on the field of painting and handicrafts, which is a part of domain art. The study aims to verify the following hypotheses:

H1: The comment sentiment under identical videos related to painting and handicrafts, posted on various platforms, differs.

H2: The sentiment of comments under the same videos on different platforms varies from blogger to blogger.

H3: There exists a particular platform that proves more advantageous for the commercial advancement of content created by bloggers operating in the field of painting and handicrafts. This platform varies from blogger to blogger.

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Related Works

The increasing interest in delving into the sentiment analysis of comments and reviews can be attributed to the evolution of e-commerce (McAlexander *et al.*, 2002). The advent of social media platforms has provided individuals with extensive opportunities for self-representation and self-expression (Chen, 2013). Unlike traditional product promotion methods based on feedback, the effectiveness of bloggers' self-marketing strategies can be assessed through the analysis of user comments on their published content.

Researches conducted in the field of comment analysis are more focused on the following aspects:

- The analysis of sentiment in relation to a specific type of content on a particular social media platform is a topic of interest (for example, Zhan & Yu, 2018, Aly & van der Haar 2020, Alrumaih *et al.*, 2020). In the study Zhan & Yu (2018), an analysis of the sentiments expressed by users who use the hashtags #read and #reading on Instagram was undertaken. The results revealed that positive sentiments regarding reading were more prevalent than negative sentiments. In Sulaiman *et al.* (2023), the attitudes of consumers towards halal products are explored. Svetlov & Platonov (2019) is focused on analysing online political communication within the VKontakte social media platform. In it is shown that posts classified as positive received a higher number of likes, views, and reposts compared to those classified as negative.
- A comparative analysis of the impact exerted by content (or influencers) on various age groups or social strata of users. An example of this can be found in Aral & Walker (2012), which demonstrates that younger users are more susceptible to influence compared to older users, and women are more likely to be influenced by other women than by men on platforms like Facebook. Balcıoğlu (2024) delves deeper into the emotional responses elicited by Instagram influencers among Turkish youth, revealing a diverse spectrum of emotions, including admiration, envy, inspiration, and apprehension.
- Analysis of user responses to various types of content, such as the study by Păvăloaia *et al.* (2019), which delves into the reactions of customers towards two distinct types of posts – photos and videos – across six social media platforms. This study, in particular, demonstrates that photos tend to elicit significantly more user engagement compared to other types of posts.
- Identification and categorisation of themes or topics that emerge in response to specific content; for example, in King & McCashin (2022), where an analysis of YouTube video comments on personality disorders was conducted. The analysis

uncovered themes such as exchange of advice, support, and encouragement, solidarity, interconnectedness, personal connection, among others.

- The evolution of comment language in general. Di Marco *et al.* (2024) conducted an analysis of user comments spanning over 34 years, revealing trends towards shorter text lengths and reduced lexical diversity, yet the addition of new words in comments remains constant.
- Identification of negative and toxic comments has also garnered significant attention, as these comments can significantly impact users' mental well-being (Almerekhi *et al.*, 2020; Obadimu *et al.*, 2019; Miller *et al.*, 2022; Kim *et al.*, 2021; Zaheri *et al.*, 2020). The study by Alshamrani *et al.* (2020) shows that the YouTube platform contains approximately 69% of toxic comments under the videos. In Smetanin & Komarov (2021), it was found that political posts elicit the highest proportion of toxic responses, followed by security and socioeconomic topics, with similar proportions observed for other categories.

Researchers have not paid much attention to a comparative analysis of comments and reviews across various platforms. According to a study conducted by Di Marco *et al.* (2024), the impact of platforms on the complexity of user-generated content was found to be relatively limited. However, another study (Xiang *et al.*, 2017), which analysed online reviews posted on platforms such as TripAdvisor, Expedia, and Yelp, using several text mining techniques, revealed significant discrepancies in how the hotel industry is represented on these platforms. In particular, sentiment analysis showed that Yelp reviews have significantly lower positive sentiment scores than on the other two platforms. Nonetheless, reviews represent a more intricate form of content that is less likely to be influenced by spontaneous emotional reactions. Kim *et al.* (2021) found that the level of toxic language in comments under media articles about politics on Facebook is notably higher compared to comments under the same articles on other platforms. The findings derived from sentiment analysis were validated through a nationwide survey.

The present study aims to bridge the gap in comparative sentiment analysis of comments posted under content on diverse platforms.

Features of comment texts

Social media communication represents a unique form of interaction, encompassing not only the act of posting content but also engaging in comment threads. The nature of comment texts is characterised by several distinctive features, such as the concise nature of messages, the incorporation of elements reminiscent of spoken discourse, including the use of irony and

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sarcasm. Additionally, these texts often incorporate informal lexical choices, employ homonyms, and make use of emoticons and emojis to convey emotions.

In Yarushkina *et al.* (2020), it was observed that analysing the sentiment of social media texts necessitates a more extensive process of data preprocessing compared to formal texts. This includes the creation of a training corpus, which differs from the approach taken for formal texts that rely on a more standardised vocabulary. Nonetheless, there exists a degree of variability in research methodologies when it comes to preparing data for analysis.

The findings of the study Ayvaz *et al.* (2017) demonstrated that incorporating emojis into the analysis of textual tone enhances the accuracy of text classification. The researchers in Li *et al.* (2019) observed that individuals frequently employ colloquial language and emoticon symbols to convey a sense of humour, which can be challenging to categorise as purely positive or negative. In response, the authors propose a novel approach, substituting the visual representation of an emoji with its corresponding textual description, thereby significantly improving the F1-score for detecting humorous phrases that may be difficult to categorise as either positive or negative comments.

Slang is a term that denotes the use of non-standard or colloquial words and phrases in everyday speech. Wu *et al.* (2018) set out to compile a comprehensive list of slang terms in order to enhance the accuracy of text classification through the application of dictionary-based methods. However, employing dictionaries for the purpose of ascertaining the emotional connotations of slang expressions proves to be a challenging task, as slang often manifests in a plethora of forms that defy inclusion in traditional dictionaries.

The detection of sarcasm in written text represents one of the most significant challenges in the field of natural language processing. Machine learning algorithms struggle to recognise irony effectively, due to the inherent ambiguity and complexity of sarcasm. Sarcasm is often employed when the intended meaning of a statement differs from its literal interpretation. Simple machine learning models are unable to effectively handle sarcasm detection, as they fail to consider the broader context. Recognising sarcasm requires a deeper understanding that goes beyond surface-level analysis.

Convolutional and recurrent neural networks, equipped with memory mechanisms, prove particularly adept at handling long sequences and contextual information. These models can effectively capture the nuances of sarcasm, enabling more accurate detection and interpretation (Jothi & Pandeeswari, 2023; Sonare *et al.*, 2023).

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Methodology

Research design

Machine learning is used to classify comments based on their sentiment. The Russian-language adaptation of the Bidirectional Encoder Representations from Transformers (BERT) language model (Devlin *et al.*, 2019), developed by Kuratov & Arkhipov (2019), is used as the pretraining model for this purpose. The advantages of BERT models include bidirectionality, which enables the model to understand the context of words based on their entire environment. This allows the model to solve problems that require a deep understanding of linguistic context and semantics. The model also has the ability to be retrained on texts with different specificities. RuBERT is a case-insensitive model that consists of 12 explicit layers and 768 hidden layers. It includes 12 attention heads (multi-head attention) and has 180 million parameters. The model was trained on Wikipedia and news articles, which have a semantic distance from the dataset used in this study. The lexicon employed in the realm of social media communication and opinion expression predominantly adopts an informal tone, liberated from adherence to linguistic conventions, characterised by a distinctive lexical repertoire encompassing slang terms, emojis, and emoticons. Moreover, it frequently incorporates grammatical inaccuracies, abbreviations, and other linguistic idiosyncrasies, which pose significant challenges for machine learning algorithms. However, the authors of the RuBERT paper conducted a tonal analysis of posts from the VKontakte social media platform and achieved a relatively high level of classification accuracy, with an F1-score of 72.63 (Kuratov & Arkhipov 2019).

To adapt the model to the specific sentiment of the investigated data, the technique of fine-tuning is used. This involves adding at least one additional fully connected layer to the existing model and recalibrating the weights. Hao *et al.* (2019) conducted a study on loss landscapes and fine-tuning trajectories of BERT, and concluded that the fine-tuning process is resistant to overfitting, leading to better generalisation. This is attributed to the presence of flat and wide optima in the loss landscape, as well as the consistency between the loss surface and generalisation error surface during training.

We tested the RuBERT model before additional training by performing classification on the Russian toxic comments dataset available on Kaggle (Belchikov, 2019). The model achieved a Macro F1-score of 0.597 for toxic comments and 0.403 for non-toxic comments. This indicates a low level of model accuracy, highlighting the need for further training and adaptation to the specific semantics of social media text. A fine-tuned model then automatically evaluates the sentiment of comments on the labelled data. The use of computational techniques is essential, as the large number of comments would make manual processing impractical. In addition,

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qualitative analysis is conducted to better understand the specific characteristics of the comments.

Data sources

This research is dedicated to the analysing of comments on identical content across different platforms. The content under consideration consists of short videos produced by Russian-language bloggers. The selected platforms include Instagram (IG), YouTube (YT), and Yandex Zen (YZ), which became a key alternative to the TikTok social network after its blocking in Russia.

The focus of this analysis is art content. Art content can be broadly categorised into the following categories: musical, fashion, literary, cinematographic, popular science, painting, and handicrafts. Musical content encompasses video essays on contemporary music. Fashion content includes product design analysis, exploration of the impact of fashion on popular culture, and examination of the legacy of prominent fashion houses. Literary content involves analysis of literary works and biographies of authors. Cinematographic content covers theory, history, and critical analysis of film and the work of filmmakers. Popular science content comprises video lectures on various art subjects. Paintings and handicrafts include videos demonstrating the process of painting and handcrafting, as well as analysis of the artistic elements in the paintings.

The selection of the domain is predicated on several factors. The field of art represents the most apolitical and socially neutral field in contrast to the subject matter delved into in Kim *et al.* (2021). Video content within various domains is produced by extensive professional teams. The comments accompanying such content undergo moderation, which may distort the true essence and sentiments expressed in the comment threads. Art content, devoid of explicit political or societal undertones, necessitates less rigorous moderation. Within the domain of art, we have chosen the field of painting and handicraft expression as the most amenable to neutrality. Bloggers operating in these domains do not possess the same level of fandom as those in the realms of contemporary music or cinema, thus reducing the likelihood of confrontations between opposing viewpoints.

Our hypothesis is that the approach to moderation across various platforms for the content under study remains consistent. We assume that there is a similar inclination to favour positive sentiment in the comments. Also, the study does not take into account the responses to initial comments that constitute the discussion thread. In our opinion, these responses no longer correlate so clearly with the content of the video itself, but rather represent an assessment of the impression left by the initial commentator in the discussion.

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The selection of bloggers was based on a comprehensive analysis of comments conducted specifically for this study. This analysis encompassed metrics such as the size of the audience, the average reach over the past ten videos, and the response to a recent publication that was replicated across all the platforms under consideration. The final list of authors: Ivan restorer (@ivan_restorer), Anastasia Neuman (@Ne.narcissa), Elizaveta Sh (@eliz_antik), Art Vetal (@ArtVetal), АРТ ОБСТРЕЛ (@Artobstrel), Tsirin88 (@Tsirin88). The content of these Russian-language bloggers is the most widely commented upon in this sphere.

Data description

The final dataset, which includes comments under the posts of all selected authors on YouTube, Instagram and Yandex Zen sites, consists of 17,329 rows and 3 columns: source – the source (content publishing site); author – the author of the publication (blogger); and text – the content of the comment. Python parsers have been designed for the purpose of scraping data. These parsers make use of the Selenium library, specifically its webdriver module, as well as fundamental libraries within Python. Table 1 shows the distribution of the number of comments of the final data set between the sites and the authors.

Table 1. The distribution of the number of comments on the final dataset between sites and authors

Author	Instagram	Yandex Zen	YouTube
@art_obstrel	1 308	3 043	–
@eliz_antik	1 303	2 035	–
@ivan_restorer	832	2 660	560
@ArtVetal	981	410	409
@Tsirin88	215	1 016	–
@ne.narcissa	261	2 738	–

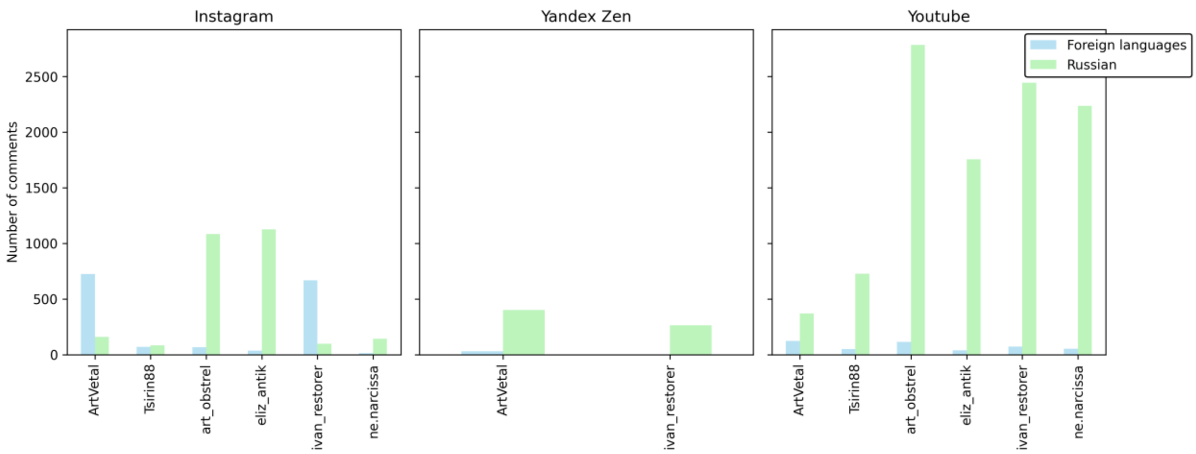

Figure 1. Distribution of comments by sources, authors and languages

The comment corpus contains 14,725 (84.9%) Russian-language comments and 2,604 foreign (15.1%). The variety of languages in the comments is also explained by the specifics of the content – most often, videos about creativity represent the captured process of drawing a

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picture with superimposed music, and therefore they are understandable to native speakers of different languages.

The distribution of comments by site, author, and language is shown in Figure 1. To build the model, comments in foreign languages were translated into Russian.

Table 2. The ratio of emoji comments compared to the total number of comments on the website for each blogger

Author	With emoji		
	Instagram	Yandex Zen	YouTube
@art_obstrel	0.56	0.03	–
@eliz_antik	0.52	0.01	–
@ivan_restorer	0.64	0.02	0.01
@ArtVetal	0.44	0.02	0.02
@Tsirin88	0.76	0.02	–
@ne.narcissa	0.69	0.02	–

Table 2 presents the ratio of emoji comments compared to the total number of comments on the website. The prevalence of emoji characters in the Instagram social media platform has long been well-documented. Note that the corpus of comments on platforms such as YouTube and Yandex Zen exhibits a relatively low prevalence of emojis. Emojis have been replaced with textual representations of their meanings, in line with the UNICODE_EMO dictionary. This dictionary is integrated into the "demoji" library for Python, which is freely available. This dictionary provides a textual interpretation of emoji symbols based on their corresponding codes. Notably, a subset of emojis present in comments failed to be included in the dictionary; however, they were subsequently incorporated by the researchers into the dictionary.

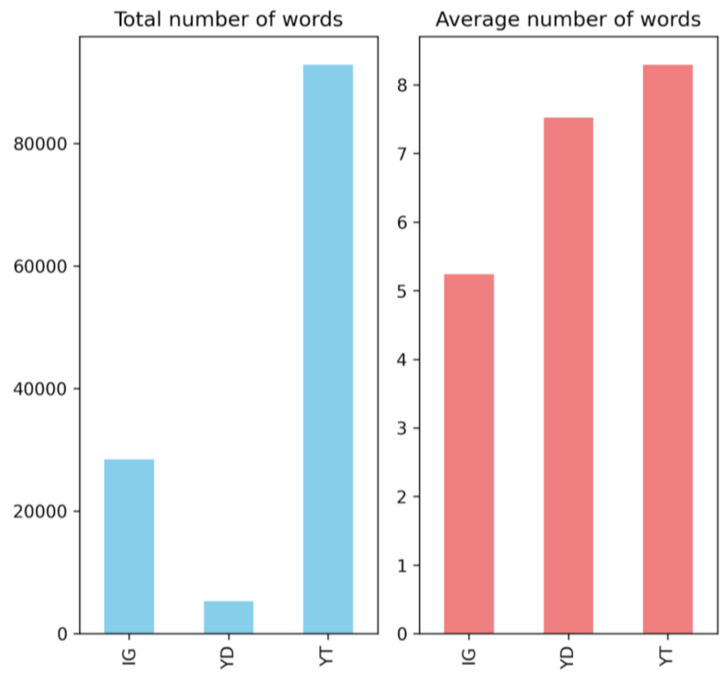

Figure 2. Distribution of comments lengths by sources

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Furthermore, apart from the lexical content of comments, it is also of interest to analyse the average length and word count of comments, as visual representations of these distributions are depicted in Figures 2 and 3.

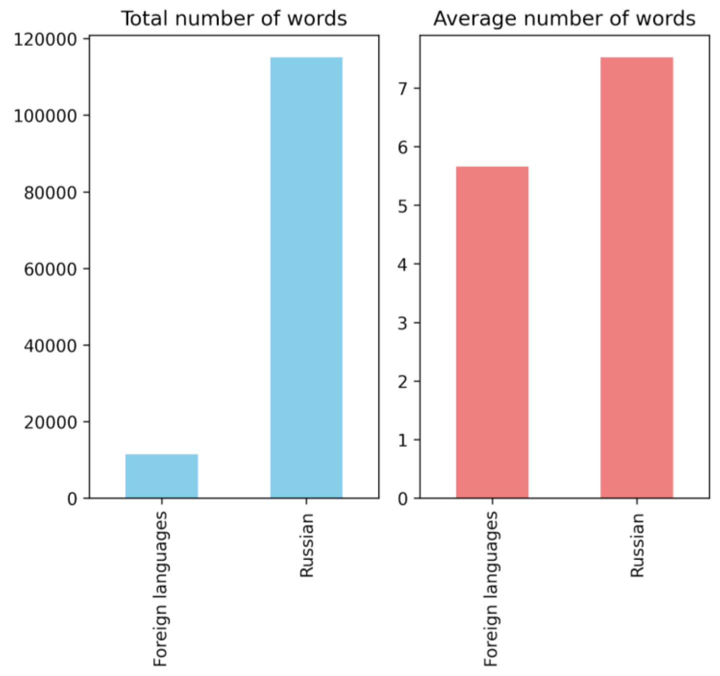

Figure 3. Distribution of comments lengths by languages

A few examples of comments made under the video are presented in Figure 4. Note the presence of comments without emojis or consisting exclusively of emojis, as well as the use of emojis inside a text comment.

source	author	text
IG	ivan_restorer	❤️❤️❤️❤️❤️❤️
IG	ivan_restorer	👌😍👏
IG	ivan_restorer	👏👏😍😍
IG	ivan_restorer	So interesting. I often wonder whether the layer you are removing is grime or purposeful glaze by the artist. How do you know?
IG	ivan_restorer	Super 😍😍😍😍
IG	ivan_restorer	👏
IG	ivan_restorer	А чем промывали? Я пользовалась вода+спирт+вайт спирит.

Figure 4. Examples of comments

Model building

Data annotation

A multi-classification scale was chosen for annotating. The following classes were included:

- Interested/Questioner – comments with questions reflecting the potential audience of product promotion: “What is the price?”, “What paints do you use?”, “Where can I buy such a canvas?", "What kind of music is in the video?"

- Angry/Toxic – comments that clearly offend or harshly criticise the author, the video, or the subject shown in the video.
- Negative/Disappointed – comments in which users express their disappointment and dissatisfaction with a video they have watched. However, unlike toxic comments, these comments are expressed in a tactful manner, emphasising that the user simply did not resonate with the spirit of the work.
- Neutral – comments that do not contain any explicit emotional evaluation of the video, the creator, or the subject matter featured in the video. Comments with personal questions, such as "Are you from Russia?", "What is the color of your eyes?", and similar, were also classified in this category, as were comments in which users shared their own stories related to the topic of discussion in the video without expressing any opinion on the video itself.
- Positive/Satisfied – positive, complimentary comments.
- Enthusiastic – comments that go beyond mere approval or satisfaction and express genuine surprise, admiration for the skill, abilities of the author, or the beauty of the work.

The entire corpus of collected comments underwent manual annotation by a team of nine experts, who were divided into three groups of three individuals each. The data were randomly partitioned into equal portions and submitted in a manner such that each comment was evaluated by a different reviewer within a group.

The objectivity of assessment was guaranteed by calculating the level of consistency among the opinions within each group. If all annotators assigned a comment to the same category, this assessment was deemed reliable. However, if only two annotators agreed, the comment was forwarded to another group for evaluation. In this case, the reliability of the assessment relied on the consensus among six reviewers, considering the expertise of the previous group. In the event that the opinions of the reviewers were not in complete agreement, the comment in question was submitted for re-evaluation to the remaining six reviewers. In this scenario, the validity of the annotation was assessed based on the combined judgments of nine reviewers, with the additional (tenth) rating provided by the author.

Fine-tuning process

The entire data set was divided into training, test and validation sets in the proportion of 70/15/15%. Figure 5 shows the distribution of the annotated corpus of comments according to their source (site), author, and sentiment. There is a significant imbalance between the different tonalities, which is why stratified sampling was used.

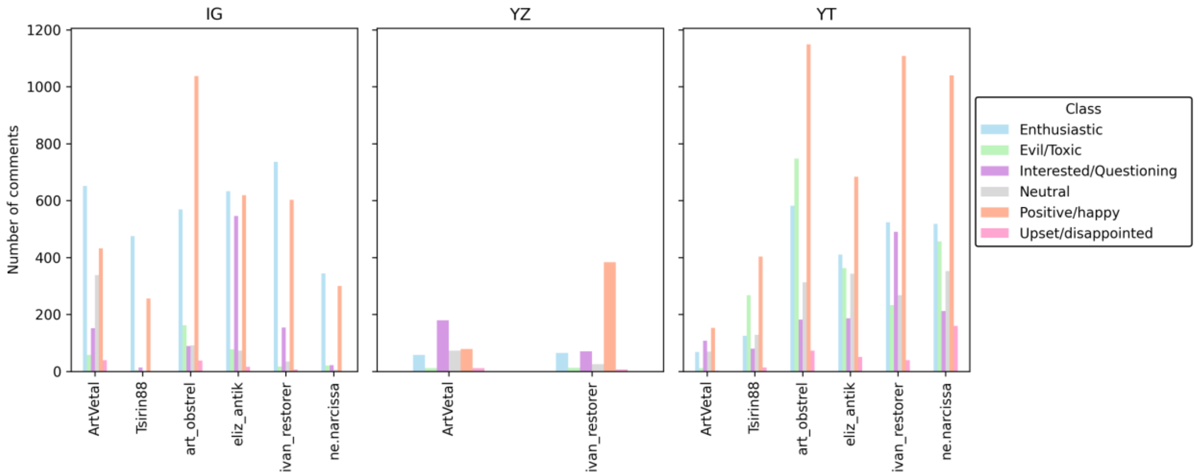

Figure 5. The distribution of annotated comments by sites, authors and classes

The posted comments from the training set were used in the process of fine-tuning the original ruBERT model. On the test data, the classification quality of the added layer was evaluated using the macro F1-score and ROC-AUC curve metrics with a one-against-all strategy. The validation set was used to form final recommendations on the choice of a promotion site.

Comments were tokenised to apply the models. In Figure 6, the distribution of the lengths of the token sequences received is presented.

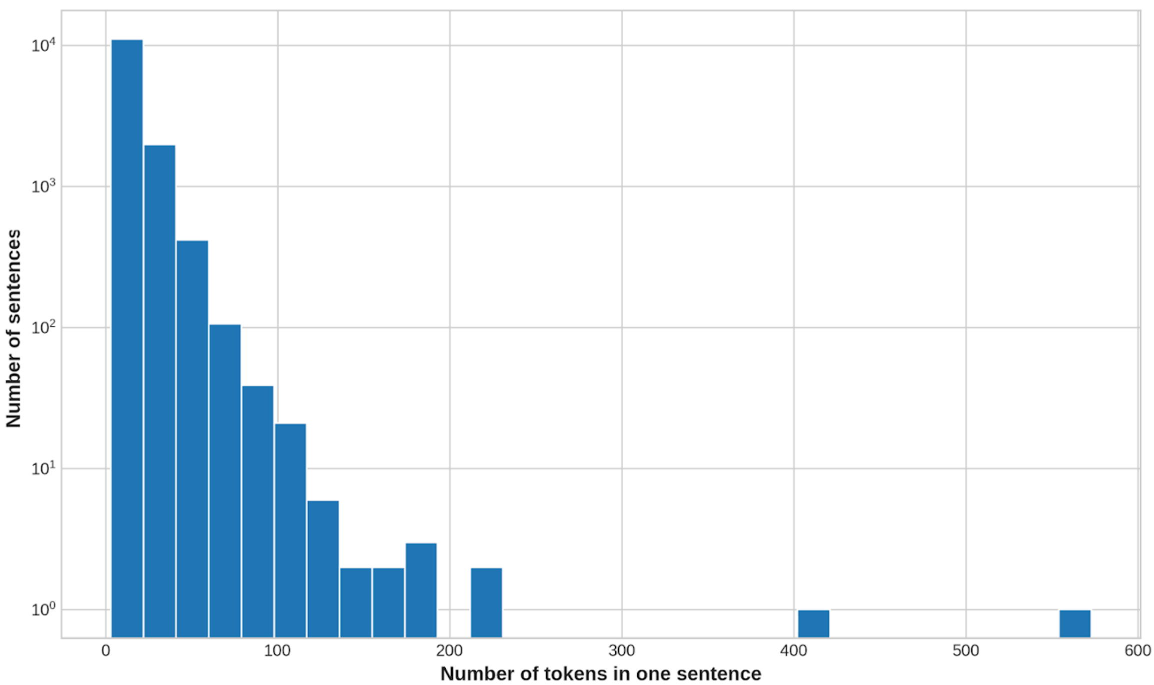

Figure 6. The distribution of the lengths of input sequences of tokens

The distribution shows that the majority of sequence lengths are within the range of 0 to 100. The longest input sequence observed was 573 tokens. In the collected dataset of comments, only one was found to be this lengthy. It was truncated due to the maximum input sequence length limit of 512 for the BERT and RuBERT models.

During the annotation process, it was noted that most long comments belong to neutral class. These comments often included personal stories from childhood or memories related to objects featured in the video, as well as advice on how to best utilise specific techniques or tools. Other classes were characterised by shorter comments, with the final dataset containing sequences ranging from 0 to 128 tokens.

The article by Devlin *et al.* (2019) recommends fine-tuning the model for 2–4 epochs. According to the final metrics of fine-tuning, the best classification result is achieved in the third epoch (see Figure 7) – the model is able to correctly detect tonality in 93.2% of cases (AUC-ROC metric).

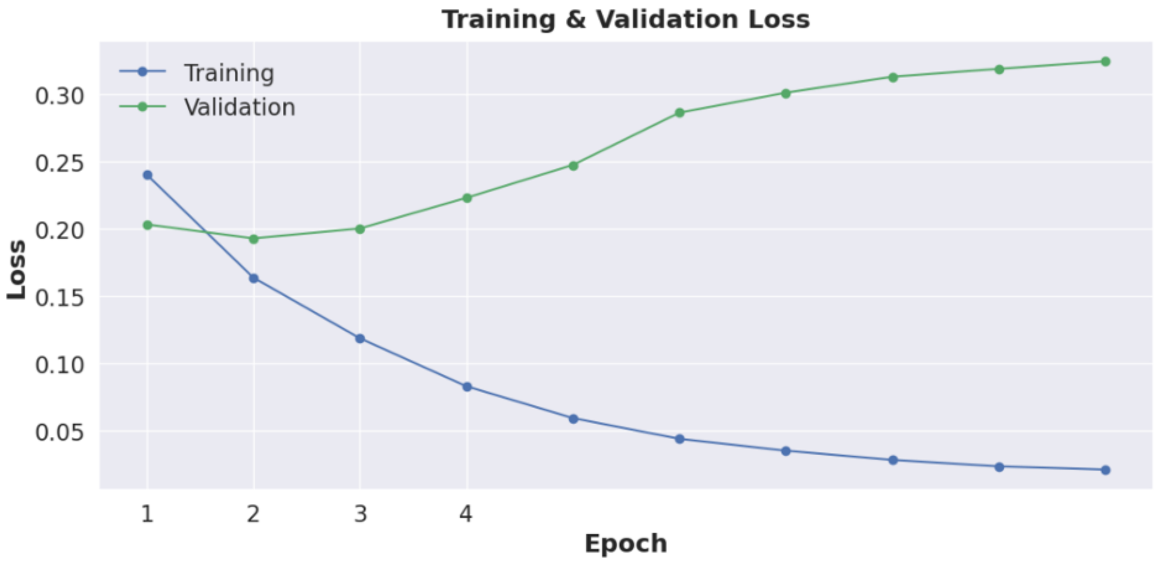

Figure 7. Training and validation loss by epoch

Results and Discussion

The final classification quality metrics for each class for the fine-tuned model for the test set, without regard to the comment platform, are presented in the Table 3.

Table 3. Quality metrics for classes

Metric/Sentiment	Binary	Macro F1-score
Enthusiastic	0.8535	0.8988
Interested/Questioning	0.8397	0.9090
Evil/Toxic	0.5850	0.7660
Neutral	0.6370	0.7999
Positive/Happy	0.8088	0.8470
Upset/Disappointed	0.3333	0.6590

Table 3 demonstrates that the model most accurately predicts the Interested/Questioning and Enthusiastic classes, while it performs least accurately on the Upset/Disappointed class.

Ten random comments included in the test set and the classification results obtained are shown in Table 4.

Table 4. Ten random comments included in the test set and the classification results obtained

Source	Author	Text	Label	Score
YT	@art_obstrel	“that's it, out of sight” all artists after sitting for a long time over a flower	Neutral	0.84101
IG	@art_obstrel	We’re doing okay! Kolka did it))	Positive/happy	0.97203
IG	@art_obstrel	“What a disgusting thing this Sanet is” I wanted to paint it	Positive/happy	0.91562
IG	@eliz_antik	“Kiss” is sweet, heartfelt and charming. Some kind of warmth blows~	Positive/happy	0.90541
YT	@Tsirin88	“Like, well, in short, really, like, well, you understand, I’m like, in short” Guys, at least read the toilet deodorant	Evil/toxic	0.85821
YT	@ne.narcissa	...the most avid critic...	Neutral	0.86171
IG	@eliz_antik	“I am forever devoted to you” warms the soul so much	Positive/happy	0.93170
IG	@art_obstrel	In general, Kolya, as usual - One love!!	Positive/happy	0.98791
IG	@ne.narcissa	Have you tried voice acting?	Interested/questioning	0.99132
YT	@eliz_antik	Where do you get these rarities?	Interested/questioning	0.99288
YT	@ne.narcissa	Where can I buy such a canvas?	Interested/questioning	0.99121
YT	@ne.narcissa	Wow, the picture is amazing. But I’m so tired of this manner of “a terrible thing happened” or “you don't believe it” or “one day...” Now I also want this picture, but how does such a presentation of creativity repel	Upset/disappointed	0.89762

The final distribution of comments by sentiment classes is shown in Table 5. These figures show the share of each author’s sentiment within all comments on social networks.

Table 5. The final distribution of comments by sentiment classes

		@art_ obstrel	@eliz_ antik	@ivan_ restorer	@Art Vetal	@Tsirin 88	@ne.nar cissa
Enthusias-tic	IG	0.0661	0.0735	0.0855	0.0756	0.0552	0.0400
	YT	0.0489	0.0344	0.0440	0.0057	0.0105	0.0435
	YZ	–	–	0.0660	0.0599	–	–
Interested/ Question-ing	IG	0.0103	0.0634	0.0179	0.0175	0.0016	0.0024
	YT	0.0152	0.0156	0.0412	0.0090	0.0066	0.0178
	YZ	–	–	0.0722	0.1847	–	–
Evil/Toxic	IG	0.0188	0.0089	0.0020	0.0066	0.0005	0.0023
	YT	0.0628	0.0304	0.0195	0.0009	0.0224	0.0383
	YZ	–	–	0.0124	0.0114	–	–
Neutral	IG	0.0106	0.0084	0.0039	0.0393	0.0001	0.0006
	YT	0.0263	0.0288	0.0224	0.0058	0.0108	0.0296
	YZ	–	–	0.0258	0.0743	–	–

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		@art_ obstrel	@eliz_ antik	@ivan_ restorer	@Art Vetal	@Tsirin 88	@ne.nar cissa
Positive/ happy	IG	0.1205	0.0719	0.0699	0.0502	0.0297	0.0348
	YT	0.0964	0.0574	0.0931	0.0129	0.0339	0.0874
	YZ	–	–	0.3953	0.0805	–	–
Upset/ disappointed	IG	0.0032	0.0019	0.0008	0.0045	0.0001	0.0001
	YT	0.0061	0.0043	0.0033	0.0002	0.0012	0.0134
	YZ	–	–	0.0062	0.0114	–	–

In order to ascertain the statistical significance of the distribution of sentiments expressed in comments, statistical hypotheses were formulated for each individual blogger's contributions and for all comments using the one-against-all approach. The null hypothesis tested the assumption that the probabilities of success in multiple groups are equivalent. Success was defined as the presence of one of the specified sentiments, while failure corresponded to any other sentiment expressed.

At the 5% significance level, there was no statistical difference between:

- for @art_obstrel, the proportions of Upset/disappointed comments for Instagram and YouTube;
- for @eliz_antik, the proportions of Evil/Toxic and Neutral comments for Instagram and YouTube;
- for @ivan_restorer, the proportions of Interested/questioning and Evil/Toxic comments for Instagram and Yandex Zen, the proportions of Positive/happy comments for Instagram and YouTube, the proportions of Upset/disappointed comments for all platforms;
- for @ArtVetal, the proportions of Evil/Toxic and Neutral comments for all platforms, Upset/disappointed comments for Instagram and Yandex Zen, Enthusiastic comments for YouTube and Yandex Zen;
- for all bloggers, the proportions of Neutral and Interested/Questioning comments for Instagram and YouTube.

Table 6 presents the type of mood that predominates for each author on each platform and the average values of the prediction quality metrics.

Table 6. Distribution of comments by sites, authors, and sentiment classes

Author	Instagram		YouTube		Yandex Zen	
	main sentiment	mean score	main sentiment	mean score	main sentiment	mean score
@art_obstrel	Enthusiastic	0.9867	Upset/ disappoint-ed	0.9512	–	–
@eliz_antik	Interested/ questioning	0.9926	Interested/ questioning	0.9685	–	–

Author	Instagram		YouTube		Yandex Zen	
	main sentiment	mean score	main sentiment	mean score	main sentiment	mean score
@ivan_restorer	Enthusiastic	0.9853	Interested/ questioning	0.9877	Interested/ questioning	0.9945
@ArtVetal	Enthusiastic	0.9781	Neutral	0.9906	Positive/ happy	0.9745
@Tsirin88	Enthusiastic	0.9830	Interested/ questioning	0.9906	–	–
@ne.narcissa	Positive/happy	0.9582	Interested/ questioning	0.9906	–	–

Thus, Hypothesis 1, "The comment sentiment under identical videos related to painting and handicrafts, posted on various platforms, differs" was partly confirmed. The highest absolute and relative numbers of angry and toxic comments are observed on YouTube video hosting platforms. This is likely due to the high level of comment activity on these platforms. However, proportions of Neutral and Interested/Questioning comments for Instagram and YouTube differ statistically insignificantly. Also, there is a clear correlation between the number of positive comments and the number of negative comments.

Hypothesis 2, "The sentiment of comments under the same videos on different platforms varies from blogger to blogger", is also confirmed. In general, individual bloggers exhibit distinct patterns of most commonly expressed sentiments, and the distribution of sentiment types also varies. For instance, the blogger @art_obstrel exhibits the greatest discrepancy in sentiment across platforms, ranging from predominantly positive on Instagram to predominantly negative on YouTube. Conversely, @eliz_antik generates a more consistent distribution of interest-related comments across all platforms.

To verify Hypothesis 3, bags of words were additionally compiled. Figure 8 presents the top 5 most frequent words in the comments, ordered by frequency (words from Russian-language comments were translated into English for this purpose).

Thus, Hypothesis 3 is indirectly confirmed in the first part: "There exists a particular platform that proves more advantageous for the commercial advancement of content created by bloggers operating in the field of painting and handicrafts". This platform varies from blogger to blogger. At the same time, a more in-depth analysis of the content of comments revealed that accounts such as @eliz_antik on Instagram and @ivan_restorer on YouTube appear to be of particular interest. Comments posted by @eliz_antik frequently raise questions regarding the price of paintings, while those posted by @ivan_restorer often express interest and request information on the methods used for cleaning ancient paintings.

The results presented in Table 6, as well as the bags of words, confirm the second part of Hypothesis 3: "The platform that proves more advantageous for the commercial advancement of content varies from blogger to blogger". In Table 7, possible recommendations for selecting a promotion platform for bloggers are provided. The recommendation was formulated based on the calculation of the proportion of positive, interested, or enthusiastic comments.

	Instagram	YouTube	Yandex Zen
@art_obstrel	• artist • good • dye • painting • like	• Nikolay • artist • painting • paint • good	–
@eliz_antik	• price • worth • beauty • hello • cost	• decoration • beauty • diamond • beautiful • earring	–
@ivan_restorer	• job • painting • beautiful • great • use	• painting • varnish • job • interesting • old	• painting • job • interesting • thanks • restoration
@ArtVetal	• level • part • knife • good • last	• paint • plz • beautiful • draw • good	• paint • level • hindu • draw • match
@Tsirin88	• job • like • color • beautiful • cool	• girl • video • paint • understand • thank you	–
@ne.narcissa	• painting • beautiful • polystyrene foam • do • voice	• painting • canvas • beautiful • rose • paint	–

Figure 8. The top 5 most frequent words in the comments for every author

Table 7. Final recommendations for the selection of a promotional platform

Author	Main sentiment	Model accuracy, %	Share of interested/questioning comments, %	Recommended promotion platform
@art_obstrel	Positive/happy	92	5.07	Instagram
@eliz_antik	Positive/happy	91	29.45	Instagram
@ivan_restorer	Positive/happy	96	19.16	YouTube
@ArtVetal	Interested/ questioning	94	44.95	Yandex Zen
@Tsirin88	Enthusiastic	92	6.72	Instagram
@ne.narcissa	Positive/happy	94	8.93	YouTube

The author of @art_obstrel enjoys the most loyal following on Instagram, but the level of interest in specific products among their subscribers is relatively low. Therefore, it is advisable to opt for more subtle promotional strategies to avoid causing discontent. Similar recommendations can be applied to bloggers @Tsirin88 and @ne.narcissa on YouTube.

The level of engagement among the audiences of @eliz_antik and @ivan_restorer falls somewhere in the middle, with the prevailing sentiment among subscribers being one of happiness and positivity. Under these circumstances, native advertising for products related

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to the specific content of these creators proves effective, particularly in the realm of art-related offerings such as art materials, courses, and exhibitions.

In the comments section of @ArtVetal's blog, the predominant tone is one of curiosity or inquiry, with almost every other commentator seeking some form of information, insight, or response from the creator. This implies his significant influence, which is likely to engender a highly dedicated and engaged following, eager to engage with the blogger's offerings, such as courses, checklists, and marathons.

The findings of this research can serve as a supplementary metric for assessing the potential success of an advertising campaign conducted by a particular creator. Advertisers prioritise metrics such as reach, impressions, engagement levels, and audience loyalty. While the first three metrics are frequently calculated by the platform itself, providing creators with an analytical overview for each video, audience loyalty is subjectively evaluated based on user feedback, comments etc. The proposed model can contribute to this evaluation by introducing a more comprehensive and objective indicator that is free from human bias.

Conclusions

The availability of similar tools, particularly the ability to publish short video content, has led to bloggers posting the same videos across various platforms. Sentiment analysis has shown that the audiences of these platforms differ.

This study makes both theoretical and practical contributions. Theoretically, it fills a gap in the literature by comparing the audiences of the same content across different platforms. Practically, it offers a methodology for selecting the most appropriate platform for promotion. This methodology can be applied to other types of content while considering comment moderation policies.

Further research may explore other platforms, potentially those with a lesser degree of user depersonalisation, which would allow for a comparison of the results of sentiment analysis with demographic data, such as gender, geographical location, and average age of users. The technical features of the platforms considered in this study make it very difficult for third parties to collect such information en masse. Therefore, the current research does not delve into the correlation between sentiment and the profile of the targeted audience.

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References

Almerekhi, H., Kwak, H., Salminen, J., & Jansen, B. J. (2020). Are these comments triggering? Predicting triggers of toxicity in online discussions. *WWW '20: Proceedings of the web conference 2020*, 3033–3040. https://doi.org/10.1145/3366423.3380074

Alshamrani, S., Abuhamad, M., Abusnaina, A., & Mohaisen, D. (2020). Investigating Online Toxicity in Users Interactions with the Mainstream Media Channels on YouTube. *The 5th International Workshop on Mining Actionable Insights from Social Networks (MAISoN'20),* 1–6. Available at https://ceur-ws.org/Vol-2699/paper39.pdf

Alrumaih, A., Al-Sabbagh, A., Alsabah, R., Kharrufa, H., & Baldwin, J. (2020). Sentiment analysis of comments in social media. *International Journal of Electrical & Computer Engineering*, *10*(6), 5917–5922. https://doi.org/10.11591/ijece.v10i6.pp5917-5922

Aly, E. S., & van der Haar, D. T. (2020). Slang-based text sentiment analysis in Instagram. *Fourth International Congress on Information and Communication Technology: ICICT 2019, London, 1027*, 321–329. https://doi.org/10.1007/978-981-32-9343-4_25

Aral, S., & Walker, D. (2012). Identifying influential and susceptible members of social networks. *Science, 337*(6092), 337-341. https://doi.org/10.1126/science.1215842

Ayvaz S., Shiha M. O. (2017). The Effects of Emoji in Sentiment Analysis. *International Journal of Computer and Electrical Engineering,* *9*(1), 360–369. https://doi.org/10.17706/ijcee.2017.9.1.360-369

Balcıoğlu, Y. S. (2024). Examining Turkish Youth's Reaction to Instagram Influencers: A Sentiment Analysis. *İletişim ve Diplomasi, 12*, 59–73. https://doi.org/10.54722/iletisimvediplomasi.1489078

Belchikov, A. (2019). Russian Language Toxic Comments. *Kaggle* https://www.kaggle.com/datasets/blackmoon/russian-language-toxic-comments

Chen, C. P. (2013). Exploring personal branding on YouTube. *Journal of internet commerce, 12*(4), 332–347. https://doi.org/10.1080/15332861.2013.859041

Cheng, Z., & Li, Y. (2024). Like, comment, and share on TikTok: Exploring the effect of sentiment and second-person view on the user engagement with TikTok news videos. *Social Science Computer Review, 42*(1), 201–223. https://doi.org/10.1177/08944393231178603

Devlin, J., Chang, M.-W., Lee, K., & Toutanova, K. (2019). BERT: Pre-training of Deep Bidirectional Transformers for Language Understanding. *Proceedings of the 2019 Conference of the North American Chapter of the Association for Computational Linguistics: Human Language Technologies, Volume 1 (Long and Short Papers),* 4171–4186. https://doi.org/10.48550/arXiv.1810.04805

Di Marco, N., Loru, E., Bonetti, A., Serra, A. O. G., Cinelli, M., & Quattrociocchi, W. (2024). The Evolution of Language in Social Media Comments. *arXiv preprint arXiv:2406.11450*. https://arxiv.org/abs/2406.11450

Eyipınar, C. D., Büyükkalkan, F., & Semiz, K. (2021). Sentiment Analysis of Youtube Videos Comments on Sports Nutrition. *International Journal of Physical Education Sport and Technologies*, *2*(2), 27–39.

Fang, Z., Zhang, Q., Tang, X., Wang, A., & Baron, C. (2020). An implicit opinion analysis model based on feature-based implicit opinion patterns. *Artificial Intelligence Review, 53*, 4547–4574. https://doi.org/10.1007/s10462-019-09801-9

Felix, R., Rauschnabel, P. A., & Hinsch, C. (2017). Elements of strategic social media marketing: A holistic framework. *Journal of business research, 70*, 118–126. https://doi.org/10.1016/j.jbusres.2016.05.001

Hao, Y., Dong, L., Wei, F., & Xu, K. (2019). Visualizing and understanding the effectiveness of BERT. In *Proceedings of the 2019 Conference on Empirical Methods in Natural Language Processing and the 9th International Joint Conference on Natural Language Processing (EMNLP-IJCNLP)*, 4143–4152. Hong Kong, China. Association for Computational Linguistics. https://doi.org/10.18653/v1/D19-1424

Jothi, S. A., & Pandeeswari, N. (2023). Enriched Glove of Word Embedding and BERT of Contextual Embedding in Sarcasm Detection with AdaGrad Optimization Technique. In *2023 3rd International Conference on Innovative Mechanisms for Industry Applications (ICIMIA)*, 1535–1539. IEEE. https://doi.org/10.1109/ICIMIA60377.2023.10426427

Kim, J. W., Guess, A., Nyhan, B., & Reifler, J. (2021). The distorting prism of social media: How self-selection and exposure to incivility fuel online comment toxicity. *Journal of Communication, 71*(6), 922–946. https://doi.org/10.1093/joc/jqab034

King, C. M., & McCashin, D. (2022). Commenting and connecting: A thematic analysis of responses to YouTube vlogs about borderline personality disorder. *Internet interventions, 28*, 100540. https://doi.org/10.1016/j.invent.2022.100540

Kuratov, Y., & Arkhipov, M. (2019). Adaptation of deep bidirectional multilingual transformers for Russian language. *Computational Linguistics and Intellectual Technologies, 18*(25), 333–339. https://doi.org/10.48550/arXiv.1905.07213

Li, D., Rzepka, R., Ptaszynski, M., & Araki, K. (2019). A Novel Machine Learning-based Sentiment Analysis Method for Chinese Social Media Considering Chinese Slang Lexicon and Emoticons. *AffCon@ AAAI, 2328*. Available at https://ceur-ws.org/Vol-2328/3_3_paper_10.pdf

McAlexander, J. H., Schouten, J. W., & Koenig, H. F. (2002). Building brand community. *Journal of marketing, 66*(1), 38–54. https://doi.org/10.1509/jmkg.66.1.38.18451

Miller, C., Cohen, S., Klug, D., Vasilescu, B., & KaUstner, C. (2022). "Did you miss my comment or what?" understanding toxicity in open source discussions. *Proceedings of the 44th International Conference on Software Engineering*, 710–722. https://doi.org/10.1145/3510003.3510111

Muniz A. M., & Schau, H. J. (2005). Religiosity in the abandoned Apple Newton brand community. *Journal of consumer research, 31*(4), 737–747. https://doi.org/10.1086/426607

Nie, R. X., Tian, Z. P., Wang, J. Q., & Chin, K. S. (2020). Hotel selection driven by online textual reviews: Applying a semantic partitioned sentiment dictionary and evidence theory. *International Journal of Hospitality Management*, *88*, 102495. https://doi.org/10.1016/j.ijhm.2020.102495

Obadimu, A., Mead, E., Hussain, M. N., & Agarwal, N. (2019). Identifying toxicity within Youtube video comment. *Social, Cultural, and Behavioral Modeling: 12th International Conference, SBP-BRiMS 2019, Washington, DC, USA,* July 9–12, 2019, Proceedings *12*, 214–223. Springer International Publishing. https://doi.org/10.1007/978-3-030-21741-9_22

Păvăloaia, V. D., Teodor, E. M., Fotache, D., & Danileţ, M. (2019). Opinion mining on social media data: sentiment analysis of user preferences. *Sustainability, 11*(16), 4459. https://doi.org/10.3390/su11164459

Poecze, F., Ebster, C., & Strauss, C. (2022). Let's play on Facebook: using sentiment analysis and social media metrics to measure the success of YouTube gamers' post types. *Personal and Ubiquitous Computing, 26*(3), 901–910. https://doi.org/10.1007/s00779-019-01361-7

Safko, L., & Brake, D. (2009). *The Social Media Bible: Tactics, Tools, and Strategies for Business Success*. John Wiley & Sons: Hoboken, New Jersey, USA.

Smetanin, S., & Komarov, M. (2021). Share of toxic comments among different topics: the case of Russian social networks. *2021 IEEE 23rd Conference on Business Informatics (CBI), 2*, 65–70. IEEE. https://doi.org/10.1109/CBI52690.2021.10056

Sonare, B., Dewan, J. H., Thepade, S. D., Dadape, V., Gadge, T., & Gavali, A. (2023). Detecting Sarcasm in Reddit Comments: A Comparative Analysis. *2023 4th International Conference for Emerging Technology (INCET),* 1–6. IEEE. https://doi.org/10.1109/INCET57972.2023.10170613

Svetlov, K., & Platonov, K. (2019). Sentiment analysis of posts and comments in the accounts of Russian politicians on the social network. *2019 25th Conference of Open Innovations Association (FRUCT),* 299–305. IEEE. https://doi.org/10.1109/INCET57972.2023.10170613

Sulaiman, A., Feizollah, A., Mostafa, M. M., & Zakaria, Z. (2023). Profiling the halal food consumer on Instagram: integrating image, textual, and social tagging data. *Multimedia Tools and Applications, 82*(7), 10867–10886. https://doi.org/10.1007/s11042-022-13685-3

Wu, L., Morstatter, F., & Liu, H. (2018). SlangSD: building, expanding and using a sentiment dictionary of slang words for short-text sentiment classification. *Language Resources and Evaluation, 52*, 839–852. https://doi.org/10.1007/s10579-018-9416-0

Xiang, Z., Du, Q., Ma, Y., & Fan, W. (2017). A comparative analysis of major online review platforms: Implications for social media analytics in hospitality and tourism. *Tourism Management, 58*, 51–65. https://doi.org/10.1016/j.tourman.2016.10.001

Yarushkina, N. G., Moshkin, V. S., & Konstantinov, A. A. (2020). Word2Vec and BERT language models used for a sentiment analysis of text posts in social network. *Automation of Control Processes*. *61*(3), 60–69. [In Russian]. https://doi.org/10.35752/1991-2927-2020-3-61-60-69

Zhan, M., Tu, R., & Yu, Q. (2018). Understanding readers: Conducting sentiment analysis of Instagram captions. *Proceedings of the 2018 2nd International Conference on Computer Science and Artificial Intelligence*, 33–40. https://doi.org/10.1145/3297156.3297270

Zaheri, S., Leath, J., & Stroud, D. (2020). Toxic comment classification. *SMU Data Science Review, 3*(1), 13. Available at https://scholar.smu.edu/datasciencereview/vol3/iss1/13

Impact of Recommendation Systems on AI-enabled Customer Experience

Mediator Role of Perceived Usefulness and Perceived Trust

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Abstract: Artificial intelligence (AI) is revolutionising the way customers interact with brands. AI-based customer experiences lack empirical research. This study aims to analyse how and to what extent integrating AI through recommendation systems in online purchases can lead to better AI-based customer experiences. We propose a theoretical model based on the theory of trust and commitment and the technology acceptance model. We conducted an online survey with customers who have experience with AI-powered online recommendation ads. We analysed 220 responses using PLS-SEM. The results of this research show that perceived trust in recommendation systems and customisation of recommendation systems have a positive impact on AI-based customer experience. Additionally, this study indicates that customisation of recommendation systems and controllability of recommendation systems have a positive impact on perceived usefulness and also have a positive impact on perceived trust. By examining the concept of controllability in AI-driven recommendation systems, an underexplored factor in the literature, this research offers a new perspective on AI-based customer experience. Finally, this research highlights the mediating role of perceived trust in the relationship between controllability and AI-based customer experience, and in the relationship between customisation and AI-based customer experience.

Keywords: Artificial Intelligence (AI), Recommendation Systems, AI-enabled Customer Experience, Perceived Usefulness, Controllability

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Introduction

In recent years, the diffusion of AI technologies in our daily lives has gained considerable momentum, influencing the way individuals consume media, and purchase and interact online (Gursoy *et al.*, 2019; Rai, 2020). Faced with a wealth of information and product diversity, consumers face challenges in finding optimal alternatives (Ewerhard *et al.*, 2019). The AI-powered service offered by a brand simplifies this process by reducing search efforts and improving the shopping experience (Gao & Liu, 2023). It thus allows consumers to benefit from increased personalisation in an environment where the abundance of information can complicate decision-making.

In this context, AI becomes a key tool for improving marketing strategies and personalising business-customer relationships. In fact, in 2023, 78% of companies reported using AI to improve customer experience (Iacoviello & Downie, 2024). As a result, creating a strong customer experience has become a critical factor and the highest priority cited by executives in the Accenture-Forrester study (2015) to gain a competitive advantage in marketing management. Although existing literature explores various aspects of AI applications in customer interactions, such as AI chatbots in tourism (Rafiq *et al.*, 2022), AI-driven innovation in the Tunisian hotel industry (Zarrad, 2024), initial trust in AI chatbots for telecommunication services (Sboui *et al.*, 2024), AI service quality in restaurants (Shah *et al.*, 2023) and AI voice assistants in hotels (Cai *et al.*, 2022), there is a lack of comprehensive empirical studies on customer perceptions and attitudes toward AI technologies to improve customer experience. AI enables a company to present product recommendations based on the analysis of consumer behaviour data, such as search and purchase history, and preferences, (Yi & Liu, 2020). Therefore, recommendation systems represent a prime example of how AI is being used to improve customer experience, as 80% of customers are more likely to make a purchase from a brand that provides them with personalised recommendations (Forrester Consulting, 2023). A recommendation system is a technology that proactively suggests items of interest to consumers based on their objective behaviour or explicitly stated preferences (Pu *et al.*, 2012). The ease of finding interesting and valuable information among the plethora of online information has prompted consumers to benefit from online recommendation systems (Pu *et al.*, 2012).

In this vein, our study focuses on online recommendation systems as an application of AI, exploring their role in the evolution of customer experience in the AI era (Deldjoo *et al.*, 2024). These online recommendation systems have attracted the attention of businesses where 91 per cent (KITRUM, 2023) of e-commerce companies are using them to personalise customer experience. In addition, Amazon's 2023 Annual Report shows a 12% revenue growth, reaching $575 billion, highlighting the effectiveness of personalised marketing, including recommendation systems, in driving sales. These recommendation systems are also attracting the attention of researchers. Ping *et al.* (2024) highlights that recommendation systems are distinguished by their diversity, novelty and accuracy. Other research focuses on the influence of these intelligent systems on customers' online purchasing behaviour (Champiri *et al.*, 2019).

Despite the growing importance of these systems, there is a gap in the literature regarding the impact of recommendation systems on AI-based customer experience. Ameen *et al.* (2021) examine how personalisation and trust contribute to AI-driven customer experience. However, their study does not address the role of user influence over AI-generated recommendations. Our study extends this work by introducing controllability, defined as the perceived ability of users to shape recommendations (Ge *et al.*, 2024), which remains underexplored despite its potential impact on trust, engagement and the system. Although research (Champiri *et al.*, 2019; Shah *et al.*, 2023; Yi & Liu, 2020) has focused on the development and improvement of algorithms, few have examined how users perceive these systems, which is essential for understanding and optimising customer experience (Ameen *et al.*, 2021; Silva-Aravena *et al.*, 2024). Gera & Kumar (2023) further highlight this gap, noting that most research remains either conceptual or experimental, with a lack of real-world empirical insights into customer attitudes toward AI. This underscores the need for empirical studies that capture how customers engage with and perceive AI technologies; a crucial step toward improving their overall experience.

To address this gap, this study attempts to conceptualise and empirically evaluate the impact of controllability, personalisation, perceived usefulness, and perceived trust of recommendation systems on AI-based customer experience, as well as the mediating role of perceived usefulness and perceived trust, thereby attempting to answer the following research question: 'To what extent can AI integration through recommendation systems improve AI-based customer experience?'

The first part of this study will propose a concise theoretical framework on the role of recommendation systems in personalising customer experience through AI, with a focus on the factors that may influence customer perception. It will also present the research hypotheses and the proposed conceptual model. The second part will describe the quantitative methodology adopted. The third part will present the data analysis and results, followed by an in-depth discussion. Finally, the last part will propose the implications of this study, address its limitations, and provide recommendations for future research.

Literature Review

This section presents a concise theoretical framework on the role of recommender systems in AI-enabled customer experience personalisation and the factors that may influence customer perception, followed by exposing the hypotheses and research model.

Recommendation systems: Personalising the customer experience through AI

The term 'recommendation system' was first introduced in 1997 by Resnick & Varian as a tool for decision-making and information retrieval (Champiri *et al.*, 2019). 'Recommender system is defined as a software product that recommends the most convenient piece, location or product that matches the user's preference' (Yassin *et al.*, 2022). These systems enable companies to offer products that meet specific consumer expectations by leveraging machine learning and behavioural data analysis (Mocean & Pop, 2012). With the use of AI, recommendation systems can adjust suggestions in real time, refining their ability to offer relevant and personalised recommendations, thereby increasing customer engagement, (Bhuiyan, 2024). Gharahighehi *et al.* (2021) highlight that recommendation systems utilise users' historical interactions to improve and personalise suggestions, enabling companies to predict customer needs accurately and personalise interactions on a granular level (Vashishth *et al.*, 2025). Today, they are central to the marketing strategies of large companies, allowing them to expand their businesses while enriching customer experience (Yi & Liu, 2020). Notable examples include Netflix, which personalises movie and series suggestions, and Amazon, which recommends products based on customers' interests. Recommendation systems also help reduce information overload and improve the relationship between the brand and the consumer, contributing to an improved customer experience (Schrotenboer, 2019). The integration of these systems, powered by AI technologies, not only optimises customer engagement but also personalised interactions on an unprecedented scale (Sicular & Vashisth, 2020).

The factors of customer perception and AI-based customer experience: The case of recommendation systems

In terms of literature, we identified the factors influencing customer perception and customer experience in the context of AI, particularly for recommender systems: personalisation, controllability, perceived usefulness and perceived trust. Initially linked to services, personalisation has evolved with the integration of technology, allowing companies to analyse customer data to offer recommendations tailored to individual preferences (Gogua &

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Smirnova, 2020; Wedel *et al.*, 2009). This integration has enabled recommender systems, powered by algorithms and AI, to provide personalised offers that meet consumers' specific needs and enhance their experience (Shen & Ball, 2009; Vashishth *et al.*, 2025). Controllability refers to 'the user's ability to change the system's behavior by adjusting aspects of the ranking model or recommendations' (Ge *et al.*, 2024). This ability to influence recommendations plays a key role in customer satisfaction (Sciascio *et al.*, 2019). It allows users to personalise their preferences by adjusting their profile and controlling the sequence of recommended activities, thus creating a more interactive and satisfying experience (Nilashi *et al.*, 2016; Tsai & Brusilovsky, 2020). Derived from Davis's (1989) technology acceptance model, perceived usefulness refers to the extent to which a recommendation system helps users in their tasks and decision-making. This usefulness motivates users to interact with online systems, especially in shopping environments, while encouraging them to share their data to receive more relevant recommendations (Acharya *et al.*, 2022; Kumar & Benbasat, 2006). Finally, trust is based on the perceived reliability of recommendations and the security of personal data (Chiou & Droge, 2006). This trust is crucial for user engagement in these AI-based recommendation systems (Harman *et al.*, 2014; Shin, 2021). Transparency and accuracy of recommendations are essential to building this trust, as users must be confident that the system can securely handle their personal information and provide recommendations that accurately reflect their preferences and interests (Liu & Wang, 2024). Thus, these factors directly influence the customer experience, particularly by creating memorable and engaging interactions with AI technologies (Foroudi *et al.*, 2018). In addition, by leveraging customer preferences and expectations, these technologies enrich the customer journey at every touchpoint, while strengthening their satisfaction and loyalty to the brand (El Gharbaoui *et al.*, 2024; Verhoef *et al.*, 2009).

Theoretical model integration: TAM and the Trust–Commitment Theory complementarity

Building on the Technology Acceptance Model (TAM) (Davis, 1989) and the Trust–Commitment Theory (Morgan & Hunt, 1994), this study examines the complexities of AI-enabled customer experience. TAM emphasises the impact of perceived usefulness and ease of use on technology adoption (Kanungo *et al.*, 2024). For example, for recommendation systems, personalisation and controllability can lead to perceived usefulness through relevance and tailoring of the information. At the same time, the trust in this system is shaped by the Trust-Commitment Theory, which explains how trust leads customers to develop a stronger commitment to the brand (Morgan & Hunt, 1994). More specifically, users are likely to use the platform more and become familiar with its brand when they find

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recommendations useful and reliable (Gefen *et al.*, 2003). For instance, Zhang & Luximon (2021) find that patient trust in healthcare technologies, such as mHealth apps, was significantly influenced by the perceived usefulness of the system, which is consistent with TAM. Similarly, Deng *et al.* (2018) show that users' behavioural intention toward mobile health services was shaped by the interaction between trust and perceived usefulness, underscoring the importance of trust as a cornerstone of commitment in technological systems. Integration of these two theoretical perspectives sheds light on the contextual and relational dimensions of AI-based customer experience, why and how it is shaped by not only technological (that is, usefulness, controllability, personalisation) but also relational factors (basically, trust).

Hypotheses' formulation and research model

Perceived usefulness of recommendation systems plays a critical role in customer experience, especially in AI-based technologies. Some studies have shown that perceived usefulness has a direct impact on customer retention, recommendation adoption and purchase decisions (Komiak & Benbasat, 2006). Davis (1989) proves that perceived usefulness is a key factor that impacts not only user satisfaction but also their willingness to continue using a product or service (Amin *et al.*, 2014; Londa *et al.*, 2022). Furthermore, Moriuchi (2019) show that perceived usefulness enhances user engagement with AI technologies. Empirical studies confirm that this usefulness significantly influences online purchasing decisions (Suhir *et al.*, 2014; Sheng & Zolfagharian, 2014) and the adoption of recommendation systems (Kowatsch & Maass, 2010). Furthermore Zamri & Idris (2013) show that perceived usefulness improves the online customer experience and positively influences purchasing behaviours. Thus, the perceived usefulness of AI-based recommendation systems is essential for optimising customer experience and purchasing decisions. Based on this, the following hypothesis (H) will be tested:

> H1: Perceived usefulness of recommendation systems has a positive impact on AI-based customer experience.

Bleier *et al.* (2019) assert that customer experience theory identifies brand trust as a key dimension of the overall customer experience, with higher levels of trust leading to enhanced experiences. The study by Ameen *et al.* (2021) highlights the crucial role of trust in AI-based customer experiences, demonstrating that when customers trust the brand, the technology and the process, their experiences are more positive. Lemon & Verhoef (2016) further note that trust reduces the cognitive effort required by customers, thereby amplifying the impact of the experience. Based on this, H2 is formulated as follows:

H2: Perceived trust of recommendation systems has a positive impact on AI-based customer experience.

Some studies, such as Ameen *et al.* (2021), explored the relationship between personalisation and AI-based customer experience, showing that these two concepts are interdependent. Lambillotte *et al.* (2022) set out to measure the effect of personalisation (real or perceived) on customer experience, while Rane *et al.* (2024) highlight that personalisation is essential for improving customer satisfaction and strengthening customer relationships. Gogua & Smirnova (2020) add that personalisation allows for the evaluation of the success of customer experience strategies through the analysis of customer behaviours. Pappas *et al.* (2017) confirm that personalisation, through the analysis of consumer data, enhances the overall experience. However, the scientific literature is currently fragmented, primarily focusing on specific aspects of personalisation or customer experience (Gogua & Smirnova, 2020). Indeed, personalisation is closely related to customer experience because it can help select particular tools and mechanisms based on predictive analysis. Thus, recommendation systems are the most frequent and important example of personalisation enabled by AI (Zanker *et al.*, 2019). Hence, we propose H3:

H3: The personalisation of recommendation systems has a positive impact on customer experience based on AI.

According to a study by Zhang *et al.* (2014), personalisation in the health field, particularly through 'mHealth' health services, increases users' perception of usefulness in their health status. Similarly, Liang *et al.* (2012) reveal that personalisation services on e-commerce sites enhance perceived usefulness compared to non-personalised services, as customers judge these systems to be more relevant to their preferences. This idea is also supported by research from Alsharari *et al.* (2020), which demonstrates that personalisation positively impacts perceived usefulness. Users consider recommendations tailored to their needs to be more useful, leading to greater satisfaction (Kim *et al.*, 2019).

On the other hand, personalisation is essential for building trust in recommendation systems. Nunes & Kambil (2001) explain that personalisation relies on data collection to offer tailored services. Searby (2003) adds that this approach enhances customer trust by personalising product recommendations, they then become more relevant and facilitate the decision-making process, leading to increased trust and customer satisfaction. Ameen *et al.* (2021) argue that AI-based service personalisation builds brand trust. Research shows that personalised experiences increase customer trust in the brand (Sheridan, 2017). Thus, we propose the following hypotheses:

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H4.1: personalisation of recommendation systems has a positive impact on perceived usefulness.

H4.2: personalisation of recommendation systems has a positive impact on perceived trust.

Research by Kim *et al.* (2008) and Sieger *et al.* (2022) show that when users have control over AI systems, they perceive these systems as more useful and relevant. Smits *et al.* (2023) also find that users with greater control rate AI systems as being more useful than those with less control. Bakalov *et al.* (2013) add that controllability significantly influences users' perceived usefulness and satisfaction with personalised systems, while Abdullah *et al.* (2016) identifies control as an antecedent of perceived usefulness.

Furthermore, environmental psychology highlights that the feeling of control motivates individuals to adopt more positive and trusting behaviours (Ittelson, *et al.*, 1974). Corritore *et al.* (2005) suggest that those who perceive greater control in the purchasing process develop greater trust in a digital environment. Lee and Lin (2005) confirms that user control positively affects trust. In the context of recommendation systems, controllability increases users' trust in recommendations. Bostandjiev *et al.* (2012) and Bourke *et al.* (2011) reveal that users appreciate the opportunity to participate and control the recommendation process, which increases their satisfaction and trust. Therefore, we formulate the following hypotheses:

H5.1: Controllability of recommendation systems has a positive impact on perceived usefulness.

H5.2: Controllability of recommendation systems has a positive impact on perceived trust.

Knijnenburg *et al.* (2020) and Mican *et al.* (2024) highlight the importance of perceived usefulness in the relationship between the controllability of recommendation systems and AI-based customer experience. These studies demonstrate that controllability positively affects customer experience, with perceived usefulness acting as a mediator, which strengthens this relationship. Furthermore, Liu *et al.* (2021) explore the mediating role of perceived usefulness in the effectiveness of personalisation systems, while Wang *et al.* (2021) shows that AI-based personalisation enhances customer experience through perceived usefulness. Accordingly, we hypothesise:

H6.1 Perceived usefulness has a mediating effect in the relationship between controllability and AI-based customer experience.

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H6.2 Perceived usefulness has a mediating effect in the relationship between personalisation and AI-based customer experience.

Previous studies have examined the relationship between trust and customer experience, considering trust either as a mediator (Martin *et al.*, 2015) or as a direct factor influencing customer experience (Ling *et al.*, 2010). The mediating role of perceived trust between controllability and AI-based customer experience has gained increasing interest in recent years. Lutz *et al.* (2023) examine how individuals' sense of control over AI systems influences their trust in these systems, thereby impacting their overall customer experience. Furthermore, Kaduškeviit & Božena (2022) highlight the mediating role of trust in the context of online shopping and AI-based recommendation systems, while Bawack *et al.* (2021) investigate the role of trust in the relationship between personalisation and customer experience. Zhang & Benyoucef (2016) find that when users perceive personalised recommendations as trustworthy, their satisfaction and purchase intention increase. Therefore, we hypothesise:

H7.1 Perceived trust mediates the relationship between controllability and AI-based customer experience.

H7.2 Perceived trust mediates the relationship between personalisation and AI-based customer experience.

In light of the literature review presented above, we constructed a conceptual framework, illustrating the dependent and independent variables in Figure 1 below:

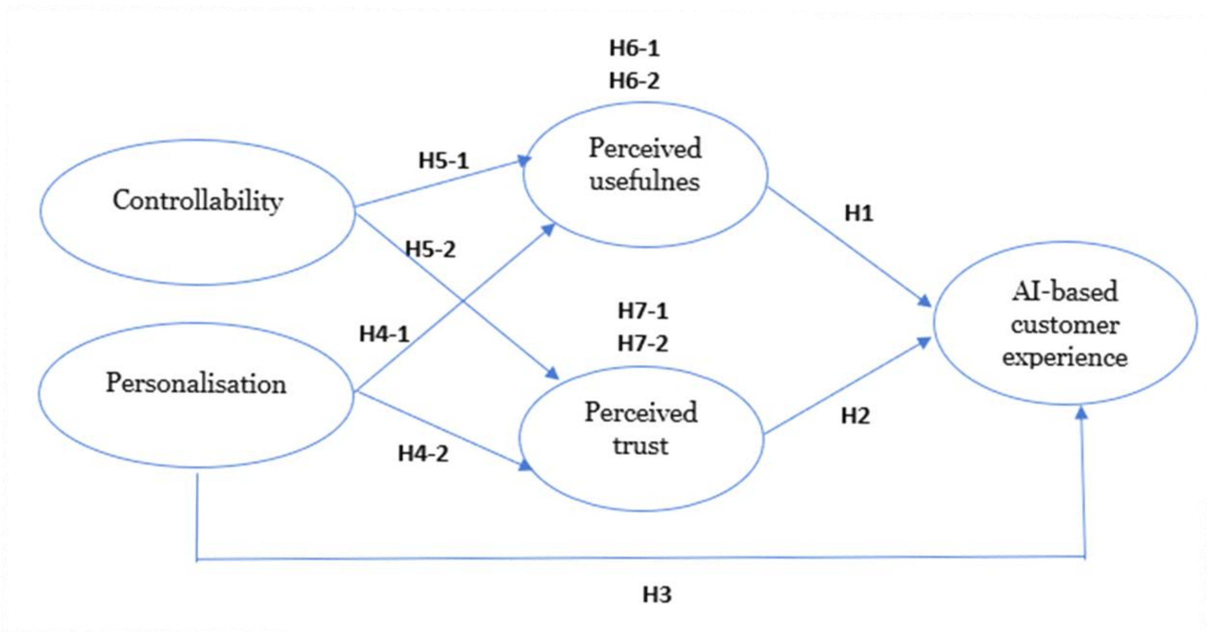

Figure 1. Conceptual model

Methodology

Measurement scales

The items used for measuring all constructs, found in Appendix 1, were taken from existing literature: Perceived usefulness (Acharya *et al.*, 2022), controllability (Jin *et al.*, 2021), personalisation (Yoon & Lee, 2021), perceived trust (Choung *et al.*, 2023) and customer experience (Sheng & Zolfagharian, 2014).

Sample population, data collection and statistical methods

This research involved a survey of 220 randomly selected participants from Tunisia, following the 10-fold rule, which states that: '*The sample size should be equal to the greater of 10 times the largest number of formative indicators used to measure a concept or 10 times the largest number of structural trajectories directed toward a particular latent concept in the structural model*' (Hair *et al.*, 2017, page 24). Tunisia was chosen as the study's context due to its growing adoption of AI technologies, thereby providing a relevant backdrop for examining consumer attitudes towards AI-driven recommendation systems.

A questionnaire was used for primary data collection, designed to assess a research model through a multidimensional Likert-type scale. The survey was distributed using Google Forms, with data collected from 1 January to 28 February 2024. The 5-point Likert scale was selected for its ease of use and reliability in capturing varying levels of agreement or disagreement, making it particularly effective for measuring complex constructs.

Statistical analyses were performed using the Statistical Package for the Social Sciences version 25 (SPSS25) and Partial Least Squares Structural Equation Modeling (PLS-SEM). The PLS-SEM approach was chosen for its ability to handle complex models, small sample sizes, and non-normally distributed data, making it ideal for estimating relationships among variables and assessing predictive power.

Frequency and descriptive analysis

A frequency analysis of the digitized responses from 220 participants was conducted. The demographic information revealed that 61.4% of the total participants were women. The age distribution was as follows : 63.6% were aged 18–24, 31.4% were aged 25–44, and 5% were aged over 45. In terms of occupation, 45.9% were students, 39.1% were professionals, and 15% were looking for a job.

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We provided respondents with this type of announcement, as shown in Appendix 2 Appendix 2, and we asked the question: ‘Have you ever come across this kind of ad?’ In response, 71.2% of the surveyed population said that they had already encountered this type of advertisement, while 28.8% said that they had never come across this type of advertisement.

Reliability and validity of measurements

Appendix 3 presents an overview of the five main variables of the theoretical background and research model: Cronbach’s alpha value ranges from 0.908 to 0.945 for different variables, which are well above the commonly accepted threshold of 0.7 (Hair, 2010), indicating a strong internal consistency of the items of each construct. Typically, for a scale to be considered reliable, the correlation between items should be between 2 and 0.8 (Hair, 2010). The range of correlations between items meets this criterion, indicating good reliability.

Convergent validity was also assessed through the average variance extracted (AVE): all values exceeded the acceptable threshold of 0.5 (Cohen, 1988), meaning that a significant proportion of the item variance is captured by the factor (see Appendix 2).

Confirmatory factor analysis (CFA)

CFA was used to confirm the underlying structure of the AI-enabled customer experience success factors: ‘perceived usefulness’, ‘perceived trust’, ‘control ability’ and ‘personalisation’. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy KMO values for all factors exceeded the acceptable threshold of 0.6 (Brown, 2006) (see Appendix 3), indicating that the data is suitable for factor analysis. Bartlett’s test of sphericity is significant (Sig. = 0.000), indicating that the variables are equally correlated and suitable for factor analysis (Brown, 2006). The Jöreskog’s rho and composite reliability values are both above the recommended threshold of 0.7, indicating strong reliability Urbach & Ahlemann, 2010) (see Appendix 3).

These results indicate a strong representation of the data structure of critical success factors across the extracted components (Hair *et al.*, 2010): perceived usefulness, perceived trust, controllability and personalisation. Furthermore, all items loaded correctly on their relevant factors. The correlation matrix of the factor analysis shows high correlations between items within the same construct and lower correlations between items from different constructs, further supporting the validity of the constructs.

Discriminant validity represents the set of variables that have a square root of the AVE greater than all correlation coefficients with other variables. According to Hair *et al.* (2019), discriminant validity is the extent to which a construct is empirically distinct from all other constructs in the structural model. Henseler *et al.* (2015) show that HTMT ratios (heterotrait–

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monotrait ratios) are indeed the best indicators of discriminant validity at present. Thus, discriminant validity is confirmed (see Appendix 4).

Structural analysis

This study evaluates the measurement model's reliability and validity through Measurement Model Evaluation, analysing indicator reliability, internal consistency, convergent validity and discriminant validity to ensure construct robustness. Structural Model Estimation then examines relationship significance, predictive power (Q^2), and explanatory power (R^2) to assess the model's ability to explain variance in the dependent variables. Detailed results are provided in Appendices 5 and 6.

Findings and Discussion

The results of the bootstrapping analysis are presented in Table 1. This table includes the calculations for both the total original effects and the total mean effects across all constructs. Additionally, it provides the corresponding values for standard deviation, t-statistics and p-values.

H1 was supported as our results suggest that perceived usefulness does not have a direct impact on AI-driven customer experience (p = 0.470, t = 0.723), aligning with the findings of Teng *et al.* (2024). According to their research, the perceived usefulness of AI is contingent upon the characteristics of the customer and the specific technology involved. Consequently, these factors may not create a definitive link between perceived usefulness and AI-enabled customer experience.

Table 1. Results of the total effects

Hypothesis	Original sample (O)	Sample mean (M)	Standard deviation (ST.DEV)	T-statistics	P-values	Decision
H1: PU-EXP	0.061	0.060	0.085	0.723	0.470	Not Supported
H2: PT-EXP	0.242	0.244	0.082	2.950	0.003	Supported
H3: Perso-EXP	0.572	0.573	0.091	6.312	0.000	Supported
H41: Perso-UP	0.664	0.662	0.048	13.790	0.000	Supported
H42: Perso-PT	0.533	0.533	0.059	8.982	0.000	Supported
H51: CT-PU	0.261	0.263	0.052	5.070	0.000	Supported
H52: CT-PT	0.380	0.381	0.062	6.175	0.000	Supported

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Table 2: Mediation analysis

	Original sample (O)	Sample mean (M)	Standard deviation (ST.DEV)	T-statistics	P-value	Decision
H61: CT-PT-EXP	0.092	0.092	0.034	2.714	0.007	Supported
H62: Perso-PU-EXP	0.041	0.039	0.057	0.720	0.472	Not supported
H71: CT-PU-EXP	0.016	0.015	0.023	0.709	0.479	Not supported
H72: Perso-PT-EXP	0.129	0.130	0.047	2.763	0.006	Supported

H2 received empirical support, indicating that perceived trust plays a crucial role in the customer experience facilitated by AI ($p = 0.003$, $t = 2.950$). This result aligns with the findings of Bach *et al.* (2024), which emphasises the significance of trust in the context of AI technologies.

In addition, the validation of H3 reveals that personalisation has a favourable effect on the AI-enabled customer experience ($p < .000$, $t = 6.312$). Various studies have indicated that personalised recommendations significantly enhance customer experience, suggesting that a higher degree of personalisation in these recommendations would lead to an improved overall experience for customers (Lv *et al.*, 2024). This observation aligns with findings from prior research, such as those by Frimousse & Peretti (2019) and Gogua & Smirnova (2020), which assert that AI-based personalisation provides a contemporary customer experience and contributes positively to the overall customer experience.

The results for both hypotheses concerning H4 were affirmed: H4.1 demonstrates that personalisation positively influences perceived usefulness ($p < .000$, $t = 13.790$), while H4.2 reveals that personalisation significantly affects perceived trust ($p < .000$, $t = 8.982$). These outcomes reinforce the concept that personalisation enhances the perceived usefulness of recommendation systems, rendering them more pertinent and beneficial for users. According to Adawiyah *et al.* (2024), personalised product recommendations were associated with increased perceived usefulness among online shoppers relative to non-personalised recommendations.

Both H5.1 and H5.2 were confirmed through the analysis. H5.1 reveals a significant relationship between controllability and perceived usefulness, evidenced by ($p < .000$, $t = 5.070$). This finding is supported by Lee & Kozar (2012), who find that the level of user control over technology significantly impacts satisfaction and perceived usefulness. With H5.2, the controllability of recommendation systems is associated with an increase in perceived trust ($p < .000$, $t=6.175$). Tintarev & Masthoff (2007) suggest that improving transparency and allowing users to exercise control can significantly strengthen their trust in recommendation systems.

Additionally, neither H6.1 nor H6.2 received validation. The findings related to H6.1 reveal that the indirect relationship between personalisation and customer experience, mediated by perceived usefulness, is not statistically significant ($p = 0.472$, $t = 0.720$). Verhoef (2020) posits that perceived usefulness acts as a mediating factor in the relationship between personalisation and customer experience. Nevertheless, findings from Liu et al., (2020) suggest that this mediation may not consistently apply.

Similarly, H6.2 perceived usefulness does not mediate the connection between controllability and customer experience ($p = 0.479$ $t= 0.709$). Perceived usefulness is an essential determinant in many technology adoption scenarios (Widiar *et al.*, 2023). However, it is important to note that other factors, such as trust, satisfaction and ease of use, may have a more significant mediating effect than perceived usefulness (Syaharani & Yasa, 2022).

Our empirical findings support this notion, demonstrating that perceived usefulness does not serve as a mediator in this context, and its direct effect on AI-based customer experience has not been validated.

The findings support H7.1 and indicate that controllability has a positive impact on customer experience, both directly and indirectly through the mediation of perceived trust, demonstrating a partial mediation effect ($p = 0.007$, $t = 2.714$). Previous researchers have also examined the link between perceived trust and customer experience, either by considering trust as a mediating factor (for example, Martin *et al.*, 2015) or as a direct contributor to customer experience (Ling *et al.*, 2010).

Additionally, H7.2 reveals that perceived trust serves as a partial mediator in the relationship between personalisation and customer experience, evidenced by a significant indirect effect ($p = 0.006$, $t = 2.763$). The result indicates that perceived trust functions as a partial mediator between personalisation and customer experience ($p = 0.006$, $t = 2.763$) and corroborates the findings of Campos *et al.* (2020), Zhang & Benyoucef (2016) and Madhuri *et al.* (2024). These studies collectively underscore the significance of trust in optimising the impact of personalised recommendations. Trust is a fundamental element that influences consumer engagement and positive reactions to personalised experiences. Therefore, businesses should prioritise not only the accuracy of their personalisation efforts but also the establishment of

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consumer trust through transparency and security measures, which can enhance customer satisfaction and foster loyalty.

Theoretical and managerial implications

This study contributes to the scholarly discourse on human-AI interaction by elucidating consumer acceptance of AI-based recommendation services designed to enhance customer experience. In contrast to earlier research that primarily examined the viewpoints of system developers or retailers (Gursoy *et al.*, 2019), our analysis focuses on the customer perspective, underscoring critical elements such as trust, perceived usefulness, personalisation and controllability. We also propose a theoretical framework that integrates these mediating factors and underscores the frequently neglected significance of controllability in fostering trust and enhancing the customer experience with AI technologies.

Understanding customer perceptions is vital for managers who are integrating AI into services, especially within recommendation systems. Our study emphasises the critical roles of trust, personalisation and controllability for e-commerce and marketing executives. Trust is particularly important in the context of AI-based services due to their inherent complexity. To mitigate this issue, companies should partner with AI designers to achieve a balance between automated processes and human engagement. By focusing on the development of personalised and controllable AI systems, along with the support of trained customer service personnel, organisations can enhance customer trust and engagement, leading to a superior overall experience. Furthermore, by prioritising user-centric AI designs that emphasise transparency and control, companies can increase consumer adoption and satisfaction. We recommend that firms implement interactive interfaces that allow customers to adjust AI recommendations based on their preferences, thereby fostering a sense of control and trust. Additionally, integrating hybrid models where AI-generated suggestions are complemented by human oversight, can enhance credibility and personalisation.

Our study also highlights the need for regulatory frameworks to ensure ethical AI-driven customer experiences. Policymakers should establish guidelines that promote transparency in AI decision-making, mandate explainability in recommendation algorithms, and protect consumer data privacy. For example, encouraging standardised AI ethics certifications could further enhance trust and accountability in AI-driven services.

Conclusion: Limitations and Future Research Directions

This study contributes to the theoretical understanding of how AI-based recommendation systems influence customer experience, highlighting their role in enhancing personalisation,

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trust and engagement. By integrating these systems into their strategies, businesses can improve customer satisfaction, optimize interactions, and gain a competitive advantage in the marketplace. A survey of 220 participants was conducted to collect data and assess a conceptual model using SPS-S25 and SmartPLS4. The results indicate that trust perception and the degree of personalisation in recommendation systems positively influence the customer experience facilitated by AI. Furthermore, the research illustrates that both the personalisation of these systems and their controllability enhance perceptions of usefulness and trust. It emphasises the significant mediating role of perceived trust in the relationships between controllability and AI-enabled customer experience, as well as between personalisation and AI-enabled customer experience. However, the findings reveal that perceived usefulness does not positively impact AI-based customer experience and does not act as a mediator in the relationships involving controllability or personalisation.

The findings of this research reveal significant limitations in the largely unexplored area of AI-enhanced customer experience and consumer perceptions, suggesting that future studies should concentrate on specific contexts and industries. Furthermore, the reliability of the results could have been affected by the use of measurement scales that are not appropriately suited for this particular context. In addition, the lack of statistical validation for perceived usefulness as a mediator in the relationships between controllability and customer experience, as well as personalisation and customer experience, underscore the pressing need to examine other potential mediating variables in future studies.

Furthermore, this investigation addresses the ethical implications of AI recommendation systems. It emphasises the necessity of implementing data protection measures that strike a balance between privacy, accuracy, fairness and algorithm interpretability. In practice, AI-based recommendation systems can enhance personalisation, trust and customer engagement, ultimately improving service quality and strengthening competitive positioning. Future research could examine how businesses can effectively combine AI-driven insights with human expertise to optimise customer interactions across various industries.

However, there are several methodological limitations to consider. The use of Google Forms for data collection may have introduced selection bias, as the sample was limited to digitally active individuals. Additionally, the sample size was determined using a general rule rather than a statistical power analysis. Future research should adopt more rigorous sampling techniques and explore mixed-mode data collection methods to increase sample diversity. Expanding the study to cover various AI applications, industries and cultural differences in AI trust and engagement would offer further insights into consumer-AI interactions.

https://doi.org/10.18080/jtde.v13n1.1137

References

Abdullah, F., Ward, R., & Ahmed, E. (2016). Investigating the influence of the most commonly used external variables of TAM on students' Perceived Ease of Use (PEOU) and Perceived Usefulness (PU) of e-portfolios. *Computers in Human Behavior, 63*, 75–90. https://doi.org/10.1016/j.chb.2016.05.014

Acharya, N., Sassenberg, A. M., & Soar, J. (2022). Consumers' behavioural intentions to reuse recommender systems: Assessing the effects of trust propensity, trusting beliefs and perceived usefulness. *Journal of Theoretical and Applied Electronic Commerce Research*, *18*(1), 55–78. https://doi.org/10.3390/jtaer18010004

Adawiyah, S. R., Purwandari, B., Eitiveni, I., & Purwaningsih, E. H. (2024). The influence of AI and AR technology in personalised recommendations on customer usage intention: a case study of cosmetic products on shopee. *Applied Sciences*, *14*(13), 5786 https://doi.org/10.3390/app14135786

Akram, S., & Kortam, W. (2020). The impact of customer experience in online brand communities on customer engagement and purchase intentions among Arab internet users: theoretical analysis, conceptual framework and research agenda. *Business and Management Studies*, *6*(3), 26–54. https://doi.org/10.11114/bms.v6i3.5021

Alsharari, N. M., Al-Shboul, M., & Alteneiji, S. (2020). Implementation of cloud ERP in the SME: evidence from UAE. *Journal of Small Business and Enterprise Development*, *27*(2), 299–327. https://doi.org/10.1108/JSBED-01-2019-0007

Amazon (2023). Annual Report. https://www.annualreports.com/HostedData/AnnualReports/PDF/NASDAQ_AMZN_2023.pdf

Ameen, N., Tarhini, A., Reppel, A., & Anand, A. (2021). Customer experiences in the age of artificial intelligence. *Computers in Human Behavior*, *114*, 106548. https://doi.org/10.1016/j.chb.2020.106548

Amin, M., Rezaei, S., & Abolghasemi, M. (2014). User satisfaction with mobile websites: the impact of perceived usefulness (PU), perceived ease of use (PEOU) and trust. *Nankai Business Review International*, *5*(3), 258–274. https://doi.org/10.1108/NBRI-01-2014-0005

Bach, T. A., Khan, A., Hallock, H., Beltrão, G., & Sousa, S. (2024). A systematic literature review of user trust in AI-enabled systems: An HCI perspective. *International Journal of Human–Computer Interaction*, *40*(5), 1251–1266. https://doi.org/10.1080/10447318.2022.2138826

Bakalov, F., Meurs, M. J., König-Ries, B., Sateli, B., Witte, R., Butler, G., & Tsang, A. (2013, March). An Approach to Controlling User Models and Personalization Effects in Recommender Systems. In *Proceedings of the 2013 International Conference on Intelligent User Interfaces* (pp. 49–56). https://doi.org/10.1145/2449396.2449405

Bawack, R. E., Wamba, S. F., & Carillo, K. D. A. (2021). Exploring the role of personality, trust, and privacy in customer experience performance during voice shopping: Evidence from SEM and fuzzy set qualitative comparative analysis. *International Journal of*

Information Management, *58*, 102309. https://doi.org/10.1016/j.ijinfomgt.2021.102309

Bhuiyan, M. S. (2024). The role of AI-enhanced personalization in customer experiences. *Journal of Computer Science and Technology Studies, 6*(1), 162–169. https://doi.org/10.32996/jcsts.2024.6.1.17

Bitkina, O. V., Jeong, H., Lee, B. C., Park, J., Park, J., & Kim, H. K. (2020). Perceived trust in artificial intelligence technologies: A preliminary study. *Human Factors and Ergonomics in Manufacturing & Service Industries, 30*(4), 282–290. https://doi.org/10.1002/hfm.20839

Bleier, A., Harmeling, C. M., & Palmatier, R. W. (2019). Creating effective online customer experiences. *Journal of marketing, 83*(2), 98–119. https://doi.org/10.1177/0022242918809930

Bostandjiev, S., O'Donovan, J., & Höllerer, T. (2012, September). TasteWeights: A visual Interactive Hybrid Recommender System. In *Proceedings of the Sixth ACM Conference on Recommender Systems* (pp. 35–42). https://doi.org/10.1145/2365952.2365964

Bourke, S., McCarthy, K., & Smyth, B. (2011, August). Using Social Ties in Group Recommendation. In *AICS 2011: Proceedings of the 22nd Irish Conference on Artificial Intelligence and Cognitive Science*, 31 August–2 September 2011: University of Ulster-Magee. Intelligent Systems Research Centre. https://hdl.handle.net/10197/3448

Brill, T. M., Munoz, L., & Miller, R. J. (2019). Siri, Alexa, and other digital assistants: a study of customer satisfaction with artificial intelligence applications. *Journal of Marketing Management*, *35*(15–16), 1401–1436. https://doi.org/10.1080/0267257X.2019.1687571

Brown, S. C., & Greene, J. A. (2006). The wisdom development scale: Translating the conceptual to the concrete. *Journal of College Student Development, 47*(1), 1–19. https://doi.org/10.1353/csd.2006.0002

Cai, R., Cain, L. N., & Jeon, H. (2022). Customers' perceptions of hotel AI-enabled voice assistants: does brand matter? *International Journal of Contemporary Hospitality Management, 34*(8), 2807–2831. https://doi.org/10.1108/IJCHM-10-2021-1313

Champiri, Z. D., Mujtaba, G., Salim, S. S., & Chong, C. Y. (2019, January). User Experience and Recommender Systems. In *2019 2nd International Conference on Computing, Mathematics and Engineering Technologies* (iCoMET) (pp. 1–5). IEEE. https://doi.org/10.1109/ICOMET.2019.8673410

Chang, W., & Park, J. (2024). A comparative study on the effect of ChatGPT recommendation and AI recommender systems on the formation of a consideration set. *Journal of Retailing and Consumer Services, 78*, 103743. https://doi.org/10.1016/j.jretconser.2024.103743

Chiou, J. S., & Droge, C. (2006). Service quality, trust, specific asset investment, and expertise: Direct and indirect effects in a satisfaction-loyalty framework. *Journal of the Academy of Marketing Science, 34*(4), 613–627. https://doi.org/10.1177/0092070306286934

Chong, L., Zhang, G., Goucher-Lambert, K., Kotovsky, K., & Cagan, J. (2022). Human confidence in artificial intelligence and in themselves: The evolution and impact of confidence on adoption of AI advice. *Computers in Human Behavior, 127*, 107018. https://doi.org/10.1016/j.chb.2021.107018

Choung, H., David, P., & Ross, A. (2023). Trust in AI and its role in the acceptance of AI technologies. *International Journal of Human–Computer Interaction*, *39*(9), 1727-1739. https://doi.org/10.1080/10447318.2022.2050543

Chua, A. Y., Pal, A., & Banerjee, S. (2023). AI-enabled investment advice: Will users buy it? *Computers in Human Behavior, 138*, 107481. https://doi.org/10.1016/j.chb.2022.107481

Cohen, J. (1988). *Statistical Power Analysis for the Behavioral Sciences* (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum Associates, Publishers. https://www.scirp.org/reference/ReferencesPapers?ReferenceID=2041144

Corritore, C. L., Marble, R. P., Wiedenbeck, S., Kracher, B., & Chandran, A. (2005). Measuring online trust of websites: Credibility, perceived ease of use, and risk. https://www.researchgate.net/publication/220890100_Measuring_Online_Trust_of_Websites_Credibility_Perceived_Ease_of_Use_and_Risk

Daqar, M. A. A., & Smoudy, A. K. (2019). The role of artificial intelligence on enhancing customer experience. *International Review of Management and Marketing, 9*(4), 22. https://doi.org/10.32479/irmm.8166

Davis, F. D. (1989). Perceived usefulness, perceived ease of use and user acceptance of information technology. *MIS Quarterly*, *13*(3). https://doi.org/10.2307/249008

Davis, F. D. (1989). Technology acceptance model: TAM. Al-Suqri, MN, Al-Aufi, AS: *Information Seeking Behavior and Technology Adoption*, *205*(219), 5. https://doi.org/10.4018/978-1-4666-8156-9.ch013

Dayal, U., Hsu, M., & Ladin, R. (2001, September). Business Process Coordination: State of the Art, Trends, and Open Issues. In the International *Conference on Very Large Data Bases*, *1*, 3–13. https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=9cf8b207ae28f55de602452148f21fd412300737

Deldjoo, Y., Jannach, D., Bellogin, A., Difonzo, A., & Zanzonelli, D. (2024). Fairness in recommender systems: research landscape and future directions. *User Modeling and User-Adapted Interaction, 34*(1), 59–108. https://doi.org/10.48550/arXiv.2205.11127

Deng, Z., Hong, Z., Ren, C., Zhang, W., & Xiang, F. (2018). What predicts patients' adoption intention toward mHealth services in China: Empirical study. *JMIR mHealth and uHealth, 6*(8), e9316. https://doi.org/10.2196/mhealth.9316

El Gharbaoui, O., El Boukhari, H., & Salmi, A. (2024). The transformative power of recommender systems in enhancing citizens' satisfaction: Evidence from the Moroccan public sector. *Innovative Marketing, 20*(3), 224–36. https://doi.org/10.21511/im.20(3).2024.18

Ewerhard, A. C., Sisovsky, K., & Johansson, U. (2019). Consumer decision-making of slow moving consumer goods in the age of multi-channels. *The International Review of*

Retail, Distribution and Consumer Research, 29(1), 1–22. https://doi.org/10.1080/09593969.2018.1537191

Ferrario, A., Loi, M., & Viganò, E. (2020). In AI we trust incrementally: A multi-layer model of trust to analyze human-artificial intelligence interactions. *Philosophy & Technology, 33*(3), 523–539. https://doi.org/10.1007/s13347-019-00378-3

Foroudi, P., Gupta, S., Sivarajah, U., & Broderick, A. (2018). Investigating the effects of smart technology on customer dynamics and customer experience. *Computers in Human Behavior, 80*, 271–282. https://doi.org/10.1016/j.chb.2017.11.014

Forrester Consulting. (2015). *Digital Transformation in the Age of the Customer*. https://www.the-digital-insurer.com/wp-content/uploads/2016/02/646-Accenture-Digital-Transformation-In-The-Age-Of-The-Customer

Forrester Consulting. (2023). *Forrester's US 2023 Customer Experience Index: Brands' CX Quality Falls For A Second Consecutive Year*. Forrester Consulting website. https://www.forrester.com/press-newsroom/forrester-us-2023-customer-experience-index/

Frimousse, S., et Peretti, J. M. (2019). '*Expérience collaborateur' et 'Expérience client': comment l'entreprise peut-elle utiliser l'Intelligence Artificielle pour progresser*? *Question (s) de management, 1*, 135–156. https://doi.org/10.3917/qdm.191.0135

Frow, P., & Payne, A. (2007). Towards the 'perfect' customer experience. *Journal of Brand Management, 15*(2), 89–101. https://doi.org/10.1057/palgrave.bm.2550120

Gao, Y., & Liu, H. (2023). Artificial intelligence-enabled personalization in interactive marketing: a customer journey perspective. *Journal of Research in Interactive Marketing, 17*(5), 663–680. https://doi.org/10.1108/JRIM-01-2022-0023

Ge, Y., Liu, S., Fu, Z., Tan, J., Li, Z., Xu, S., & Zhang, Y. (2024). A survey on trustworthy recommender systems. *ACM Transactions on Recommender Systems, 3*(2), 1–68. https://doi.org/10.1145/3652891

Gefen, D. (2003). TAM or just plain habit: A look at experienced online shoppers. *Journal of Organizational and End User Computing*, *15*(3), 1–13. https://doi.org/10.4018/joeuc.2003070101

Gera, R., & Kumar, A. (2023). Artificial Intelligence In Consumer Behaviour: A Systematic Literature Review of Empirical Research Papers Published In Marketing Journals (2000-2021). Academy of Marketing Studies Journal, 27(S1). https://doi.org/10.1108/GKMC-04-2023-0130

Gharahighehi, A., Pliakos, K., & Vens, C. (2021). Recommender systems in the real estate market – a survey. *Applied Sciences, 11*(16), 7502. https://doi.org/10.3390/app11167502

Gogua, M. M., & Smirnova, M. M. (2020). Revisiting personalization through customer experience journey. *Vestnik of Saint Petersburg University. Management* 19 (4): 430–460. http://www.vestnikmanagement.spbu.ru/archive/pdf/858.pdf

Grewal, D., Hulland, J., Kopalle, P. K., & Karahanna, E. (2020). The future of technology and marketing: A multidisciplinary perspective. *Journal of the Academy of Marketing Science, 48*, 1–8. https://doi.org/10.1007/s11747-019-00711-4

Gursoy, D., Chi, O. H., Lu, L., & Nunkoo, R. (2019). Consumers acceptance of artificially intelligent (AI) devices used in service delivery. *International Journal of Information Management, 49*, 157–169. https://doi.org/10.1016/j.ijinfomgt.2019.03.008

Hair Jr, J. F., Babin, B. J., & Krey, N. (2017). Covariance-based structural equation modeling in the *Journal of Advertising*: Review and recommendations. *Journal of Advertising, 46*(1), 163–177. https://doi.org/10.1080/00913367.2017.1281777

Hair Jr, J. F., Hult, G. T. M., Ringle, C. M., Sarstedt, M., Danks, N. P., & Ray, S. (2021). *Partial Least Squares Structural Equation Modeling (PLS-SEM) Using R: A Workbook* (p. 197). Springer Nature. https://doi.org/10.1007/978-3-030-80519-7

Hair, J. F., Black, W. C., Babin, B. J., Anderson, R. E., & Tatham, R. L. (2010). Multivariate data analysis (7. Baskı). *Pearson. Hallahan, TA, Faff, RW, McKenzie, MD (2004). An Empirical Investigation of Personal Financial Risk Tolerance. Financial Services Review-Greenwıch*, *13*(1), 57-78. https://www.scirp.org/reference/referencespapers?referenceid=2989262

Hair, J. F., Risher, J. J., Sarstedt, M., & Ringle, C. M. (2019). When to use and how to report the results of PLS-SEM. *European Business Review, 31*(1), 2–24. https://doi.org/10.1108/EBR-11-2018-0203

Hair, J. F., Sarstedt, M., Ringle, C. M., & Mena, J. A. (2012). An assessment of the use of partial least squares structural equation modeling in marketing research. *Journal of the Academy of Marketing Science, 40*, 414–433. https://doi.org/10.1007/s11747-011-0261-6

Harman, J. L., O'Donovan, J., Abdelzaher, T., & Gonzalez, C. (2014, October). Dynamics of Human Trust in Recommender Systems. In *Proceedings of the 8th ACM Conference on Recommender Systems* (pp. 305–308). https://doi.org/10.1145/2645710.2645761

Henseler, J., Ringle, C. M., & Sarstedt, M. (2015). A new criterion for assessing discriminant validity in variance-based structural equation modeling. *Journal of the Academy of Marketing Science, 43*, 115–135. https://doi.org/10.1007/s11747-014-0403-8

Hoyer, W. D., Kroschke, M., Schmitt, B., Kraume, K., & Shankar, V. (2020). Transforming the customer experience through new technologies. *Journal of Interactive Marketing, 51*(1), 57–71. https://doi.org/10.1016/j.intmar.2020.04.001

Iacoviello, A & Downie, A. (2024). 7 Customer Experience Trends in 2024. IBM. https://www.ibm.com/blog/customer-experience-trends/

Ittelson, W. H., Proshansky, H. M., Rivlin, L. G., & Winkel, G. H. (1974). *An Introduction to Environmental Psychology*. Holt, Rinehart & Winston. https://www.scirp.org /reference/referencespapers?referenceid=1628241

Jannach, D. (2010). *Recommender Systems: An Introduction*. Cambridge University Press. https://doi.org/10.1017/CBO9780511763113

Jiang, Y., Shang, J., & Liu, Y. (2010). Maximizing customer satisfaction through an online recommendation system: A novel associative classification model. *Decision Support Systems, 48*(3), 470–479. https://doi.org/10.1016/j.dss.2009.06.006

Jin, Y., Chen, L., Cai, W., & Pu, P. (2021, November). Key Qualities of Conversational Recommender Systems: From Users' Perspective. In *Proceedings of the 9th International Conference on Human-Agent Interaction* (pp. 93–102). https://doi.org/10.1145/3472307.3484164

Kaduškeviit Vaida, Mackevi?i?t? Božena (2022), When Users Meet AI: Customer Acceptance of Recommendation Systems in Online Shopping. Proceedings of the European Marketing Academy, 50th, (111795). https://proceedings.emac-online.org/pdfs/R2022-111795.pdf

Kailani, C., & Ciobotar, N. (2015). Experiential Marketing: An efficient Tool to Leverage Marketing Communication Impact on Consumer Behaviour. In *International Conference on Marketing and Business Development*, (Vol. 1, No. 1, pp. 281–287). Bucharest University of Economic Studies Publishing House. https://ideas.repec.org/a/aes/icmbdj/v1y2015i1p281-287.html

Kanungo, R. P., Liu, R., & Gupta, S. (2024). Cognitive analytics enabled responsible artificial intelligence for business model innovation: A multilayer perceptron neural networks estimation. *Journal of Business Research, 182*, 114788. https://doi.org/10.1016/j.jbusres.2024.114788

Kim, G. S., Park, S. B., & Oh, J. (2008). An examination of factors influencing consumer adoption of short message service (SMS). *Psychology & Marketing, 25*(8), 769–786. https://doi.org/10.1002/mar.20238

Kim, H. G., Kim, G. Y., & Kim, J. Y. (2019). Music recommendation system using human activity recognition from accelerometer data. *IEEE Transactions on Consumer Electronics, 65*(3), 349–358. https://doi.org/10.1109/TCE.2019.2924177

KITRUM. (2023). Recommendation Systems in E-commerce: How It Works? https://kitrum.com/blog/recommendation-systems-in-e-commerce-how-it-works/?utm_source=chatgpt.com

Knijnenburg, B. P., Willemsen, M. C., Gantner, Z., Soncu, H., & Newell, C. (2012). Explaining the user experience of recommender systems. *User Modeling and User-adapted Interaction, 22*, 441–504. https://doi.org/10.1007/s11257-011-9118-4

Komiak S.X., Benbasat I. (2006) The effects of personalization and familiarity on trust and adoption of recommendation agents. *MIS Quarterly*, *30*(4), 941–960. https://doi.org/10.2307/25148760

Konstan, J. A., & Riedl, J. (2012). Recommender systems: from algorithms to user experience. *User Modeling and User-adapted Interaction, 22,* 101–123. https://doi.org/10.1007/s11257-011-9112-x

Kowatsch, T., & Maass, W. (2010). In-store consumer behavior: How mobile recommendation agents influence usage intentions, product purchases, and store preferences. *Computers in Human Behavior, 26*(4), 697–704. https://doi.org/10.1016/j.chb.2010.01.006

Kumar, N., & Benbasat, I. (2006). Research note: the influence of recommendations and consumer reviews on evaluations of websites. *Information Systems Research, 17*(4), 425–439. https://doi.org/10.1287/isre.1060.0107

Lambillotte, L., Magrofuoco, N., Poncin, I., & Vanderdonckt, J. (2022). Enhancing playful customer experience with personalization. *Journal of Retailing and Consumer Services, 68*, 103017. https://doi.org/10.1016/j.jretconser.2022.103017

Lee, G.-G. and Lin, H.-F. (2005) Customer Perceptions of E-Service Quality in Online Shopping. International Journal of Retail & Distribution Management, 33, 161-176. https://doi.org/10.1108/09590550510581485

Lee, Y., & Kozar, K. A. (2012). Understanding of website usability: Specifying and measuring constructs and their relationships. *Decision Support Systems, 52*(2), 450–463. https://doi.org/10.1016/j.dss.2011.10.004

Lemon, K. N., & Verhoef, P. C. (2016). Understanding customer experience throughout the customer journey. *Journal of Marketing*, 69–96. https://doi.org/10.1509/jm.15.0420

Li, Q., Choi, I., & Kim, J. (2020). Evaluation of recommendation systems for sustainable E-commerce: accuracy, diversity and customer satisfaction. Preprints. https://doi.org/10.20944/preprints202001.0015.v1

Li, S. S., & Karahanna, E. (2015). Online recommendation systems in a B2C E-commerce context: a review and future directions. *Journal of the Association for Information Systems, 16*(2), 2. https://doi.org/10.17705/1jais.00389

Liang, T. P., Chen, H. Y., Turban, E. (2012). Effect of Personalization on the Perceived Usefulness of Online Customer Services: A Dual-core Theory. In *Proceedings of the 11th International Conference on Electronic Commerce* (pp. 279–288). https://doi.org/10.1145/1593254.1593296

Ling, K. C., Chai, L. T., & Piew, T. H. (2010). The effects of shopping orientations, online trust and prior online purchase experience toward customers' online purchase intention. *International Business Research, 3*(3), 63. https://doi.org/10.5539/ibr.v3n3p63

Liu, H., Shao, M., Liu, X., & Zhao, L. (2021). Exploring the influential factors on readers' continuance intentions of E-Book APPs: personalization, usefulness, playfulness, and satisfaction. *Frontiers in Psychology, 12*, 640110. https://doi.org/10.3389/fpsyg.2021.640110

Liu, W., & Wang, Y. (2024). Evaluating trust in recommender systems: A user study on the impacts of explanations, agency attribution, and product types. *International Journal of Human–Computer Interaction*, 1–13. https://doi.org/10.1080/10447318.2024.2313921

Londa, D. R., Worang, F. G., & Arie, F. V. (2022). The influence of perceived credibility, perceived ease of use, and perceived usefulness toward customer satisfaction in using BSGtouch. *Jurnal EMBA: Jurnal Riset Ekonomi, Manajemen, Bisnis dan Akuntansi, 10*(4), 934–945. https://ejournal.unsrat.ac.id/index.php/emba/article/view/43902

Lutz, K., Williams, J. R., & Purakal, J. D. (2023). Assessment of emergency department health care providers' readiness for managing intimate partner violence and correlation with perceived cultural competence. Journal of emergency nursing, 49(5), 724-732. https://doi.org/10.1016/j.jen.2023.04.009

Lv, L., Chen, S., Liu, G. G., & Benckendorff, P. (2024). Enhancing customers' life satisfaction through AI-powered personalized luxury recommendations in luxury tourism marketing. *International Journal of Hospitality Management*, *123*, 103914. https://doi.org/10.1016/j.ijhm.2024.103914

Madhuri, A., Shireesha, M., Reddy, S. M., & Kumar, B. R. (2024). Exploring the Role of Personalization in E-commerce: Impacts on Consumer Trust and Purchase Intentions. *European Economic Letters*. https://www.eelet.org.uk/index.php/journal/article/view/2385/2142

Martin, J., Mortimer, G., & Andrews, L. (2015). Re-examining online customer experience to include purchase frequency and perceived risk. *Journal of Retailing and Consumer Services, 25,* 81–95. https://doi.org/10.1016/j.jretconser.2015.03.008

Meyer, C., & Schwager, A. (2007). Understanding customer experience. *Harvard Business Review, 85*(2), 116. https://www.academia.edu/8781181/Understanding_Customer_Experience

Mican, D., Sitar-Tăut, D. A., & Moisescu, O. I. (2020). Perceived usefulness: A silver bullet to assure user data availability for online recommendation systems. *Decision Support Systems, 139*, 113420. https://doi.org/10.1016/j.dss.2020.113420

Mocean, L., & Pop, C. M. (2012). Marketing recommender systems: a new approach in the digital economy. *Informatica Economica, 16*(4), 142. https://www.researchgate.net/publication/281082534_Marketing_Recommender_Systems_A_New_Approach_in_Digital_Economy

Morgan, R. M., & Hunt, S. D. (1994). The commitment-trust theory of relationship marketing. *Journal of Marketing, 58*(3), 20–38. https://doi.org/10.2307/1252308

Moriuchi, E. (2019). Okay, Google!: An empirical study on voice assistants on consumer engagement and loyalty. *Psychology & Marketing, 36*(5), 489–501. https://doi.org/10.1002/mar.21192

Nilashi, M., Jannach, D., bin Ibrahim, O., Esfahani, M. D., & Ahmadi, H. (2016). Recommendation quality, transparency, and website quality for trust-building in recommendation agents. *Electronic Commerce Research and Applications, 19*, 70–84. https://doi.org/10.1016/j.elerap.2016.09.003

Niska, M. (2020). *Engaging Customers with Recommendations – A Study about How Customers Can Be Engaged Using a Recommender System*. Dissertation. Linköping University. https://liu.diva-portal.org/smash/get/diva2:1460556/FULLTEXT01.pdf

Nunes, P. F., & Kambil, A. (2001). Personalization? No thanks. *Harvard Business Review, 79*(4), 32–33. https://hbr.org/2001/04/personalization-no-thanks

Pappas, I. O., Kourouthanassis, P. E., Giannakos, M. N., & Lekakos, G. (2017). The interplay of online shopping motivations and experiential factors on personalized e-commerce: A complexity theory approach. *Telematics and Informatics, 34*(5), 730–742. https://doi.org/10.1016/j.tele.2016.08.021

Park, D. H., Kim, H. K., Choi, I. Y., & Kim, J. K. (2012). A literature review and classification of recommender systems research. *Expert Systems with Applications, 39*(11), 10059–10072. https://doi.org/10.1016/j.eswa.2012.02.038

Peng, M., Xu, Z. & Huang, H. (2021). How does information overload affect consumers' online decision process? An event-related potential study. *Frontiers in Neuroscience, 15,* 695852. https://doi.org/10.3389/fnins.2021.695852

Ping, Y., Li, Y., & Zhu, J. (2024). Beyond accuracy measures: the effect of diversity, novelty and serendipity in recommender systems on user engagement. Electronic Commerce Research, 1-28.https://link.springer.com/article/10.1007/s10660-024-09813-w

Pu, P., Chen, L., & Hu, R. (2012). Evaluating recommender systems from the user's perspective: survey of the state of the art. *User Modeling and User-Adapted Interaction, 22*, 317–355. https://doi.org/10.1007/s11257-011-9115-7

Purwanto P., Kuswandi K., Fatmah F. (2020). Interactive Applications with Artificial Intelligence: The Role of Trust among Digital Assistant Users. *Foresight and STI Governance, 14*(2), 64–75. https://cyberleninka.ru/article/n/interactive-applications-with-artificial-intelligence-the-role-of-trust-among-digital-assistant-users/viewer

Rafiq, F., Dogra, N., Adil, M., & Wu, J. Z. (2022). Examining consumer's intention to adopt AI-chatbots in tourism using partial least squares structural equation modeling method. *Mathematics, 10*(13), 2190. https://doi.org/10.3390/math10132190

Rai, A. (2020). Explainable AI: From black box to glass box. *Journal of the Academy of Marketing Science, 48*, 137–141. https://doi.org/10.1007/s11747-019-00710-5

Rane, N., Paramesha, M., Choudhary, S., & Rane, J. (2024). Artificial intelligence in sales and marketing: Enhancing customer satisfaction, experience and loyalty. *Experience and Loyalty* (17 May 2024). https://doi.org/10.2139/ssrn.4831903

Resnick, P., & Varian, H. R. (1997). Recommender systems. *Communications of the ACM*, *40*(3), 56-58. https://dl.acm.org/doi/10.1145/245108.245121

Rodríguez, M., Paredes, F., & Yi, G. (2016). Towards future customer experience: trends and innovation in retail. *Форсайт, 10*(3), (eng), 18–28. https://doi.org/10.17323/1995-459X.2016.3.18.28

Ruan, Y., & Mezei, J. (2022). When do AI chatbots lead to higher customer satisfaction than human frontline employees in online shopping assistance? Considering product attribute type. *Journal of Retailing and Consumer Services, 68*, 103059. https://doi.org/10.1016/j.jretconser.2022.103059

Sboui, M., Baati, O., & Sfar, N. (2024). Influencing factors and consequences of chatbot initial trust in AI telecommunication services: A study on Generation Z. *The TQM Journal*. https://doi.org/10.1108/TQM-02-2024-0085

Schnall, R., Higgins, T., Brown, W., Carballo-Dieguez, A., & Bakken, S. (2015). Trust, perceived risk, perceived ease of use and perceived usefulness as factors related to mHealth technology use. In *MEDINFO 2015: eHealth-enabled Health*, (pp. 467–471). IOS Press. https://pubmed.ncbi.nlm.nih.gov/26262094/

Schrotenboer, D. W. (2019). *The Impact of Artificial Intelligence along the Customer Journey: A Systematic Literature Review*. University of Tewnte. https://purl.utwente.nl/essays/78520

Sciascio, C. D., Brusilovsky, P., Trattner, C., & Veas, E. (2019). A roadmap to user-controllable social exploratory search. *ACM Transactions on Interactive Intelligent Systems*, *10*(1), 1–38. https://doi.org/10.1145/3241382

Searby, S. (2003). personalization – an overview of its use and potential. *BT Technology Journal, 21*(1), 13–19. https://doi.org/10.1023/A:1022439824138

Shah, T. R., Kautish, P., & Mehmood, K. (2023). Influence of robot service quality on customers' acceptance in restaurants. *Asia Pacific Journal of Marketing and Logistics, 35*(12), 3117–3137. https://doi.org/10.1108/APJML-09-2022-0780

Shen, A. (2014). Recommendations as personalized marketing: insights from customer experiences. *Journal of Services Marketing, 28*(5), 414–427. https://doi.org/10.1108/JSM-04-2013-0083/10.1108/JSM-04-2013-0083

Shen, A., & Ball, A. D. (2009). Customer perceptions and sustained usage of recommender systems. *International Journal of Electronic Business, 7*(6), 642–663. https://doi.org/10.1504/IJEB.2009.029056

Sheng, X., & Zolfagharian, M. (2014). Consumer participation in online product recommendation services: augmenting the technology acceptance model. Journal of *Services Marketing, 28*(6), 460–470. https://doi.org/10.1108/JSM-04-2013-0098

Sheridan, J. (2017). *An Exploration into the Potential Impact in Adopting a personalization Strategy and How It Could Affect the Customer's Experience on a Company's Own Website* (doctoral dissertation, Dublin, National College of Ireland). https://norma.ncirl.ie/2919/1/johnsheridan.pdf

Shin, D. (2021). The effects of explainability and causability on perception, trust, and acceptance: Implications for explainable AI. *International Journal of Human-Computer Studies, 146*, 102551. https://doi.org/10.1016/j.ijhcs.2020.102551

Sicular, S. & Vashisth, S. (2020). *Hype Cycle for Artificial Intelligence*, 2020 Gartner. https://www.gartner.com/en/documents/3988006

Sieger, L. N., Hermann, J., Schomäcker, A., Heindorf, S., Meske, C., Hey, C. C., & Doğangün, A. (2022, December). User Involvement in Training Smart Home Agents: Increasing Perceived Control and Understanding. In *Proceedings of the 10th International Conference on Human-Agent Interaction* (pp. 76–85). https://doi.org/10.1145/3527188.3561914

Silva-Aravena, F., Morales, J., Sáez, P., Jorquera, J., & Cornide-Reyes, H. (2024). Use of Artificial Intelligence as a Mechanism to Evaluate Customer Experience. Literature Review. In *International Conference on Human-Computer Interaction* (pp. 338–354). Springer, Cham. https://doi.org/10.1007/978-3-031-61305-0_24

Smits, A., Detweiler, C., Bartels, E., Pott, K., van der Stappen, E., van Rossen, S., & van Turhout, K. (2023, August). Assessing the Utility of an Interaction Qualities Framework in Systematizing the Evaluation of User Control. In *IFIP Conference on Human-Computer Interaction* (pp. 185–195). Cham: Springer Nature Switzerland.

https://www.hu.nl/onderzoek/publicaties/assessing-the-utility-of-an-interaction-qualities-framework-in-systematizing-the-evaluation-of

Suhir, M., & Imam Suyadi, R. (2014). Pengaruh persepsi risiko, kemudahan dan manfaat terhadap keputusan pembelian secara online. *Jurnal Administrasi Bisnis*, *8*(1). https://www.neliti.com/publications/79853/pengaruh-persepsi-risiko-kemudahan-dan-manfaat-terhadap-keputusan-pembelian-seca

Suresh, A., & Rani, N. J. (2020). Consumer perception towards artificial intelligence in E-commerce with reference to Chennai city, India. *Journal of Information Technology and Economic Development, 11*(1), 1–14. https://rochester.userservices.exlibrisgroup.com/permalink/01ROCH_INST/ts7lro/cdi_proquest_journals_2412995876

Syaharani, D. P., & Yasa, N. K. (2022). The role of trust as mediation between perceived usefulness and perceived ease of use on repurchase intention. *European Journal of Development Studies, 2*(3), 36–40. https://doi.org/10.24018/ejdevelop.2022.2.3.91

Tang, J. H., Chen, M. C., Yang, C. Y., Chung, T. Y., & Lee, Y. A. (2016). Personality traits, interpersonal relationships, online social support, and Facebook addiction. *Telematics and Informatics, 33*(1), 102–108. https://doi.org/10.1016/j.tele.2015.06.003

Teng, Z., Wu, A., & Song, Z. (2024, June). Research on the influence of the artificial intelligence chatbots' service quality on the consumers' purchase intention. In *International Conference on Human-Computer Interaction* (pp. 119–130). Cham: Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-76806-4_9

Tintarev, N., & Masthoff, J. (2007, April). A survey of explanations in recommender systems. In *2007 IEEE 23rd international conference on data engineering workshop* (pp. 801-810). IEEE. https://ieeexplore.ieee.org/abstract/document/4401070

Trawnik, A., Al-Masaeed, S., Alsoud, M., & Alkufahy, A. (2022). Understanding artificial intelligence experience: A customer perspective. *International Journal of Data and Network Science, 6*(4), 1471–1484. https://doi.org/10.5267/j.ijdns.2022.5.004

Tsai, C. H., & Brusilovsky, P. (2021). The effects of controllability and explainability in a social recommender system. *User Modeling and User-Adapted Interaction, 31*, 591–627. https://doi.org/10.1007/s11257-020-09281-5

Tulcanaza-Prieto, A. B., Cortez-Ordoñez, A., & Lee, C. W. (2023). Influence of customer perception factors on AI-enabled customer experience in the Ecuadorian banking environment. *Sustainability, 15*(16), 12441. https://doi.org/10.20944/preprints202306.1938.v1

Urbach, N., & Ahlemann, F. (2010). Structural equation modeling in information systems research using partial least squares. *Journal of Information Technology Theory and Application, 11*(2), 5–40. https://aisel.aisnet.org/jitta/vol11/iss2/2

Vashishth, T. K., Sharma, K. K., Kumar, B., Chaudhary, S., & Panwar, R. (2025). Enhancing customer experience through AI-enabled content personalization in e-commerce marketing. *Advances in Digital Marketing in the Era of Artificial Intelligence, 7*–32. https://doi.org/10.1201/9781003450443-2

Verhoef, P. C. (2020). Customer experience creation in today's digital world. In *The Routledge companion to strategic marketing* (pp. 107-122). Routledge https://pure.rug.nl/ws/portalfiles/portal/790710188/Customer_experience_creation_in_today_s_digital_world.pdf

Verhoef, P. C., Lemon, K. N., Parasuraman, A., Roggeveen, A., Tsiros, M., & Schlesinger, L. A. (2009). Customer experience creation: Determinants, dynamics and management strategies. *Journal of Retailing, 85*(1), 31–41. https://doi.org/10.1016/j.jretai.2008.11.001

Walls, A. R., Okumus, F., Wang, Y. R., & Kwun, D. J. W. (2011). An epistemological view of consumer experiences. *International Journal of Hospitality Management, 30*(1), 10–21. https://doi.org/10.1016/j.ijhm.2010.03.008

Wang, W., Guan, J., Guo, Z., Chan, J. H., & Qi, X. (2021). Customer experience and brand loyalty in the full-service hotel sector: the role of brand affect. *International Journal of Contemporary Hospitality Management*, *33*(5), 1620-1645. https://doi.org/10.1108/IJCHM-10-2020-1177

Wedel, M., Rust, R. T., & Chung, T. S. (2009, October). Up close And Personalized: A Marketing View of Recommendation Systems. In *Proceedings of the Third ACM Conference on Recommender Systems* (pp. 3–4). https://doi.org/10.1145/1639714.1639716

Widiar, G., Yuniarinto, A., & Yulianti, I. (2023). Perceived ease of use's effects on behavioral intention mediated by perceived usefulness and trust. *Interdisciplinary Social Studies, 2*(4), 1829–1844. https://doi.org/10.55324/iss.v2i4.397

Xiao, B., & Benbasat, I. (2007). E-commerce product recommendation agents: Use, characteristics, and impact. *MIS Quarterly*, 137–209. https://doi.org/10.2307/25148784

Yassin, F. M., Ouarda, W., & Alimi, A. M. (2022). Fuzzy ontology as a basis for recommendation systems for traveler's preference. *Multimedia Tools and Applications, 81*(5), 6599–6631. https://doi.org/10.1007/s11042-021-11780-5

Yi, S., & Liu, X. (2020). Machine learning based customer sentiment analysis for recommending shoppers, shops based on customers' reviews. *Complex & Intelligent Systems, 6*(3), 621–634. https://doi.org/10.1007/s40747-020-00155-2

Yoon, N., & Lee, H. K. (2021). AI recommendation service acceptance: Assessing the effects of perceived empathy and need for cognition. Journal of Theoretical and Applied Electronic Commerce Research, 16(5), 1912-1928. https://www.mdpi.com/0718-1876/16/5/107

Zaid, S., & Patwayati, P. (2021). Impact of customer experience and customer engagement on satisfaction and loyalty: A case study in Indonesia. *The Journal of Asian Finance, Economics and Business, 8*(4), 983–992. https://doi.org/10.13106/JAFEB.2021.VOL8.NO4.0983

Zamri, N., & Idris, I. (2013, June). The effects of attitude, social influences and perceived behavioral control on intention to purchase online shopping apparels in Malaysia: Case

https://doi.org/10.18080/jtde.v13n1.1137

study on Zalora. In the *3rd International Conference on Management, Penang*. https://doi.org/10.4236/jssm.2015.83032

Zanker, M., Rook, L., & Jannach, D. (2019). Measuring the impact of online personalization: Past, present and future. *International Journal of Human-Computer Studies, 131*, 160–168. https://doi.org/10.1016/j.ijhcs.2019.06.006

Zarrad, A. (2024). *Artificial Intelligence in Tunisian International Hotel Industry*. (Doctoral dissertation.) https://hdl.handle.net/10198/30160

Zhang, J., Li, Q., & Luximon, Y. (2021). Building Trust in Mobile Medical Consultations: The Roles of Privacy Concerns, Personality Traits, and Social Cues. In *Proceedings of the 23rd HCI International Conference, Washington, DC, USA*, 24–29 July 2021, (pp. 293–30). https://doi.org/10.1007/978-3-030-78108-8_22

Zhang, K. Z., & Benyoucef, M. (2016). Consumer behavior in social commerce: A literature review. *Decision Support Systems, 86*, 95–108. https://doi.org/10.1016/j.dss.2016.04.001

Zhang, X., Guo, X., Lai, K. H., Guo, F., & Li, C. (2014). Understanding gender differences in m-health adoption: a modified theory of reasoned action model. *Telemedicine and e-Health, 20*(1), 39–46. https://doi.org/10.1089/tmj.2013.0092

Appendices

Appendix 1. Measurement scales

Items	**Statements**	**References**
Perceived usefulness: UP	UP1: The use of the recommendation system has made the search task easier. UP2: Overall, I found the recommendation system useful for finding the right product. UP3: I found that the recommendation system's suggestions were helpful when shopping online. UP4: I think the recommendation system will be very useful in the future to help me make purchasing decisions. UP5: I expect that using a recommendation system will make my life easier.	Acharya, N., *et al.* (2022)
Controllability: CT	CT1: I have some control over the recommendations I receive. CT2: I feel free to do anything with this recommendation system. CT3: I feel in control of changing my preferences using this system. CT4: I felt in control when telling	Jin *et al.* (2021)

Items	Statements	References
	the system what I like.	
Personalisation: Perso	Perso1: I appreciate the application of the recommendation system as it is personalised for my user experience. Perso2: I think the recommended items reflect my personal preferences. Perso3: The recommended items perfectly match my needs. Perso4: The recommendation service is personalised for me.	Yoon & Lee (2021)
Perceived trust: PT	PT1: The items recommended by algorithmic processes are trustworthy. PT2: I trust the recommendations of algorithm-based services. PT3: I believe that the results of the algorithm service are reliable. PT4: I believe that the recommendation system was honest, sincere, and authentic. PT5: I believe that the recommendation system interacts with me to find the best product.	Brill *et al.* (2019)
Customer experience: EXP	EXP1: Shopping with the help of the recommendation system made me feel like I was in another world. EXP2: I had a lot of fun interacting with the recommendation system. EXP3: Overall, the algorithm services meet my initial expectations. EXP4: While relying on the recommendation system for my purchase decision, I felt assured, comfortable, and supported.	Acharya, N., *et al.* (2022)

Appendix 2. A model of advertising recommender systems

Appendix 3. Summary of measurements' reliability and validity

Variable constructs	Cronbach's alpha	Items	Code	Items' loadings
Perceived usefulness (PU)	.934	5	PU1 PU 2 PU 3 PU 4 PU5	.933 .802 .869 .838 .932
Own values = 3.959; Average Variance Extracted (AVE) = .792; KMO = .859; Bartlett's Test of Sphericity = 0.000; Jöreskog's Rho =.936; Composite Reliability =.950				
Perceived trust (PT)	.945	5	PT 1 PT 2 PT 3 PT 4 PT 5	.819 .839 .822 .867 .755
Own values = 4.103; Average Variance Extracted (AVE) = .820; KMO = .878; Bartlett's Test of Sphericity = 0.000; Jöreskog's Rho =.946; Composite Reliability =.958				
personalization (PERSO)	.938	4	PERSO 1 PERSO 2 PERSO 3 PERSO 4	.818 .871 .851 .834
Own values = 3.375; Average Variance Extracted (AVE) = .844; KMO = .867; Bartlett's Test of Sphericity = 0.000; Jöreskog's Rho =.939; Composite Reliability =.956				
Controllability (CA)	.909	4	CA 1 CA 2 CA 3 CA 4	.698 .831 .824 .782
Own values = 2.143; Average Variance Extracted (AVE) = .785; KMO= .818; Bartlett's Test of Sphericity = 0.000; Jöreskog's Rho =.919; Composite Reliability =.937				
AI-enabled customer experience (AICE)	.930	4	AICE 1 AICE 2 AICE 3 AICE 4	.804 .882 .868 .810
Own values = 3.371; Average Variance Extracted (AVE) = .843; KMO = .808; Bartlett's Test of Sphericity = 0.000' Jöreskog's Rho =.920; Composite Reliability =.955				

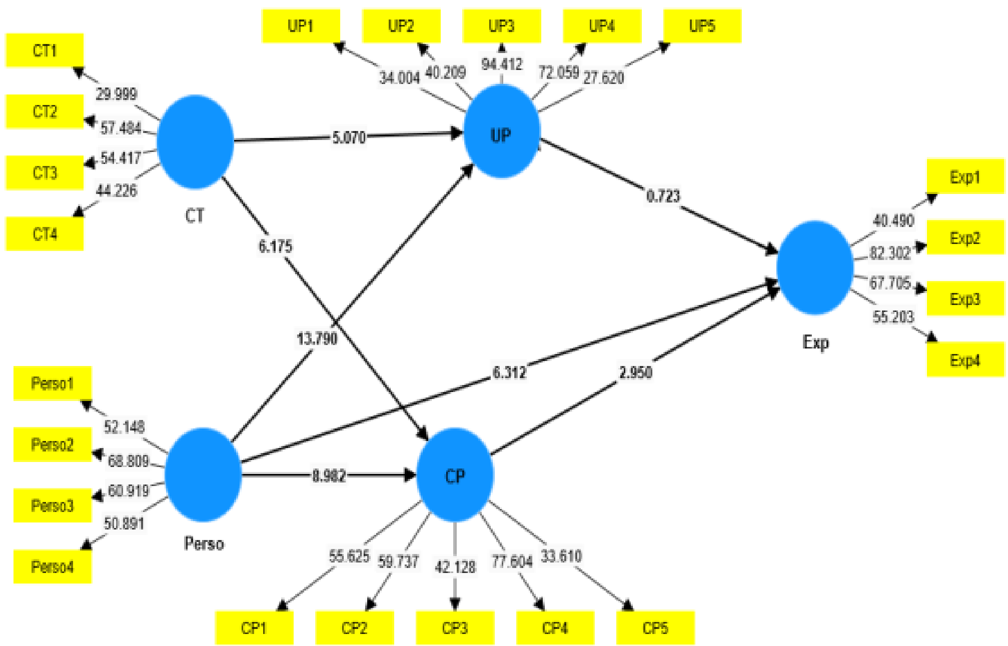
Appendix 4. Test of discriminant validity

	Perceived Trust	Controllability	AI-enabled customer experience	personalization	Perceived usefulness
Perceived trust					
Controllability	.809				
AI-enabled customer experience	.791	.683			
personalization	.846	.751	.871		
Perceived usefulness	.811	.782	.778	.802	

Appendix 5. Predictive Power of the Model: R² and Q² Values for Key Constructs

	R^2	Q^2
Perceived trust	0.710	0.702
Customer experience	0.694	0.672
Perceived usefulness	0.750	0.744

Appendix 6. Structural model (PLS-SEM analysis)



Why Micro-influencers are Sharing Digital Brand Content in a B2B Context

A Psycho-Social Investigation Using the Theory of Planned Behaviour

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Abstract: This research aims to understand micro-influencers' behaviour in sharing digital brand content by focusing on business networking sites (LinkedIn and Xing). This choice was influenced by two considerations: first, marketing influence literature which is highly dominated by studies of B2C digital context to the detriment of B2B digital context despite their crucial importance in the marketing arena (Cartwright *et al.*, 2022; Iankova *et al.*, 2019). And second, given their particularity, micro-influencers are more likely to have motivations that are totally or partially different from what the literature suggests for all influencers in general. Based on a mixed-technique analysis (MLM) and bias-corrected bootstrap method, this research was conducted by administering a large survey to 312 micro-influencers, who were selected according to a new methodological algorithmic approach called metric-behavioural (Skorr/Kred). The results not only cover the identification of salient drivers that lead the sharing of digital brand content by micro-influencers in a specific area but also validate the robustness of the use of the theory of planned behaviour in a B2B social media context. By considering these results, the paper provides a practical guidance for companies, urging them to tailor their influence marketing strategies for effective engagement in B2B and B2G contexts.

Keywords: Micro-influencers, Business Networking Sites, Digital Brand Content, Digital Advertising, Theory of Planned Behaviour

Introduction

Inbound marketing has gained a lot of interest in recent years at the expense of outbound marketing (Soegoto & Simbolon, 2018; Dakouan & Benabdelouahed, 2019). Given the rise and rapid growth of inbound marketing, researchers have become increasingly interested in studying its techniques and tools (Aljohani, 2020; Vasquez-Reyes *et al.*, 2023). Thus, influencer marketing as a powerful inbound marketing tool has been studied with great interest.

However, the study of influencers has often been used globally without taking into consideration the specificity and uniqueness of each category of influencers. Micro-influencers, for example, are logically expected to generate motivations different from what typically the literature revealed for influencers in a general. Therefore, the use of these classifications seems fundamental (Ouvrein *et al.*, 2021), given that each type of influencer has very different objectives and motivations, as well as presenting singular relationships with their followers and their own community (Wellman *et al.*, 2020).

For example, research concerning the study of the influencer marketing concept emphasises that consumers often question the authenticity of influencers (Mardon *et al.*, 2023; Audrezet *et al.*, 2018). However, with the recent emerging typologies of influencers (Ouvrein *et al.*, 2021), there is still a lack of research based on these classifications in the literature, particularly in the B2B (business to business) context, in order to compare the effects of these influencer marketing practices across these categories. Given their unique characteristics, micro-influencers—renowned for their authenticity(Kim & Kim, 2021; Audrezet *et al.*, 2018), their effectiveness (Leung *et al.*, 2022), their high engagement rate (Hughes *et al.*, 2019) and their proximity to the community (Influencer Marketing Hub, 2023), are expected to demonstrate motivations that differ considerably from those generally highlighted in the literature on influencers as a whole (Hughes *et al.*, 2019).

Hence the crucial importance of taking into account, in the B2B context, the distinction between the different profiles of influencers. This would allow companies to rethink, adjust and correctly anticipate the deployment of their influencer marketing strategy according to the motivations and characteristics of a unique and homogeneous influencer profile, in order to obtain the best results adapted to the expected objectives. For example, companies primarily interested in cognitive and visibility goals within their communication campaigns should base their strategies on the specific motivations and characteristics of mega/giga-influencers. Conversely, companies wishing to strengthen the authenticity of their messages, or seeking a regional impact, or having simply assigning conative and conversion objectives to their communication campaigns must target micro/nano-influencers (Influencer Marketing Hub 2023).

For this reason, we propose to focus on studying the motivations for sharing digital brand content by micro-influencers (that is, 10,000–50,000 followers) on a specific and homogeneous social media category, more precisely business networking sites, because of their crucial importance in the B2B context. Especially given that the B2B context has clearly

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received less attention from researchers' studies in the marketing influence domain (Cartwright *et al.*, 2022; Crisafulli *et al.*, 2022; Mero *et al.*, 2023; Grissa, 2024).

To achieve this goal, we will first look into the theoretical background of social media and specifically DBC sharing. Second, we will analyse the literature on influencers, particularly micro-influencers and their particularities. Finally, we intend to present the methodology and finish by highlighting results and their discussion.

Theoretical Background

Motivations for sharing content on social media

Aware of the potential and opportunities offered by social media, authors (Haikel-Elsabeh *et al.*, 2014; Florenthal, 2015; Alves *et al.*, 2016; Grissa, 2020) have paid great attention to these platforms. Among the important research areas examined within social media literature, we particularly cite the one that studies the motivations of the different behaviours observed on these platforms (joining platforms/groups, disclosure and self-exposure, information seeking and lurking, information sharing). The activity of sharing content was then exploited with much interest by researchers (Jayasingh & Venkatesh, 2015; Araujo & van de Meer, 2015; Dessart, 2017; Haikel-Elsabeh *et al.*, 2019). However, this was most often done in a general and in a large sense, without specifying the context of use (B2C/B2B) and the nature of studied platforms. Especially given that social media is characterised by a strong intrinsic heterogeneity (Stenger & Coutant, 2013; Grissa, 2020), which encouraged researchers to propose several social media classifications and categorisations (Cardon, 2008; Kaplan & Haenlein, 2010; Brandtzaeg & Heim, 2011; Stenger & Coutant, 2013).

The categorisation by Stenger & Coutant (2013) is particularly interesting in our research context. In addition to the fact that it is built on solid empirical work, it makes it possible to clearly explain the mechanisms of navigation and transmission of information on social media. In this sense, the Stenger & Coutant (2013) classification permits us to distinguish and contrast between two major categories of social media, namely: the *friendship-oriented social media* category like social networking sites SNS (for example, Facebook, Instagram, TikTok, snapchat, etc.), and the *interest-oriented social media* category, like professional social networks (LinkedIn, Xing, Viadeo, SkilledAfricans, etc.). By using this classification (Stenger & Coutant, 2013), we quickly noticed that previous researches have been largely dominated by the category of SNS (that is, friendship-oriented social media), and more particularly Facebook. Thus, several researchers studied the determinants and motivations of content sharing on Facebook. For example, Haikel-Elsabeh (2014) highlights the importance of reciprocity when explaining content sharing and member engagement on brand pages on

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Facebook. Similarly, Papacharissi & Mendelson (2011) and Wu & Sukoco (2010) emphasise the role of the social factor and group membership affiliation in the activity of brand content sharing.

In addition to these generic motivations, it is crucial to emphasise other determinants that are more contextual and appropriate to SNS platforms. De Vries & Leeflang (2012) highlight the role of the 'pin to the top page' feature in boosting share activity on Facebook pages. Jayansighe & Venkatesh (2015) also emphasise the impact of diverse formats, particularly photos and videos, on fan engagement.

These investigations demonstrate the importance of contextual determinants, in addition to generic/general ones, in the study of sharing brand content in the friendship-oriented social media category (SNS). Therefore, the examination of contextual determinants should follow the same research approach applied to the SNS context but extend it to business networking sites, which have been largely overlooked due to the predominant focus on B2C platforms like Facebook. Additionally, it is crucial to consider the distinct profiles of social media users, particularly the most active and influential figures, such as influencers.

From influencers to micro-influencers

The study of influencers and more generally opinion leaders is not a recent subject but has been revived with the rise of the digital context. Historically, virtual communities were the first research objects explored, in order to study the application of opinion leaders in the digital age. For example, Fejlaoui & Vernette (2009) used the MacBidouille Forum for Macintosh users to highlight opinion leaders' influence and their significant differences with their traditional counterparts (that is, offline opinion leaders). Then comes the era of social networks where studies have been expanded, particularly for Facebook (Turcotte *et al.*, 2015; Karlsen, 2015), but also for Twitter (now X), which has dominated most of the research on this topic (Goldenberg *et al.*, 2009; Gallan & Vignolles, 2013; Ruspil *et al.*, 2017).

It is important to note in this context that applying the concept of opinion leader to the digital area may create and induce some confusion with other terminologies such as influencers. Given that influencers are also supposed to influence individuals' attitudes and behaviours, this role may seem similar to the role of an opinion leader in general as described by Katz & Lazarsfeld (1955). However, some nuances and differences should be highlighted (Farivar *et al.*, 2021). In this context, we reiterate that opinion leaders, whose origin and genesis of the concept come from political and sociological sciences, are knowledgeable individuals who act as information gatekeepers, transmitting media information to others within their extended networks, often thanks to their transversal and multidisciplinary knowledge. However,

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influencers whose origin of the concept comes from consumer and management sciences, are considered in this research as individuals who are uniquely and exclusively associated with social media and who have contextualised knowledge of a brand or product category. In summary, while both opinion leaders and influencers have the ability to shape the attitudes and behaviours of others, opinion leaders are typically associated with personal and community influence, while influencers are associated with the digital realm and social media platforms, and often associated with a commercialised and transactional form of influence, as it is typically mediated through endorsement, content creation and online engagement (Farivar *et al.*, 2021).

More generally, the significant interest in studying influencers on social networks is highly due to the strong concentration of DBC sharing activity around a small segment of members, who are the influencers (Bo & Somarriba, 2020). As a consequence, considering their crucial importance, it is necessary to carefully study influencers, so that companies can manage and adapt the deployment of their DBC strategy according to their motivations, incentives and objectives. Yet, for more accurate results and better conclusions, it is appropriate to distinguish between the different categories of influencers. In this context, we reiterate that social networks are the subject of a distinction between at least two major types of influencers: *smallest influencers* (nano-influencers and micro-influencers) and *largest influencers* (mega-influencers, giga-influencers and celebrities). These two categories of influencers exhibit distinct motivations and objectives, which differ significantly from one another.Consequently, in order to attract and drive influencers towards companies' needs and expectations, managers need to adapt and personalise their strategies of engaging influencer on the basis of motivations and characteristics of each profile. For example, companies with visibility and cognitive objectives aiming to spread their messages widely and on a larger scale, the choice and deployment of largest influencers would be more relevant.

On the other hand, for companies with conative objectives, smallest influencers would be more suitable because of their high rate of engagement and conversion with the community (according to Infinity Agency, lead conversion is eight times higher for micro-influencers than celebrities). The same results are also confirmed in a study published by Hubspot (2021). Similarly for companies aiming for regional impact or niche markets rather than international ones, it would be then more relevant to focus on a DBC strategy based on the mobilisation of micro-influencers, the reason being their authenticity and proximity to communities give them a higher level of trust and credibility. It is obvious that collaboration with largest influencers such as celebrities is often monetised and remains unlikely possible from an approach based on psycho-social motivations.

This is why we propose to investigate the motivations of micro-influencers to share DBC on business networking sites, as these platforms are best suited to the B2B context. The literature highlights that marketing influence in the B2B domain has been largely overlooked compared to the B2C context. To address this gap, we suggest structuring our research using the theory of planned behavior as a conceptual framework. Influencer marketing in a B2B context

Despite the lack of research on influencer marketing in the B2B context, there are some research areas that are slowly starting to develop (Grissa 2024a; Mero *et al.*, 2023; Cartwright *et al.*, 2022; Crisafulli *et al.*, 2022). One of the first research areas consists of conceptualizationmarketing influencers in a B2B context and their conceptualisation, with the intention of understanding how influencer marketing differs from its counterpart in B2C.

This has often been accomplished through the study of its distinctive features (Mero *et al.*, 2023; Crisafulli *et al.*, 2022; Belanche *et al.*, 2021; De Veirman *et al.*, 2017), as well as through the distinction between its different forms of influence sources and its various categories. In this context, Huotari et al. (2015) identify two main forms of B2B contexts: internal influencers and external influencers.

Internal influencers (also called corporate) are the executives of organisations, known for their reliability and high expertise in the business sector and who, through their own voices and outside those of the official channels of the organisation, try to promote content related to the ideas and values of their organisations (Smith *et al.*, 2021).

Concerning external influencers in a B2B context, they most often correspond to influential people such as economic journalists, consultants, facilitators and intermediaries, analysts and more generally specialists in the sector/market who, in addition to their specialised expertise and their perceived credibility, have developed a diversified contact portfolio allowing them to exert a certain influence on key people in the organisation's ecosystem (Cartwright *et al.*, 2021).

Among the other important research areas that have particularly attracted the interest of researchers (Casalô *et al* 2020; Terho *et al.*, 2022; Taiminen & Rawaweera, 2019), we specifically highlight the study of the impact of influencers in a B2B context at different levels and on different parties. Indeed, likewise as in the B2C context, the study of influencers in B2B has traditionally focused on analysing their impact on attitudes and behaviours such as preferences and purchases (Yuan *et al.*, 2020; Diba *et al.*, 2019; Paulssen & Roulet., 2017). However, this is likely to be more different for the B2B context since its impact is embodied at various levels (recommendations, content creation, social interactions, co-creation), in addition to involving different parties such as suppliers (purchase), employees (strengthening the feelings of belonging to the company, employer brand), shareholders (think tank, investment advice) and other stakeholders of the organisation's ecosystem (journalists, company decision-makers, civil society).

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The study of influencers was also examined from an organisational perspective, by studying companies' strategies for stimulating and managing influencers (Borchers & Enke, 2021; Childers *et al.*, 2019). From this perspective, special attention was given to studying motivations and more generally determinants of influencers in the creation of brand content (Grissa, 2024a; Taiminen & Ranaweera, 2019; Hollebeek & Macky, 2019; Paulssen & Roulet, 2017). Thus, several determinants/motivations were then highlighted including obviously the monetary and financial motivations (Bun & Alversia, 2020; Holle Beek & Macky, 2019). Beyond these financial and monetary motivations, some studies have also highlighted the importance of studying the impact of the psycho-sociological factors stimulating influencer engagement (Grissa, 2024a; Paulssen & Roulet, 2017). Some attempts have been made in this direction, highlighting the role of e-reputation research, the desire to expand the community of followers and feeling of self-efficacy, as a key motivations for the engagement of influencers in sharing brand content (Grissa, 2024a).

Although these research works may be useful, their contribution is still limited because they focus on B2B influencers instead of distinguishing between the various influencers' profiles and their specific features when studying motivations/determinants for brand content engagement. As explained above, the motivations and behaviours of influencers can vary greatly depending on the size of their communities and their goals. It is therefore relevant to focus on the B2B context in a homogeneous category such as the micro-influencers, due to their authenticity, effectiveness and high engagement rate (Grissa, 2024b; Crisafulli *et al.*, 2022).

Likewise, beyond identifying and validating the key drivers and motivations specific to micro-influencers, this approach enables companies to refine, anticipate, and tailor the implementation of their influencer marketing strategy. By aligning their approach with the motivations and characteristics of this distinct and relatively homogeneous target group (i.e; micro-influencers), businesses can achieve more effective and contextually relevant results.

Theory of planned behaviour

The theory of planned behaviour (TPB) arises from the domain of social cognitive psychology (Ajzen 1991, 2020). Specifically, it represents an extension and refinement of the Theory of Reasoned Action (Fishbein & Ajzen, 1975) through the incorporation of a crucial additional dimension: perceived behavioural control. As a result, the TPB is composed of three dimensions that form the basis of its conceptual model: attitude, subjective norms and perceived control. The theory states that the 'conducted behaviour' would be the result of the deliberate and reasoned intention to engage in it.

Several meta-analyses studies show the explanatory power of TBP and its constitutive dimensions in the explanation of behaviours (Ajzen, 2016; McEachan *et al.*, 2011). In the digital context, Limayem *et al.* (2000) and George (2004) demonstrate the robustness of the TBP in explaining online shopping behaviour by validating its three constitutive dimensions, while pointing out a clear predominance of the attitude dimension.

In the context of SNSs (that is, friendship-oriented platforms), Mlaiki et al. (2012) highlight only the role of attitude and to a lesser extent the perceived behavioural control over the intention of continued use of Facebook. However, the impact of subjective norms appears to vary depending on the nature of the behaviour being studied, with injunctive norms potentially exerting a strong or weak influence accordingly.

Concerning opinion leaders on social media, little research has used the TPB to analyse its suitability for the study of these profiles. Nevertheless, we cite Wang (2016) who shows the relevance of the TBP in explaining the influence of opinion leaders on members' adoption of e-WOM. Similarly, for Raghpathi & Fogel (2015), who study the impact of digital opinion leaders on the completion of a purchase after publishing a promotional message on Facebook.

Despite its robustness, the TPB is not immune to certain limits. The major criticisms of TPB often refer to its strong cognitive and rational orientation, thus limiting its ability to explain hedonistic and experiential behaviours (impulse buying, snobbery, ostentatious and conspicuous consumption, etc.) as well as behaviours driven by feelings.

In response to this criticism, Ajzen (2016) justified the exclusion of these behaviours from the TPB by arguing that they already exert an indirect influence on the predictors of the model, particularly through the beliefs that shape them at an earlier stage. Finally, the TPB is criticised for its weakness in explaining general behaviour, since it has been shown to be effective only in studying specific and well-defined behaviours. This is why in our research we do not suggest studying the determinants of DBC sharing in general, but rather the determinants of DBC sharing by micro-influencers on professional social networks.

More generally, our choice to opt for this social cognitive theory is justified by the first results of our qualitative research (Grissa, 2020) which demonstrate that influencers' engagement drivers in a DBC sharing activity are primarily focused on utilitarian motives.

This choice is further reinforced by the nature of business networking sites, whose use is mainly focused on interest. In addition to this, in the organisational context (B2B context) decisions are more considered and reasoned, which makes the TBP conceptual framework more suitable.

Thus, the mobilisation of the TCP in our research allows us to build the following theoretical framework (Figure 1), composed from the literature and enriched with our qualitative results.

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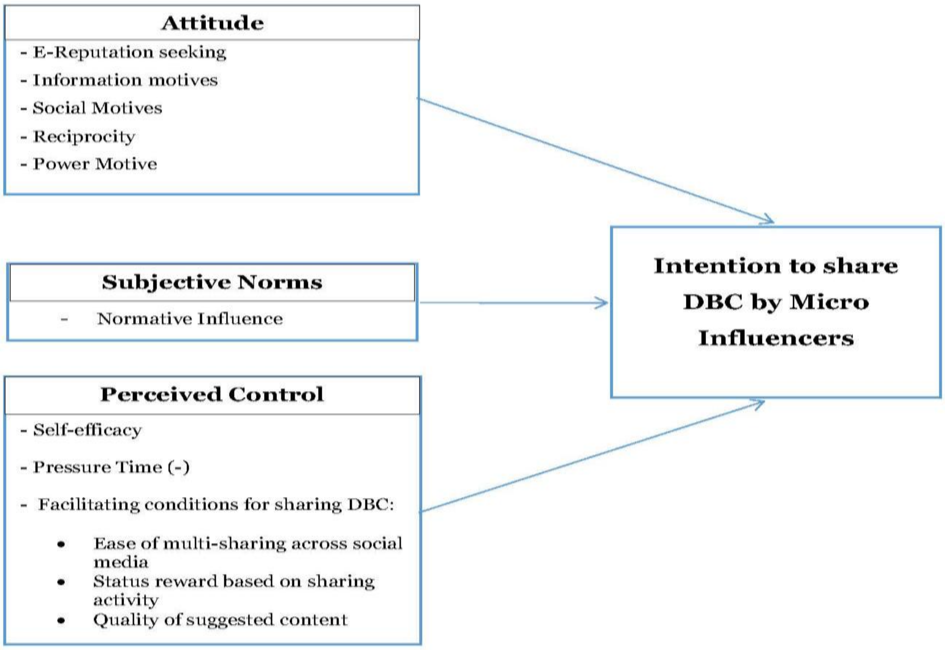

Figure 1. Theoretical framework: The determinant of sharing DBC by micro-influencers in business networking sites (B2B context)

Methodology

The research was conducted in two main phases: a qualitative phase and a quantitative phase. The qualitative phase involved six in-depth interviews with experts and managers of professional social networks in France, and five focus groups conducted with micro-influencers (10,000 to 50,000 followers community). The quantitative phase consists of administering 312 online questionnaires administered to micro-influencers.

The first qualitative phase, which was covered in previous publications (Grissa, 2016; Grissa, 2020), clearly demonstrated the dominant utilitarian motives in DBC sharing behaviour among micro-influencers. In light of this, the first four motivations, which are strongly focused on utility, account for approximately 70% of all the categories identified in the analysis (Appendix 1).

The prominence of these utilitarian motivations can be explained by the nature of the platforms studied (that is, LinkedIn, Xing, skilled Africans), which are highly interest-oriented compared to SNSs (Facebook, TikTok, Snapchat), which are more highly friendship-oriented (Stenger & Coutant, 2013). On the other hand, this can be explained by the specificity of micro-influencers who, when they invest their time, energy and knowledge, expect a certain gain to be obtained later.

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The second quantitative phase is designed to test the constructed conceptual model with 312 micro-influencers having between 10,000 to 50,000 followers (Appendix 2), whose influence has been previously verified by the influence score program Skorr (formerly known as Klout).

The selection and recruitment of micro-influencers were accomplished through three administrative survey channels (Appendix 3):

- Influencer LinkedIn (member with influencer badge)
- specialised groups across all social professional networks
- content aggregators like LinkedIn Pulse.

Concretely, it involves systematically going to one of the aforementioned interfaces and trying to identify each time the authors whose content is related to the brands and generating the most possible interactions (shares, comments, likes, etc.). Once identified, we extract the identity of the member to check their influence score in the Skorr program. If their score is above 60, an 'InMail' through a premium account is then sent to solicit their participation as an expert in our survey. However, if the score is slightly lower than 60 (meaning between 55 and 60), we proceed to check their Kred score to verify their ability as an influencer. Otherwise, the sending of the email is totally cancelled. Thus, in our methodological approach, we incorporated both the informational approach based on the volume of interactions and the metric algorithmic approach (Skorr/Kred) during our selection process for micro-influencers.

Finally, due to a limited audience at the national level, we had to expand and broaden our reach internationally to ensure the highest number of responses. Thus, our questionnaire was administered in French and English.

To do this, we used the back-translation protocol, better known as a 'reverse translation' created by Brislin (1976). Thus, a chi-square test was applied to test differences between the English and French versions, but they appear to be insignificant except for the last two items of power motive.

Concerning the operationalisation of model variables, we favour the use of measurement scales that have been tested in consumption contexts similar to ours in the literature (Appendix 4).

Findings

Measurement model

In order to evaluate each used measurement scales on the basis of the psychometric validation criteria (unidimensionality, reliability, convergent validity and discriminant validity), a confirmatory factor analysis (CFA) was applied to the measurement model based on the

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covariance structure methodology (Bentler & Bonett, 1980; Anderson & Gerbing, 1988; Bagozzi et Heatherton, 2004; Ping 2004).

Since the maximum likelihood estimation representing the preferred method for covariance structure models assumes the multivariate normality of the manifest variables, this hypothesis was tested using the tests presented in Table 1.

Table 1. The whole tests of multivariate normality of manifest variables

Test	**Skew**[1]	**Kurtosis**[2]	**S-W**[3]	**D-H**[4]	**A-D**[5]	**C-M**[6]	**H-Z**[7]	**R**[8]
statistics	198.52	1210.65	.97	827.89	10.62	1.02	1.06	2013.24
p	.66	0	0	0	0	0	0	0

[1] Testing the multivariate asymmetry of Mardia (1970).
[2] Testing the multivariate flattening of Mardia 1970).
[3] Shapiro-Wilk multivariate normality test (Villasenor-Alva & Gonzalez Estrada 2009).
[4] Testing the multivariate normality of Doornik-Hansen (1994).
[5] Testing the multivariate normality of Anderson-Darling (Paulson, Roohan & Sullo 1987).
[6] Testing the multivariate normality of Cramer-von Mises (Koziol 1982).
[7] Testing the multivariate normality of Henze & Zirkler (1990).
[8] Testing the multivariate normality of Royston (1982).

As shown in the table above, tests indicate clearly that the hypothesis of multivariate normality is clearly violated because there is an excess of flatness, even though the joint distribution is relatively symmetric.

Therefore, the measurement model was estimated using the MLM (Maximum Likelihood Mean-adjusted) estimation method, which is robust to data non-normality. This approach relies on the chi-square coefficient proposed by Satorra & Bentler, (1994). The selected method enables parameter estimation based on the maximum likelihood principle while adjusting the likelihood ratio statistic (X^2) and correcting the standard errors of the estimates. These adjustments enhance the model's robustness against both heteroscedasticity and violations of the multivariate normality assumption.

Applying this method, it seems that the results of the estimation do not qualify the initial measurement model under the ratio of unidimensionality since no adjustment index allows guaranteeing it, without the need to mention the likelihood ratio test X^2.

As a result, it becomes necessary to eliminate some problematic items (that is, informational motives 4 and 5, social motives 3 and 4, power motive 3). By estimating the purified model, analysis problems are reduced so that there are no parameters suffering with non-trivial specification errors.

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Unidimensionality

As shown in Table 2, the unidimensionality of the measurements (Gerbing & Anderson, 1988) is then well approved, in respect with the most rigorous criteria (RMESEA= 0.03<0.06; P(RMSEA<0.05)=1; CFI=0.97>0.95; SRMR= 0.04<0.08).

Table 2. Testing the significance of the overall measurement model fit and evaluation of its goodness-of-fit indices

q[1]	LV[2]	χ^{2}[2, 3]	DF[4]	p[5]	C[6]	CFI	RMSEA	p_{RMSEA}[7]	SRMR	BIC[8]
230	-11838.2	477.76	364	0	1.03	.97	.03	1	.04	24980.52

[1] Number of model parameters.
[2] Likelihood logarithm function.
[3] Statistics of the likelihood ratio test that follows the chi-square law.
[4] Degrees of freedom of the likelihood ratio test.
[5] Significance level of the likelihood ratio test (p-value).
[6] Correction factor for the likelihood ratio test statistic.
[7] Significance level of a test close to perfect fit (RMSEA<.05).
[8] Bayesian information criterion.

Reliability, convergent validity and discriminant validity

The reliability is often estimated in a confirmatory logic by the rhô coefficient of Jöreskog whose value is supposed to be greater than 0.6.

Table 3. Coefficients rhô and AVE of constructs studied after modification, with their confidence intervals

	Rhô 1	LB(CI(rhô))2	UB(CI(rhô))3	AVE 4	LB(CI(AVE))5	UB(CI(AVE))6
INF MOTVE	0.814	0.757	0.872	0.702	0.616	0.788
SOC MOTVE	0.790	0.747	0.832	0.564	0.502	0.627
EREP	0.807	0.757	0.858	0.583	0.505	0.662
RECIP	0.828	0.785	0.872	0.707	0.643	0.771
POWER	0.931	0.914	0.949	0.872	0.841	0.902
INTEN	0.620	0.535	0.704	0.449	0.360	0.538
PRESST	0.903	0.882	0.925	0.758	0.712	0.803
SELFEFF	0.839	0.799	0.879	0.723	0.664	0.783

[1] Rhô coefficient of Jöreskog.
[2] Lower bound of the 95% confidence interval of the Rhô coefficient, based on the multivariate delta method.
[3] Upper bound of the 95% confidence interval of the Rhô coefficient, based on the multivariate delta method.
[4] AVE (Average Variance Extracted).
[5] Lower bound of the 95% confidence interval of the AVE, based on the multivariate delta method.
[6] Upper bound of the 95% confidence interval of the AVE, based on the multivariate delta method.

Table 3 contains all the rhô values of Jôreskog, presented in inferential statistics logic, based on confidence intervals calculated according to the standard deviations which are obtained using the multivariate delta method and more precisely through its transposition to the analysis of covariance structure (Folmer, 1981). These results show that the measurement reliability is validated in the strongest sense since all the constructs have a rhô coefficient value greater than the threshold of 0.6, even for the lower bounds of the confidence intervals which exceed the indicated threshold.

Similarly for the convergent validity, Table 3 reveals that all the constructs have an AVE exceeding the level of 0.5 except for the sharing DBC intention variable which is slightly below this limit (0.449) but whose value of 0.5 is still included in its confidence interval.

Finally, the discriminant validity is also confirmed given that the square root of the AVE for each construct is superior to its correlation with any other construct.

Structural model

Evaluation of model fit

In this context, due to a problem of the violation of multivariate normality, the evaluation of the model fit and its hypothesis were made by the MLM estimator which is a maximum likelihood method robust to the non-normality of data (Satorra & Bentler, 1994) and by using the software Mplus 6.12 (Muthen & Muthen, 2015; Caron, 2019).

The results of the estimation of the linear structural model in terms of assessment of model fit and goodness-of-fit indices are presented in the following Table 4:

Table 4. Testing the significance of the overall structural model fit and evaluation of its goodness-of-fit indices

q[1]	LV[2]	$\chi^{2,3}$	DF[4]	p[5]	C[6]	CFI	RMSEA	p_{RMSEA}[7]	SRMR	BIC[8]
132	-9963.23	374.57	245	0	1.04	0.951	0.045	0.92	0.05	20675.34

[1] Number of model parameters.
[2] Likelihood logarithm function.
[3] Statistics of the likelihood ratio test that follows the chi-square law.
[4] Degrees of freedom of the likelihood ratio test.
[5] Significance level of the likelihood ratio test (p-value).
[6] Corrections factor for of the likelihood ratio test statistic.
[7] Significance level of a test close to perfect fit (RMSEA<.05).
8 Bayesian information criterion.

Despite the insignificant likelihood test ratio ($p=0<5\%$), the goodness-of-fit indices demonstrate the high quality of its adjustment (RMESEA = 0.045< 0.05; $p_{(RMESEA)}$ = 0.92 ; CFI = 0.951>0.9 ; SRMR = 0.053<0.08) according to the most stringent standards (Hu & Bentler, 1995). Consequently, the structural model provides a satisfactory fit for the data collected, making it possible to test the model hypotheses.

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Testing the hypothesis of the structural model

Table 5 presents the results of the hypothesis tests studied in the linear structural model. The results are verified using the asymptotic standard deviations of the MLM estimator and also with their confidence intervals calculated using the bias-corrected bootstrap method.

For the MLM method, the validated effects are presented according to three levels of significance (p value***<1%; p value*<5%, p value*<10%), as shown at the end of the table below.

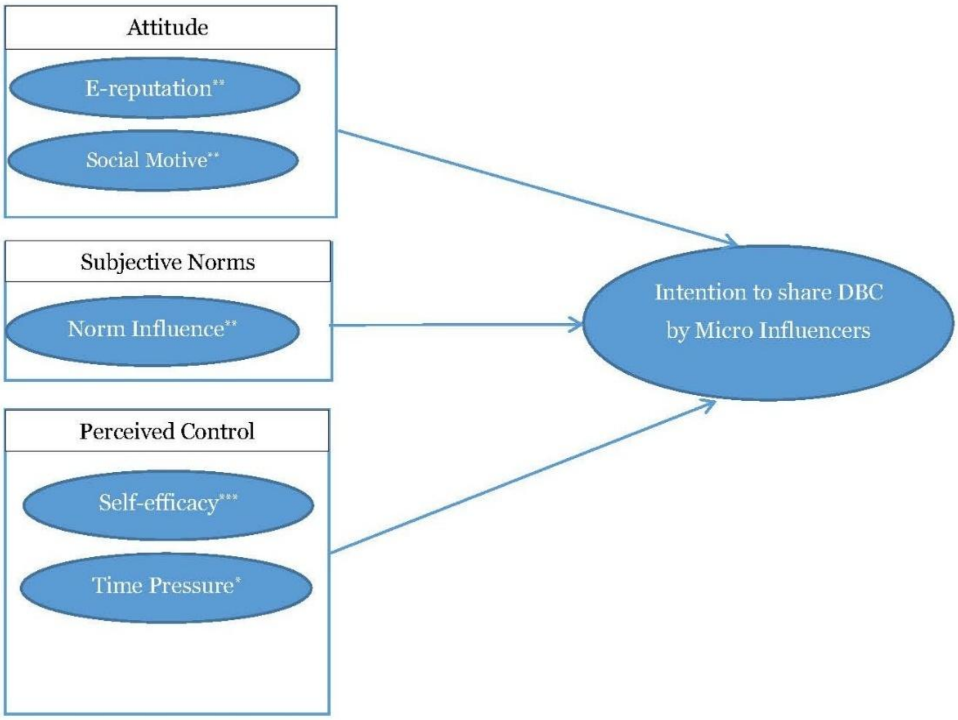
For the bootstrap method, which is intended for multiplication and data analysis triangulation to achieve better results and conclusions, the significance is validated (α = 5%) when its confidence interval does not contain the zero unit (Efron & Tibshirani, 1986).

Table 5. Testing the structural model hypothesis using the MLM method and the bias-corrected bootstrap method

Effect[1]	est[2]	P[3]	BI($IC_{95\%}$)'[4]	BS($IC_{95\%}$)[5]
INTPART←INF MOTIVE	.277*	.067	-.114	.552
INTPART←SOC MOTVE	.030	.810	-.121	.457
INTPART<-EREP	.414**	.047	-.009	.843
INTPART<-POWER	.120	.352	-.200	.430
INTPART<-RECIP	-.110	.647	-.606	.393
INTPART<NORM INF	.533	.225	-.859	1.203
INTPART<-SELFEFF	.383***+	.005	.158	.810
INTPART<-PRESST	-.163	.126	-.431	.080
INTPART<-EASE	-.068**	.033	-.127	.011
INTPART<-STAT	.002	.954	-.091	.096
INTPART<-QLT	-.028	.459	-.101	.051

[1] Dependent variable <- Independent variable.
[2] Estimation by MLM method.
"P-value: Significance level of the effect
[4]Lower bound of the 95% confidence interval, obtained by bias-corrected bootstrap methods.
[5] Upper bound of the 95% confidence interval, obtained by bias-corrected bootstrap methods.
* Significant effect at α = 10% level based on standard deviations of MLM method.
** Significant effect at α = 5% level based on standard deviations of MLM method.
*** Significant effect at α = 1% level based on standard deviations of MLM method.
+ Significant effect on the basis of 95% confidence interval, obtained by the bias-corrected bootstrap method.

Finally, in order to summarise the hypothesis testing for each significant effect specified in the model, we present Figure 2 presenting all of the following results.



Significance Level *P value*:P*<0.1, P**<0.05, P***<0.001

Figure 2. Research framework with the validated effect

The analysis and results presented enable us to propose several conclusions and contributions that are discussed in the next section.

Discussion and Research Implications

This research validates the robustness of the use of the TPB in the context of professional social networks as all of its factors have been proven salient and significant.

The attitude factor which is manifested by pursuing e-reputation and social gain enables us to emphasise the instrumental and utilitarian motives of micro-influencers, which demonstrate the rationality characterising their behaviour.

In addition, our research also confirms the salient impact of subjective norms. This result may seem at first glance counter-intuitive and incongruous to what the literature indicates, given that numerous meta-analyses (Armitage & Conner, 2001; Ajzen, 2016) have highlighted the weakness of the factor in the digital context, or even the absence of its effect. Along the same lines, some research suggests that it has either a weak impact on online shopping behaviour (Limayem *et al.*, 2000) or is completely insignificant for online shopping or the continuity of the use of SNSs (Mlaiki *et al*., 2012). This contradiction is due to the contextual nature of our study focusing on micro-influencers, as they are extremely sensitive to normative injunctions related to the community of followers' expectations for their continuous and regular publications. Otherwise, followers' communities may start campaigns to unsubscribe from their micro-influencers.

This research confirms the impact of perceived behavioural control, which, through its variables of self-efficacy and socio-technical factors, contribute to explain micro-influencers' intention to share DBC on social professional networks. This result corroborates the literature since, in the digital context, it has been shown that the perceived control factor has a significant effect on online shopping behaviour (Limayem *et al*., 2000), as well as on the continuity of using Facebook (Mlaiki *et al*., 2012).

To conclude, the verification of the salient impact of these three factors leads to validate the robustness of the use of the TBP in the context of professional social networks, which endorses and makes its use more adapted and preferable to other theories (TRA, TAM, UTAUT, U&G…) in studying similar and related behaviours on the context on professional social networks, (Networking, lurking, Prospecting…). As well as demonstrating its suitability and adaptability to the study of the profile of micro-influencers, marked clearly by the rationality.

On the other hand, this research highlights some contextual motivations that are specific to micro-influencers and professional social networks and it is important to examine and discuss their managerial implications, for both brands and social professional network platforms.

The e-reputation search has revealed to be one of the most decisive motivations for micro-influencers to be involved in intense and regular sharing of DBC. Given this result, developers and web designers must give more importance to the impact of the content posted by Micro Influencers and their regularity, within the functioning of the algorithm of their platforms, in such a way as to promote the organic referencing of micro influencers and respond favourably to their SEO (Search Engine Optimisation) issues, so to encourage them to publish more.

Social motive also significantly influences the intention of micro-influencers to actively share DBC. The impact of this motivation seems to be already checked in the literature specific to the digital context (Butler *et al*., 2004; Wasko & Faraj, 2005; Kankahalii *et al*., 2005; Haikel-Elsabeh, 2014). In this sense, Haikel-Elsabeh (2014) highlights the role of the social motivation in encouraging the content publication on Facebook brand pages. However, our research presents some adaptation of this concept to the specificity of micro-influencers' profile. In fact, if, theoretically, social motivation is defined as the willingness of ordinary members to engage in multiple social interactions and maintain existing relationships (Boyd & Ellison, 2009; Haikel-Elsabeh, 2014; Grissa, 2024a), in our study it is primarily focused on acquiring new fans to expand the community of followers.

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The managerial consequences of such a result suggest that both brand and platform managers should organise and coordinate in such a way as to promote the visibility of micro-influencers on brand pages in order to facilitate their acquisition of new subscribers.

Such visibility can be done through suggestions made to members to subscribe to Micro Influencers' publications, depending on the fit between their specialisation field and the company brand pages/product category.

Always considering the managerial consequences and given the difficulty of establishing a financial partnership, especially for micro-influencers and small businesses, brands must understand how to approach and stimulate this important target in order to fully encourage them in participating spontaneously in DBC campaigns. Our recommendation is that brand managers develop their editorial strategies not only based on the scope of activity generated by the publication but also based on the salient motivations of micro influencers, as revealed in this research. In general, managers must rethink their brand strategies and position micro-influencers as partners, by considering their motivations from a psycho-social perspective.

Conclusion, Limitations and Future Research

This research attempts, from a theoretical perspective, to contribute to the understanding of micro-influencers' behaviour not only by identifying motivations for sharing DBC, but also by revealing additional contextual factors specific to professional networks and the profile of micro-influencers, and this in the B2B context that has clearly received much less attention in the literature compared to the B2C context.

From a managerial perspective too, understanding micro-influencers' behaviour, in the digital age, particularly in the B2B domain, is greatly beneficial. Micro-influencers with their perceived authenticity (Mardon *et al.*, 2023; Audrezet and al., 2018) and their highly engaged and niche audiences (Leung *et al.*, 2022; Influencer Marketing Hub, 2023) present a unique opportunity for brands to rethink, adjust and correctly anticipate the deployment of their influencer marketing strategy for effective engagement in the B2B context, according to the motivations and characteristics of a unique and homogeneous influencer profile, namely micro-influencers. Like any other research work, our study certainly contains some limitations. Therefore, it cannot claim to have the power of norms and laws. We remain aware that our model is not exhaustive and that additional determinants could have been included in the conceptual model. But for practical reasons, we intentionally limited ourselves to the most recurring determinants in the literature and those that would be most appropriate and suitable for influencers in general.

Similarly, when collecting data, we are still conscious of the predominance of the LinkedIn platform over the other professional social networks. But professional social networks' internal

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validity should not be affected by this small sampling problem, as they have similar functioning and navigation mechanisms.

Still on the sampling issue, the composition of our sample is not based on the most rigorous and recommended probabilistic methods, but on the convenience sampling method. The reason for this forced choice is the lack of a reliable sampling base for micro-influencers.

Beyond the above-mentioned limits (i.e. collecting data, sampling method), our research highlights numerous research perspectives that help ensure the continuity and completeness of its results.

First, the continuation of this research may be viewed from a comparative perspective. Indeed, as this research demonstrated the robustness and the adequacy of the conceptual framework for studying the category of professional social networks, it would be interesting to test this model on the SNS category (friendship-oriented social media such as Facebook, TikTok, Snapchat, Instagram). Such a perspective would enable a better understanding of the specificity of the functioning of DBC sharing activity in each of the two categories (professional interest-oriented social media versus friendship-oriented social media). Still using comparative logic, it would also be interesting to test this conceptual model on 'largest influencers' (macro/giga-influencers). Such a perspective can provide a better definition and comparison of these profiles by visualising the change and adaptation adaptations in the hierarchy of motivations for each of the two profiles.

Second, we also strongly encourage studying the engagement drivers of micro-influencers in unfavourable DBC campaigns for firms. This makes it possible to better understand their role in the growth and amplification of boycott phenomenon, and, in particular, to analyse the role of micro-influencers in the creation and reinforcement of the 'Herding Effect' phenomenon during DBC sharing activities that are favourable or unfavourable to brands.

Third, exploring this research from a purely cultural perspective would also be interesting. Consequently, we can apply this model to micro-influencers from two cultures sufficiently differentiated according to Hofstede (2011) (individualistic culture versus collectivist culture) such as China and France. By doing this, it becomes easier to recognise the differences and disparities in the motivations of micro-influencers from both cultures.

Finally, we recommend that future research deepens the analysis of the socio-technical factor behind the intention to share DBC, by focusing on the role of new technologies such as artificial intelligence or technologies like 'Blockchain and/or Recommender System'.

References

Audrezet, A., de Kerviler, G., & Guidry Moulard, J. (2018). Authenticity under threat: When social media influencers need to go beyond self-presentation. *Journal of Business Research*, *117*, 557–569. https://doi.org/10.1016/j.jbusres.2018.07.008

Bagozzi, R., & Heatherton, T. (1994). A general approach for representing multifaceted personality constructs: Application to state self-esteem. *Structural Equation Modeling*, *1*(1), 35–67. https://doi.org/10.1080/10705519409539961

Barreto, A. M. (2014). The word-of-mouth phenomenon in the social media era. *International Journal of Market Research*, *56*(5), 631–654. https://doi.org/10.2501/IJMR-2014-043

Belanche, D., Casaló, L., Marta Flavián, M., & Ibáñez-Sánchez, S. (2021). Understanding influencer marketing: The role of congruence between influencers, products and consumers. *Journal of Business Research*, *132*, 186–195. https://doi.org/10.1016/j.jbusres.2021.04.067

Bentler, P. M., & Bonett, D. G. (1980). Significance tests and goodness-of-fit in the analysis of covariance structures. *Psychological Bulletin*, *88*(3), 588–600. https://doi.org/10.1037/0033-2909.88.3.588

Bô, D., & Somarriba, P. (2020). *Brand Content – Les clés d'une stratégie éditoriale efficace et pérenne*: Les clés d'une stratégie éditoriale efficace et pérenne. Dunod.

Borchers, N. S., & Enke, N. (2021). Managing strategic influencer communication: A systematic overview on emerging planning, organization, and controlling routines. *Public Relations Review*, *47*(3), 102041. https://doi.org/10.1016/j.pubrev.2021.102041

Boyd, D., & Ellison, N. (2007). Social network sites: Definition, history, and scholarship. *Journal of Computer-Mediated Communication*, *13*(1), 210–230. https://doi.org/10.1111/j.1083-6101.2007.00393.x

Brandtzaeg, P. B., & Heim, J. (2011). A typology of social networking sites users. International *Journal of Web Based Communities*, *7*(1), 28–51. https://doi.org/10.1504/IJWBC.2011.038124

Brislin, R. W. (1970). Back-translation for cross-cultural research. *Journal of Cross-Cultural Psychology*, *1*(3), 185–216. https://doi.org/10.1177/135910457000100301

Bun, S., & Alversia, Y. (2020). Incentives and food blogger influence on customer engagement through Instagram. *Advances in Economics, Business and Management Research*, *160*, 21–28. https://doi.org/10.2991/aebmr.k.201124.005

Butler, B., Kiesler, S., & Kraut, R. (2002). Community effort in online groups: Who does the work and why? In S. Weisband & L. Atwater (Eds.), *Leadership at a Distance* (pp. 171–194). Taylor and Francis Group.

Cardon, D. (2008). Le design de la visibilité. Un essai de cartographie du web 2.0. *Réseaux*, *152*(6), 93–137. https://doi.org/10.3917/res.152.0093

Caron, P. (2018). *Modélisation par équations structurelles avec Mplus*. Presses de l'Université du Québec.

Cartwright, S., Davies, I. A., & Archer-Brown, C. (2021). Managing relationships on social media in business-to-business organisations. *Journal of Business Research*, *125*, 120–134. https://doi.org/10.1016/j.jbusres.2020.11.044

Cartwright, S., Liu, H., & Davies, I. A. (2022). Influencer marketing within business-to-business organisations. *Industrial Marketing Management*, *106*, 338–350. https://doi.org/10.1016/j.indmarman.2022.08.018

Casaló, L. V., Flavián, C., & Ibáñez-Sánchez, S. (2020). Influencers on Instagram: Antecedents and consequences of opinion leadership. *Journal of Business Research*, *117*, 510–519. https://doi.org/10.1016/j.jbusres.2018.11.015

Childers, C. C., Lemon, L. L., & Hoy, M. G. (2018). #Sponsored #Ad: Agency perspective on influencer marketing campaigns. *Journal of Current Issues & Research in Advertising*, *40*(3), 258–274. https://doi.org/10.1080/10641734.2018.1526255

Crisafulli, B., Quamina, L.-T., & Singh, J. (2022). Competence is power: How digital influencers impact buying decisions in B2B markets. *Industrial Marketing Management*, *104*, 384–399. https://doi.org/10.1016/j.indmarman.2022.05.009

Dakouan, M. C., & Benabdelouahed, M. R. (2019). Digital inbound marketing: Particularities of business-to-business and business-to-customer strategies. *Strategic Innovative Marketing and Tourism*, *7*(1), 1–6. https://doi.org/10.1007/978-3-030-12453-3_1

Darija, A., Katja, M. K., Matej, Č., & Miha, Š. (2017). Interactive effects of perceived time pressure, satisfaction with work-family balance (SWFB), and leader-member exchange (LMX) on creativity. *Personnel Review*, *46*(3), 662–679. https://doi.org/10.1108/PR-04-2015-0085

De Veirman, M., Cauberghe, V., & Hudders, L. (2017). Marketing through Instagram influencers: The impact of number of followers and product divergence on brand attitude. *International Journal of Advertising*, *36*(5), 798–828. https://doi.org/10.1080/02650487.2017.1348035

De Vries, L., Gensler, S., & Leeflang, P. (2012). Popularity of brand posts on brand fan pages: An investigation of the effects of social media marketing. *Journal of Interactive Marketing*, *26*(1), 83–91. https://doi.org/10.1016/j.intmar.2012.01.003

Dessart, L. (2017). Social media engagement: A model of antecedents and relational outcomes. *Journal of Marketing Management*, *33*(5–6), 375–399. https://doi.org/10.1080/0267257X.2017.1302972

Dholakia, U. M., Bagozzi, R. P., & Pearo, L. K. (2004). A social influence model of consumer participation in network- and small-group-based virtual communities. International *Journal of Research in Marketing*, *21*(3), 241–263. https://doi.org/10.1016/j.ijresmar.2003.12.004

Diba, H., Vella, J. M., & Abratt, R. (2019). Social media influence on the B2B buying process. *Journal of Business & Industrial Marketing*, *34*(7), 1482–1496. https://doi.org/10.1108/JBIM-06-2018-0200

Efron, B., & Tibshirani, R. (1986). Bootstrap methods for standard errors, confidence intervals, and other measures of statistical accuracy. *Statistical Science*, *1*(1), 54–75. https://doi.org/10.1214/ss/1177013815

Farivar, S., Wang, F., & Yuan, Y. (2021). Opinion leadership vs. para-social relationship: Key factors in influencer marketing. *Journal of Retailing and Consumer Services*, *59*, 102371. https://doi.org/10.1016/j.jretconser.2020.102371

Fejlaoui, Y., & Vernette, E. (2009). Repérer les leaders d'opinion dans les communautés virtuelles de consommation: Une nouvelle échelle de mesure. Proceedings of 25th International Conference of the AFM. London, CD-ROM.

Fishbein, M., & Ajzen, I. (1975). *Belief, Attitude, Intention and Behavior: An Introduction to Theory and Research*. Addison-Wesley.

Florenthal, B. (2015). Applying uses and gratifications theory to students' LinkedIn usage. *Young Consumers*, *16*(1), 17–35. https://doi.org/10.1108/YC-12-2013-00416

Folmer, H. (1981). Measurement of the effects of regional policy instruments by means of linear structural equation models and panel data. *Environment and Planning A*, *13*(11), 1435–1448. https://doi.org/10.1068/a131435

Galan, J.-P., & Vignolles, A. (2013). Tweetnographie: Perspectives théoriques et managériales d'un service de microblogging. *Revue Française du Marketing*, *244*, 113–124.

George, J.-F. (2004). The theory of planned behavior and internet purchasing. *Internet Research*, *14*(3), 198–212. https://doi.org/10.1108/10662240410542634

Gerbing, D., & Anderson, J. (1988). An updated paradigm for scale development incorporating unidimensionality and its assessment. *Journal of Marketing Research*, *25*(2), 186–192. https://doi.org/10.2307/3172650

Goldenberg, J., Sangman, H., Lehmann, D., & Hong, J. (2009). The role of hubs in the adoption process. *Journal of Marketing*, *73*(2), 1–13. https://doi.org/10.1509/jmkg.73.2.1

Grissa, K. (2016). What makes opinion leaders share brand content on professional networking sites (e.g., LinkedIn, Viadeo, Xing, Skilled Africans…). International Conference on Digital Economy, Carthage, 8–15.

Grissa, K. (2020). Les determinants de partage de brand contend digital par les leaders d'opinion numerous sur les reseaux semi-professionals [Doctoral dissertation, Université de Poitiers, France].

Grissa, K. (2024a). Studying the drivers of sharing digital brand content by micro-influencers: A multicultural perspective between French and English speaking countries. American Marketing Association (AMA-GMSIC), 25–26 May 2024, Verona, Italy.

Grissa, K. (2024b). How to make influencers participating in spontaneous digital brand content campaigns in B2B context. Proceedings of Finnish Academy Marketing Conference (FAMAC 2024), Helsinki, 11–23.

Haikel-Elsabeh, M. (2014). Understanding brand implication and engagement on Facebook. In J. Pellet & P. Papadopoulou (Eds.), *User Behavior in Ubiquitous Online Environments* (pp. 216–237). IGI Global. https://doi.org/10.4018/978-1-4666-4566-0.ch011

Haikel-Elsabeh, M., Zhao, Z., Ivens, B., & Brem, A. (2019). When is brand content shared on Facebook? A field study on online word-of-mouth. *International Journal of Market Research*, *61*(3), 287–301. https://doi.org/10.1177/1470785318805301

Hanafi Zadeh, P., & Shafia, S. (2021). Appropriate social media platforms commensurate with the maturity of organizations. *Journal of Telecommunications and the Digital Economy*, *9*(3), 12–57. https://doi.org/10.18080/jtde.v9n3.405

Hofstede, G. (2011). Dimensionalizing cultures: The Hofstede model in context. *Online Readings in Psychology and Culture*, *2*(1), 1–26. https://doi.org/10.9707/2307-0919.1014

Hollebeek, L. D., & Macky, K. A. (2019). Digital content marketing's role in fostering consumer engagement, trust, and value: Framework, fundamental propositions, and implications. *Journal of Interactive Marketing*, *45*, 27–41. https://doi.org/10.1016/j.intmar.2018.07.003

Hu, L.-T., & Bentler, P. (1995). Evaluating model fit. In R. Hoyle (Ed.), Structural Equation Modeling: Concepts, Issues, and Application (pp. 76–99). Sage.

Hubspot. (2021). Drive revenue high-quality leads. Retrieved December 20, 2022, from https://www.hubspot.fr/use-case/drive-revenue-high-quality-leads

Hughes, C., Swaminathan, V., & Brooks, G. (2019). Driving brand engagement through online social influencers: An empirical investigation of sponsored blogging campaigns. *Journal of Marketing*, *83*(5), 78–96. https://doi.org/10.1177/0022242919854374

Huotari, L., Akinyemi, P., Saraniemi, S., & Malaka, M. (2015). Analysis of content creation in social media by B2B companies. *Journal of Business & Industrial Marketing*, *30*(6), 761–770. https://doi.org/10.1108/JBIM-05-2013-0121

Iankova, S., Davies, I., Archer-Brown, C., Marder, B., & Yau, A. (2019). A comparison of social media marketing between B2B, B2C and mixed business models. *Industrial Marketing Management*, *81*, 169–179. https://doi.org/10.1016/j.indmarman.2018.01.001

Influencer Marketing Hub. (2025). Influencer Marketing Benchmark Report: 2025. Retrieved January 28, 2025, from https://influencermarketinghub.com/influencer-marketing-benchmark-report/

Jamshidian, M., & Jalal, S. (2010). Tests of homoscedasticity, normality, and missing at random for incomplete multivariate data. *Psychometrika*, *75*(4), 649–674. https://doi.org/10.1007/s11336-010-9175-3

Jayasinghe, S., & Venkatesh, R. (2015). Customer engagement factors in Facebook brand pages. *Asian Social Science*, *11*(26), 19–29. https://doi.org/10.5539/ass.v11n26p19

Kankanhalli, A., Tan, B., & Wei, K. (2005). Contributing knowledge to electronic knowledge repositories: An empirical investigation. *MIS Quarterly*, *29*(1), 113–143. https://doi.org/10.2307/25148669

Kaplan, A., & Haenlein, M. (2010). Users of the world, unite! The challenges and opportunities of social media. *Business Horizons*, *53*(1), 59–68. https://doi.org/10.1016/j.bushor.2009.09.003

Karlsen, R. (2015). Followers are opinion leaders: The role of people in the flow of political communication on and beyond social networking sites. *European Journal of Communication*, *30*(3), 301–318. https://doi.org/10.1177/0267323115577305

Katz, E., & Lazarsfeld, P. F. (1955). *Personal Influence: The Part Played by People in the Flow of Mass Communications*. Free Press.

Kim, D. Y., & Kim, H. Y. (2021). Trust me, trust me not: A nuanced view of influencer marketing on social media. *Journal of Business Research*, *134*, 223–232. https://doi.org/10.1016/j.jbusres.2021.05.034

Leung, F. F., Gu, F. F., Li, Y., Zhang, J. Z., & Palmatier, R. W. (2022). Influencer marketing effectiveness. *Journal of Marketing*, *86*(6), 93–115. https://doi.org/10.1177/00222429221102889

Limayem, M., Khalifa, M., & Frini, A. (2000). What makes consumers buy from internet? A longitudinal study of online shopping. *IEEE Transactions on Systems, Man, and Cybernetics*, *30*(4), 421–432. https://doi.org/10.1109/3468.852435

Mardia, K. V. (1970). Measures of multivariate skewness and kurtosis with applications. *Biometrika*, *57*(3), 519–530. https://doi.org/10.1093/biomet/57.3.519

Mardon, R., Cocker, H., & Daunt, K. (2023). When parasocial relationships turn sour: Social media influencers, eroded and exploitative intimacies, and anti-fan communities. *Journal of Marketing Management*, *39*(13–14), 1132–1162. https://doi.org/10.1080/0267257X.2023.2187162

Marett, K., & Joshi, K. D. (2009). The decision to share information and rumors: Examining the role of motivation in an online discussion forum. *Communications of the AIS*, *24*(1), 47–66. https://doi.org/10.17705/1CAIS.02404

McEachan, R., Conner, M., Taylor, N., & Lawton, R. (2011). Prospective prediction of health-related behaviours with the theory of planned behaviour: A meta-analysis. *Health Psychology Review*, *5*(2), 97–144. https://doi.org/10.1080/17437199.2010.521684

Mero, J., Vanninen, H., & Keränen, J. (2023). B2B influencer marketing: Conceptualization and four managerial strategies. *Industrial Marketing Management*, *108*, 79–93. https://doi.org/10.1016/j.indmarman.2022.11.003

Mlaiki, A., Kefi, H., & Kalika, M. (2012). Facteurs psychosociaux et continuité d'utilisation des réseaux sociaux numériques: Le cas de Facebook. *Revue Recherches en Sciences de Gestion-Management Science*, *92*, 83–111.

Muthén, L., & Muthén, B. O. (2015). *Mplus User's Guide* (7th ed.). Muthén & Muthén.

Ouvrein, G., Pabian, S., Giles, D., Hudders, L., & De Backer, C. (2021). The web of influencers: A marketing-audience classification of (potential) social media influencers. *Journal of Marketing Management*, *37*(13–14), 1313–1342. https://doi.org/10.1080/0267257X.2021.1912142

Papacharissi, Z., & Mendelson, A. (2011). Toward a new(er) sociability: Uses, gratifications, and social capital on Facebook. In S. Papathanassopoulos (Ed.), *Media Perspectives for the 21st Century* (pp. 212–230). Routledge.

Paulssen, M., & Roulet, R. (2017). Social bonding as a determinant of share of wallet and cross-buying behaviour in B2B relationships. *European Journal of Marketing*, *51*(5/6), 1011–1028. https://doi.org/10.1108/EJM-07-2015-0450

Ping, R. A., Jr. (2004). On assuring valid measures for theoretical models using survey data. *Journal of Business Research*, *57*(2), 125–141. https://doi.org/10.1016/S0148-2963(01)00297-1

https://doi.org/10.18080/jtde.v13n1.1082

Raghupathi, V., & Fogel, J. (2015). The impact of opinion leadership on purchases through social networking websites. *Journal of Theoretical and Applied Electronic Commerce Research*, *10*(3), 18–29. https://doi.org/10.4067/S0718-18762015000300003

Ruspil, T., Bertrandias, L., & Vernette, E. (2016). Proposal for a new conceptualization of e-opinion leadership on online social networks? EMAC Proceedings, 46th Conference, Oslo.

Satorra, A., & Bentler, P. M. (1994). Corrections to test statistics and standard errors in covariance structure analysis. In A. von Eye & C. C. Clogg (Eds.), *Latent Variable Analysis: Applications to Developmental Research* (pp. 399–419). Sage.

Smith, D., Jacobson, J., & Rudkowski, J. (2021). Employees as influencers: Measuring employee brand equity in a social media age. *Journal of Product & Brand Management*, *30*(6), 834–853. https://doi.org/10.1108/JPBM-02-2020-2758

Soegoto, E., & Simbolon, T. (2018). Inbound marketing as a strategy in digital advertising. Proceedings of IOP Conference Series: Materials Science and Engineering, 407, 012153. https://doi.org/10.1088/1757-899X/407/1/012153

Sokolowski, K., Schmalt, H. D., Langens, T. A., & Puca, R. M. (2000). Assessing achievement, affiliation, and power motives all at once: The Multi-Motive Grid (MMG). *Journal of Personality Assessment*, *74*(1), 126–145. https://doi.org/10.1207/S15327752JPA740109

Stenger, T., & Coutant, A. (2013). Médias sociaux: Clarification et cartographie pour une approche sociotechnique. *Décisions Marketing*, *70*(24), 107–117. https://doi.org/10.7193/DM.070.107.117

Taiminen, K., & Ranaweera, C. (2019). Fostering brand engagement and value-laden trusted B2B relationships through digital content marketing. *European Journal of Marketing*, *53*(9), 1759–1781. https://doi.org/10.1108/EJM-10-2017-0790

Terho, H., Mero, J., Siutla, L., & Jaakkola, E. (2022). Digital content marketing in business markets: Activities, consequences, and contingencies along the customer journey. *Industrial Marketing Management*, *105*, 294–310. https://doi.org/10.1016/j.indmarman.2022.06.006

Turcotte, J., York, J., Irving, J., Scholl, R., & Pingree, R. (2015). News recommendations from social media opinion leaders: Effects on media trust and information seeking. *Journal of Computer-Mediated Communication*, *20*(5), 520–535. https://doi.org/10.1111/jcc4.12127

Vasquez-Reyes, B., Bravo-Martinez, M., Coral-Morante, J., & Cordova-Buiza, F. (2023). Inbound marketing strategy on social media and the generation of experiences in fast food consumers. *Innovative Marketing*, *19*(2), 143–154. https://doi.org/10.21511/im.19(2).2023.13

Wang, Y. (2016). The influence of opinion leaders towards consumer information adoption in the virtual communities of consumption. In Proceedings of DEStech Transactions on Economics, Business and Management (pp. 444–452). DEStech Publications.

Wasko, M., & Faraj, S. (2005). Why should I share? Examining social capital and knowledge contribution in electronic networks of practice. *MIS Quarterly*, *29*(1), 35–57. https://doi.org/10.2307/25148667

https://doi.org/10.18080/jtde.v13n1.1082

Wellman, M. L., Stoldt, R., Tully, M., & Ekdale, B. (2020). Ethics of authenticity: Social media influencers and the production of sponsored content. *Journal of Media Ethics*, *35*(2), 68–82. https://doi.org/10.1080/23736992.2020.1736078

Wu, W.-Y., & Sukoco, B. (2010). The personal and social motivation of customers' participation in brand community. African Journal of Business Management, *5*(1), 770–778.

Yuan, C., Moon, H., Kim, K. H., Wang, S., & Yu, X. (2020). Third-party organization endorsement impacts on perceived value and B2B customer loyalty. Industrial Marketing Management, 90, 221–230. https://doi.org/10.1016/j.indmarman.2020.07.005

Appendices

Appendix 1. Summary of qualitative research

	Frequency (verbatims)	**Relative frequency (%)**
Interest in the content	74	22%
Positioning oneself as expert	56	17%
Motivational/informational Dimension	53	16%
Motivation/social dimension	47	14%
Technical incentives	38	11%
Anticipation of return on publication	27	8%
Time pressure (-)	17	5%)
Seeking to be different/narcissism/ego enhancement	10	3%)
Visibility on internal network search engine	9	3%
Fear of shocking others (-)	4	1%

Appendix 2. Sample composition

	Gender	**Audience size (number of subscribers)**	**Influence score (scale from 0 to 100)**	**Activity area**
Sample features	• 68% Men • 32% Women	• [10 to 20k]: 12% of the sample • [20 to 30k]: 23% • [30 to 50k]: 44% • [50 to 100k]: 22%	• a score above 70: 9% of the composed sample • [60–70]: 72% of the composed sample • [55–60]: 19% of the composed sample	• 42% training and coaching • 28% consulting, surveys and advices service • 19% sale of computer, technological and office equipment • 11% others: (industrial engineers, R&D, research organisations, etc.)

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Appendix 3. Response rate based on survey administration

Survey administration channel	Response rate
Specialised groups across social professional networks	39%
Influencer LinkedIn (member with Influencer Badge)	16%
Content aggregators like LinkedIn Pulse	45%

Appendix 4. Measurement scale

VARIABLES	Measurement scales adapted from:
e-reputation seeking	Wasko & Faraj (2005)
Information motives	Dholakia et al. (2004)
Social Motives	Butler et al. (2002)
Reciprocity	Haikel-Elsabeh (2014)
Power motive	Sokolowski et al. (2000)
Normative influence	Marett & Joschi (2009)
Self-efficacy	Kankahalii et al. (2005)
Time pressure	Darija et al. (2017)
Facilitating conditions for sharing DBC	Single item for each variable
Intention sharing content	Marett & Joshi (2009)

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How Travel Agencies Innovate their Business Models

The Role of Artificial Intelligence and Market Automation

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Abstract: Although artificial intelligence (AI) technologies have considerable potential to solve various problems, there are still many challenges related to a lack of knowledge on how to strategically use these technological advances in order to innovate the business model. This research aims to explore the role of AI and marketing automation (MA) in business model innovation in the Tunisian tourism sector. We employed a dual qualitative approach, integrating 16 semi-structured interviews and six projective techniques, both conducted with travel agency managers. The resulting framework presents three phases of the business model (BM). In the first phase, the classic BM, based on the knowledge-based view (KBV), integrates business strategy, market positioning and organisational culture. In the second phase, this traditional BM evolves into a dynamic BM by modifying its components. Thus, the BM is adapted through digital offerings and customer value creation. The final phase is BM innovation, driven by the integration of AI and MA. The obtained results also highlight several barriers to the adoption of these technologies, such as trust-related issues, technology fusion, and the availability of resources and market challenges that hinder the transition from Phase 1 to Phase 3.

Keywords: Artificial intelligence, Marketing Automation, Business Model, Dynamic Business Model, Business Model Innovation

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Introduction

Over the past two decades, there has been a rapid development of the theory of business models (BMs), generating significant interest among academics and business leaders (Andreini *et al.*, 2022; Kanbach *et al.* 2024). Business model (BM) innovation using modern digital technologies is crucial for enhancing companies' commercial potential (Sabatini *et al.*, 2022). Industries are currently embracing advanced technologies across various functional areas and business operations, particularly in marketing, leading to a significant impact on the internal operations and functionalities of a company (Hicham *et al.*, 2023; Singh *et al.*, 2022). Among emerging technologies, AI has taken centre stage, garnering significant attention from both researchers and business organisations (Panetta, 2018). Davenport (2018) argued that AI represents the most disruptive technological force currently shaping industries. Likewise, Borges *et al.* (2021) identified AI as the most critical general-purpose technology of our time.

AI's role in BM innovation has revolutionised industries (Centobelli *et al.*, 2020; Wåge & Crawford, 2020), particularly in tourism sectors where it enhances service delivery and supports economic growth in developing countries (Buhalis, 2020; Dwivedi *et al.*, 2023; Mpofu, 2024).

The World Tourism Organization (UNWTO, 2021) highlighted that international tourist arrivals dropped by around 85% in 2021 compared to 2019, while accommodation businesses and travel agencies recorded a decline in turnover of 9.3% (Palazzo *et al.*, 2022). In addition, according to a report written by the Arab Institute of Business Leaders and the Tunisian National Tourist Office, 80% of hoteliers reported a 50% loss in revenue in 2021 (ONTT report). This decline was due to the COVID-19 pandemic that triggered economic crises around the world and seriously affected the tourism sector (Palazzo *et al.*, 2022).

The volatility caused by recent crises has created significant challenges in anticipating and responding to demand fluctuations (Drammeh, 2024). As a result, the tourism sector is increasingly turning to intelligent tools for effective demand management. These tools primarily rely on unstructured data in the form of voice, text and video (Cai *et al.*, 2022, Côté & Su, 2021). For example, voice-based AI systems like Google Assistant and Amazon Alexa assist customers by processing spoken language, providing real-time support and tailored responses. Similarly, text-based tools, such as chatbots on platforms like Kayak and Booking.com, use natural language processing to manage bookings and provide personalised recommendations (Côté & Su, 2021; Rafiq *et al.*, 2022). Furthermore, AI-powered robots, such as Watson-enabled concierge robots and service robots like Dash, enhance guest experiences by automating tasks like check-in, room service and customer engagement

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(Doborjeh *et al.*, 2022). This automation not only improves production management but also streamlines operations, leading to more efficient and personalised services for guests. Moreover, these technologies are expected not only to transform communication, advertising, payment and booking systems, service delivery, productivity, efficiency, as well as profitability in the tourism sector (Mpofu, 2024), but also to accelerate the shift towards Marketing 4.0 (Yakut, 2022).

However, despite its growing significance, AI remains the least understood technology. It is emerging as a key catalyst for BM innovation and represents a major technological advance (Lee *et al.*, 2019). The advent of AI has vast potential to completely revolutionise the world of marketing (Hicham *et al.*, 2023) and render marketing solutions more effective than ever. Based on AI, marketers can automate routine tasks (Kotler *et al.*, 2021), process vast amounts of data, conduct personalised sales, meet customer expectations, develop effective marketing strategies (Hicham *et al.*, 2023) and make appropriate decisions (Sahebi *et al.*, 2022). The processing of these large volumes of data and the customisation of customer needs using AI can help companies adjust and innovate their BMs.

Despite the visible and considerable impact of AI on a wide range of industries, including healthcare, transportation, agriculture, education, and urban development (Păvăloaia & Necula, 2023), research on its direct effect on BM innovation remains scarce (for example, Kanbach *et al.*, 2024; Reim *et al.*, 2020; Saleem, 2024). This research addresses a specific theoretical gap: the adoption of AI and MA in the process of BM innovation, particularly within Tunisian travel agencies. While existing studies on AI adoption in the hospitality and tourism sectors are limited (Huang *et al.*, 2022; Mohiuddin, 2024), these sectors hold significant potential for improving economic growth and boosting gross domestic product (Sahebi *et al.*, 2022). Tunisian travel agencies, as a case study, are relevant due to the country's strategic reliance on tourism as a key driver of economic performance. However, these agencies face challenges in adopting their BMs to integrate AI and MA. Thus, the present study aims to explore the role of AI and MA used by Tunisian travel agencies based on the KBV of BM innovation. This research addresses the following research question:

> How are travel agencies innovating their BM using both AI and MA?

The rest of this paper is structured as follows: In section 2, we review the related works suggested in the literature. In section 3, we illustrate the proposed methodology. Finally, in section 4, we summarise the key findings, discuss the obtained results, present implications and highlight major directions for future research.

Theoretical Background

This section examines the foundational theories and key concepts underpinning this study.

New technology adoption: Theoretical frameworks and explanatory models

TAM and UTAUT

With the advancement of technology, particularly in AI and task automation, the decision to accept or reject these innovations remains difficult. According to the Technology Acceptance Model (TAM), two key variables – perceived ease of use and perceived usefulness – play a significant role in facilitating users' adoption of new technologies (Kanungo *et al.* 2024; Marangunić & Granić, 2015). Building on this, the Unified Theory of Acceptance and Use of Technology (UTAUT) introduces additional constructs, such as facilitating conditions, which explain how environmental support influences the use of technology. Furthermore, social influence highlights the impact of others' opinions on the adoption of new tools, reinforcing the importance of ease of use and performance expectancy (Sohn & Kwon, 2020; Ahmad, 2015).

Knowledge-based theory (KBV)

KBV has been of significant interest in knowledge integration. It refers to the process of applying or sharing specific knowledge to create new knowledge (Kogut & Zander, 1992). Researchers have developed expert systems and other knowledge-intensive computer programs to manage knowledge and find solutions to different problems. Knowledge management systems, as the fundamental components of AI, have been developed to facilitate knowledge integration. Additionally, AI applications are generally best suited for acquiring explicit knowledge. Overall, KBV highlights the pivotal role of automation in the production, codification, transfer and application of knowledge. This, in turn, enables a more comprehensive understanding of consumer needs and behaviours across diverse devices, platforms and products (Seranmadevi & Kumar, 2019).

Business Model Innovation Based on Artificial Intelligence

Foss & Saebi (2018) defined BM innovation as 'designed, novel and nontrivial changes to the key elements of a firm's BM and the architecture linking these elements' (page 13). BM innovation can also be described as a mediating construct between technology and economic value and can thus be understood as the mechanism that transforms digital applications into profitable outcomes (Reim *et al.*, 2022).

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AI enhances operations by identifying and maximising business outcomes (Manogaran *et al.*, 2021). Lindgren (2016) extended this view by asserting that firms must implement advanced technologies, such as AI to stay competitive. Different studies have recently investigated the influence of generative AI on BMs (Kanbach *et al.*, 2024). Other researches have presented the difference between the BMs of AI firms and traditional IT organisations in order to better explain how AI can contribute to innovation (Widayanti & Meria, 2023). Furthermore, Sjödin *et al.* (2023) examined the AI capabilities to help circular BM innovation for industrial manufacturers and capacities needed for commercialisation.

The role of AI and MA in Industry 4.0

In the context of Industry 4.0, Papadopoulos *et al.* (2017) classified digital technologies into three main categories based on their function: data collection, for example, sensors, RFID, IoT, cyber-physical systems (Gligoric *et al.*, 2019), data integration, for example, cloud computing, blockchain (Ardolino *et al.*, 2018) and data analysis, for example, big data and AI (Soroka *et al.*, 2017).

In the digital age, embracing AI is crucial for companies (Limna, 2023; Mednini *et al.*, 2024), as it enables them to optimise BMs and improve organisational performance (Berman, 2012). Huang & Rust (2018) viewed AI as 'machines that exhibit aspects of human intelligence'. According to marketing studies, Longoni *et al.* (2019) explained this technology as 'any machine that uses any kind of algorithm or statistical model to perform perceptual, cognitive, and conversational functions typical of the human mind'.

In this context, MA has emerged as a strategic tool for businesses. It relies on cloud-based software to execute and streamline marketing processes (Gartner, 2022 cited by Guercini, 2023). By transforming repetitive tasks into performance-driven automated applications (Lyu *et al.*, 2023), it covers various areas such as marketing analytics, inventory and customer information management, budgeting and planning (Shuai *et al.*, 2016). According to Grimaldi (2016), MA's goal is to optimise marketing management by systematically separating strategic functions from operational activities. Furthermore, the KBV emphasises that MA contributes to building a comprehensive knowledge base on customer engagement behaviour, fostering innovation and enhancing business competitiveness (Fernandes *et al.*, 2022; Elhajjar *et al.*, 2023).

Methodology

Our research aims to explore the role of both AI and MA in the innovation of BMs used by Tunisian travel agencies. We conducted semi-structured interviews and we employed projective techniques. In fact, in the Tunisian context, new technologies represent particularly relevant new dynamics, as evidenced by the *Government AI Readiness Index* report (2022), which showed that the country ranked 4th at the continental level and 70th in the world.

This ranking displays Tunisia's readiness to adopt and exploit AI technologies. This favourable position indicates that the country has infrastructure, policies and resources conducive to the integration of these technologies in various sectors, including tourism.

Data collection and sampling

In this study, we conducted 16 semi-structured interviews to deepen our understanding of themes identified in the literature, including the role of AI and MA in the innovation of BMs used by Tunisian travel agencies. The characteristics of the interviewees and the duration of the interviews are presented in Appendix 1. Semi-structured interviews offer flexibility in formulating questions (Henriksen *et al*., 2022) and allow the researcher to explore topics in depth, while adjusting questions based on participants' responses. This is particularly relevant in contexts where prior knowledge is limited or exploratory (Kallio *et al*., 2016). Furthermore, we used projective techniques by asking six travel agency managers to complete sentences and we were able to access their deepest thoughts. The characteristics of the managers are presented in Appendix 2. These techniques are particularly useful for revealing opinions or perceptions that are often unintentionally difficult to express directly (Qazi *et al*., 2022).

The sampling method employed a purposive sampling approach, selecting participants based on their expertise and experience relevant to the research question (Easterby-Smith *et al*., 2021; Giannelloni & Vernette, 2012, page 285). This method ensures the reliability of the responses, which are closely aligned with the study's objectives, as highlighted by Curtis *et al*. (2000).

We applied the two sampling principles of diversification and saturation for the qualitative research design (Blanchet & Gottman, 1992). Diversification was respected, following Michelat's (1975) recommendations. The sample size was determined based on the principle of data saturation, where data collection continued until no new insights or themes emerged from the interviews (Guest *et al*. 2020). Furthermore, we created our interview guide and designed incomplete sentences in order to align and address our research objectives, as illustrated in Appendices 3 and 4.

Data analysis

In order to analyse our qualitative data, all interviews and projective techniques were recorded and transcribed. Based on Braun & Clarke (2006), our data analysis was carried out using

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NVivo 10 and followed six different steps, namely (1) familiarising with the data, (2) generating initial codes, (3) looking for themes, (4) reviewing themes, (5) defining and identifying themes and (6) creating the report. To examine its scope and detail, we first scrutinised the data gathered from interviews and projective tools. Then, we systematically organised our data and directly generated initial codes, which would be then analysed to explore the way they can be categorised into broader themes. Afterwards, we reviewed the coded data for each theme by depicting consistent patterns. During the data analysis process, our data themes are defined and clarified to capture their meanings. Furthermore, we identified relevant sub-themes in order to enhance their structure, as demonstrated in Appendix 5. Finally, we documented the overall analysis process and its outcomes in a detailed report (Kumar, 2022).

Results and Discussion

This section focuses on a discussion of the findings from the interviews and projective techniques.

AI advantages

We first noticed that a considerable percentage of the interviewees (62.39%) used AI in business practices. These managers believe that AI has a positive effect on working conditions and that they are called upon to enhance the AI opportunities by anticipating their impact on the human factor. This aligns with facilitating conditions, one of the key factors in the UTAUT model (Sohn & Kwon, 2020). Saving time is one of the most commonly cited advantages of this technology. Indeed, the technical assistance offered by chatbots frees up employees to concentrate on other high value-added tasks. In this respect, one manager has articulated his idea as follows:

> AI allows us to save valuable time and focus our efforts on higher value-added activities. Ultimately, this helps increase our productivity and improve the quality of our services for our customers. (Network Director, 16 years of experience)

According to the Technology Acceptance Model (TAM), perceived usefulness and ease of use are essential factors influencing technology adoption. According to Otto *et al.* (2024), findings demonstrate a range of attitudes toward AI adoption, with the AI feedback system generally receiving positive evaluations.

The second advantage is the improvement of marketing performance and the strengthening of competitive position by offering the customer a virtual experience of their trip. Using software based on either virtual reality or augmented reality, these agencies offer their customers a concrete preview of their services. This personalisation helps strengthen

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commitment to the travel agency, distinguishing it from its competitors, building customer loyalty and attracting new customers. This perspective allows these agencies to increase their sales and improve their reputations. As shown by Guo (2020) and Tuo *et al.* (2021), AI enables tourism organisations to personalise experiences through virtual tours and language translation services, making travel more accessible and enjoyable for international tourists.

In other sectors, retail giants such as Walmart and Amazon are using AI to facilitate dynamic pricing, inventory management and personalised recommendations through chatbots and virtual assistants, who improve customer services by answering questions and offering product recommendations (Nagalakshmi & Reddy, 2024). In this context, a director stated that:

> AI enables us to analyze customer data in order to understand their preferences, purchasing behaviors, and specific needs. This will not only allow us to remain competitive in the market, but also provide an exceptional customer experience, which can increase customer satisfaction and sales. (Human Resource Director 1, 17 years of experience)

Marketing automation

A significant percentage of the respondents using AI in their operations (79.7%) utilised MA, which is a widespread norm perceived as a natural evolution of marketing and one of the most requested tools (for example, targeted emails, ads and CRM). As Hoffman *et al.* (2022) demonstrated, the MA software allows marketers to adaptively respond to the behaviours of customers, competitors and influencers, producing effective proposals and identifying preferences. AI, as elucidated by a manager:

> has an effect on automation because the requests that come from the site are automatically integrated into CRM, which is directly connected to emails for follow-up to remind travelers who have been set up automatically on the calendar or task software. (Manager 1, 15 years of experience)

Although MA takes forms based particularly on CRM, there are other more advanced forms based on digitalisation, like AI. Indeed, more than 70% of AI-using respondents develop MA through using machine learning. From this perspective, Ritter & Pedersen (2020) proclaimed that both MA and AI are two essential elements in business processes. From a marketing perspective, as in other disciplines, 'the boundaries between humans and computers in decision-making are evolving' (Stone *et al.*, 2020). Potentially, AI (for example, machine learning) can have a significant impact on marketing activities, such as online advertising, programmatic advertising, e-commerce or recommendation engines through chatbots (Guercini, 2023; Ilzetzki & Jain, 2023). In this regard, a manager contended that:

> when it comes to MA, AI allows the company to automate many marketing tasks, such as sending promotional emails, managing social media, and tracking advertising campaigns. This frees up time and resources, which can be reinvested in innovation and the development of new products and services. (Manager, 26 years of experience)

BM, dynamic BM and BM innovation

The effect of digitalisation on BM revealed that travel agencies using AI and MA bring innovations to their BM by making the classic BM more dynamic and subsequently innovative.

> AI and MA greatly facilitate many tasks and replace manual methods with more precise, insightful, and innovative approaches. In my opinion, they create a more dynamic BM. (Manager, 11 years of experience)

> The integration of AI and MA is a real innovation in our field. These technologies directly influence our BM. (Marketing director)

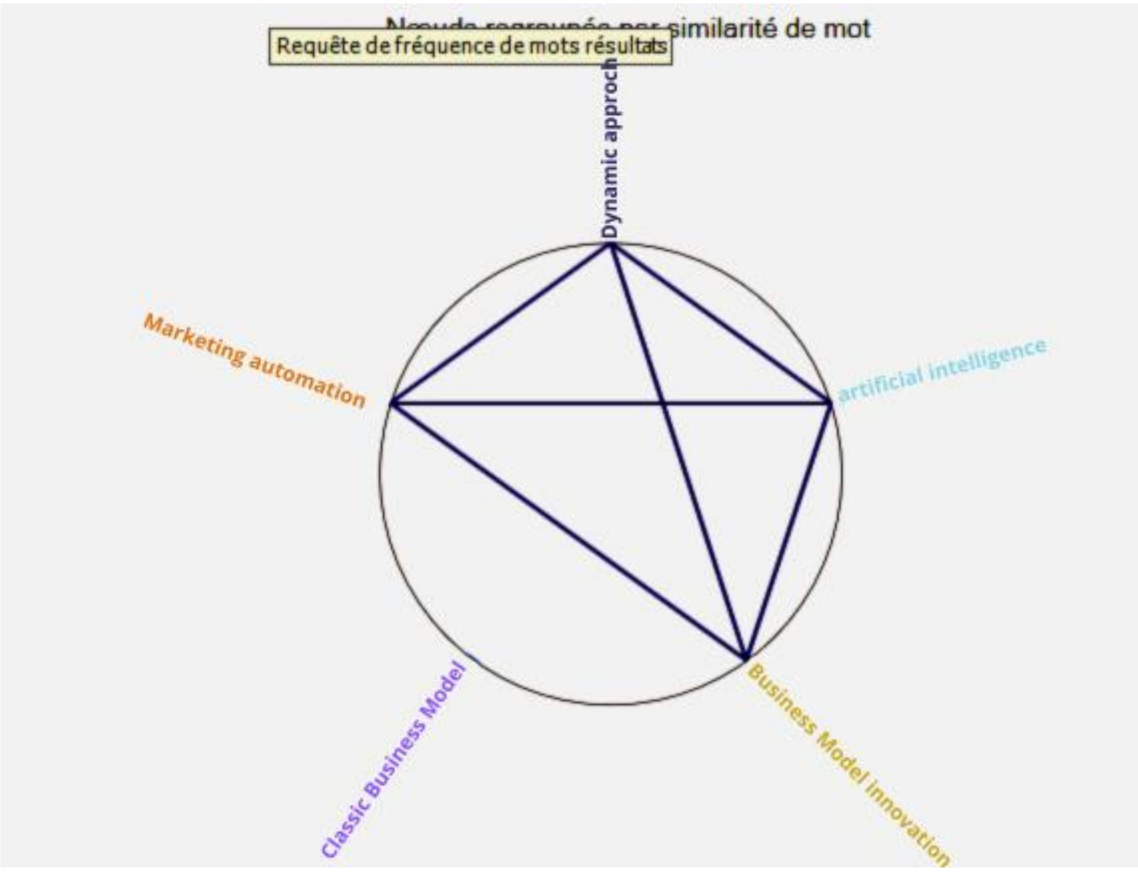

Figure 1. Relationship between the classic BM, dynamic BM, BMI, AI and MA (figure designed by the authors)

According to Figure 1, there is a relationship between the classic BM, dynamic BM, BMI, AI and MA. This link can be explained by the commercial and technological evolution. Indeed, based on structured interviews and projective techniques, the classic BM relies on traditional marketing strategies and direct customer relationships. The dynamic BM, however, adapts to changes in market demand. It is based on flexibility and speed in the face of these changes, thus allowing innovation and the creation of new values. For instance, two other views can be illustrated as follows:

> We have modernized our BM by making it dynamic and innovative while remaining faithful to our commitments to quality and customer satisfaction. (Marketing director, 22 years of experience)

According to travel agency managers, AI is a fundamental pillar that innovates the classic BM (for example, intelligent chatbots, personalised recommendations and virtual reality experiences), seizes opportunities and anticipates the constraints of a constantly evolving market. Arnold (2024) confirmed this finding by stating that this embryonic technology is evolving rapidly, leading to a significant impact on BMI. Organisations, such as Airbnb, Uber, eBay, Amazon, etc. have integrated AI to innovate and develop their BMs (Mishra & Tripathi, 2020, 2021).

> The integration of AI and MA is a real innovation in our field. These technologies directly influence our BM. (Manager, 12 years of experience)

> The use of automation tools and AI allows us to better understand customer behavior and preferences. This allows us to offer personalized offers adapted to the specific needs of travelers, thus increasing customer satisfaction and loyalty. This dynamic personalization makes the BM more responsive and customer-centric. (Human resource director)

Thus, both travellers and managers acknowledge the acceptance of using AI and automation tools in travel agency tasks. Consistent with the UTAUT, this framework aids in identifying the factors influencing acceptance, facilitating the implementation of proactive measures such as customised marketing strategies, according to Thaker *et al.* (2020).

To explain the relationship between concepts illustrated in Figure 1, MA allows to create fully personalised customer journeys, manage huge volumes of data in real time (Jarrahi *et al.*, 2023), and exploit machine learning algorithms in order to anticipate customer needs using machine learning (Tuo *et al.*, 2021). The latter offers novelties and innovations in the organisational strategy and subsequently at the BM level (Gebauer *et al.*, 2020).

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Challenges of AI and MA

Despite the advantages of adopting these technologies, 37.61% of the interviewees were reluctant to use AI and 20.3% of those who do not use AI did not work with MA. This scepticism can be explained by the fact that these respondents are small travel agency managers with limited knowledge of AI and MA. According to the Technology Acceptance Model (TAM), perceived usefulness and perceived ease of use are key determinants of technology adoption (Kanungo *et al.*, 2024). However, many respondents view AI and MA as complex and difficult to implement, which negatively affects their willingness to adopt these technologies.

Moreover, managers are worried that AI will not only replace employees with robots, as the concept of the travel agency is mainly based on direct contact with the customer, but will also compromise this essential interaction and jeopardise the entire concept of the traditional agency. This fear aligns with the effort expectancy component of UTAUT (Sohn and Kwon, 2020), as the transition to AI-based services may require significant behavioural change and adaptation.

Another challenge mentioned by our respondents is related to the protection of privacy and personal data. Indeed, AI requires rigorous supervision to ensure that it is used ethically (Dwivedi *et al.*, 2023). Some managers' statements are illustrated as follows:

> The major challenge is the appropriate use of these technologies, that is, using data in an ethical and responsible manner to provide an added value to customers without compromising their privacy. Another technical challenge is the use of these technologies since they require specialized expertise. (Manager with five years of experience)

> Adopting advanced technologies, such as AI and MA, requires a significant financial investment. Our travel agency, like various mid-sized agencies, faces budget constraints related to software, staff training, and maintenance of these new technologies. (Manager)

Evolution of the business model through AI and MA

Based on our results, we propose the following diagram (Figure 2) that illustrates the progression of the BM first toward a dynamic BM and then BMI facilitated by the integration of both AI and MA.

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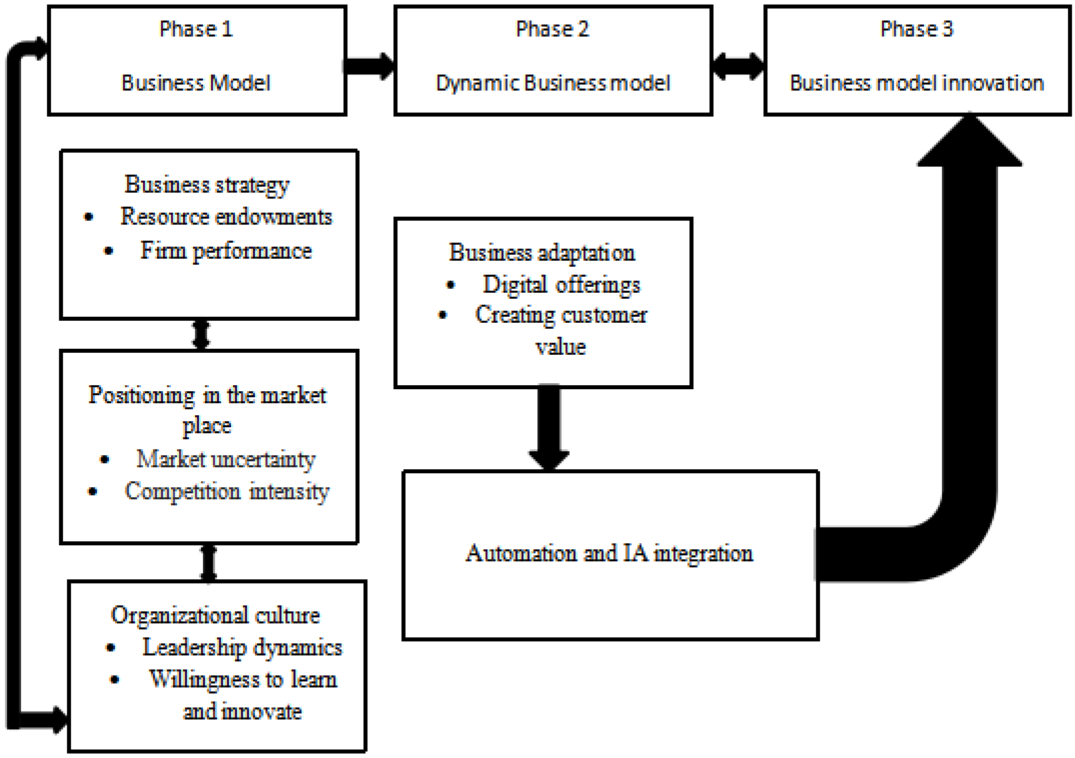

Figure 2. The effect of AI and MA on BMI (table designed by the authors)

This theoretical framework diagram explains the transition from a BM to an AI-based BMI and MA. The starting point is the BM as it describes and explains how a company operates and generates revenue. The BM and the business strategy represent the basic conditions for the existence of a company (Štefan & Branislav, 2016). It can be considered as a 'structured knowledge cluster' that helps to explain its nature and knowledge structure from the perspective of the KBV (Chen *et al.*, 2021). The KBV can be reconceptualised, developed, advanced and revisited in new contexts of analysis and in the light of recent global developments (Cooper *et al.*, 2023).

Based on the KBV business strategy, positioning in the market place and organisational culture represent the basic business elements in our study. An organisation's strategy is based on resource endowment and firm performance. Indeed, the availability of resources is a crucial factor that can have a significant impact on the performance of an organisation (Handoyo *et al.*, 2023). Resource endowments are related to the resources available to companies. These resources include human capital, financial capabilities, technical innovation and government policy (Zhang *et al.*, 2022). They can influence the operational and strategic choices of firms, which in turn can affect the organisational performance (Sarpong-Danquah *et al.*, 2022; Zhang *et al.*, 2022).

The goal of any company's strategy is to obtain a positional advantage (Iyer *et al.*, 2019). In other words, a larger market share signifies a more powerful impact and stronger competitive position. If the strategy does not achieve this goal, it will fail to fulfill its essential role (Štefan & Branislav, 2016). A company's market positioning must be strong and flexible enough to withstand intense competition and adapt to environmental uncertainty (Giachetti & Torrisi, 2018).

BMs and competitiveness cannot be considered without organisational culture, as a high-performance culture enhances almost all developments (Azeem *et al.*, 2021). In the tourism industry, several studies have investigated the importance of organisational culture (Ntalakos *et al.*, 2022). In fact, travel agencies and hotels cultivate an organisational culture, foster collaboration in missions and strategies, shape the future of the organisation, and support both organisational and individual development. Organisational culture is also related to leadership, as leaders can influence the competitiveness of a company (Anning-Dorson, 2021). Leaders can also foster flexibility that allows the company to connect and coordinate to take advantage of new market opportunities (Al-Sharif *et al.*, 2023).

By incorporating these dimensions, the BM evolves into a framework dynamic characterised by 'evolution', 'learning,' and 'erosion' (Saebi, Lien & Foss, 2017). BM dynamics is considered as BM adaptation, that is, the process by which managers align their firms' BMs to changing business environments. Moreover, the BM dynamics describe the discovery and adoption of a fundamentally different business logic. This is about redefining the current offering and how it is provided to customers, which includes searching for novel ways to propose value to the customer, as well as creating and capturing value (Casadesus-Masanell & Zhu, 2013).

Rapid advancements in AI technology, particularly the introduction of AI tools such as ChatGPT and machine learning, and the ever-changing dynamics of digital marketing highlight the need to continuously update our understanding of their crucial interplay (Appio *et al.*, 2021; Ziakis & Vlachopoulou, 2023). Indeed, AI is considered as a portfolio of technologies, serving distinct purposes and applications. Due to their continuous evolution, the potential of AI technologies to transform the marketing landscape expands, as is the case of MA in our present study.

The deployment of AI technologies plays a pivotal role as an enabler of BMI by transforming the way businesses create, capture and deliver value (Mishra & Tripathi, 2021). In this sense, businesses should allocate more resources to AI and MA technologies in order to improve operational efficiency, customer engagement and revenue streams, as these factors are positively interrelated. By building a digital transformation strategy based on AI and MA, a company's BM can become innovative in several ways, such as improving decision making,

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personalising offers, improving customer experience, strengthening competitiveness and optimising operational processes.

This third phase of this transformation highlights the strategic adoption of AI and MA as key drivers of innovation within the travel industry. AI serves as a powerful enabler by automating repetitive and time-consuming tasks, such as data entry, booking management, and customer queries (Ancillai *et al.*, 2023; Aström *et al.*, 2022; Kanbach *et al.*, 2024). This automation not only increases operational efficiency but also frees up employees to concentrate on higher-value activities, such as designing innovative travel packages, expanding service portfolios and strengthening client relationships. These efforts ultimately position travel agencies to gain a sustainable competitive advantage in the market.

MA complements AI by revolutionising traditional methods and replacing them with advanced, data-driven processes. Tasks such as lead nurturing, customer segmentation, personalised communication and campaign management are streamlined, ensuring greater precision and effectiveness (Boozary *et al.*, 2024; Sjödin *et al.*, 2023). This approach allows agencies to engage customers at the right time, with the right message, through the right channels, thereby fostering loyalty and improving overall customer satisfaction.

When combined, AI and MA unlock new opportunities for travel agencies to optimise their internal operations while simultaneously delivering exceptional, personalised customer experiences. For example, AI-driven analytics can anticipate customer preferences and suggest tailored travel packages, while automated systems can ensure seamless follow-ups and real-time support.

These technologies empower agencies to remain agile and responsive in an ever-evolving market. By embracing AI and MA, travel agencies can transition from reactive to proactive BMs, adapting swiftly to changing customer needs and market trends. This integration not only enhances profitability but also establishes a framework for long-term innovation and sustainable growth in the highly competitive travel industry.

Theoretical implications

This study aims to provide an overview of how AI and MA can improve a BM by innovating its elements. Building on TAM and UTAUT, our research has provided a better understanding of the behavioural drivers behind the adoption process and explore how perceptions, environmental support and social influences shape the integration of these technologies into BM innovation. This theoretical lens not only enhances the analysis but also offers actionable insights for overcoming barriers and fostering technology adoption in the tourism sector. Furthermore, this study highlights how AI enhances MA through advanced personalisation,

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improving customer experience and driving sales. By automating complex tasks such as lead scoring, campaign optimisation and real-time engagement, AI strengthens customer loyalty and increases conversions while maintaining high-quality interactions. It enables businesses to dynamically adapt their strategies to evolving customer needs, fostering a more agile and customer-centric marketing approach. In addition, this study explores the role of AI and MA in BM innovation, demonstrating how companies can rethink their value propositions and customer segments to drive innovation and gain a competitive advantage. Moreover, it extends the discussion on AI and data analytics in management, emphasising their strategic roles beyond operational efficiency. Finally, it examines AI and MA from a knowledge-based perspective, illustrating how organisational culture, strategy and market positioning facilitate digital transformation and BM innovation.

Managerial implications

Our study highlights different practical implications. First, this research guides Tunisian travel agency managers on how to strategically implement AI and MA to foster BM innovation. They can then understand how these tools can be integrated into their various business stages to enhance customer engagement. Second, this work suggests the need for collaboration between diverse industry stakeholders, such as technology providers, to manage the complexity of available resource and technology integration. Third, this paper defines the three phases of BM transformation and provides a roadmap for companies. In fact, managers can use this approach to gradually shift from traditional models to more innovative frameworks, which present specific guidance on value creation. Fourth, the obtained findings present key barriers (for example, trust issues, resources constraints and market challenges) to the adoption of AI and MA. To address these obstacles, managers can use these insights to develop useful strategies, such as building trust and AI investment in necessary resources. Fifth, the integration of AI technologies, such as chatbots, offers travel agencies a way to automate repetitive tasks and to free up employee time. This allows staff to focus on higher-value activities, such as strategy making and personalised customer services. In fact, the use of AI and MA provides agencies with a significant competitive advantage by improving dynamic pricing, inventory management and personalised services.

Limitations and Future Directions

As with other studies, this paper has limitations. Our work focuses on the Tunisian tourism sector, which has its own unique market characteristics, regulatory environment and cultural elements. Future research should examine other travel agencies, especially in more developed countries, for a comparison with developing countries. Second, while this paper presents

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issues from a managerial perspective, future studies can explore the consumer perspective by examining the way AI and MA tools influence customer satisfaction. Third, it is crucial to consider the growing concerns related to ethical use and privacy. Future research is needed to develop guidelines for travel agencies to ensure the effective use of advanced technologies.

References

Ahmad, M. I. (2015). Unified theory of acceptance and use of technology (UTAUT). *LinkedIn Pulse*, 179–211. https://doi.org/10.1007/978-3-031-56121-4_47

Al-Sharif, A. M., Ali, M. H., Jaharuddin, N. S., Abdulsamad, A., & Jandab, A. (2023). The role of innovation capability in the relationship between entrepreneurial leadership and innovation performance in the SMEs service industry. *Advances in Social Sciences Research Journal*, *10*(1), 264–278. https://doi.org/10.14738/assrj.101.13802

Ancillai, C., Sabatini, A., Gatti, M., & Perna, A. (2023). Digital technology and business model innovation: A systematic literature review and future research agenda. *Technological Forecasting and Social Change*, *188*, 122307. https://doi.org/10.1016/j.techfore.2022.122307

Andreini, D., Bettinelli, C., Foss, N. J., & Mismetti, M. (2022). Business model innovation: A review of the process-based literature. *Journal of Management and Governance*, 26(4), 1089–1121. https://doi.org/10.1007/s10997-021-09590-w

Anning-Dorson, T. (2021). Organizational culture and leadership as antecedents to organizational flexibility: Implications for SME competitiveness. *Journal of Entrepreneurship in Emerging Economies*, *13*(5), pp. 1309–1325. https://doi.org/10.1108/JEEE-08-2020-0288

Appio, F. P., Frattini, F., Petruzzelli, A. M., & Neirotti, P. (2021). Digital transformation and innovation management: A synthesis of existing research and an agenda for future studies. *Journal of Product Innovation Management*, *38*(1), 4–20. https://doi.org/10.1111/jpim.12562.

Ardolino, M., Rapaccini, M., Saccani, N., Gaiardelli, P., Crespi, G., & Ruggeri, C. (2018). The role of digital technologies for the service transformation of industrial companies. *International Journal of Production Research*, 56(6), 2116–2132. https://doi.org/10.1080/00207543.2017.1324224

Arnold, L. (2024). *Navigating the Dynamics of Digital B2B Platform Ecosystem Emergence and Orchestration* (Doctoral dissertation). Universitaet Bayreuth (Germany). https://www.proquest.com/openview/0c569f605b487b1e210e12c1477b43d0/1?cbl=2026366&diss=y&pq-origsite=gscholar

Åström, J., Reim, W., & Parida, V. (2022). Value creation and value capture for AI business model innovation: a three-phase process framework. *Review of Managerial Science*, *16*(7), 2111–2133. https://doi.org/10.1007/s11846-022-00521-z

Azeem, M., Ahmed, M., Haider, S., & Sajjad, M. (2021). Expanding competitive advantage through organizational culture, knowledge sharing and organizational innovation. *Technology in Society*, *66*, 101635. https://doi.org/10.1016/j.techsoc.2021.101635.

Berman, S. J. (2012). Digital transformation: opportunities to create new BMs. *Strategy & leadership, 40*(2), 16–24. https://doi.org/10.1108/10878571211209314

Blanchet, A., & Gottman, A. (1992). *L'enquête et Ses Méthodes: L'entretien*, Nathan, Paris, p. 125. https://www.unige.ch/fapse/life/archives/livres/alpha/B/Blanchet_Gotman_1992_A.html

Boozary, P. (2024). The impact of marketing automation on consumer buying behavior in the digital space via artificial intelligence. *Power System Technology*, *48*(1), 1008–1021. https://powertechjournal.com/index.php/journal/article/view/358

Borges, A. F., Laurindo, F. J., Spínola, M. M., Gonçalves, R. F., & Mattos, C. A. (2021). The strategic use of artificial intelligence in the digital era: Systematic literature review and future research directions. *International Journal of Information Management*, 57, 102225. https://doi.org/10.1016/j.ijinfomgt.2020.102225

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

Buhalis, D., Efthymiou, L., Uzunboylu, N., & Thrassou, A. (2024). Charting the progress of technology adoption in tourism and hospitality in the era of industry 4.0. *EuroMed Journal of Business*, *19*(1), 1–20. https://doi.org/10.1108/EMJB-11-2023-0310.

Cai, R., Cain, L. N., & Jeon, H. (2022). Customers' perceptions of hotel AI-enabled voice assistants: does brand matter? *International Journal of Contemporary Hospitality Management, 34*(8), 2807–2831. https://doi.org/10.1108/IJCHM-10-2021-1313

Casadesus-Masanell, R., & Zhu, F. (2013). Business model innovation and competitive imitation: The case of sponsor-based business models. *Strategic Management Journal*, *34*(4), 464–482. https://doi.org/10.1002/smj.2022

Centobelli, P., Cerchione, R., Chiaroni, D., Del Vecchio, P., & Urbinati, A. (2020). Designing BMs in circular economy: A systematic literature review and research agenda. *Business Strategy and the Environment, 29*(4), 1734–1749. https://doi.org/10.1002/bse.2466

Chen, J., Liu, L. & Wang, Y. (2021). , Business model innovation and growth of manufacturing SMEs: a social exchange perspective. *Journal of Manufacturing Technology Management*, *32*(2), 290–312. https://doi.org/10.1108/JMTM-03-2020-0089

Coelho, V. N., Coelho, I. M., Coelho, B. N., de Oliveira, G. C., Barbosa, A. C., Pereira, L., ... & Guimarães, F. G. (2017). A communitarian microgrid storage planning system inside the scope of a smart city. Applied Energy, 201, 371-381. https://doi.org/10.1016/j.apenergy.2016.12.043

Cooper, C., Pereira, V., Vrontis, D., & Liu, Y. (2023). Extending the resource and knowledge based view: Insights from new contexts of analysis. *Journal of Business Research*, *156*, 113523. https://doi.org/10.1016/j.jbusres.2022.113523

Côté, A. M., & Su, Z. (2021). Évolutions de l'intelligence artificielle au travail et collaborations humain-machine. *Ad Machina, (5),* 144–160. https://doi.org/10.1522/radm.no5.1413

Curtis S., Gesler W., Smith G. & Washburn S. (2000). Approaches to sampling and case selection in qualitative research: examples in the geography of health. *Social Science and Medicine, 50*, 1001–1014. https://doi.org/10.1016/S0277-9536(99)00350-0

Davenport, T. H. (2018). From analytics to artificial intelligence. *Journal of Business Analytics, 1*(2), 73–80. https://doi.org/10.1080/2573234X.2018.1543535

Doborjeh, Z., Hemmington, N., Doborjeh, M., & Kasabov, N. (2022). Artificial intelligence: a systematic review of methods and applications in hospitality and tourism. *International Journal of Contemporary Hospitality Management*, *34*(3), 1154–1176. https://doi.org/10.1108/IJCHM-06-2021-0767

Drammeh, F. Y. (2024). Managing tourism during the COVID-19 pandemic. A systematic review of crisis management in the tourism industry. *Cogent Social Sciences*, *10*(1). 2311955. https://doi.org/10.1080/23311886.2024.2311955

Dwivedi, Y. K., Kshetri, N., Hughes, L., Slade, E. L., Jeyaraj, A., Kar, A. K., Baabdullah, A. K., Koohang, A., Raghavan, V., Ahuja, M., Albanna,H., Albashrawi, M. A., Al-Busaidi, A. S., Balakrishnan, J., Barlette, Y., Basu, S., Bose, I., Brooks, L., Buhalis, D., Carter, L., & Wright, R. (2023). Opinion paper: 'So what if ChatGPT wrote it?' Multidisciplinary perspectives on opportunities, challenges and implications of generative conversational AI for research, practice and policy. *International Journal of Information Management*, *71*. 102642. https://doi.org/10.1016/j.ijinfomgt.2023.102642

Easterby-Smith, M., Jaspersen, L. J., Thorpe, R., & Valizade, D. (2021). Management and Business Research. Sage. https://www.torrossa.com/en/resources/an/5018209

Elhajjar, S., Yacoub, L., & Yaacoub, H. (2023). Automation in business research: systematic literature review. *Information Systems and e-Business Management*, 21(3), 675–698. https://doi.org/10.1007/s10257-023-00645-z

Fernandes, K. J., Milewski, S., Chaudhuri, A., & Xiong, Y. (2022). Contextualising the role of external partnerships to innovate the core and enabling processes of an organisation: A resource and knowledge-based view. *Journal of Business Research*, *144*, 146–162. https://doi.org/10.1016/j.jbusres.2022.01.091

Foss, N. J., & Saebi, T. (2018). Business models and business model innovation: Between wicked and paradigmatic problems. *Long Range Planning*, *51*(1), 9–21. https://doi.org/10.1016/j.lrp.2017.07.006

Gebauer, H., Arzt, A., Kohtamäki, M., Lamprecht, C., Parida, V., Witell, L., & Wortmann, F. (2020). How to convert digital offerings into revenue enhancement – Conceptualizing business model dynamics through explorative case studies. *Industrial Marketing Management*, *91*, 429–441. https://doi.org/10.1016/j.indmarman.2020.10.006

Giachetti, C., & Torrisi, S. (2018). Following or running away from the market leader? The influences of environmental uncertainty and market leadership. *European Management Review*, *15*(3), 445–463. https://doi.org/10.1111/emre.12130

Giannelloni, J. L., & Vernette, E. (2012). *Etudes de Marché*. Paris: Edition Vuibert.

Gligoric, N., Krco, S., Hakola, L., Vehmas, K., De, S., Moessner, K., Jansson, K., Polenz, I., & Van Kranenburg, R. (2019). SmartTags: IoT product passport for circular economy based on printed sensors and unique item-level identifiers. *Sensors, 19*(3), 586. https://doi.org/10.3390/s19030586

Grimaldi, D., & Fernandez, V. (2017). The alignment of University curricula with the building of a Smart City: A case study from Barcelona. Technological Forecasting and Social Change, 123, 298-306. https://doi.org/10.1016/j.techfore.2016.03.011

Guercini, S. (2023). Marketing automation and the scope of marketers' heuristics. *Management Decision, 61*(13), 295–320. https://doi.org/10.1108/MD-07-2022-0909

Guest, G., Namey, E., & Chen, M. (2020). A simple method to assess and report thematic saturation in qualitative research. *PloS One, 15*(5), e0232076. https://doi.org/10.1371/journal.pone.0232076

Guo, R. (2020). Exploration and analysis on the development path of smart tourism in Shandong Province in the era of artificial Intelligence. *Journal of Physics: Conference Series, 1575*(1), 012022. https://doi.org/10.1088/1742-6596/1575/1/012022/meta

Handoyo, S., Suharman, H., Ghani, E. K., & Soedarsono, S. (2023). A business strategy, operational efficiency, ownership structure, and manufacturing performance: The moderating role of market uncertainty and competition intensity and its implication on open innovation. *Journal of Open Innovation: Technology, Market and Complexity*, *9*(2), 100039. https://doi.org/10.1016/j.joitmc.2023.100039

Henriksen, M.G., Englander, M., & Nordgaard, J. (2022). Methods of data collection in psychopathology: The role of semi-structured, phenomenological interviews. *Phenomenology and the Cognitive Sciences*, 21(1), 9–30. https://doi.org/10.1007/s11097-021-09730-5

Hicham, N., Nassera, H., & Karim, S. (2023). Strategic framework for leveraging artificial intelligence in future marketing decision-making. *Journal of Intelligent Management Decision*, *2*(3), 139–150. https://doi.org/10.56578/jimd020304

Hoffman, D.L., Moreau, C.P., Stremersch, S., & Wedel, M. (2022). The rise of new technologies in marketing: a framework and outlook. *Journal of Marketing*, 86(1), 1–6. https://doi.org/10.1177/00222429211061636

Huang, A., Chao, Y., de la Mora Velasco, E., Bilgihan, A., & Wei, W. (2022). When artificial intelligence meets the hospitality and tourism industry: an assessment framework to inform theory and management. *Journal of Hospitality and Tourism Insights, 5*(5), 1080–1100.https://doi.org/10.1108/JHTI-01-2021-0021

Huang, M. H., & Rust, R. T. (2018). Artificial intelligence in service. *Journal of Service Research, 21*(2), 155–172. https://doi.org/10.1177/1094670517752459

Ilzetzki, E., & Jain, S. (2023, June 20). The impact of artificial intelligence on growth and employment. *CEPR*. https://cepr.org/voxeu/columns/impact-artificial-intelligence-growth-and-employment

Iyer, P., Davari, A., Zolfagharian, M., & Paswan, A. (2019). Market orientation, positioning strategy and brand performance. *Industrial Marketing Management*, *81*, 16–29. https://doi.org/10.1016/j.indmarman.2018.11.004

Jarrahi, M.H., Askay, D., Eshraghi, A. & Smith, P. (2023). , Artificial intelligence and knowledge management: A partnership between human and AI. *Business Horizons, 66*(1). https://doi.org/10.1016/j.bushor.2022.03.002

Kallio, H., Pietilä, A. M., Johnson, M., & Kangasniemi, M. (2016). Systematic methodological review: Developing a framework for a qualitative semi-structured interview guide. *Journal of Advanced Nursing, 72*(12), 2954–2965. https://doi.org/10.1111/jan.13031

Kanbach, D. K., Heiduk, L., Blueher, G., Schreiter, M., & Lahmann, A. (2024). The GenAI is out of the bottle: Generative artificial intelligence from a business model innovation perspective. *Review of Managerial Science*, *18*(4), 1189–1220. https://doi.org/10.1007/s11846-023-00696-z

Kanungo, R. P., Liu, R., & Gupta, S. (2024). Cognitive analytics enabled responsible artificial intelligence for business model innovation: A multilayer perceptron neural networks estimation. *Journal of Business Research*, *182*, 114788. https://doi.org/10.1016/j.jbusres.2024.114788

Kogut, B., & Zander, U. (1992). Knowledge of the firm, combinative capabilities, and the replication of technology. *Organization Science*, *3*(3), 383–397. https://doi.org/10.1287/orsc.3.3.383

Kotler, P., Kartajaya, H., & Setiawan, I. (2021). *Marketing 5.0: Technology for Humanity*. Hoboken, NJ: John Wiley & Sons.

Kumar, P. (2022). Market-focused flexibility and innovative performance in public healthcare: Evidence from India. *Journal of Public Affairs, 22*(S1), e2809. https://doi.org/10.1002/pa.2809

Lee, K. H., & Kim, D. (2019). A peer-to-peer (P2P) platform business model: The case of Airbnb. *Service Business, 13*(4), 647–669. https://doi.org/10.1007/s11628-019-00399-0

Limna, P. (2023). Artificial intelligence (AI) in the hospitality industry: A review article. *International Journal of Computing Sciences Research, 7*, 1306–1317. https://stepacademic.net/ijcsr/article/view/337

Lindgren, P. (2016). The business model ecosystem. *Journal of Mobile Multimedia, 4*(2), 1. https://do.org/10.13052/jmbmit2245-456X.421

Longoni, C., Bonezzi, A., & Morewedge, C. K. (2019). Resistance to medical artificial intelligence. *Journal of Consumer Research, 46*(4), 629–650. https://doi.org/10.1093/jcr/ucz013

Lyu, X., Jia, F., & Zhao, B. (2023). Impact of big data and cloud-driven learning technologies in healthy and smart cities on marketing automation. *Soft Computing*, *27*(7), 4209–4222. https://doi.org/10.1007/s00500-022-07031-w

Manogaran, G., Alazab, M., Shakeel, P. M., & Hsu, C. H. (2021). Blockchain assisted secure data sharing model for Internet of Things based smart industries. *IEEE Transactions on Reliability*, *71*(1), 348–358. https://doi.org/10.1109/TR.2020.3047833

Marangunić, N., & Granić, A. (2015). Technology acceptance model: a literature review from 1986 to 2013. *Universal Access in the Information Society, 14*, 81–95. https://doi.org/10.1007/s10209-014-0348-1

McKinsey, (2024, June 14) *The economic potential of generative AI: The next productivity frontier*. McKinsey and Company Report. https://www.mckinsey.com/capabilities/mckinsey-digital/our-insights/the-economic-potential-of-generative-ai-the-next-productivity-frontier

Mednini, L., Noubigh, Z., & Turki, M. D. (2024). Natural language processing for detecting brand hate speech. *Journal of Telecommunications and the Digital Economy, 12*(1), 486509. https://doi.org/10.18080/jtde.v12n1.859

Michelat, G. (1975), Sur l'utilisation de l'entretien non directif en sociologie. *Revue française de sociologie,* 229–247. https://sciencespo.hal.science/hal-01026467v1

Mishra, S., & Tripathi, A. R. (2020). IoT platform business model for innovative management systems. *International Journal of Financial Engineering*, 2050030. https://doi.org/10.1142/S2424786320500309

Mishra, S., & Tripathi, A.R. (2021). AI business model: An integrative business approach. *Journal of Innovation and* Entrepreneurship, *10*, 18. https://doi.org/10.1186/s13731-021-00157-5

Moeuf, A., Pellerin, R., Lamouri, S., Tamayo-Giraldo, S., & Barbaray, R. (2018). The industrial management of SMEs in the era of Industry 4.0. *International Journal of Production Research, 56*(3), 1118–1136. https://doi.org/10.1080/00207543.2017.1372647

Mohiuddin, N. O. O. R. (2024). Innovation in the tourism industry: How artificial intelligence is reshaping management of meetings & events. Thesis. https://doi.org/10.13140/RG.2.2.19952.06400

Mpofu, F. Y. (2024). The fourth industrial revolution technologies in the tourism sector in African countries: Opportunities, barriers, and ethical considerations. Inn: Ndhlovu, E., Dube, K., Kifworo, C.M. (eds) *Tourism and Hospitality for Sustainable Development: Volume Two: Emerging Trends and Global Issues* (pp. 179–201). Cham: Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-63073-6_11.

Nagalakshmi, M. V. N., & Reddy, C. (2024). AI-driven business model innovation – where technology meets strategy. *RVIM Journal of Management Research*, 5–17. https://doi.org/10.70599/rvim/2024/306

Ntalakos, A., Belias, D., Koustelios, A., & Tsigilis, N. (2022, May). Organizational culture and group dynamics in the tourism industry. In *International Conference on Tourism Research*, 15(1), 286–293. https://doi.org/10.34190/ictr.15.1.150

ONTT report, (2022). https://www.ontt.tn/sites/default/files/inline-files/Rapport%20ONTT%202022.pdf

Otto, D., Assenmacher, V., Bente, A., Gellner, C., Waage, M., Deckert, R., Siepermann,M., Kammer,J & Kuche, J. (2024). Student Acceptance Of AI-Based Feedback Systems: An Analysis Based On The Technology Acceptance Model (TAM). In *INTED 2024 Proceedings* (pp. 3695–3701). https://doi.org/10.21125/inted.2024.0973

Palazzo, M., Gigauri, I., Panait, M. C., Apostu, S. A., & Siano, A. (2022). Sustainable tourism issues in European countries during the global pandemic crisis. *Sustainability*, *14*(7), 3844, 87–99. https://doi.org/10.3390/su14073844

Panetta, F. (2018). Fintech and banking: today and tomorrow. *Speech of the Deputy Governor of the Bank of Italy, Rome, 12th May*. Banca-Italia-Panetta-Intervento-Fintech.pdf

Papadopoulos, T., Gunasekaran, A., Dubey, R., & Fosso Wamba, S. (2017). Big data and analytics in operations and supply chain management: managerial aspects and practical challenges. *Production Planning & Control*, 28(11–12), 873–876. https://doi.org/10.1080/09537287.2017.1336795

Păvăloaia, V. D., & Necula, S. C. (2023). Artificial intelligence as a disruptive technology – a systematic literature review. *Electronics,* *12*(5), 1102. https://doi.org/10.3390/electronics12051102

Qazi, A., Cova, V., Hussain, S., & Khoso, U. (2022). When and why consumers choose supersized food? *Spanish Journal of Marketing – ESIC*, *26*(2), 247–266. https://doi.org/10.1108/SJME-10-2021-0187

Rafiq, F., Dogra, N., Adil, M., & Wu, J. Z. (2022). Examining consumer's intention to adopt AI-chatbots in tourism using partial least squares structural equation modeling method. *Mathematics*, *10*(13), 2190. https://doi.org/10.3390/math10132190

Reim, W., Yli-Viitala, P., Arrasvuori, J., & Parida, V. (2022). Tackling business model challenges in SME internationalization through digitalization. *Journal of Innovation & Knowledge, 7*(3), 100199. https://doi.org/10.1016/j.jik.2022.100199

Ritter, T., & Pedersen, C. L. (2020). Digitization capability and the digitalization of business models in business-to-business firms: Past, present, and future. *Industrial Marketing Management*, *86*, 180–190. https://doi.org/10.1016/j.indmarman.2019.11.019

Rogerson, A., Hankins, E., Fuentes Nettel, P., & Rahim, S. (2022). *Government AI Readiness Index 2022*. Oxford Insights. Government_AI_Readiness_2022_FV.pdf

Sabatini, A., Cucculelli, A., & Gregori, G.L. (2022). Business model innovation and digital technology: The perspective of Italian incumbent small and medium-sized firms. *Entrepreneurial Business and Economics Review,* *10*(3), 23–35. https://doi.org/10.15678/EBER.2022.100302

Saebi, T., & Foss, N. J. (2017). Business models for open innovation: Matching heterogeneous open innovation strategies with business model dimensions. *European Management Journal*, *33*(3), 201–213. https://doi.org/10.1016/j.emj.2014.11.002

Sahebi, A. G., Kordheydari, R., & Aghaei, M. (2022). A new approach in marketing research: Identifying the customer expected value through machine learning and big data analysis in the tourism industry. *Asia-Pacific Journal of Management and Technology (AJMT)*, *2*(3), 26–42. https://doi.org/10.46977/apjmt.2022v02i03.004

Saleem, I., Al-Breiki, N. S. S., & Asad, M. (2024). The nexus of artificial intelligence, frugal innovation and business model innovation to nurture internationalization: A survey of SME's readiness. *Journal of Open Innovation: Technology, Market, and Complexity,* *10*(3), 100326. https://doi.org/10.1016/j.joitmc.2024.100326

Sarpong-Danquah, B., Oko-Bensa-Agyekum, K., & Opoku, E. (2022). Corporate governance and the performance of manufacturing firms in Ghana: Does ownership structure matter? *Cogent Business & Management*, *9*(1), 2101323. https://doi.org/10.1080/23311975.2022.2101323

Seranmadevi, R., & Kumar, A. S. (2019). Experiencing the AI emergence in Indian retail – Early adopters approach. *Management Science Letters, 10*(2), 33–42,. https://doi.org/10.5267/j.msl.2018.11.002

Shuai, W., Maille, P., & Pelov, A. (2016). Charging electric vehicles in the smart city: A survey of economy-driven approaches. *IEEE Transactions on Intelligent Transportation Systems 17*(8), 2089–2106. https://doi.org/10.1109/TITS.2016.2519499

Singh, R. K., Agrawal, S., & Modgil, S. (2022). Developing human capital 4.0 in emerging economies: An industry 4.0 perspective. *International Journal of Manpower*, *43*(2), 286–309. .https://doi.org/10.1108/IJM-03-2021-0159

Sjödin, D., Parida, V., & Kohtamäki, M. (2023). Artificial intelligence enabling circular business model innovation in digital servitization: Conceptualizing dynamic capabilities, AI capacities, business models and effects. *Technological Forecasting and Social Change, 197*, 122903. https://doi.org/10.1016/j.techfore.2023.122903

Sohn, K., & Kwon, O. (2020). Technology acceptance theories and factors influencing AI-based intelligent products. *Telematics and Informatics*, *47*, 101324. https://doi.org/10.1016/j.tele.2019.101324

Soroka, A., Liu, Y., Han, L., & Haleem, M. S. (2017). Big data driven customer insights for SMEs in redistributed manufacturing. *Procedia CIRP, 63*, 692–697. https://doi.org/10.1016/j.procir.2017.03.319

Štefan, S., & Branislav, Z. (2016). Relationship between business strategy and BM studied in a sample of service companies. *Journal of Competitiveness*, *8*(4), 72. https://doi.org/10.7441/joc.2016.04.05

Stone, M., Aravopoulou, E., Ekinci, Y., Evans, G., Hobbs, M., Labib, A., Laughlin, P., Machtynger, J., & Machtynger, L. (2020). Artificial intelligence (AI) in strategic marketing decision-making: a research agenda. *The Bottom Line, 33*(2), 183–200. https://doi.org/10.1108/BL-03-2020-0022

Thaker, M. T. T., Khaliq, A., Mand, A. A., Hussain, H. I., Thaker, M. A. B .M .T., & Pitchay, A. B. A. (2020). Exploring the drivers of social media marketing in Malaysian Islamic banks. *Journal of Islamic Marketing, 12*(1), 145–165. https://doi.org/10.1108/JIMA-05-2019-0095

Tuo, Y., Ning, L., & Zhu, A. (2021). How artificial intelligence will change the future of tourism industry: The practice in China. *Information and Communication Technologies in Tourism 2021*, 83–94. https://doi.org/10.1007/978-3-030-65785-7_7

United Nations World Tourism Organization (UNWTO). (2021). World Tourism Barometer, In *The Europa Directory of International Organizations* , 393-397. https://doi.org/10.18111/wtobarometereng

Wåge, D., & Crawford, G. E. (2020). Innovation in digital business models. In : *Managing Digital Open Innovation, chapter 2,* (pp. 35–45). https://doi.org/10.1142/9789811219238_0002

Widayanti, R., & Meria, L. (2023). Business modeling innovation using artificial intelligence technology. *International Transactions on Education Technology*, *1*(2), 95–104. https://doi.org/10.33050/itee.v1i2.270

Yakut, E. (2022). Effects of technological innovations on consumer behavior: Marketing 4.0 perspective. In *Industry 4.0 and Global Businesses: A Multidisciplinary Investigation* (pp. 55–68). Emerald Publishing Limited. https://doi.org/10.1108/978-1-80117-326-120211004

Zhang, H., Chen, H.H., Lao, K., & Ren, Z. (2022). The impacts of resource endowment, and environmental regulations on sustainability – empirical evidence based on data from renewable energy enterprises. *Energies, 15*, 4678. https://doi.org/10.3390/en15134678

Ziakis, C., & Vlachopoulou, M. (2023). Artificial intelligence in digital marketing: Insights from a comprehensive review. *Information*, *14*(12), 664. https://doi.org/10.3390/info14120664

Appendices

Appendix 1. Demographic overview of the semi-structured interviews (table designed by the authors)

Participants	**Position**	**Years of experience**	**Time in minutes (mn)**
P1	Manger	15 years	45 mn
P2	Director	7 years	60 mn
P3	Marketing Director	5 years	50 mn
P4	Manager	8 years	40 mn
P5	Manager	11 years	42 mn
P6	Director	12 years	55 mn
P7	Technical Director	15 years	57 mn
P8	Manager	13 years	45 mn
P9	Manager	26 years	30 mn
P10	Human Resources Director	17 years	60 mn
P11	Marketing Director	22 years	55 mn
P12	Network Director	16 years	45 mn
P13	Marketing Director	14 years	45 mn
P14	Manager	15 years	44 mn
P15	Director	11 years	35 mn
P16	Manager	5 years	60 mn

Appendix 2. Demographic overview of projective techniques (table designed by the authors)

Participants	Profession	Years of experience	Time in minutes (mn)
P1	Manager	15 years	5 mn
P2	Manager	5 years	7 mn
P3	Director	11 years	6 mn
P4	Director	12 years	5 mn
P5	Manager	13 years	4 mn
P6	Director	7 years	3 mn

Appendix 3. Interview guide

1. Can you give us an overview of your travel agency and its Tunisian market positioning?
2. What are the main challenges facing your agency in the current context of the travel industry in Tunisia?
3. How has your agency traditionally managed its marketing and business model innovation operations?
4. Is your agency currently using artificial intelligence in its operations? If so, can you tell us more about it?
5. What types of AI applications does your agency use (for example, chatbots, predictive analytics, recommendation engines, etc.)?
6. How have these AI applications been integrated into your agency's processes and what benefits were brought by these technologies?
7. How does your agency use marketing automation to interact with customers?
8. Which automated marketing channels does your agency use (for example, targeted emails, social media, targeted ads, etc.)?
9. What are the main goals of marketing automation in your agency?
10. How has the use of AI and marketing automation influenced the innovation of business models in your agency?
11. Can you share specific examples of new products, services or processes that have been developed thanks to these technologies?
12. What are the main challenges faced by your agency in integrating AI and marketing automation?

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13. What are the opportunities you expect to see in your agency by continuously investing in these technologies in the future?

14. Do you have any other things to add regarding this topic?

Appendix 4. Incomplete sentences

- Among the main advantages, artificial intelligence presents … to travel businesses.
- The most important factor to consider in integrating AI into travel agencies is …
- Travel agencies must integrate AI and …
- Travel agencies should automate … in order to improve the efficiency of their operations.
- The observed changes in the business models of travel agencies due to AI integration are …
- A major barrier to business model innovation through AI and marketing automation in travel agencies is …

Appendix 5. Cross-tabulation matrix for NVivo data analysis

Requête de croisements matric

	A : artificial intelligence	B : Marketing automatis…
1 : Business Model Inno…	58,31 %	41,69 %

Utilization or Not IA - Aperçu d — Utilization MA - Aperçu des rés

	A : No Utilization MA	B : Utilization MA
1 : Marketing automatisa…	20,3 %	79,7 %

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Deep Learning-Based Facial Emotion Recognition for Detecting Brand Hate

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Abstract: This paper aims to recognise three levels of consumer hate – cold hate, cool hate and hot hate – through facial emotion recognition. It compares the use of transfer learning approaches and custom convolutional neural network (CNN) approaches. Five classes of emotions were considered in this research: fear, anger, disgust and contempt as indicators of a brand with hate, and happy as an indicator of non-brand hate. The databases used are AffectNet and RAF_DB. Multiple facial expressions are included in our dataset, which consists of about 23,529 images belonging to five classes in the training set and 10,088 images belonging to five classes in the testing set. The custom CNN model achieved an accuracy of 78.4% when validated on the testing set, compared to the VGG-16 model, which achieved an accuracy 79%, respectively. The confusion matrix was used to verify the findings, confirming that the custom CNN model outperforms the pre-trained models. Notably, it successfully detected brand hate emotions with an accuracy of 85%. This paper employs facial emotion recognition – a behavioural expression measure – to help companies capture the emotional responses of haters.

Keywords: Brand Hate, Facial Emotion Recognition, Deep Learning, Negative Emotions

Introduction

Consumers' emotions toward brands are diverse and complex. While some customers experience positive emotions, others may develop negative ones, such as hate (Hashim & Kasana, 2019). Recent research has increasingly focused on these negative emotions, particularly brand hate (Sameeni *et al*., 2024).

One of the most pressing challenges for companies today is effectively addressing brand haters without disregarding them entirely (Baer, 2016). However, ignoring brand hate presents a significant risk to businesses (Kucuk, 2019a). As academic interest in brand hate grows, marketers face a crucial question: How to be certain that customers genuinely hate a brand? Managers must ensure that the negative sentiments expressed by so-called haters are genuine

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and not merely the work of paid bloggers affiliated to competitors or other third parties (Mednini & Turki, 2022).

Interpersonal deception theory suggests that the cognitions and behaviours of an individual receiving a message play an active role in shaping the consequences of deceptive messages (Buroon *et al.*, 1996). Consumers may engage in deceptive communication by fabricating negative experiences with a service or a product. Such deception could stem from a desire to harm the brand (Dong *et al.*, 2024). Such false claims fuel brand hate, especially when shared publicly on social media (Sharma *et al.*, 2022).

Decades of deception research have consistently shown that individuals are generally poor at recognising lies and deception (Bond & DePaulo, 2006; Zloteanu *et al.*, 2021). This has led to the growing use of advanced technologies such as AI methods, like facial expression analysis, to detect deception. In fact, the study of facial expression has gained significant importance over the past few decades, with applications extending beyond behavioural science into fields such as marketing (Naidoo *et al.*, 2022; Wan & Sun, 2024). However, to the best of our knowledge, little research has explored understanding brand hate through facial expression recognition.

Previous research has made significant strides in investigating brand hate through quantitative and qualitative methods, primarily focusing on self-reported data on experiences and emotions (Abbas *et al.*, 2023; Akrout & Mrad, 2023; Rahimah *et al.*, 2023; Yadav, 2024). However, these approaches often rely on verbal communication, which may not fully capture the authenticity of customers' emotions toward a brand, particularly brand hate. To address this research gap, this article aims to explore studying a novel AI approach for recognising brand hate levels through facial expression analysis.

The structure of this article is as follows: In Section 2, we present a literature review. The research methodology is exposed in Section 3. The findings and discussion thereof are presented in Sections 4 and 5 respectively, and the implications, limitations and future directions are addressed in Section 6.

Literature Review

Brand hate definition

Brand hate has been defined by Kucuk (2019b, p. 20) as: 'A psychological state whereby a consumer forms intense negative emotions and detachment toward brands that perform poorly and give consumers bad and painful experiences on both individual and social levels'.

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Referring to brand hate scholars, these emotions have been categorised into three different levels, which are: hot hate: anger, fear; cool hate: disgust; cold hate: contempt (Fetscherin, 2019; Kucuk, 2019a; Sternberg, 2003). The first component, '*anger and fear*', is driven by a sense of '*us versus them*' and a desire for revenge. This intense anger often results in actions aimed at removing the object of one's fear. Sternberg (2003, p. 308) confirmed that anger 'is aimed at eliminating the object of danger'. The second component '*negation of intimacy*' involves feelings of disgust and repulsion, which can stem from a person's behaviour or particular traits. Rozin *et al.* (1999) stated that disgust arises from violations of personal beliefs, cleanliness or health. When someone experiences hate, they seek to distance themselves from what they find repulsive. Sternberg (2003, p. 306) noticed that: 'Distance is sought from a target individual because that individual arouses repulsion and disgust in the person who experiences hate'. The third component '*devaluation and diminution*' involves efforts to influence others to view the hated objects negatively.

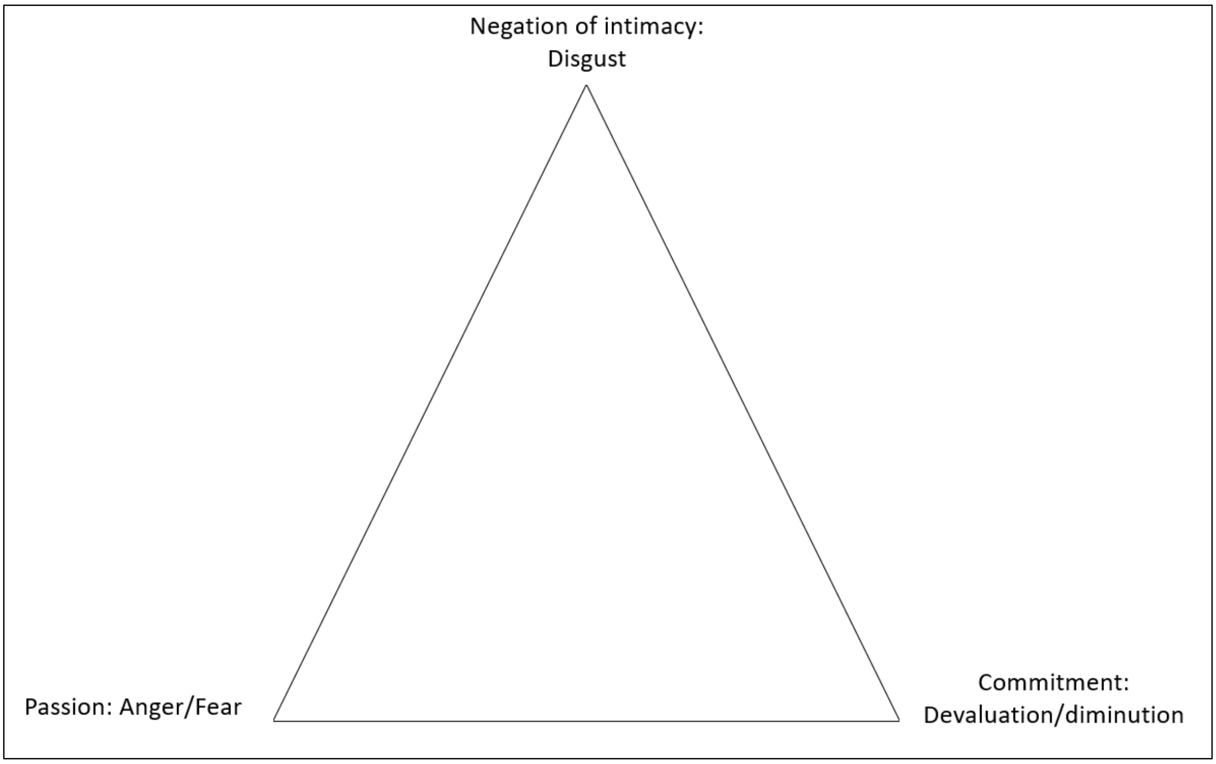

Figure 1. Duplex theory of hate (adopted by Sternberg, 2003)

An approach to measuring brand hate via facial emotion recognition

Hate has become a significant research topic in marketing literature (Mushtaq *et al.*, 2024; Noor *et al.*, 2022; Odoom, 2024). According to Scherer (2009), the component process model of emotion helps in understanding the various elements that make up an individual's emotional experience. This model breaks down emotions into distinct components.

First, individuals subjectively experience emotions in a unique and distinct way. This is the most familiar and universal aspect of emotions – everyone understands how sadness, disgust etc. feel like. Various studies have been focusing on this experienced approach, such as qualitative studies (Atwal *et al.*, 2022; Mednini & Hmida, 2023; Pereira & Loureiro, 2020; Valenzuela *et al.*, 2022), quantitative studies (Akrout & Mrad, 2023; Bryson *et al.*, 2021; Curina *et al.*, 2021; Iranzo Barreira *et al.*, 2024), mixed-method studies (Husnain *et al.*, 2023), and AI method studies like natural language processing (NLP) (Mednini *et al.*, 2024) in order to measure and understand brand hate.

Second, Scherer (2009) suggested that emotions are frequently associated with physiological changes, particularly in response to the autonomic nervous system. Experiencing an unexpected stomach ache is an example of a physiological reaction. In fact, neuromarketing can be useful in understanding changes in consumer physiology (Alsharif *et al.*, 2021).

Third, emotions have a behavioural component, meaning they can influence an individual's actions such as posture, speech patterns, gestures or facial expressions (Danner & Duerrschmid, 2018). Using facial expression recognition will help detect hate specifically with consumers who may conceal their true emotions.

According to the literature, special attention has been devoted to automatic facial expressions analysis technology which has advanced considerably in recent years (Naga *et al.*, 2023). Facial expression has been investigated in different marketing applications such as advertising (Hamelin *et al.*, 2017; Wang & Lin, 2022), food sciences (Arnade, 2014; Crist *et al.*, 2018), e-commerce (Xue *et al.*, 2024), and retail (Generosi *et al.*, 2018; Pantano, 2020). Appendix 1 illustrates the different applications of facial emotion recognition in literature.

Research Methodology

Our research introduces a method for detecting brand hate using facial expression recognition. Based on the classification proposed by Kucuk (2019a), brand hate is categorised into three distinct levels, as shown in Figure 2.

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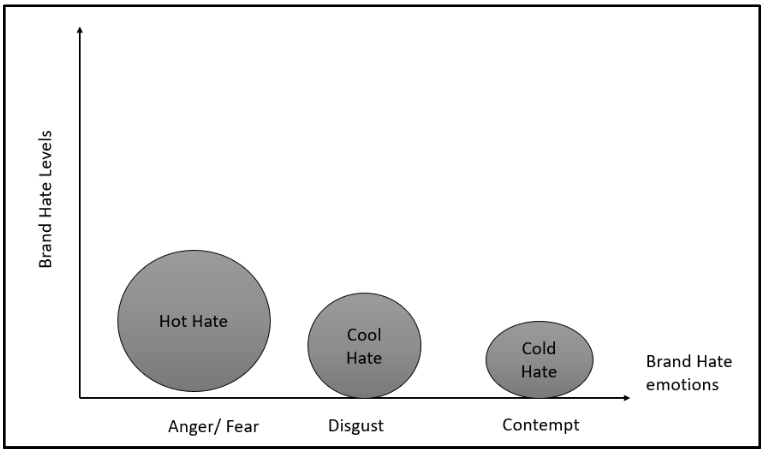

Figure 2. Brand hate levels (inspired by Kucuk, 2019a)

Our study explores two different approaches for identifying facial emotions, using deep learning models. The first approach involves transfer learning, where we fine-tune pre-trained networks that were originally trained on a large dataset. In this process, we update only the weights of the fully connected layers, keeping the other layers of the pre-trained networks fixed. The output of these fully connected layers is then used to classify emotions.

Following the study by Noubigh *et al.* (2021), the second approach employs a custom CNN architecture that emphasises feature reuse. In this research, details regarding the databases and data augmentation techniques applied are provided in the subsequent sections. Moreover, we analyse the specific models implemented in both approaches.

Data collection and data augmentation for brand hate detector

To evaluate the effectiveness of our proposed method, we used two facial emotion recognition datasets, AffectNet and the Real-World Affective Faces Database (RAF-DB). These datasets contain a large amount of data across various racial and cultural contexts (Kopalidis, 2024). According to Kopalidis (2024), authors demonstrated that AffectNet has consistently outperformed other leading databases since 2019 and has remained the dataset of choice through 2023. AffectNet has been cited in 207 open-access publications between 2018 and 2023. Additionally, RAF-DB was specifically used to supplement and extend the dataset.

AffectNet dataset

AffectNet is a comprehensive dataset compiled from online images using 1250 emotion-related search terms (Mollahosseini *et al.*, 2017). These terms were combined with descriptors related to gender, age and ethnicity, resulting in approximately 362 unique combinations in English, such as '*joyful girl*', '*blissful Spanish man*', '*furious young lady*', '*astonished senior*', '*across six languages*'. The dataset was collected from major search engines (Google, Bing and Yahoo) (Huang *et al.*, 2023). About half of the images were manually annotated, with annotations including facial expressions as well as the intensity of valence and arousal. The remaining images were annotated using a distribution-based model, which differs from the traditional categorical approach. In our study, we employed this dataset, which consists of 14,491 images categorised into five classes of interest: disgust, contempt, fear, anger and happiness.

RAF-DB dataset

The RAF-DB is a comprehensive collection of facial images sourced from the Internet (Huang *et al.*, 2023). It includes seven different emotional categories: surprise, fear, disgust, anger, sadness, happiness and neutrality. This large dataset features 37 automatically generated landmark locations for each image. The annotations were created through crowdsourcing, involving approximately 40 annotators. RAF-DB offers a wide range of facial expressions, encompassing individuals of different ages, races and head orientations (Naga *et al.*, 2023). We used this dataset, focusing on 6,475 images classified into four target classes: disgust, fear, anger and happiness.

Data augmentation of brand hate detector

Data augmentation is crucial in deep learning-based facial expression recognition (FER) due to the limited number of images available in public datasets (Febrian *et al.*, 2023). There are two main strategies for data augmentation: online and offline (Kopalidis *et al.*, 2024).

Online augmentation introduces variability directly into the dataset during the training phase. While this approach can enhance model accuracy, it is computationally intensive and may require additional training time. On the other hand, offline augmentation reduces the computational load during training by creating augmented datasets in advance. This method is especially effective in scenarios where labelling and data collection are expensive or unfeasible. In the current research, we employed both online and offline augmentation techniques to introduce diverse facial expression variations into the training dataset. Techniques such as rotations allow the model to learn from different angles of facial features, while horizontally flipping facial images doubles the number of training examples, enhancing the model's ability to recognise expressions from various orientations.

We also adjusted contrast to simulate real-world lighting conditions, ensuring that the model is robust to different lighting scenarios. Similarly, varying brightness levels enables the model to adapt to images captured in both well-lit and poorly lit environments. The statistics for the gathered dataset used in this investigation are shown in Appendix 2.

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Models

CNN model approach

CNNs have become the standard approach for deep learning across various applications (Taye, 2023). CNNs learn hierarchical representations of images and are especially effective in image recognition tasks (Abd El-Rahiem *et al.*, 2023). Their effectiveness spans a broad spectrum of computer vision tasks, including object detection (Kaur & Singh, 2024), facial expression recognition (Meena *et al.*, 2024), self-driving or autonomous vehicles (Alfred Daniel et al., 2023) and automatic translation (Gunvantray & Ananthan, 2024).

This resilience allows CNNs to effectively capture and extract features regardless of alterations in facial position or scale (Huang *et al.*, 2023). As illustrated in Figure 3, a typical CNN design consists of three main types of layers: convolutional, pooling and fully connected. The input image is initially processed through a series of learnable filters in the convolutional layer, generating activation maps that highlight specific features.

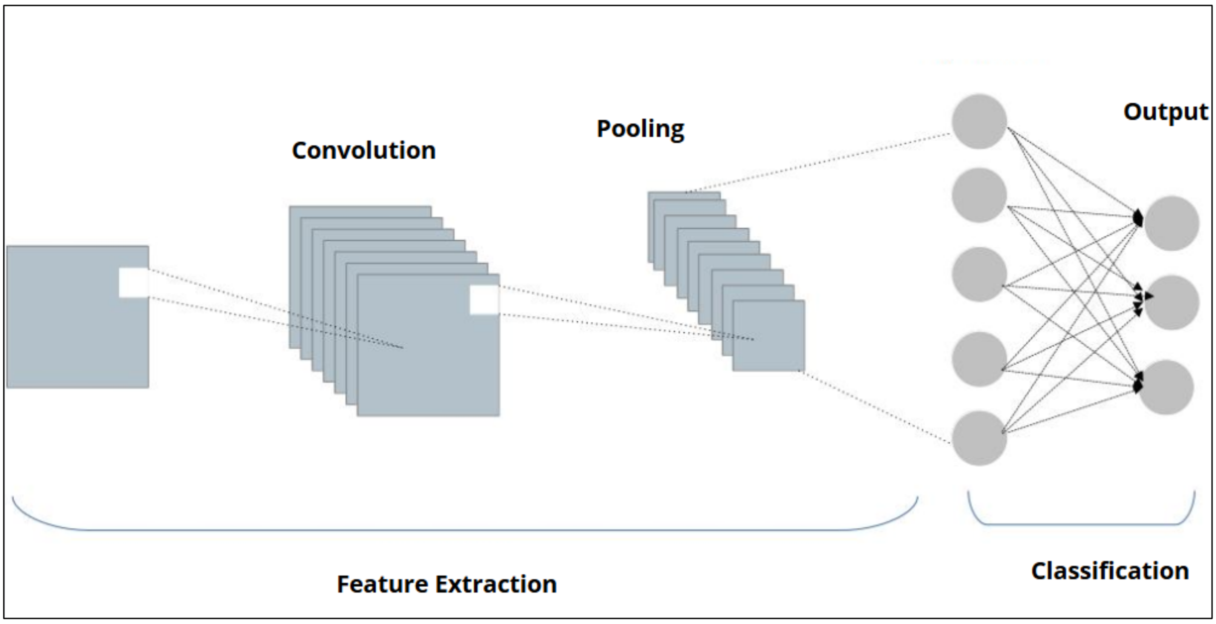

Figure 3. CNN principal layers (figure by the authors)

As the data moves through the network layers, these layers increasingly capture complex patterns, ranging from basic shapes to detailed facial features and ultimately, entire objects. CNNs with multiple convolutional layers facilitate the creation of hierarchical representations of the input images. The stride hyperparameter controls the pixel shift during the convolution step across the input matrix, while the depth hyper parameter monitors the complexity of deeper networks. A pooling layer, also known as a down-sampling layer, is commonly applied after convolutional layers to reduce the size of convolved features. This not only lowers computational costs and improves efficiency but also reduces the risk of overfitting. The final layer of a CNN, typically consisting of fully connected layers, performs the classification tasks based on the features extracted by the preceding layers.

Pre-trained CNN model: VGG-16

Pre-trained CNN models are particularly useful for applications such as facial expression detection (Akhand *et al.*, 2021; Alam *et al.*, 2022). These models effectively assist in the classification process by leveraging the diverse features and filters from their earlier layers. In this study, we employed one pre-trained model, VGGNet, to harness its capacity for facial expression recognition-based brand hate detection.

The VGG architecture, developed by the Visual Geometry Group (VGG) at the University of Oxford, is a well-known CNN that has made significant contributions to the field of computer vision (Bustamam, 2023). Renowned for its simplicity and effectiveness in image classification tasks, VGG-16 consists of 16 layers: 13 convolutional layers and three fully connected layers. Each convolutional layer uses small 3x3 filters, stacked consecutively to produce deeper representations of the input image. This approach allows the network to learn complex features while remaining relatively compact.

Despite its impressive accuracy, VGG-16 is computationally demanding, requiring substantial resources for both training and inference. Additionally, the model's large number of parameters can lead to overfitting, particularly when trained on smaller datasets. VGG-16 remains a benchmark in the field, against other newer models. Its legacy continues to influence the design of modern CNN architectures, inspiring researchers to explore innovative methods for enhancing recognition performance.

Custom CNN model

One of the key challenges when working with VGGNet is the phenomena of information loss as data propagates through the network. To address this issue, we drew on insights from previous studies by Noubigh (2021), and enhanced VGGNet performance by incorporating a new concatenation designed to mitigate information degradation. Our enhancements to VGGNet struck a balance between efficiency and complexity. We optimised the network ability to extract significant features input images by using a streamlined architecture consisting of only five layers, paired with well-executed max-pooling operations. Each convolutional layer was carefully tuned to maximise relevant information extraction, providing optimal performance while minimising computational overhead.

This innovative addition facilitates the integration of feature maps, enhances inter-layer communication, and improves the network's capacity to retain information. By allowing learned features to be reused across multiple levels of the network, this augmentation

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significantly boosts the efficiency and robustness of feature extraction. In addition, we applied batch normalisation to ensure the network's effectiveness and stability, which is essential for normalising input data, enhancing generalisation performance, and speeding up convergence.

Our improvements to VGGNet offered a synergistic combination of computational efficiency and architectural innovation. By incorporating recent advances in deep learning, we presented an enhanced model that excels in emotion detection tasks, capable of extracting strong features. In the proposed CNN design, each block consists of dropout, activation, batch normalisation, convolutional, and max-pooling layers. The concatenation layer plays a critical role by linking the output of these layers to the activation layer in the subsequent level. The proposed architecture includes three repetitions of this concatenation process.

Experiments, results and comparison of brand hate detector

The implementation parameters for both models are detailed in Table 1. Each model maintains a consistent input shape. The VGG-16 network is initialised using pre-trained weights from the ImageNet dataset, while the custom CNN is trained from scratch. A Softmax classifier combined with the Adam optimiser and the categorical cross-entropy loss function is used for classification purposes. Batch normalisation is employed as the regularisation method across all models. Additionally, the model shares identical characteristics, such as batch size, epoch size and dropout rate. The evaluation includes key performance metrics, specifically accuracy and the confusion matrix, with the latter broken down into true-positive (TP), false-positive (FP), false-negative (FN) and true-negative (TN).

- TP = model predicts the positive class accurately
- TN = model predicts the negative class accurately
- FP = model predicts the positive class inaccurately
- FN = model predicts the negative class inaccurately.

Accuracy: This metric represents the ratio of correct predictions to the total number of predictions made by the model. However, accuracy can be misleading, especially when dealing with imbalanced datasets. Accuracy is calculated using the formula (1).

$$\text{Accuracy} = (\text{TP} + \text{TN}) \div \text{Total observations} \quad (1)$$

Confusion matrix: The confusion matrix provides a detailed view of the model's performance by presenting the counts of true positives, true negatives, false positives and false negatives. Each cell represents the number of occurrences for a combination of actual and predicted classes.

Diagonal elements represent correct predictions, while off-diagonal elements indicate errors. Analysing the confusion matrix helps identify misclassifications, thereby enhancing prediction accuracy.

Table 1. Implementation parameters (table by the authors)

Parameters	**VGG-16**	**Custom CNN**
Input shape	(96,96,3)	(96,96,3)
Weights	Initialised to ImageNet	From scratch
Epochs	50	50
Batch size	64	64
Classifier	Softmax	Softmax
Optimiser	Adam	Adam
Loss function	Categorical_crossentropy	Categorical_crossentropy
Dropout	0,5	0,5
Regularisation	Batch normalisation	Batch normalisation

Results of VGG-16 model

In this section, we present the performance evaluation of the fine-tuned VGG-16 model. Figure 4 illustrates the accuracy results obtained when utilising VGG-16 as feature extractor. The model was initialised using transfer learning. From the initial epoch, the model demonstrated notably high accuracy on both training and testing sets, with significant improvements observed over time.

The VGG-16 model exhibited a substantial improvement, with an accuracy rising from 0.45 to 0.75 over the 50 first epochs. To further assess the model convergence and alignment with the dataset, we employed a confusion matrix to validate its performance.

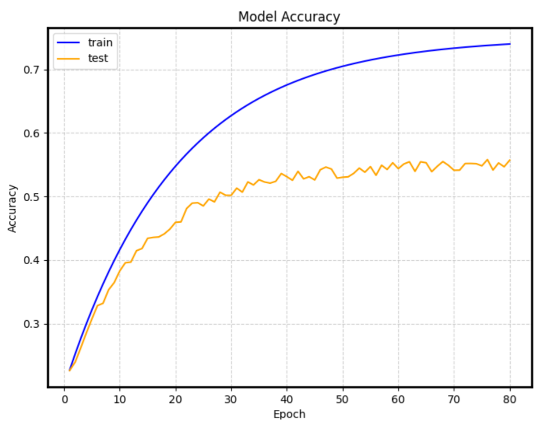

Figure 4. Accuracy evaluation using VGG-16 (figure by the authors)

The confusion matrix is displayed in Figure 5. It indicates that the VGG-16 model shows higher accuracy in predicting emotions associated with anger and happiness, categorised as 'hot hate' and 'no hate,' respectively. However, it struggles to accurately predict the remaining three emotions associated with hate.

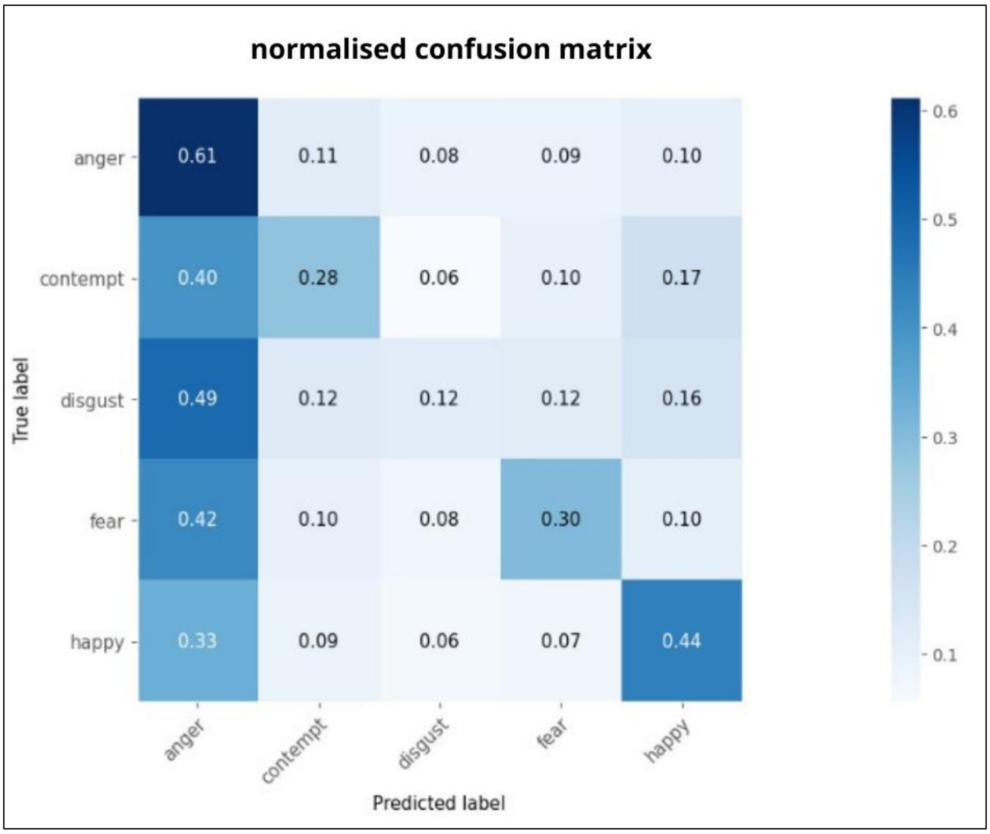

Figure 5. Confusion matrix using VGG-16 (figure by the authors)

Further analysis of the confusion matrix shows that despite the improvement achieved by VGG-16, misclassifying non-hate images as hate images occur with a significant error rate of 56%. Similarly, hate emotions are misclassified as non-hate more than 50% of the time. Consequently, we decided to continue our experimentation by developing a customised CNN model inspired by the architecture of VGG-16. However, we optimised this model by reducing the number of layers to enhance computational efficiency while maintaining the core features that make VGG-16 effective. To tackle the challenge presented by our limited dataset, we implemented feature reuse techniques to maximise the utilisation of available data and potentially improve the model's performance beyond that achieved with the pre-trained VGG-16 model.

Results of custom CNN model

The proposed custom CNN model was trained on the collected database without pre-trained weights. The custom CNN model demonstrated significant computational efficiency compared

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to VGG-16. With only five layers, the model required 60% fewer parameters, resulting in reduced memory consumption and faster training times. On average, the custom CNN achieved inference speeds of 15 ms per image, compared to 25 ms for VGG-16. This efficiency makes the custom model more suitable for resource-constrained environments, such as Edge computing devices used in real-time applications.

As illustrated in Figure 6, the accuracy ranged from 0.4 to 0.98 on the training set and from 0.32 to 0.78,4 on the testing set. This model demonstrated a higher accuracy than the pre-trained models. To further verify the model's performance, we extended the training by an additional 30 epochs compared to previous experiments. The accuracy trend indicated that the model was approaching stability, as illustrated in Figure 7, with a noticeable improvement compared to the confusion matrix of the pre-trained VGG-16 model.

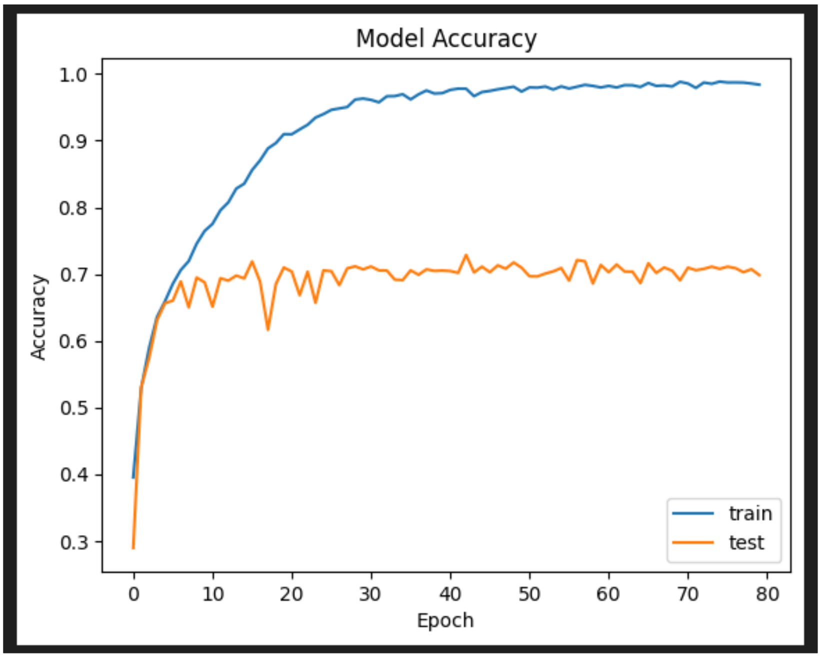

Figure 6. Accuracy evaluation using custom CNN model (figure by the authors)

For the custom CNN model, the testing set accuracy of 78.4% was derived by averaging class-specific accuracies obtained from the confusion matrix. The confusion matrix analysis further revealed that the custom CNN excelled in detecting brand hate emotions, yielding 85% accuracy specifically for hate-related emotions. In contrast, the VGG-16 model showed a more generalised accuracy of 67% for the same category due to misclassifications in nuanced emotional states like 'cool hate' and 'cold hate.' The detailed confusion matrix and calculations supporting these results are illustrated in Figure 7.

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In examining the confusion matrix, we observed frequent misclassifications between the ‘cool hate’ and ‘cold hate’ categories. These errors can be attributed to overlapping facial features, as both expressions share subtle similarities in mouth curvature and eye activity. Moreover, misclassifications of ‘hot hate’ into ‘fear’ likely arise from the intensity of certain expressions resembling each other. Addressing these issues requires incorporating a larger, more diverse training dataset and utilising fine-grained emotion labelling.

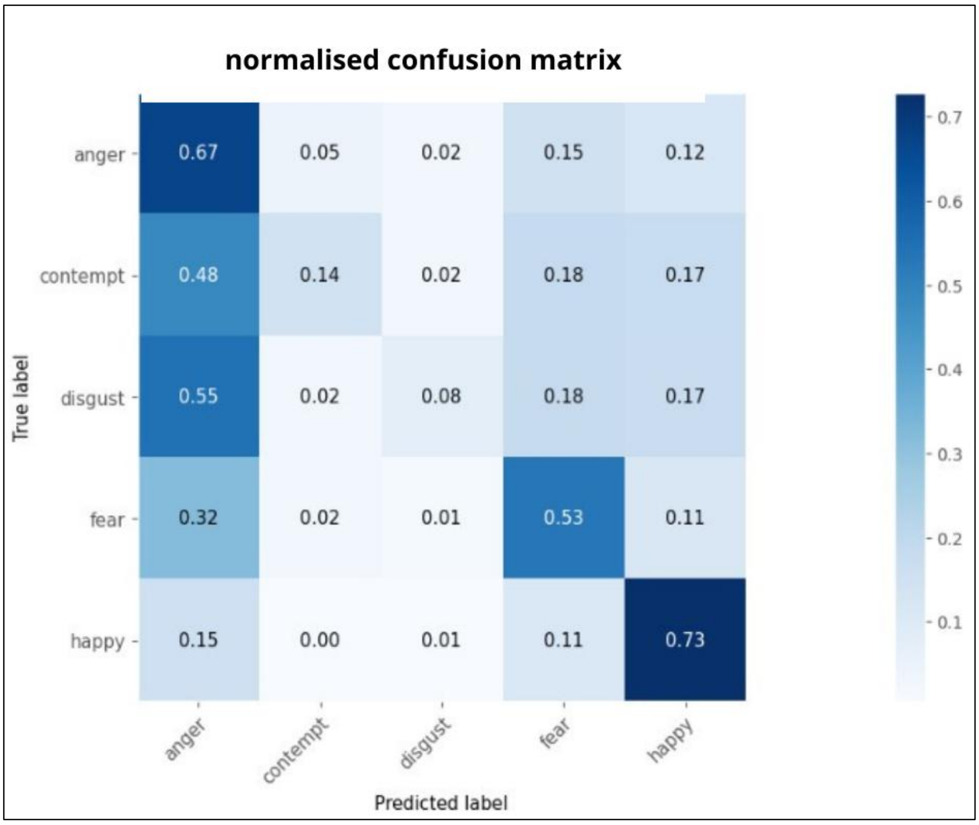

Figure 7. Confusion matrix using custom CNN Model (figure by the authors)

Figure 8 presents examples of predicted emotions from randomly selected images in the validation dataset, categorised into different classes. Among these examples, some show slight deviations between the predicted emotions and the human annotations (true labels). For instance, an emotion labelled as ‘cool hate’ might be classified by the model as ‘hot hate’ which, in this specific case, could be a more accurate assessment. This observation demonstrates the potential of the proposed model to exceed human annotation accuracy in certain cases.

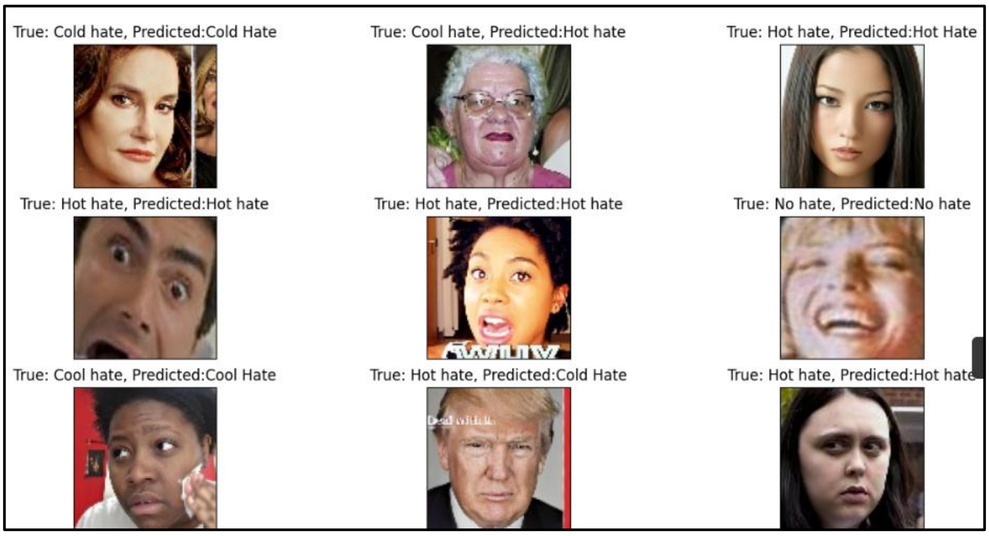

Figure 8. Random examples selection with true and predicted emotions (figure by the authors)

Discussion and Implications

In this study, we investigated brand hate recognition using two distinct CNN models for feature extraction. The pre-trained CNN model, VGGNet, was selected for its robustness and efficiency in feature extraction. Additionally, we developed a custom CNN architecture, inspired by the work of Noubigh (2021), specifically designed to recognise hate sentiment in facial expressions. Consistent with prior studies, CNNs have demonstrated their effectiveness in emotion recognition (Dada *et al.*, 2023; Shahzad *et al.*, 2023).

The misclassification of 'disgust' and 'contempt' was especially evident, due to the nuanced and overlapping visual cues between these categories. For instance, a furrowed brow and tightened lips are common in both. This challenge can be addressed by introducing hierarchical classification models that first identify broader emotion categories before fine-tuning the predictions. Additionally, incorporating an attention mechanism in the custom CNN model could improve feature detection by focusing on critical facial regions, such as the eyes and mouth.

Failure to detect high stakes deception can lead to significant consequences for both society and individuals (Ten Brinke & Porter, 2012). In the context of brand hate, consumers' reactions to brand hate can vary significantly (Ren *et al.*, 2024). First, hot hate, characterised by anger may lead consumers to make financial sacrifices to harm the brand as a means of expressing their hatred (Ren *et al.*, 2024). Second, cool hate, driven by disgust or fear often results in brand switching, as consumers avoid further engagement with the brand (Fetscherin, 2019). Third, cold hate, marked by contempt involves consumers distancing themselves by downplaying the brand's role in their lives (Kucuk, 2019a). Understanding these different levels of hate enables brands to develop more effective strategies.

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Previous studies on brand hate have predominantly focused on measuring hot, cool and cold hate emotions using standardised measurement scales (Kucuk, 2019a; Fetscherin, 2019). To the best of our knowledge, this paper is the first to introduce a novel approach using facial expression analysis across diverse datasets spanning different cultures, ages and genders. Facial expression analysis is considered a valuable method for exploring these emotions (Huang *et al.*, 2023).

Additionally, the process model of emotion suggests that emotions are often more effectively conveyed through behavioural expressions (Mauss & Robinson, 2009; Webb *et al.*, 2012), These expressions can be more accurately captured and analysed through facial recognition technology. This aligns with existing studies that emphasise the importance of facial expressions in accurately reflecting underlying emotional states (Bhavana, *et al.*, 2023). Interpersonal deception theory supports this, stating that deceivers may attempt to mask their true emotions to maintain a favourable image or avoid conflict (Markowitz, 2024). Scholars have previously confirmed the effectiveness of facial emotions recognition in detecting deception (Durga *et al.*, 2023; Solbu *et al.*, 2024).

Theoretical implications

Existing research has primarily focused on antecedents of brand hate (Abbas *et al.*, 2023; Ali *et al.*, 2020; Hashim & Kasana, 2019) and the consequences of brand hate (Hegner *et al.*, 2017; Sameeni *et al.*, 2024), while others have focused on its components (Ren *et al.*, 2024) and management strategies (Mednini & Damak Turki, 2024). The negative impacts of brand hate include brand avoidance (Gusnadi *et al.*, 2024) and negative WOM (Odoom *et al.*, 2023). However, there has been limited attention given to verifying consumer hate (Mednini *et al.*, 2024). Building on the work of Mednini *et al.* (2024) that used NLP to detect brand hate through speech, this research contributes to the marketing literature by exploring another aspect of consumer emotional expression.

Our findings emphasise the crucial role of nonverbal communication in emotions recognition. These findings support previous studies (Khaydarova, 2024) showing that facial expressions are a key method for recognising both positive and negative emotions. While most studies on brand hate have focused on verbal communication channels (Akrout & Mrad, 2023; Pinto & Brandão, 2021; Sharma *et al.*, 2022), our research significantly contributes by emphasising the importance of nonverbal cues, such as facial expressions, in understanding consumer hate.

Moreover, building on previous studies in facial emotion recognition within computer science (Leong *et al.*, 2023), this study makes a significant contribution to brand management studies. In fact, brand hate is a complex phenomenon that can have a profound impact on consumer behaviour, particularly in dynamic markets (Kucuk, 2019b). Our study makes notable contributions in two key areas. First, it contributes to consumer–brand relationship theory by extending research on negative consumer–brand relationships (Anaza *et al.*, 2021) through the creation and development of a brand hate detector. Second, it highlights the critical role of crisis management in addressing these challenges (Rachman *et al.* 2024). A crisis is an unexpected and unusual event that creates uncertainty, threatens an organisation's key objectives, and can result in financial losses and reputational damage (Cleeren *et al.*, 2013; Siomkos *et al.*, 2010).

Managerial implications

By integrating a facial emotion recognition application, businesses can detect the varying levels of customer hate (hot, cool, and cold hate) and tailor their responses accordingly. First, when certain facial expressions signal hate, companies can adjust their communication strategies to be more empathetic and proactive. Recognising hate is a crucial initial step toward implementing effective strategies for different customer groups. For instance, hot hate, which is driven by anger and likely to cause significant damage can be managed with sincere apologies, tangible compensation or discounts. Cool hate, which is marked by disengagement, requires a focus on retention. Strategies might include personalised loyalty programs, and an understanding of consumer preferences. Cold hate that is characterised by contempt and emotional detachment towards brand necessitates efforts to rebuild trust through re-evaluation. Marketers need to engage in socially responsible initiatives and personally address customer concerns to highlight the brand's evolution.

Second, using brand hate emotions detectors, managers will be alerted to potential issues with products or services, even when there is no actual negative experience. If the detector shows no signs of hate (hot, cool, cold), it suggests that customers are not experiencing significant dissatisfaction with the brand. Managers need also to be vigilant about fake complaints that may be fabricated by customers for personal gain or a brand's reputational damage. As a practical example, an e-commerce platform can leverage these detectors to differentiate between genuine service failures and orchestrated smear campaigns. Similarly, the tourism industry can monitor emotional sentiment across reviews and social media to proactively manage and enhance brand perception. If customers fail to substantiate their negative experience, their complaints may be driven by personal motives. In such cases, brands can either engage in direct communication to clarify concerns or implement strategic measures, such as loyalty incentives for dissatisfied customers or public transparency initiatives to counter false narratives.

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Limitations and Future Research

Although this study adds significant value to the marketing literature, it has certain limitations. First, the focus of this paper is to explain the three categories of hate: cool, cold, and hot hate. Further research is needed to explore additional levels of hate, such as burning and simmering hate. Second, emotions trigger changes in facial expressions, voice, body language and posture. Future studies could investigate advanced artificial intelligence (AI) methods for detecting brand hate and develop comprehensive systems that can recognise these various expressions.

References

Abbas, A., Shar, A. H., & Junejo, M. A. (2023). Why brands fail? Antecedents and consequences of brand hate. A study of fashion industry in Pakistan. *Journal of Managerial Sciences*, *17*(1), 1–26. https://journals.qurtuba.edu.pk/ojs/index.php/jms/article/view/696

Abd El-Rahiem, B., Sedik, A., El Banby, G. M., Ibrahem, H. M., Amin, M., Song, O. Y., Khalaf, A. M. M., & Abd El-Samie, F. E. (2023). An efficient deep learning model for classification of thermal face images. *Journal of Enterprise Information Management*, *36*(3), 706–717. https://doi.org/10.1108/JEIM-07-2019-0201

Ahmed, M. U., Woo, K. J., Hyeon, K. Y., Bashar, M. R., & Rhee, P. K. (2018). Wild facial expression recognition based on incremental active learning. *Cognitive Systems Research*, *52*, 212–222. https://doi.org/10.1016/j.cogsys.2018.06.017

Akrout, H., & Mrad, M. (2023). Measuring brand hate in a cross-cultural context: Emic and Etic scale development and validation. *Journal of Business Research*, *154*, 113289. https://doi.org/10.1016/j.jbusres.2022.08.053

Akhand, M. A. H., Roy, S., Siddique, N., Kamal, M. A. S., & Shimamura, T. (2021). Facial emotion recognition using transfer learning in the deep CNN. *Electronics*, *10*(9), 1036. https://doi.org/10.3390/electronics10091036

Alam, I. N., Kartowisastro, I. H., & Wicaksono, P. (2022). Transfer learning technique with EfficientNet for facial expression recognition system. *Revue d'Intelligence Artificielle*, *36*(4). https://doi.org/10.18280/ria.360405

Alfred Daniel, J., Chandru Vignesh, C., Muthu, B. A., Senthil Kumar, R., Sivaparthipan, C. B., & Marin, C. E. M. (2023). Fully convolutional neural networks for LIDAR–camera fusion for pedestrian detection in autonomous vehicle. *Multimedia Tools and Applications*, *82*(16), 25107–25130. https://doi.org/10.1007/s11042-023-14417-x

Alhussan, A. A., Talaat, F. M., El-kenawy, E. S. M., Abdelhamid, A. A., Ibrahim, A., Khafaga, D. S., & Alnaggar, M. (2023). Facial expression recognition model depending on optimized support vector machine. *Computers, Materials & Continua*, *76*(1). https://www.techscience.com/cmc/v76n1/53096

Ali, S., Attiq, S., & Talib, N. (2020). Antecedents of brand hate: Mediating role of customer dissatisfaction and moderating role of narcissism. *Pakistan Journal of Commerce and Social Sciences* (PJCSS), *14*(3), 603–628. https://hdl.handle.net/10419/224953

Alsharif, A. H., Salleh, N. Z. M., & Baharun, R. (2021). Neuromarketing: The popularity of the brain-imaging and physiological tools. *Neuroscience Research Notes*, *3*(5), 13–22. https://doi.org/10.31117/neuroscirn.v3i5.80

Anaza, N. A., Saavedra, J. L., Hair Jr, J. F., Bagherzadeh, R., Rawal, M., & Osakwe, C. N. (2021). Customer-brand disidentification: Conceptualization, scale development and validation. *Journal of Business Research*, *133*, 116–131. https://doi.org/10.1016/j.jbusres.2021.03.064

Arnade, E. A. (2014). Measuring Consumer Emotional Response to Tastes and Foods through Facial Expression Analysis. (Doctoral dissertation, Virginia Tech). https://hdl.handle.net/10919/54538

Atwal, G., Bryson, D., & Kaiser, M. (2022). The chopsticks debacle: How brand hate flattened Dolce & Gabbana in China. *Journal of Business Strategy*, *43*(1), 37–43. https://doi.org/10.1108/JBS-07-2020-0160

Baer, J. (2016). Hug your haters: How to embrace complaints and keep your customers. Portfolio, Penguin Publishing Group. https://archive.org/details/hugyourhatershow0000baer

Bhavana, V., Dhanalakshmi, M., & Aishwarya, S. (2023, December). A brief survey on facial expression detection. In *2023 10th IEEE Uttar Pradesh Section International Conference on Electrical, Electronics and Computer Engineering* (UPCON) (Vol. 10, pp. 110–115). IEEE. https://doi.org/10.1109/UPCON59197.2023.10434419

Bond Jr, C. F., & DePaulo, B. M. (2006). Accuracy of deception judgments. *Personality and Social Psychology Review*, *10*(3), 214–234. https://doi.org/10.1207/s15327957pspr1003_2

Bryson, D., Atwal, G., Hultén, P., & Heine, K. (2021). Antecedents of luxury brand hate: A quantitative study. *Strategic Change*, *30*(1), 35–43. https://doi.org/10.1002/jsc.2387

Bustamam, A. (2023). Arrhythmia classification using the deep learning visual geometry group (VGG) model. *Nusantara Science and Technology Proceedings*, 7–18. https://nstproceeding.com/index.php/nuscientech/article/view/1080

Buroon, J. K., Bulkr, D. B., Ebesu, A. S., White, C. H., & Rockwell, P. A. (1996). Testing interpersonal deception theory: Effects of suspicion on communication behaviors and perceptions. *Communication Theory*, *6*(3), 243–267. https://doi.org/10.1111/j.1468-2885.1996.tb00128.x

Cleeren, K., Van Heerde, H. J., & Dekimpe, M. G. (2013). Rising from the ashes: How brands and categories can overcome product-harm crises. *Journal of Marketing*, *77*(2), 58–77. https://doi.org/10.1509/jm.10.0414

Crist, C. A., Duncan, S. E., Arnade, E. A., Leitch, K. A., O'Keefe, S. F., & Gallagher, D. L. (2018). Automated facial expression analysis for emotional responsivity using an aqueous bitter model. *Food Quality and Preference*, *68*, 349–359. https://doi.org/10.1016/j.foodqual.2018.04.004

Curina, I., Francioni, B., Cioppi, M., and Savelli, E. (2021). Traits and peculiarities of different brand hate behaviours, *Journal of Strategic Marketing*, Vol. 29 No. 3, 227–246. https://doi.org/10.1080/0965254X.2019.1676293

Dada, E. G., Oyewola, D. O., Joseph, S. B., Emebo, O., & Oluwagbemi, O. O. (2023). Facial emotion recognition and classification using the Convolutional Neural Network-10 (CNN-10). *Applied Computational Intelligence and Soft Computing, 2023*(1), 2457898. https://doi.org/10.1155/2023/2457898

Danner, L., & Duerrschmid, K. (2018). Automatic facial expressions analysis in consumer science. In *Methods in Consumer Research*, Volume 2 231–252. Woodhead Publishing. https://doi.org/10.1016/B978-0-08-101743-2.00010-8

Dong, X., Veloutsou, C., & Morgan-Thomas, A. (2024). Negative online brand engagement: conceptualisation, scale development and validation. *Journal of Research in Interactive Marketing*, (ahead of print). https://doi.org/10.1108/JRIM-09-2023-0303

Durga, B. K., Rajesh, V., Jagannadham, S., Kumar, P. S., Rashed, A. N. Z., & Saikumar, K. (2023). Deep learning-based micro facial expression recognition using an adaptive tiefes FCNN model. *Traitement du Signal*, *40*(3). https://doi.org/10.18280/ts.400319

Ezati, A., Dezyani, M., Rana, R., Rajabi, R., & Ayatollahi, A. (2024). A Lightweight Attention-based Deep Network via Multi-Scale Feature Fusion for Multi-View Facial Expression Recognition. arXiv preprint arXiv:2403.14318. https://doi.org/10.48550/arXiv.2403.14318

Febrian, R., Halim, B. M., Christina, M., Ramdhan, D., & Chowanda, A. (2023). Facial expression recognition using bidirectional LSTM-CNN. *Procedia Computer Science*, *216*(2022), 39–47. https://doi.org/10.1016/j.procs.2022.12.109

Fetscherin, M. (2019). The five types of brand hate: How they affect consumer behavior. *Journal of Business Research*, *101*, 116–127. https://doi.org/10.1016/j.jbusres.2019.04.017

Generosi, A., Ceccacci, S., & Mengoni, M. (2018, September). A deep learning-based system to track and analyze customer behavior in retail store. In *2018 IEEE 8th International Conference on Consumer Electronics – Berlin* (ICCE-Berlin) (pp. 1–6). IEEE. https://doi.org/10.1109/ICCE-Berlin.2018.8576169

Gunvantray, T. D., & Ananthan, T. (2024, March). Sign language to text translation using convolutional neural network. In *2024 International Conference on Emerging Smart Computing and Informatics* (ESCI) (pp. 1–5). IEEE. https://doi.org/10.1109/ESCI59607.2024.10497209

Gusnadi, F., Efendi, M., & Apriyana, N. (2024). Analisis brand hate terhadap brand avoidance pada merek Starbucks konteks issue Israel-Palestina. *Jurnal Cahaya Mandalika ISSN* 2721–4796 (online), *5*(1), 265–277. https://doi.org/10.36312/jcm.v5i1.2726.

Hamelin, N., El Moujahid, O., & Thaichon, P. (2017). Emotion and advertising effectiveness: A novel facial expression analysis approach. *Journal of Retailing and Consumer Services*, *36*, 103–111. https://doi.org/10.1016/j.jretconser.2017.01.001

Hashim, S., & Kasana, S. (2019). Antecedents of brand hate in the fast food industry. *Spanish Journal of Marketing – ESIC, 23*(2), 227–248. https://doi.org/10.1108/SJME-10-2018-0047

Hegner, S. M., Fetscherin, M., & Van Delzen, M. (2017). Determinants and outcomes of brand hate. *Journal of Product & Brand Management*, *26*(1), 13–25. https://doi.org/10.1108/JPBM-01-2016-1070

Hess, U., & Thibault, P. (2009). Darwin and emotion expression. *American Psychologist*, *64*(2), 120. https://psycnet.apa.org/buy/2009-01602-003

Huang, Z. Y., Chiang, C. C., Chen, J. H., Chen, Y. C., Chung, H. L., Cai, Y. P., & Hsu, H. C. (2023). A study on computer vision for facial emotion recognition. *Scientific Reports*, *13*(1), 8425. https://doi.org/10.1038/s41598-023-35446-4

Husnain, M., Syed, F., Hussain, K., Zhang, Q., Usman, M., & Javed, M. (2023). Explaining the mechanism of brand hate: a mixed-method investigation using moderated mediation in emerging markets. *Kybernetes*, *52*(10), 3857–3877. https://doi.org/10.1108/K-12-2021-1246

Iranzo Barreira, Á., Kuster, I., & Ruiz Mafe, C. (2024). Inward negative emotions and brand hate in users of snow-sports' brands. *Journal of Product & Brand Management*, 33(6), 745-760. https://doi.org/10.1108/JPBM-05-2023-4541

Kaur, J., & Singh, W. (2024). A systematic review of object detection from images using deep learning. *Multimedia Tools and Applications*, *83*(4), 12253-12338. https://doi.org/10.1007/s11042-023-15981-y

Khaydarova, N. (2024). Some features of verbal and non-verbal types of communication. *XALQARO ILMIY-AMALIY KONFERENSIYALAR*, *1*(1), 288–291. https://tkti.uz/uz/events/detail/xalqaro-ilmiy-amaliy-konferentsiya/

Kopalidis, T., Solachidis, V., Vretos, N., & Daras, P. (2024). Advances in facial expression recognition: A Survey of methods, benchmarks, models, and datasets. *Information*, *15*(3), 135. https://doi.org/10.3390/info15030135

Kucuk, S. U. (2019a). Consumer brand hate: Steam rolling whatever I see. *Psychology & Marketing, 36*(5), 431–443. https://doi.org/10.1002/mar.21175

Kucuk, S. U., (2019b). What is brand hate? . In: Brand Hate. Palgrave Macmillan, Cham. https://doi.org/10.1007/978-3-030-00380-7_2

Kumar, S., Sagar, V., & Punetha, D. (2023). A comparative study on facial expression recognition using local binary patterns, convolutional neural network and frequency neural network. *Multimedia Tools and Applications*, *82*(16), 24369–24385. https://doi.org/10.1007/s11042-023-14753-y.

Leong, S. C., Tang, Y. M., Lai, C. H., & Lee, C. K. M. (2023). Facial expression and body gesture emotion recognition: A systematic review on the use of visual data in affective computing. *Computer Science Review*, *48*, 100545. https://doi.org/10.1016/j.cosrev.2023.100545

Li, J., & Lam, E. Y. (2015, September). Facial expression recognition using deep neural networks. In *2015 IEEE International Conference on Imaging Systems and Techniques* (IST) (pp. 1–6). IEEE. https://doi.org/10.1109/IST.2015.7294547

Markowitz, D. M. (2024). Deconstructing deception: Frequency, communicator characteristics, and linguistic features of embeddedness. *Applied Cognitive Psychology*, *38*(3), e4215. https://doi.org/10.1002/acp.4215

Mauss, I. B., & Robinson, M. D. (2009). Measures of emotion: A review. *Cognition and emotion*, *23*(2), 209–237. https://doi.org/10.1080/02699930802204677

Mednini, L., & Turki, M. D. (2022, May). What leads customer to create and participate in anti-brand community: a netnographic approach. In *International Conference on Digital Economy* (pp. 159–169). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-031-17037-9_11

Mednini, L., Noubigh, Z., & Turki, M. D. (2024). Natural language processing for detecting brand hate speech. *Journal of Telecommunications and the Digital Economy*, *12*(1), 486–509. https://search.informit.org/doi/abs/10.3316/informit.T2024040300011091695498163

Mednini, L., & Damak Turki, M. (2024). How to transform brand haters into forgivers through emotional intelligence? *Management Decision*, *62*(1), 183–199. https://doi.org/10.1108/MD-06-2022-0819

Mednini, L., & Hmida, I. C. B. (2023, May). Antecedents and outcomes of brand hate: A case of anti-brand community. In *International Conference on Digital Economy* (pp. 222–234). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-031-42788-6_14

Meena, G., Mohbey, K. K., Indian, A., Khan, M. Z., & Kumar, S. (2024). Identifying emotions from facial expressions using a deep convolutional neural network-based approach. *Multimedia Tools and Applications*, *83*(6), 15711–15732. https://doi.org/10.1007/s11042-023-16174-3

Mollahosseini, A., Hasani, B., & Mahoor, M. H. (2017). AffectNet: A database for facial expression, valence, and arousal computing in the wild. *IEEE Transactions on Affective Computing*, *10*(1), 18–31. https://doi.org/10.1109/TAFFC.2017.2740923

Mushtaq, F. M., Ghazali, E. M., & Hamzah, Z. L. (2024). Brand hate: a systematic literature review and future perspectives. *Management Review Quarterly*, 1–34. https://doi.org/10.1007/s11301-023-00402-z

Naga, P., Marri, S. D., & Borreo, R. (2023). Facial emotion recognition methods, datasets and technologies: A literature survey. *Materials Today: Proceedings*, *80*, 2824–2828. https://doi.org/10.1016/j.matpr.2021.07.046

Naidoo, S. W., Naicker, N., Patel, S. S., & Govender, P. (2022). Computer vision: the effectiveness of deep learning for emotion detection in marketing campaigns. *International Journal of Advanced Computer Science and Applications*; *13*(5). doi: https://doi.org/10.14569/ijacsa.2022.01305100

Noubigh, Z., Mezghani, A., & Kherallah, M. (2020, November). Transfer learning to improve Arabic handwriting text recognition. In 2020 *21st International Arab Conference on Information Technology* (ACIT) (pp. 1–6). IEEE. https://doi.org/10.1109/ACIT50332.2020.9300105

Noor, U., Mansoor, M., & Rabbani, S. (2022). Brand hate and retaliation in Muslim consumers: Does offensive advertising matter? *Journal of Islamic Marketing*, *13*(6), 1395–1413. https://doi.org/10.1108/JIMA-10-2020-0316

Noubigh, Z., Mezghani, A., & Kherallah, M. (2021). Densely connected layer to improve VGGnet-based CRNN for Arabic handwriting text line recognition. I*nternational Journal of Hybrid Intelligent Systems*, *17*(3–4), 113–127. https://doi.org/10.3233/HIS-210009

Odoom, R., Kosiba, J. P. B., & Odoom, P. T. (2024). Brand hate experiences and the role of social media influencers in altering consumer emotions. *Journal of Brand Management*, 1–14. https://doi.org/10.1057/s41262-024-00356-x

Pantano, E. (2020). Non-verbal evaluation of retail service encounters through consumers' facial expressions. *Computers in Human Behavior, 111*, 106448. https://doi.org/10.1016/j.chb.2020.106448

Pereira, J., and Loureiro, S. M. C. (2020), The different shades of brand hate: A qualitative approach, 2020 Global Marketing Conference at Seoul Proceedings: 632-636 (November 2020), pp. 632–636. https://db.koreascholar.com/Article/Detail/401143

Pinto, O., & Brandão, A. (2021). Antecedents and consequences of brand hate: Empirical evidence from the telecommunication industry. *European Journal of Management and Business Economics*, *30*(1), 18–35. https://doi.org/10.1108/EJMBE-04-2020-0084

Rachman, R., Hamid, M. A., Wijaya, B. K., Wibowo, S. E., & Intan, D. N. (2024). Brand storytelling in the digital age: challenges and opportunities in online marketing. *Jurnal Ekonomi*, *13*(01), 355–364. https://ejournal.seaninstitute.or.id/index.php/Ekonomi/article/view/3748

Rahimah, A., Dang, H. P., Nguyen, T. T., Cheng, J. M. S., & Kusumawati, A. (2023). The subsequent effects of negative emotions: From brand hate to anti-brand consumption behavior under moderating mechanisms. *Journal of Product & Brand Management, 32*(4), 618–631. https://doi.org/10.1108/JPBM-12-2021-3778

Ren, C., Moisieiev, D., Rodrigo, P., & Johnson, E. (2024). Hot and cold: How do consumers hate and forgive offending charity brands? *Journal of Philanthropy and Marketing*, *29*(3), e1875. https://doi.org/10.1002/nvsm.1875

Rozin, P., Haidt, J., McCauley, C., Dunlop, L., & Ashmore, M. (1999). Individual differences in disgust sensitivity: Comparisons and evaluations of paper-and-pencil versus behavioral measures. *Journal of Research in Personality*, *33*(3), 330–351. https://doi.org/10.1006/jrpe.1999.2251

Sameeni, M. S., Qadeer, F., Ahmad, W., & Filieri, R. (2024). An empirical examination of brand hate influence on negative consumer behaviors through NeWOM intensity. Does consumer personality matter? *Journal of Business Research*, *173*, 114469. https://doi.org/10.1016/j.jbusres.2023.114469

Scherer, K. R. (2009). The dynamic architecture of emotion: Evidence for the component process model. *Cognition and emotion*, *23*(7), 1307–1351. https://doi.org/10.1080/02699930902928969

Shahzad, F., Qazi, T. A., & Shehzad, R. (2023). Framing of Israel and Palestine conflict in RT news, Al-Jazeera, CNN & BBC News. *Global Digital & Print Media Review*, *6*(II), 1–14. https://doi.org/10.31703/gdpmr.2023(VI-II).01

Sharma, A., Fadahunsi, A., Abbas, H., & Pathak, V. K. (2022). A multi-analytic approach to predict social media marketing influence on consumer purchase intention. *Journal of Indian Business Research*, *14*(2), 125–149. https://doi.org/10.1108/JIBR-08-2021-0313

Siomkos, G., Triantafillidou, A., Vassilikopoulou, A., & Tsiamis, I. (2010). Opportunities and threats for competitors in product-harm crises. *Marketing Intelligence & Planning*, *28*(6), 770–791. https://doi.org/10.1108/02634501011078156

Solbu, A., Frank, M. G., Xu, F., Nwogu, I., & Neurohr, M. (2024). The effect of synchrony of happiness on facial expression of negative emotion when lying. *Journal of Nonverbal Behavior*, *48*(1), 73–92. https://doi.org/10.1007/s10919-023-00447-4

Sternberg, R. J. (2003). A duplex theory of hate: Development and application to terrorism, massacres, and genocide. *Review of General Psychology, 7*(3), 299–328. https://doi.org/10.1037/1089-2680.7.3.299

Sternberg, R. J. (2005). Understanding and combating hate. In R. J. Sternberg (Ed.), *The Psychology of Hate*, 37–49. American Psychological Association. https://doi.org/10.1037/10930-002

Taye, M. M. (2023). Theoretical understanding of convolutional neural network: Concepts, architectures, applications, future directions. *Computation*, *11*(3), 52. https://doi.org/10.3390/computation11030052

Ten Brinke, L., & Porter, S. (2012). Cry me a river: identifying the behavioral consequences of extremely high-stakes interpersonal deception. *Law and Human Behavior, 36*(6), 469. https://psycnet.apa.org/doi/10.1037/h0093929

Valenzuela, C., Castellucci, L., Mena, M. T., & Bianchi, C. (2022). Consumer brand hate: The role of ambivalence. *The International Review of Retail, Distribution and Consumer Research*, *32*(1), 100–125. https://doi.org/10.1080/09593969.2021.2018017

Wang, C. Y., & Lin, F. S. (2022, June). Assessing the effectiveness of digital advertising for green products: A facial expression evaluation approach. In *International Conference on Human-Computer Interaction* (pp. 221–232). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-031-05544-7_17

Wang, W., & Sun, L. (2024). Brand marketing strategy based on user emotion recognition model of consumer. *Computer-Aided Design and Applications, 21*(S12), 115–129. https://doi.org/10.14733/cadaps.2024.S12.115-129

Webb, T. L., Miles, E., & Sheeran, P. (2012). Dealing with feeling: a meta-analysis of the effectiveness of strategies derived from the process model of emotion regulation. *Psychological bulletin*, *138*(4), 775. https://psycnet.apa.org/doi/10.1037/a0027600

Xue, Y., Sun, J., Liu, Y., Li, X., & Yuan, K. (2024). Facial expression-enhanced recommendation for virtual fitting rooms. *Decision Support Systems, 177*, 114082. https://doi.org/10.1016/j.dss.2023.114082

Xu, X., Ruan, Z., & Yang, L. (2020, July). Facial expression recognition based on graph neural network. In *2020 IEEE 5th International Conference on Image, Vision and Computing* (ICIVC) (pp. 211–214). IEEE. https://ieeexplore.ieee.org/document/7832107/

Yadav, A. (2024). When personalities collide: Examining the impact of consumer and brand personalities' interplay on brand hate development. *Journal of Product & Brand Management*. https://doi.org/10.1108/JPBM-01-2023-4307

Zloteanu, M., Bull, P., Krumhuber, E. G., & Richardson, D. C. (2021). Veracity judgement, not accuracy: Reconsidering the role of facial expressions, empathy, and emotion recognition training on deception detection. *Quarterly Journal of Experimental Psychology*, *74*(5), 910–927. https://doi.org/10.1177/1747021820978851

Appendices

Appendix 1. Different applications of facial expression in literature (table by authors)

Author and date	**Method**	**Database**	**Results**
Li & Lam (2015)	Deep Neural Network	Cohn–Kanade	Accuracy= 91.7%
Ahmed *et al.* (2018)	Convolutional	CK and CK+	Accuracy= 96.24%
Xu *et al.* (2020)	Convolutional Neural Network (CNN)	FER 2013	Accuracy=95.85%
Alhussan *et al.* (2023)	Convolutional Neural Network (CNN)	The MUG Facial Expression Database	Accuracy= 99%
Kumar *et al.* (2023)	Facial Expression Recognition Model (FERM), Support Vector Machine (SVM)	KDEF and AKDEF, and KinFaceW – I and II	High-performance accuracy
Ezati *et al.* (2024)	Convolutional Neural	JAFFE, FER 2013 and CK+	90.77%, 70.44%, and 86.96% accuracy rates on KDEF, FER 2013 and FERPlus datasets, respectively

Appendix 2. Statistics of the used datasets (table by the authors)

Category	**Number of images in AffectNet**	**Number of images in RAF-DB**	**Total of images after data augmentation**	
			Train	Test
Disgust	2,477	717	4,335	1,859
Contempt	2,871	None	5,049	2,165
Fear	3,176	281	4,519	1,938
Anger	3,218	705	4,846	2,077
Happy	3,000	700	4,781	2,049

The Relationship Between Reward, Attitude and Intentions in a Gamified App Context

Evidence from an Emerging Economy

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Abstract: Gamification has become a popular marketing strategy with positive implications in various contexts. This paper examines the effect of a single gamification element (reward) on behavioural intentions through attitude. Furthermore, this study investigates the moderating influence of individuals' perception of the ethical nature of rewards. Following a survey method, the data was received from 414 respondents using gamified e-commerce application (app). The analysis was done using Structural Equation Modelling (SEM). This study revealed the positive and negative impact of rewards on behavioural intentions (app stickiness intention and app discontinuance intention). Results also show that the perceived ethicality of rewards significantly influences the relationship between rewards and negative attitude. The study makes a valuable contribution to the extant body of literature on gamification and e-commerce by empirically shedding light on the paucity of ethical perspectives on gamification in a gamified e-commerce app context. In addition, apart from prior studies which predominantly portray the positive implications of gamification, this study examined the bivalent effect of gamification element reward. It also provides some suggestions for improving gamified e-commerce business practices.

Keywords: Gamification, Perceived Ethicality, Attitude, Intention, e-Commerce Application

Introduction

The rapid increase in Internet consumers and smartphone penetration fuelled the growth of the e-commerce market in India, and the e-retail market is projected to reach US$120–140 billion by FY26, expanding by 25–30% annually over the next five years (India Brand Equity Foundation, 2023). The significant rise of the mobile application (hereafter referred to as

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'app') industry in emerging nations (Nandi *et al.*, 2021), combined with the availability of faster Internet (Chin *et al.*, 2022), have become major marketing triggers in influencing customers' e-commerce experiences (Kumar *et al.*, 2018). Nowadays, e-commerce has become a key contributor to the economy of many countries (García-Jurado *et al.*, 2021) and e-commerce mobile apps are becoming increasingly gamified as gamification has a huge impact on consumer decision-making (Tobon *et al.*, 2020).

The discovery that games engage players and the possibility of achieving the same result by applying game design principles to other non-game scenarios have sparked marketers' interest in gamification. (Insley & Nunan, 2014). A startlingly high number of businesses already provide gamification services, and investments are being made in gamification-related initiatives (Hamari *et al.*, 2014). Deterding *et al.* (2011) defined gamification as 'the use of game design elements in non-game contexts'. Elements of the game's design may be found in the form of rewards, points, badges, leaderboard and levels (Yu & Huang, 2022). In this paper, the components that are distinctive to games are referred to as game design elements (Groening & Binnewies, 2019). Among various elements, reward is the most studied gamification element (Tobon *et al.*, 2020). Marketers feel that integrating games with monetary participation incentives (such as price reductions) delivers a more successful business outcome (Bauer *et al.*, 2020). In gamified services, rewards are often used for consumers' participation in the service delivery process (Feng *et al.*, 2020). However, Deci *et al.*, (2001) suggest that external rewards have adverse impacts on internal motivation, and in some cases this may also apply to gamification (Hanus & Fox, 2015). This argument is supported by the findings of Zhou *et al.* (2023). Gamification experiences have been shown to evoke emotional responses such as changes in attitude and behavioural intentions. A majority of prior studies exhibited a positive impact of gamification on behavioural intentions (Aydınlıyurt *et al.*, 2021; Shi *et al.*, 2022).

Despite the fact that academics and professionals alike recognise the potential of gamification in a variety of contexts, there is a lack of knowledge on the effect of specific game elements (Abou-Shouk & Soliman, 2021; Xi & Hamari, 2020) in gamified application. The rising gamification of e-commerce apps (Xu *et al.*, 2022) makes it relevant for analysis in an e-commerce context, considering that different game characteristics may lead to varied behavioural results (Feng *et al.*, 2020). This is because certain gamification components may not impact all targeted users in the desired way and could have major negative outcomes (Zhou *et al.*, 2023). To our best knowledge, the individual gamification element (reward) trigger dualistic effect (positive and negative attitude) and behavioural responses (stickiness intention and discontinuance intention) in gamified e-commerce settings are under-researched. Moreover, the empirical evidence on the ethical perception of gamification is scant

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(Zhou *et al.*, 2023), which is essential when considering a developing economy like India, especially given the rising popularity of gamification.

Overall, this research's intent is to empirically investigate the effect of game element (reward) on users' app stickiness and app discontinuance intentions through attitude. In addition, we examine the moderating role of the perceived ethicality of rewards. Given the importance of e-commerce to India's economic development and the growing use of gamification in mobile apps, this study offers pertinent insights into how behavioural intentions are impacted by rewards, a crucial component of gamification.

Theoretical Background and Hypotheses

S-O-R model

The Stimulus-Organism-Response model propounded by Mehrabian-Russell (1974) provides the theoretical explanation for the effect of rewards on behavioural intentions in this study. The S-O-R model evinces that attributes of an environment (stimulus) evoke the internal states (organism) of individuals, which further induce their behavioural outcome (approach or avoidance response) (Donovan & Rossiter, 1982). When an individual experiences a stimulus from the external environment, it activates their accumulated experiences, beliefs, attitudes, predispositions and emotions, which in turn shape their response, leading them to either approach or avoid the stimulus (Bigne *et al.*, 2020; Tsou & Putra, 2023). Leveraging the S-O-R model in consumer behaviour research helps online retailers determine the external triggers they need to adjust to evoke desired internal cognitive and behavioural responses from consumers (Tsou & Putra, 2023).

The S-O-R paradigm has been used in various consumer behaviour contexts to study the impact of gamification on marketing outcomes (Lim *et al.*, 2025; Shankar, 2022). The stimulus (S) denotes any outside force that can affect an individual's actions, which can take the form of an object, an occurrence, or any environmental aspect that influences the individual (Erensoy *et al.*, 2024). Recent work shows that gamification elements act as triggers (Tsou & Putra, 2023), which influence the psychological state of individuals. This study considers rewards gamification in the e-commerce app as the stimuli which activate the organismic state of attitude. Organism (O) is defined as an individual's psychological affective and cognitive states (or change) in response to environmental stimuli (Jiang & Lyu, 2024). The work by Sultan *et al.* (2021) examined hedonic and utilitarian attitude as a mediating variable (organism) while assessing the relationship between marketing communication sources and behavioural intention. This study posits that rewards (gamification element) as a stimuli trigger the attitudinal response (organism state) of users in an e-commerce app.

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Response is defined as the intention to perform a behaviour based on cognitive and emotional responses (Bigne *et al.*, 2020). The organism state of attitude processes the reward stimuli and enables consumers to exhibit their behavioural response in the form of stickiness intention and discontinuance intention. Accordingly, it is fit for this study to use the S-O-R model as the underlying mechanism for examining the influences of an environmental feature (that is, reward) as stimuli on users' organisms (that is, positive and negative attitude elicited by reward) and in turn on their response (that is, app stickiness intention and app discontinuance intention). Based on the S-O-R framework, the research model developed for this study is illustrated in Figure 1.

Rewards and positive attitude

In this study, a reward is the monetary benefit received by a person in return for a certain action performed or a goal achieved (Gil-Aciron, 2022) in a gamified e-commerce app. Attitudes are defined as an individual's positive or negative evaluation of a focal entity or a behaviour (Ajzen & Fishbein, 1980; Hwang & Choi, 2020). In many studies about attitudes, researchers often think of attitude as one overall opinion about something, ranging from negative to positive (like or dislike). This single-dimensional view of attitude overlooks the complexity and potential depth of the attitude construct (Ng *et al.*, 2021). A person's attitude toward something can be mixed, with both positive and negative feelings or beliefs about the same thing at the same time (Videbæk & Grunert, 2020). For example, a person might like certain features of a product but dislike others. So, their overall attitude isn't just one-sided; it's a mix of both good and bad feelings or thoughts about that object, which can be described as ambivalence (Videbæk & Grunert, 2020; Zhang *et al.*, 2024). Ambivalence is commonly defined as 'holding simultaneously at least two contradictory attitudes toward the same attitude object' (Moody *et al.*, 2014). Based on this reasoning, in this study we have treated positive and negative attitudes separately and formulated our hypotheses accordingly.

Users' interactions with rewards influence the attitudes of users toward gamification elements (Unurlu, 2021). In a gamified e-commerce app, users need to put some effort (perform a task or requirement as specified by the service provider) to acquire exciting rewards (for example, coins, special deals). Hence, as suggested by previous gamification studies (Aydinliyurt *et al.*, 2021; Feng *et al.*, 2018), we assume that rewards may induce psychological reactions of consumers to be more positive. Thus, we hypothesise that:

> *H1*. A user's interaction with reward positively influences their positive attitude.

Rewards and negative attitude

Evidence from research in the setting of online communities emphasises the undermining impacts of monetary rewards (Garnefeld *et al.*, 2012) on intrinsic drive, rendering them ineffectual or counter-effective (Sun *et al.*, 2017). This might be because consumers see the benefits as having ulterior purposes (Pongjit & Beise-Zee, 2015). It was determined that reduction of reward (for example, reward worthlessness) and refusing reward (for example, qualification barrier) induce negative emotions (Stauss *et al.*, 2005). In light of the aforementioned literature support, we thus anticipate that rewards may lead to unfavourable attitudes. Therefore, we hypothesise that:

H2. A user's interaction with reward positively influences their negative attitude.

Rewards, perceived ethicality, attitudes and intentions

Numerous studies demonstrate that ethical behaviour is favourable for brands (Singh *et al.*, 2012) as the expectations of consumers and other stakeholders continue to rise, urging brands to reflect their ethical concerns (Maxfield, 2008). Brunk (2012) defined consumer-perceived ethicality as the degree to which consumers perceive a company, product, brand or service as ethical, reflecting their subjective assessment of the moral character of that brand/service. The characteristics most often associated with an ethical brand/entity are honesty, integrity, diversity, responsibility, quality, respect and accountability (Fan, 2005). Similarly, in line with the evolved stream of literature on ethical perceptions of consumers, we conceptualise perceived ethicality in the context of gamified app as the users' perception of gamification elements as being honest, responsible and accountable toward various stakeholders (Singh *et al.*, 2012).

With the rising popularity of gamification, we agree with the researchers Thorpe & Roper (2019) that it is crucial to examine and reflect on the ethical implications of game features in the context of a gamified e-commerce app. How users perceive ethicality of reward can greatly affect their ongoing interaction with an app. If users sense that rewards stem from ethical motives, such as safeguarding privacy and avoiding ulterior motives, this perception can strengthen the alignment with their personal values and moral codes. Moreover, the belief in being justly compensated for their time and financial contribution can further nurture positive attitude and intentions. This is supported by the psychological principle of Schema Congruity Theory (SCT). A schema is a cognitive structure representing the pre-existing understanding of an object or idea (Clemente *et al.*, 2014). When consumers perceive a reward as congruent with their schema, they evaluate it positively due to the confirmation of their expectations (Soni & Kumar, 2024), whereas rewards that deviate from these expectations (incongruent) may trigger negative emotions (Bhaduri, 2020; Mandler, 1982). SCT argues that consumers are likely to exhibit positive attitudes toward brands consistent with their beliefs (Gao *et al.*, 2022; Soni & Kumar 2024). For example, customers who experience a connection to a company's ethical stance will reciprocate with increased spending and positive word of mouth, rewarding the company for its efforts (Luchs *et al*., 2010). Conversely, when users hold weak ethical perceptions, they may develop negative attitudes and unfavourable intentions. According to a recent study (Sheetal *et al*., 2023), the perception of ethics in gamification was negative. As a consequence, the following hypotheses are posited:

H3. Perceived ethicality of reward negatively moderates the influence of reward on positive attitude.

H4. Perceived ethicality of reward positively moderates the influence of reward on negative attitude.

H5. Perceived ethicality of reward negatively moderates the effect of reward on app stickiness intention.

H6. Perceived ethicality of reward positively moderates the effect of reward on app discontinuance intention.

Rewards, positive attitude and app stickiness intention

Prior studies have demonstrated that users' perceptions of the value of gamified rewards can affect their behavioural decisions for consistent use and that effective reward stimuli play a vital role in behaviour reinforcement (Hwang & Choi, 2020). Hsu & Lin (2016) defined 'app stickiness' as the user's propensity to return to and spend more time within a certain app. According to Jang & Namkung's (2009) research, atmospherics and behavioural intents in service contexts are strongly correlated. When users receive price advantages or promotional discounts for products or services from platform gamification activities, their expectations are satisfied (Liao *et al*., 2020), resulting in a stronger stickiness to continue using products or services.

As suggested by previous studies of gamified products, the cost-benefit analysis (for example, costs such as investing time, sharing private data and benefits such as discounts, recognition) of gamification can drive consumers' experiences to be more positive and likely to affect consumer attitude (Bittner & Schipper, 2014; Hwang & Choi, 2020; Noble & Phillips, 2004). Positive attitude is an internal psychological trait that is always linked to an optimistic view of life's many occurrences (Mohanty, 2016). The Technology Acceptance Model (TAM) developed by Davis *et al*. (1989) asserted that positive attitudes about technology are the primary predictor of an individual's intent to engage in technology-related behaviours (Bitrián *et al*., 2021). The significant relationship between people's attitudes and their desire for continuance intention has been supported by earlier research in the field of information systems and technology (Alhassan *et al*., 2020; Foroughi *et al*., 2023; Foroughi *et al*., 2019).

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Yu *et al.* (2017) and Hsu & Lin (2016) identified a significant association between attitude and stickiness. Hence, rewards in an e-commerce app may induce a positive attitude towards reward, and this attitude will further enhance app stickiness intention. Therefore, we hypothesise the following:

H7. A user's interaction with rewards has an influence on app stickiness intention.

H8. Positive attitude acts as a mediator between rewards and app stickiness intention.

Rewards, negative attitude and app discontinuance intention

Rewards are a key motivating factor for consumers to engage with an e-commerce app (Meder *et al.*, 2018). However, discontinuance of application might result from the mismatch with the principles of user motivation (Huang *et al.*, 2019). For instance, a consumer's perception of value from rewards, based on the balance between value received and effort invested, can influence their behavioural responses, such as the intention to use the application (Huang *et al.*, 2019; Yang & Peterson, 2004). An individual's decision to discontinue can take several forms, including a gradual decrease in use, complete withdrawal, temporary discontinuance, replacement (Lin *et al.*, 2020), and even the temporary or permanent deactivation of an account (Wang *et al.*, 2021). In the context of the present study, a discontinuous intention is an intent to reduce gamified e-commerce app usage or even suspend usage and deleting accounts. Similarly, when the rewards offered by an app do not meet the interests of the user, they may tend to develop negative feelings that cause them to reconsider the use of a gamified e-commerce app. Pongjit & Beise-Zee (2015) state that financial rewards lower brand attitudes. Early studies (Huang *et al.*, 2019; López, Sicilia & Verlegh, 2022; Wang *et al.*, 2021) have revealed that attitude affects discontinuation intention. Thus, we hypothesise that:

H9. A user's interaction with rewards has a direct influence on app discontinuance intention.

H10. Negative attitude acts as a mediator between rewards and app discontinuance intention.

Research Methodology

Procedure

The provided hypotheses were tested using a cross-sectional research methodology, which is consistent with earlier gamification studies (Mulcahy *et al.*, 2018; Whittaker *et al.*, 2021). Flipkart, a gamified e-commerce app, was chosen for this study not only because it had a gamification element (reward) that was aligned to address the objectives of the study but also because the application belongs to a recognised brand in India. This app offers redeemable

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monetary rewards in the form of super coins, discount coupon and vouchers to evoke consumer engagement. The current study relied upon a convenience sampling method which is consistent with prior gamification research (Hwang & Choi, 2020; Whittaker *et al.*, 2021). A questionnaire consisting of 41 items was used. 'Google form' was used for designing the survey form, the link of which can be used only once by a person and was shared through a valid email ID of users. Participants were also asked to share the survey with friends and family. Upon completing the questionnaire, respondents were acknowledged.

Participants

The younger segment of gamified e-commerce app (Flipkart) users in the Ernakulam district of Kerala were chosen as the sampling participants. Young consumer segments are known to be more innovative, possess a flexible mindset and are quicker to adopt novel ideas and technology as compared to other shopper groups (Wong *et al.*, 2012). The Department of Youth Affairs (2024) defines youth as individuals between the ages of 15 and 29 years and account for nearly 40% of India's overall population. In this study, the age cohort of the sample received was between 21 and 30 (79%), which is aligned with recent studies (Kumar *et al.*, 2021; Tewari *et al.*, 2022; Whittaker *et al.*, 2021). The data was gathered from (N=414) respondents with valid email IDs. The sample size of 414 exceeds the threshold as per the 10-times rule (Hair *et al.*, 2011), under which at least 10 times the largest number of structural paths or indicators in a model is preferred. The gender divide of the selected sample is 58.2% females and 41.8% males, respectively. Most of the respondents are university graduates (43%) and have one to two years of app usage experience (38.2%).

Measurement instrument

The survey instrument was adapted from previously developed and validated measurement scales. Some of the measurement items were reworded to relate specifically to the context of the gamification app. Adapting and expanding prior questions ensures an up-to-date questionnaire that fits the current literature (Rodrigues *et al.*, 2021). Using a 7 point Likert scale ('1 = not at all important' to '7 = extremely important'), the items were adapted from Whittaker *et al.* (2021) and measured the interaction between users and rewards. All the remaining constructs were measured with a 7-point scale ranging from ('strongly disagree = 1' to 'strongly agree = 7'). The positive and negative attitude was measured with eight items adapted and modified from Yang *et al.* (2017). The measurement of perceived ethicality of rewards with six items (one item removed due to statistical insignificance) was based on Das *et al.* (2019). App stickiness intention was measured with seven items taken from Yu *et al.* (2017) and Hsu & Lin (2016). Finally, from the work of Lin *et al.* (2020), we derived four items used to measure app discontinuation intention.

Results

Measurement model analysis

The data analysis was performed using SmartPLS4. In order to ensure the accuracy of the measurement model, reliability, convergent validity and discriminant validity of the constructs were assessed. Partial Least Squares Structural Equation Modeling (PLS-SEM) was selected due to its suitability for exploratory research, predictive modelling, and handling complex models with multiple paths and non-normal data distributions (Hair *et al.*, 2017; Chin, 1998). As shown in Table 1, item loadings and Cronbach's alpha for each construct have exceeded the criterion of 0.7 (Nunnally & Berstein, 1994), along with the composite reliability greater than the benchmark of 0.7 (Anderson & Gerbing, 1988). This indicates good internal consistency and reliability of the items (Chin *et al.*, 2013). Additionally, the convergent validity of the measurement model is statistically significant since all item construct loadings have values greater than 0.7 and the average variance extracted (AVE) from each component is more than 0.5 (Fornell & Larcker, 1981).

Table 1. Measurement model (scale dimensionality, reliability and validity)

Scales and items	Standardised loading	Cronbach's alpha	AVE	Composite reliability
Rewards (Whittaker *et al.*, 2021)				
• The frequency of interacting with rewards.	.899	.801	0.833	0.909
• The importance of interacting with rewards.	.926			
Positive attitude (Yang *et al.*, 2017)				
• The rewards make me feel more emotionally connected.	0.837	.960	0.783	0.966
• The rewards evoked positive feelings.	0.877			
• The rewards make me more inclined to make future purchases.	0.899			
• The rewards make me want to derive pleasure from the experience.	0.897			
• The rewards make me delighted to engage with the app further.	0.898			
• The rewards motivate me to explore other products.	0.901			
• I like the experience of earning rewards.	0.885			
• I may recommend the reward program of app to others.	0.884			

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Scales and items	Standardised loading	Cronbach's alpha	AVE	Composite reliability
Negative attitude (Yang *et al.*, 2017)				
• The rewards makes me feel emotionally disconnected.	.893	.975	.853	.979
• The rewards evoke negative feelings.	.918			
• The rewards make me less inclined to make future purchases.	.926			
• The rewards make me derive no pleasure from the experience.	.935			
• The rewards make me feel disappointed and disengaged.	.940			
• The rewards fail to motivate me to explore other products.	.929			
• I did not like the experience of earning rewards.	.931			
• I may not recommend the reward program of app to others.	.918			
Perceived ethicality of reward (Das *et al.*, 2019)				
• The rewards comply with moral principles.	.896	.952	.839	.963
• The rewards are always designed in adherence to the law.	.923			
• The rewards avoid any harmful or unethical practices.	.935			
• The rewards in the app are good.	.915			
• The rewards are offered after careful consideration of both positive and negative consequences for all stakeholders.	.911			
App stickiness intention (Hsu & Lin, 2016; Yu *et al.*, 2017)				
• I intend to keep using this app.	.899	.969	.845	.974
• I intend to remain a customer of this app rather than look for new app.	.913			
• I intend to expand my use of this app.	.943			
• I would stay longer on this app than other apps.	.923			
• I intend to spend more time on this app.	.940			
• I use this app as often as I can.	.926			
• I use this app every time I am online.	.899			

Scales and items	Standardised loading	Cronbach's alpha	AVE	Composite reliability
App discontinuance intention ([Lin *et al.*, 2020](#))				
• In the near future, I will use Flipkart far less than today.	.929	.962	.898	.972
• In the near future, I will use another gamified e-commerce app.	.950			
• In the near future, I will unregister from Flipkart.	.965			
• If I could, I would discontinue the use of Flipkart in the near future.	.946			

Table 2. Heterotrait–Monotrait ratio (HTMT)

	App discontinuance intention	Negative attitude	Positive attitude	Perceived ethicality	Rewards	App stickiness intention	Perceived ethicality x reward
App discontinuance intention							
Negative attitude	0.754						
Positive attitude	0.511	0.558					
Perceived ethicality	0.683	0.755	0.747				
Rewards	0.596	0.639	0.784	0.791			
App stickiness intention	0.661	0.723	0.719	0.742	0.699		
Perceived ethicality x reward	0.192	0.195	0.066	0.136	0.184	0.071	

The discriminant validity has been assessed using the Heterotrait–Monotrait ratio (HTMT). In accordance with Table 2, each of the HTMT values is lower than the established threshold value of 0.85, indicating an acceptable and high degree of discriminant validity in the measurement model (Henseler *et al.*, 2015).

Table 3. Common method bias

	App discontinuance intention	Negative attitude	Positive attitude	Perceived ethicality	Rewards	Dummy variable	App stickiness intention
App discontinuance intention						2.34	
Negative attitude						3.018	
Positive attitude						2.935	
Perceived ethicality						2.797	
Rewards						2.397	
Dummy variable							
App stickiness intention						2.88	

A statistical analysis was conducted to determine whether common method bias exists. Data from Table 3 shows that VIF (variance inflation factor) values for all first-order indicators fall

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below the threshold value of 3.3. This suggests that multicollinearity is not an issue in our research (Hair *et al.*, 2021; Kock & Lynn, 2012). To further ensure that positive and negative attitudes are distinct constructs, we calculated the correlation between these constructs. The correlation coefficient between positive and negative attitudes was found to be 0.541, indicating a significant moderate positive correlation ($p < 0.01$). This suggests that while there is a relationship between the two constructs, they still measure distinct dimensions of user attitudes. This moderate positive correlation supports the use of separate constructs for positive and negative attitudes, acknowledging that users' positive feelings about rewards are related but not identical to their negative feelings, and both are influenced by different factors (Deci *et al.*, 2001; Groening & Binnewies, 2019; Hanus & Fox, 2015; Seaborn & Fels, 2015; Xi & Hamari, 2020).

Structural model analysis for the full sample

Structural model analysis was carried out to identify the research model's explanatory power and path links. Using the bootstrapping method, we tested the statistical significance of parameter estimations to determine appropriate standard errors and *t*-values (Temme *et al.*, 2006). Figure 1 and Table 4 depict our analysis results.

As shown in Table 4, rewards are positively related to a positive attitude ($\beta = 0.423$, $p < 0.000$), thus supporting *H1*. Rewards also have a significant positive impact on negative attitude ($\beta = 0.158$, $p < 0.006$), thus supporting *H2*. The relationship between rewards and app discontinuance intention is found to be significant ($\beta = 0.085$, $p < 0.045$), thus supporting *H9*. Additionally, rewards have a significant influence on app stickiness intention ($\beta = 0.175$, $p < 0.001$), thus supporting *H7*.

Table 4. Hypotheses testing (direct effects)

	Path coefficients	SE	*t*-value	P value	Hypothesis
Reward -> Positive attitude	0.423	0.048	8.763	0.000	H1: Accepted
Reward -> Negative attitude	0.158	0.057	2.77	0.006	H2: Accepted
Reward -> App stickiness intention	0.175	0.055	3.176	0.001	H7: Accepted
Reward -> App discontinuance intention	0.085	0.043	2.012	0.045	H9: Accepted

In terms of the predictive power of the research model, the R^2 reveals that our model accounts for 61.6% of the variation in a positive attitude, 55.5% of the variation in a negative attitude, 59.3% of the variation in app stickiness intention, and 57.3% of the variation in the intention to discontinue using the app (see Figure 1). Furthermore, the computed SRMR (standardised root mean square residual) is 0.067, demonstrating a high level of model fit (Hair *et al.*, 2021).

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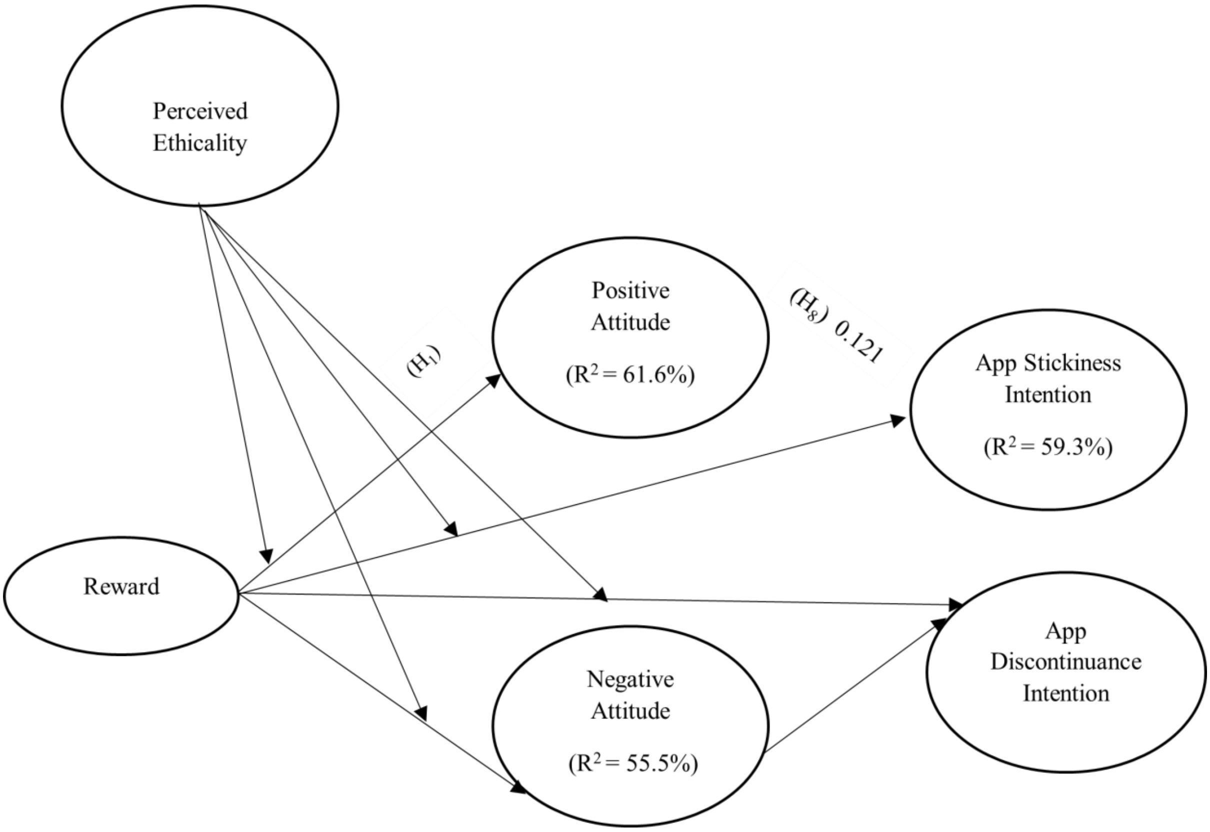

Figure 1. Conceptual model of the research

Mediation test

This study followed the procedures outlined by Hayes (2009) and Hair *et al.* (2021) to determine whether positive and negative attitudes mediate the relationship between rewards and app stickiness intention as well as app discontinuance intention. As shown in Table 5, the mediation analysis revealed partial mediation effects for both constructs. Specifically, positive attitude partially mediates the relationship between rewards and app stickiness intention (β = 0.121, SE = 0.034), supporting *H8*. Similarly, negative attitude partially mediates the relationship between rewards and app discontinuance intention (β = 0.082, SE = 0.032), supporting *H10*.

Table 5. Mediation analysis result

IV	M	DV	Total effect	Direct effect	Indirect effect	Mediation	Hypothesis
Reward	Positive attitude	App stickiness intention	0.297	0.175	0.121	Partial mediation	H8: Accepted
Reward	Negative attitude	App discontinuance intention	0.167	0.085	0.082	Partial mediation	H10: Accepted
Note(s): IV = Independent variable; M = Mediator; DV = Dependent variable; SE = Standard error							

Moderation test

In SmartPLS4, we conducted a moderation test to evaluate whether perceived ethicality of rewards moderates the relationships between rewards and positive attitude, negative attitude, app stickiness intention and app discontinuance intention, following the procedure outlined by Hayes (2009). The results, as shown in Table 6, indicate that perceived ethicality of reward significantly moderates the relationship between rewards and both positive attitude (β = -0.072, p = 0.024) and negative attitude (β = 0.085, p = 0.018), thereby supporting *H3* and *H4*. However, the moderation effects of perceived ethicality on the relationships between rewards and app stickiness intention (β = -0.032, p = 0.361) and rewards and app discontinuance intention (β = 0.040, p = 0.305) were not significant, leading to the rejection of *H5* and *H6*.

Table 6. Moderation analysis result

	Path coefficient	**SE**	***t*-value**	**P value**	**Hypothesis**
PE x reward -> PAT	-0.072	0.032	2.268	0.024	H3: Accepted
PE x reward -> NAT	0.085	0.036	2.381	0.018	H4: Accepted
PE x reward -> SI	-0.032	0.035	0.914	0.361	H5: Rejected
PE x reward -> DI	0.040	0.039	1.027	0.305	H6: Rejected

Note(s): PE = Perceived ethicality of reward; R = Reward; PA = Positive attitude; NA = Negative attitude; ASI = App stickiness intention; ADI = App discontinuance intention; SE = Standard error

Discussion and Conclusions

The primary goal of this study was to find out the dualistic impact of the gamification element, ‘rewards’ in a gamified e-commerce setting and to establish connections among gamification, attitude, behavioural intentions and perceived ethicality of reward in the specific context of gamified e-commerce app Flipkart. This was done in response to the call for further research that uses empirical methods to assess the effect of gamification in different regions and contexts (Pasca *et al.*, 2021).

Lu & Ho (2020) pointed out that companies are making efforts to incorporate gamification with the motive of increasing stickiness intention. This viewpoint is confirmed in the current research by demonstrating that gamification mechanism of rewards has significant influences on app stickiness intention directly and through the partial mediation effect of positive attitude. The result is also supported by the findings of Raman (2020). We found that rewards as a gamification feature stimulate psychological reactions (that is, positive attitude). This is consistent with prior works which demonstrated positive effects of reward in a gamification context (Aydinliyurt *et al.*, 2021; Plangger *et al.*, 2022) and correlation between gamification and psychological mechanisms in general (Tan, 2021). Although the effect of gamification elements vary depending on the subjects and contexts (Legaki *et al.*, 2020), we argue that

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reward in isolation acts as a strong stimulating source (Groening & Binnewies, 2019) for users interacting with a gamified app.

While rewards are often seen as tools to engender positive responses, the present study's results suggest that rewards may trigger negative sentiments. This may be attributed to the user's characteristics and context-dependent nature of this relationship. People who value intrinsic reward (for example, achievement of a badge) aren't motivated much by external rewards, and those with a favourable attitude toward external rewards aren't motivated much by intrinsic reward (Kaushal & Nyoni, 2022). The individual's ethical perception of rewards might have also played a significant role in the outcome. Previous studies suggest that sceptical individuals often have negative attitudes toward products and services (Romani *et al.*, 2016). Similarly, consumers may not have a favourable attitude toward a gamified app if they are sceptical about the rewards provided. To overcome consumer scepticism toward rewards in a gamified app, it is essential to clearly communicate the value and benefits of the rewards, ensuring they are relevant and appealing to the target audience. Marketers have capitalised on the power of surprise as a central component in their strategies for acquiring and retaining customers, such as offering bonus points for sign-ups or purchases (Shibly & Chatterjee, 2020). However, the downside is that surprise can escalate a mildly unpleasant experience into a highly negative one, making it essential for marketers to be mindful of this potential drawback. It should be noted that the current study attempted to investigate effects of the reward element of a gamified app within the e-commerce app context, which is different from the extant results.

The acceptance of the hypothesis that rewards influence app discontinuance intention could be attributed to different reasons. Many retail strategies today are built on the assumption that enhancing external rewards for certain actions will boost consumers' willingness to engage in those actions. According to motivation crowding theory, offering tangible external rewards in advance for a particular behaviour may, in fact, lower people's willingness to engage in that behaviour by undermining their intrinsic motivation (Anghelcev, 2013). When users are provided with rewards for using an app, their intrinsic motivation to use the app might diminish. They may come to rely on the external rewards rather than their original interest or enjoyment, leading to discontinuance once the rewards are no longer appealing. Besides, users might perceive the rewards as a manipulation tactic, prompting users to discontinue the app.

According to the mediation test, positive attitude partially mediates rewards and app stickiness intention, whereas negative attitude partially mediates rewards and app discontinuation intention. Overall, these empirical findings are consistent with earlier studies, indicating that certain website design elements (in this study, reward is regarded as a characteristic of a gamified e-commerce app) are good for driving users' behavioural intents

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through affective reactions (Hsu & Chen, 2021; Hsu *et al.*, 2017). These results reveal the underlying mechanisms in explaining the nuances between rewards and behavioural intentions (stickiness and discontinuance).

Furthermore, with growing interest in consumer-perceived ethicality (Grappi *et al.*, 2024), this study offers empirical evidence by uncovering the moderating effect of perceived ethicality of reward on the association between rewards and attitudes. When users perceive a reward as unethical, it weakens the reward's positive impact on their attitude. This aligns with Maxfield's (2008) observation that consumers often seek brands that reflect their own ethical values. When rewards do not align with these values, they can create moral discomfort and reduce the perceived credibility of the brand, leading to a less favourable attitude. Similarly, when users perceive a reward as ethical, it amplifies the impact of the reward on reducing negative attitudes. This suggests that when users perceive rewards as ethically aligned, they may not develop negative attitudes, even when they engage extensively with rewards. According to the study of Das *et al.* (2019), customers that are obsessed with certain brands, that is, displaying obsessive passion, are unaffected by perceptions of the brand's ethicality. Similarly, users who have developed a strong attachment or engagement with a gamified app may have a more enduring commitment to the app itself, which can overshadow the influence of perceived ethicality on their attitudes and intentions. This interpretation aligns with our findings, as we observed that perceived ethicality does not have a moderating effect on app stickiness intention and app discontinuance intention. While our study did not explicitly measure user passion or attachment, it hints at the importance of considering the depth of user engagement in future research to gain a more comprehensive understanding of how perceived ethicality interacts with user behaviour within gamified contexts. This divergence in results could also be attributed to the multifaceted nature of user responses within gamified contexts, where factors beyond ethical considerations, such as user motivations, satisfaction or the specific design of rewards, might play more significant roles.

Theoretical contribution

First, the study contributes to the gamification and e-commerce literature by empirically investigating the bivalent nature of specific gamification element, that is, reward on attitudes (positive and negative) and behavioural intentions. This nuanced understanding can provide insights that go beyond the conventional positive effects of rewards, offering a more comprehensive view of how gamification elements shape user attitudes and responses. Additionally, the study contributes empirical evidence to support and enrich the existing theoretical frameworks in the gamification and e-commerce literature, making it a valuable addition to the academic discourse in these fields.

Second, the ethical dimension of gamification was rarely examined in relation to gamification. Therefore, this paper addresses the dearth of research on ethics and gamification (Thorpe & Roper, 2019) by providing empirical evidence on 'perceived ethicality' as a moderator in the relationship between gamification element and attitude and intentions. This is an important step forward in understanding gamification, as prior studies have not included this aspect in the actual context of gamified e-commerce apps. It underscores the critical role of ethical perception in the realm of gamification and e-commerce. In today's digital landscape, where user trust and ethical concerns are paramount, this result highlights the importance of aligning gamification practices with ethical standards. Businesses and e-commerce platforms should take heed of this insight and proactively work to enhance the perceived ethicality of their gamified elements. This might involve transparent communication about reward systems, ensuring that rewards are aligned with user values, and avoiding manipulative or coercive practices. By doing so, they can mitigate the risk of generating negative attitudes and instead foster positive user experiences.

Third, this study adds significantly to our understanding of gamification from a contextual standpoint by concentrating on gamified app users from an emerging economy – India – as most previous gamification studies have relied on samples from developed nations (Tanouri *et al.*, 2019). Furthermore, the study's insights extend beyond geographical confines, offering global relevance for businesses striving to optimise user engagement through gamification strategies.

Managerial implications

The findings of the study deliver the following practical implications for e-commerce business developers and system designers interested in promoting gamified business practices. We found that gamification element (reward) generates positive attitudes. Hence, practitioners or designers can take advantage of this insight to design appropriate and different reward categories (for example, tangible and intangible) that will help motivate users intrinsically and extrinsically. For example, a rewards structure can also be designed in a way that does not set an expiry period for earned rewards (Dorotic *et al.*, 2014), offers personalised and flexible rewards (Wei *et al.*, 2023) and sets achievable goals to gain more rewards, thereby helping users build a sense of achievement. If this is followed, gamification design with the inclusion of reward as a game element is more likely to be a successful strategy.

Beyond monetary rewards, people may be extrinsically motivated by non-tangible or symbolic rewards (plaques, badge, certificates or trophies) (Barbera *et al.*, 2024). These non-tangible rewards, which convey social approval and appreciation, can motivate users without incurring significant costs. To optimise the reward system, managers can strategically plan rewards at

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different touchpoints of the customer's journey. For example, in the pre-purchase stage, a retail app can use a welcome quiz and bonus to attract potential customers. During the purchase phase, monetary rewards can be offered to incentivise buying, and finally, in the post-purchase phase, a special badge can be awarded to acknowledge customer progress and foster loyalty.

We believe it is paramount for online gamified service providers to comprehend users' perceived ethicality of rewards in gamified e-commerce scenarios. It is essential to prevent gamification elements from prompting users' disgust or moral discomfort. Managers should recognise that relying on monetary rewards can harm users' perception of ethicality, potentially leading to negative outcomes. To counter this, they should implement enjoyable and meaningful reward mechanisms that enhance the perceived quality of rewards. Providing testimonials or examples from other users who have benefited from gamification, and promoting credible firm or brand activities, can build trust and convert app users into loyal customers. In addition, the potential of social media can be leveraged to improve the quality perception of rewards.

In varied gamified service delivery apps, practitioners who wish to integrate game elements may use a similar model of our study to evaluate whether certain gamification features encourage users to continue with the app or hinder usage intention. This assessment would allow organisations to determine whether to maximise the payoff of rewards and pay considerable attention to channelling their resources into more productive areas.

Limitations and Future Research Directions

The shortcomings of our study and suggested directions for future research will be acknowledged in this section. Although we sought to address the bidirectional effects of rewards, this study concentrated on a specific gamification element, as opposed to an entire gamification system which may not be applicable to other gamified service environments. However, we agree with the thoughts shared by Groening & Binnewies (2019) and encourage future research to study the contribution of other individual game elements (for example, challenges, leaderboards, progress bar and badges) to better understand the suitability of integrating game elements in the e-commerce app context. Besides, our study did not account for different reward categories (for example, fixed, flexible, extrinsic, intrinsic) or user characteristics. Future research should explore how these reward types interact with user traits to influence consumer behavioural intentions.

In addition, we suggest that future research should seek to conduct a longitudinal study to observe the long-term impact of rewards in gamified e-commerce apps on perceptions and behavioural intentions of users since reward is considered one of the most significant

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components of gamification design and as per the existing literature (Garnefeld *et al.*, 2012), rewards are expected to have short-term positive effects.

People vary greatly in the extent to which their opinions and actions may be influenced by external factors (Terlutter & Capella, 2013). Future research could seek to investigate whether relationships relating to gamification element, psychological and behavioural intentions may differ based on the personality traits of users using the gamified e-commerce app, as the presence of such moderators was not considered within the current study. This may help gamified app developers to design the gamification elements according to a targeted market audience.

This research measured perceived ethicality of reward as a unidimensional construct. We believe it is worthy to investigate the ethical perceptions of gamification elements considering a multidimensional perspective which would help to identify specific ethical concerns (for example, privacy, security, risk, non-deception, etc.) perceived by the users in relation to particular gamification elements.

Furthermore, the current study focused on a youth segment of the population using a convenient sampling technique, which limits the generalisability of results among other user segments. Therefore, it is suggested that future research should focus on different user groups and random sampling technique for improved generalisability of results.

References

Abou-Shouk, M., & Soliman, M. (2021). The impact of gamification adoption intention on brand awareness and loyalty in tourism: The mediating effect of customer engagement. *Journal of Destination Marketing & Management*, *20*. Available from: https://doi.org/10.1016/j.jdmm.2021.100559

Ajzen, I., & Fishbein, M. (1980). *Understanding attitudes and predicting social behavior*. Englewood Cliffs, NJ: Prentice-Hall.

Alhassan, M.D., Kolog, E.A., & Boateng, R. (2020). Effect of gratification on user attitude and continuance use of mobile payment services: A developing country context. *Journal of Systems and Information Technology*, *22*(4), 351–378. https://doi.org/10.1108/JSIT-01-2020-0010

Anderson, J. C., & Gerbing, D. W. (1988). Structural equation modeling in practice: A review and recommended two-step approach. *Psychological Bulletin*, *103*(3), 411. https://psycnet.apa.org/doi/10.1037/0033-2909.103.3.411

Anghelcev, G. (2015). Unintended effects of incentivizing consumers to recommend a favorite brand. *Journal of Marketing Communications*, *21*(3), 210–223. https://doi.org/10.1080/13527266.2012.747980

Aydınlıyurt, E. T., Taşkın, N., Scahill, S., & Toker, A. (2021). Continuance intention in gamified mobile applications: A study of behavioral inhibition and activation

https://doi.org/10.18080/jtde.v13n1.1047

systems. *International Journal of Information Management*, *61*. https://doi.org/10.1016/j.ijinfomgt.2021.102414

Barbera, C., Nabatchi, T., Sancino, A., & Sicilia, M. (2024). Monetary and symbolic rewards: Do they matter for fostering co-commissioning and co-delivery of public services? *Public Management Review*, 1–28. https://doi.org/10.1080/14719037.2023.2219265

Bauer, J. C., Linzmajer, M., Nagengast, L., Rudolph, T., & D'Cruz, E. (2020). Gamifying the digital shopping experience: Games without monetary participation incentives increase customer satisfaction and loyalty. *Journal of Service Management*, *31*(3), 563–595. https://doi.org/10.1108/JOSM-10-2018-0347

Bhaduri, G. (2020). Expectations matter: Evaluation of brand's pro-environmental initiatives based on consumers' brand schemas and brand familiarity. *Journal of Global Fashion Marketing*, *11*(1), 37–55. https://doi.org/10.1080/20932685.2019.1663232

Bigne, E., Chatzipanagiotou, K., & Ruiz, C. (2020). Pictorial content, sequence of conflicting online reviews and consumer decision-making: The stimulus-organism-response model revisited. *Journal of Business Research*, *115*, 403–416. https://doi.org/10.1016/j.jbusres.2019.11.031

Bittner, J. V., & Shipper, J. (2014). Motivational effects and age differences of gamification in product advertising. *Journal of Consumer Marketing*, *31*(5), 391–400. https://doi.org/10.1108/JCM-04-2014-0945

Bitrián, P., Buil, I., & Catalán, S. (2021). Making finance fun: the gamification of personal financial management apps. *International Journal of Bank Marketing*, *39*(7), 1310–1332. https://doi.org/10.1108/IJBM-02-2021-0074

Brunk, K. H. (2012). Un/ethical company and brand perceptions: Conceptualising and operationalising consumer meanings. *Journal of Business Ethics*, *111*, 551–565. https://doi.org/10.1007/s10551-012-1339-x

Chin, W. W. (1998). The partial least squares approach to structural equation modeling. In G. A. Marcoulides (Ed.), *Modern Methods for Business Research*. Mahwah, NJ: Lawrence Erlbaum Associates Publishers.

Chin, A. G., Harris, M. A., & Brookshire, R. (2022). An empirical investigation of intent to adopt mobile payment systems using a trust-based extended valence framework. *Information Systems Frontiers*, 1–19. https://doi.org/10.1007/s10796-020-10080-x

Clemente, S., Dolansky, E., Mantonakis, A., & White, K. (2014). The effects of perceived product extrinsic cue incongruity on consumption experiences: The case of celebrity sponsorship. *Marketing Letters*, *25*(4), 373–384. https://doi.org/10.1007/s11002-013-9257-y

Das, G., Agarwal, J., Malhotra, N. K., & Varshneya, G. (2019). Does brand experience translate into brand commitment?: A mediated-moderation model of brand passion and perceived brand ethicality. *Journal of Business Research*, *95*, 479–490. https://doi.org/10.1016/j.jbusres.2018.05.026

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly*, 319–340. https://doi.org/10.2307/249008

Deci, E. L., Koestner, R., & Ryan, R. M. (2001). Extrinsic rewards and intrinsic motivation in education: Reconsidered once again. *Review of Educational Research*, *71*(1), 1–27. https://doi.org/10.3102/00346543071001001

Department of Youth Affairs. (2024). About youth department. Ministry of Youth Affairs and Sports. India. Accessed 11 September 2024. https://yas.gov.in/youth-affairs/about-youth-department

Deterding, S., Dixon, D., Khaled, R., & Nacke, L. (2011, September). From game design elements to gamefulness: Defining 'gamification'. In *Proceedings of the 15th International Academic Mindtrek Conference: Envisioning Future Media Environments*, 9–15. https://doi.org/10.1145/2181037.2181040

Donovan, R. J., & Rossiter, J. R. (1982). Store atmosphere: An environmental psychology approach. *Journal of Retailing*, *58*(1), 34–57.

Dorotic, M., Verhoef, P. C., Fok, D., & Bijmolt, T. H. (2014). Reward redemption effects in a loyalty program when customers choose how much and when to redeem. *International Journal of Research in Marketing*, *31*(4), 339–355. https://doi.org/10.1016/j.ijresmar.2014.06.001

Erensoy, A., Mathrani, A., Schnack, A., Elms, J., & Baghaei, N. (2024). Consumer behavior in immersive virtual reality retail environments: A systematic literature review using the stimuli-organisms-responses (S-O-R) model. *Journal of Consumer Behaviour*, *23*(6), 2781–2811. https://doi.org/10.1002/cb.2374

Fan, Y. (2005). Ethical branding and corporate reputation. *Corporate Communications: An International Journal*, *10*(4), 341–350. https://doi.org/10.1108/13563280510630133

Feng, W., Tu, R., & Hsieh, P. (2020). Can gamification increase consumers' engagement in fitness apps? The moderating role of commensurability of the game elements. *Journal of Retailing and Consumer Services*, *57*. https://doi.org/10.1016/j.jretconser.2020.102229

Feng, Y., Ye, H. J., Yu, Y., Yang, C., & Cui, T. (2018). Gamification artifacts and crowdsourcing participation: Examining the mediating role of intrinsic motivations. *Computers in Human Behavior*, *81*, 124–136. https://doi.org/10.1016/j.chb.2017.12.018

Fornell, C., & Larcker, D. F. (1981). Evaluating structural equation models with unobservable variables and measurement error. *Journal of Marketing Research*, *18*(1), 39–50. https://doi.org/10.2307/3151312

Foroughi, B., Iranmanesh, M., & Hyun, S.S. (2019). Understanding the determinants of mobile banking continuance usage intention. *Journal of Enterprise Information Management*, *32*(6), 1015–1033. https://doi.org/10.1108/JEIM-10-2018-0237

Foroughi, B., Iranmanesh, M., Kuppusamy, M., Ganesan, Y., Ghobakhloo, M., & Senali, M.G. (2023). Determinants of continuance intention to use gamification applications for task management: An extension of technology continuance theory. *The Electronic Library*, *41*, 286–307. https://doi.org/10.1108/EL-05-2022-0108

Gao, X., De Hooge, I.E., & Fischer, A.R. (2022). Something underneath? Using a within-subjects design to examine schema congruity theory at an individual level. *Journal of Retailing and Consumer Services*, *68*. https://doi.org/10.1016/j.jretconser.2022.102994

García-Jurado, A., Torres-Jiménez, M., Leal-Rodríguez, A. L., & Castro-González, P. (2021). Does gamification engage users in online shopping? *Electronic Commerce Research and Applications*, *48*. https://doi.org/10.1016/j.elerap.2021.101076

Garnefeld, I., Iseke, A., & Krebs, A. (2012). Explicit incentives in online communities: Boon or bane? *International Journal of Electronic Commerce*, *17*(1), 11–38. https://doi.org/10.2753/JEC1086-4415170101

Gil-Aciron, L. A. (2024). The gamer psychology: A psychological perspective on game design and gamification. *Interactive Learning Environments*, *32*(1), 183–207. https://doi.org/10.1080/10494820.2022.2082489

Grappi, S., Bergianti, F., Gabrielli, V., & Baghi, I. (2024). The effect of message framing on young adult consumers' sustainable fashion consumption: The role of anticipated emotions and perceived ethicality. *Journal of Business Research*, *170*. Available from: https://doi.org/10.1016/j.jbusres.2023.114341

Groening, C., & Binnewies, C. (2019). 'Achievement unlocked!' The impact of digital achievements as a gamification element on motivation and performance. *Computers in Human Behavior*, *97*, 151–166. https://doi.org/10.1016/j.chb.2019.02.026

Hair, J. F., Ringle, C. M., & Sarstedt, M. (2011). PLS-SEM: Indeed a silver bullet. *Journal of Marketing Theory and Practice*, *19*(2), 139–152. https://doi.org/10.2753/MTP1069-6679190202

Hair, J. F., Hult, G. T. M., Ringle, C. M., & Sarstedt, M. (2017). *A Primer on Partial Least Squares Structural Equation Modeling (PLS-SEM).* Thousand Oaks CA: Sage Publications.

Hair Jr, J. F., Hult, G. T. M., Ringle, C. M., Sarstedt, M., Danks, N. P., & Ray, S. (2021). *Partial Least Squares Structural Equation Modeling (PLS-SEM) Using R: A Workbook* (p. 197): Springer Nature.

Hamari, J., Koivisto, J., & Sarsa, H. (2014). Does gamification work? A literature review of empirical studies on gamification. In *2014 47th Hawaii International Conference On System Sciences*, 3025–3034, IEEE. https://doi.org/10.1109/HICSS.2014.377

Hanus, M. D., & Fox, J. (2015). Assessing the effects of gamification in the classroom: A longitudinal study on intrinsic motivation, social comparison, satisfaction, effort, and academic performance. *Computers & education*, *80*, 152–161. https://doi.org/10.1016/j.compedu.2014.08.019

Hayes, A. F. (2009). Beyond Baron and Kenny: Statistical mediation analysis in the new millennium. *Communication Monographs*, *76*(4), 408–420. https://doi.org/10.1080/03637750903310360

Henseler, J., Ringle, C. M., & Sarstedt, M. (2015). A new criterion for assessing discriminant validity in variance-based structural equation modeling. *Journal of the Academy of Marketing Science*, *43*, 115–135. https://doi.org/10.1007/s11747-014-0403-8

Hsu, C. L., & Chen, M. C. (2021). Advocating recycling and encouraging environmentally friendly habits through gamification: An empirical investigation. *Technology in Society*, *66*. https://doi.org/10.1016/j.techsoc.2021.101621

Hsu, C. L., Chen, Y. C., Yang, T. N., & Lin, W. K. (2017). Do website features matter in an online gamification context? Focusing on the mediating roles of user experience and attitude. *Telematics and Informatics*, *34*(4), 196–205. https://doi.org/10.1016/j.tele.2017.01.009

Hsu, C. L., & Lin, J. C. C. (2016). Effect of perceived value and social influences on mobile app stickiness and in-app purchase intention. *Technological Forecasting and Social Change*, *108*, 42–53. https://doi.org/10.1016/j.techfore.2016.04.012

Huang, C. K., Chen, C. D., & Liu, Y. T. (2019). To stay or not to stay? Discontinuance intention of gamification apps. *Information Technology & People*, *32*(6), 1423–1445. https://doi.org/10.1108/ITP-08-2017-0271

Hwang, J., & Choi, L. (2020). Having fun while receiving rewards?: Exploration of gamification in loyalty programs for consumer loyalty. *Journal of Business Research*, *106*, 365–376. https://doi.org/10.1016/j.jbusres.2019.01.031

India Brand Equity Foundation. (2023). *Retail Industry in India*. Accessed 30 March 2023. https://www.ibef.org/industry/retail-india.

Insley, V., & Nunan, D. (2014). Gamification and the online retail experience. *International Journal of Retail & Distribution Management*, *42*(5), 340–351. https://doi.org/10.1108/IJRDM-01-2013-0030

Jang, S. S., & Namkung, Y. (2009). Perceived quality, emotions, and behavioral intentions: Application of an extended Mehrabian–Russell model to restaurants. *Journal of Business Research*, *62*(4), 451–460. https://doi.org/10.1016/j.jbusres.2008.01.038

Jiang, Z., & Lyu, J. (2024). The role of augmented reality app attributes and customer-based brand equity on consumer behavioral responses: An S-O-R framework perspective. *The Journal of Product and Brand Management*, *33*(6), 702–716. https://doi.org/10.1108/JPBM-09-2023-4706

Kaushal, S., & Nyoni, A. M. (2022). Why do rewards fail to motivate knowledge sharing behavior among employees? *VINE Journal of Information and Knowledge Management Systems*, *55*(1), 34–55. https://doi.org/10.1108/VJIKMS-06-2022-0202

Kumar, D. S., Purani, K., & Viswanathan, S. A. (2018). Influences of 'appscape 'on mobile app adoption and m-loyalty. *Journal of Retailing and Consumer Services*, *45*, 132–141. https://doi.org/10.1016/j.jretconser.2018.08.012

Kumar, A., Prakash, G., & Kumar, G. (2021). Does environmentally responsible purchase intention matter for consumers? A predictive sustainable model developed through an empirical study. *Journal of Retailing and Consumer Services*, *58*. https://doi.org/10.1016/j.jretconser.2020.102270

Kock, N., & Lynn, G. (2012). Lateral collinearity and misleading results in variance-based SEM: An illustration and recommendations. *Journal of the Association for Information Systems*, *13*(7). https://doi.org/10.17705/1jais.00302

Legaki, N. Z., Xi, N., Hamari, J., Karpouzis, K., & Assimakopoulos, V. (2020). The effect of challenge-based gamification on learning: An experiment in the context of statistics education. *International Journal of Human-Computer Studies*, *144*. https://doi.org/10.1016/j.ijhcs.2020.102496

Liao, W.H., Liu, Y., & Qiao, H. (2020). No fun no use? The impact of gamification on user's continuous usage intention toward E-business app. Paper presented at the 19th Annual Wuhan International Conference on E-Business (WHICEB), Wuhan, China. Available from: https://aisel.aisnet.org/whiceb2020/74

Lim, S. Y., Tan, Y., Loh, X. M., Cham, T. H., Ooi, M. Y., & Tan, G. W. H. (2025). It's not all fun and games: gamification in e-commerce on consumers' impulse buying of retail food products. *British Food Journal*, *127*(3). https://doi.org/10.1108/BFJ-04-2024-0361

Lin, J., Lin, S., Turel, O., & Xu, F. (2020). The buffering effect of flow experience on the relationship between overload and social media users' discontinuance intentions. *Telematics and Informatics*, *49*. https://doi.org/10.1016/j.tele.2020.101374

López, M., Sicilia, M., & Verlegh, P. W. (2022). How to motivate opinion leaders to spread e-WoM on social media: Monetary vs non-monetary incentives. *Journal of Research in Interactive Marketing*, *16*(1), 154–171. https://doi.org/10.1108/JRIM-03-2020-0059

Lu, H. P., & Ho, H. C. (2020). Exploring the impact of gamification on users' engagement for sustainable development: A case study in brand applications. *Sustainability*, *12*(10). https://doi.org/10.3390/su12104169

Luchs, M. G., Naylor, R. W., Irwin, J. R., & Raghunathan, R. (2010). The sustainability liability: Potential negative effects of ethicality on product preference. *Journal of Marketing*, *74*(5), 18–31. https://doi.org/10.1509/jmkg.74.5.018

Mandler, G. (1982). The structure of value: Accounting for taste. In Margaret S. Clark and Susan T. Fiske (Eds.), *Affect and cognition: The 17th Annual Carnegie Mellon Symposium on Cognition*, Hillsdale, NJ: Lawrence Erlbaum Associates, 3–36.

Maxfield, S. (2008). Reconciling corporate citizenship and competitive strategy: Insights from economic theory. *Journal of Business Ethics*, *80*, 367–377. https://doi.org/10.1007/s10551-007-9425-1

Meder, M., Plumbaum, T., Raczkowski, A., Jain, B., & Albayrak, S. (2018). Gamification in e-commerce: Tangible vs. intangible rewards. *Proceedings of the 22nd International Academic Mindtrek Conference*, *Finland*, 11–19. https://doi.org/10.1145/3275116.3275126

Mehrabian, A. and Russell, J. A. (1974). *An Approach to Environmental Psychology*. The MIT Press, Cambridge.

Mohanty, M. S. (2016). Relationship between positive attitude and job satisfaction: Evidence from the US data. *Eastern Economic Journal, 42*, 349–372. https://doi.org/10.1057/eej.2014.76

Moody, G. D., Galletta, D. F., & Lowry, P. B. (2014). When trust and distrust collide online: The engenderment and role of consumer ambivalence in online consumer behavior. *Electronic Commerce Research and Applications*, *13*(4), 266–282. https://doi.org/10.1016/j.elerap.2014.05.001

Mulcahy, R. F., Russell-Bennett, R., Zainuddin, N., & Kuhn, K. A. (2018). Designing gamified transformative and social marketing services: An investigation of serious m-games. *Journal of Service Theory and Practice*, *28*(1), 26–51. https://doi.org/10.1108/JSTP-02-2017-0034

Nandi, S., Nandi, M. L., & Khandker, V. (2021). Impact of perceived interactivity and perceived value on mobile app stickiness: An emerging economy perspective. *Journal of Consumer Marketing*, *38*(6), 721–737. https://doi.org/10.1108/JCM-02-2020-3661

Ng, K. C., Zhang, X., Thong, J. Y., & Tam, K. Y. (2021). Protecting against threats to information security: An attitudinal ambivalence perspective. *Journal of Management Information Systems*, *38*(3), 732–764. https://doi.org/10.1080/07421222.2021.1962601

Noble, S. M., & Phillips, J. (2004). Relationship hindrance: Why would consumers not want a relationship with a retailer? *Journal of Retailing*, *80*(4), 289–303. https://doi.org/10.1016/j.jretai.2004.10.005

Nunnally, J., & Bernstein 3rd, I. (1994). *Psychometric Theory*. New York: McGrawHill.

Pasca, M. G., Renzi, M. F., Di Pietro, L., & Guglielmetti Mugion, R. (2021). Gamification in tourism and hospitality research in the era of digital platforms: A systematic literature review. *Journal of Service Theory and Practice*, *31*(5), 691–737. https://doi.org/10.1108/JSTP-05-2020-0094

Plangger, K., Campbell, C., Robson, K., & Montecchi, M. (2022). Little rewards, big changes: Using exercise analytics to motivate sustainable changes in physical activity. *Information & Management*, *59*(5). https://doi.org/10.1016/j.im.2019.103216

Pongjit, C., & Beise-Zee, R. (2015). The effects of word-of-mouth incentivization on consumer brand attitude. *Journal of Product & Brand Management*, *24*(7), 720–735. https://doi.org/10.1108/JPBM-11-2014-0752

Raman, P. (2021). Examining the importance of gamification, social interaction and perceived enjoyment among young female online buyers in India. *Young Consumers*, *22*(3), 387–412. https://doi.org/10.1108/YC-05-2020-1148

Rodrigues, I., Lopes, J. M., Borges, A., Oliveira, J., & Oliveira, M. (2021). How can gamified applications drive engagement and brand attitude? The case of Nike run club application. *Administrative Sciences*, *11*(3), 92. https://doi.org/10.3390/admsci11030092

Romani, S., Grappi, S., & Bagozzi, R. P. (2016). Corporate socially responsible initiatives and their effects on consumption of green products. *Journal of Business Ethics*, *135*, 253–264. https://doi.org/10.1007/s10551-014-2485-0

Seaborn, K., & Fels, D. I. (2015). Gamification in theory and action: A survey. *International Journal of Human-Computer Studies*, *74*, 14–31. https://doi.org/10.1016/j.ijhcs.2014.09.006

Shankar, A. (2022). Does reward gamification drive brand relationship quality?: An experimental approach. *Journal of Promotion Management*. 28(4), 443–466. https://doi.org/10.1080/10496491.2021.2008578

Sheetal, Tyagi, R., & Singh, G. (2023). Gamification and customer experience in online retail: A qualitative study focusing on ethical perspective. *Asian Journal of Business Ethics*, *12*(1), 49–69. https://doi.org/10.1007/s13520-022-00162-1

Shibly, S. A., & Chatterjee, S. (2020). Surprise rewards and brand evaluations: The role of intrinsic motivation and reward format. *Journal of Business Research*, *113*, 39–48. https://doi.org/10.1016/j.jbusres.2020.03.009

Shi, S., Leung, W. K., & Munelli, F. (2022). Gamification in OTA platforms: A mixed-methods research involving online shopping carnival. *Tourism Management*, *88*. https://doi.org/10.1016/j.tourman.2021.104426

Singh, J. J., Iglesias, O., & Batista-Foguet, J. M. (2012). Does having an ethical brand matter? The influence of consumer perceived ethicality on trust, affect and loyalty. *Journal of Business Ethics*, *111*, 541–549. https://doi.org/10.1007/s10551-012-1216-7

Soni, N., & S. Kumar. (2024). What drives new luxury consumption? Application of schema congruity theory and heuristic systematic framework. *Asia Pacific Journal of Marketing and Logistics*, *36*, 2213–2233. https://doi.org/10.1108/APJML-04-2023-0319

Sultan, P., Wong, H.Y., & Azam, M.S. (2021). How perceived communication source and food value stimulate purchase intention of organic food: An examination of the stimulus-organism-response (SOR) model. *Journal of Cleaner Production*, *312*. https://doi.org/10.1016/j.jclepro.2021.127807

Stauss, B., Schmidt, M., & Schoeler, A. (2005). Customer frustration in loyalty programs. *International Journal of Service Industry Management*, *16*(3), 229–252. https://doi.org/10.1108/09564230510601387

Sun, Y., Dong, X., & McIntyre, S. (2017). Motivation of user-generated content: Social connectedness moderates the effects of monetary rewards. *Marketing Science*, *36*(3), 329–337. https://doi.org/10.1287/mksc.2016.1022

Tan, C. S. (2021). Gamifying OTT: A study on consumer attitudes toward game elements and OTT media service provider brands in gamification. *Young Consumers*, *22*(3), 328–347. https://doi.org/10.1108/YC-11-2020-1245

Tanouri, A., Mulcahy, R., & Russell-Bennett, R. (2019). Transformative gamification services for social behavior brand equity: A hierarchical model. *Journal of Service Theory and Practice*, *29*(2), 122–141. https://doi.org/10.1108/JSTP-06-2018-0140

Temme, D., Kreis, H., & Hildebrandt, L. (2006). *PLS Path Modeling: A Software Review* (No. 2006–084). SFB 649 discussion paper, Humboldt University Berlin, Collaborative Research Center 649: Economic Risk. https://hdl.handle.net/10419/25167.

Terlutter, R., & Capella, M. L. (2013). The gamification of advertising: Analysis and research directions of in-game advertising, advergames, and advertising in social network games. *Journal of Advertising*, *42*(2–3), 95–112. https://doi.org/10.1080/00913367.2013.774610

Tewari, A., Mathur, S., Srivastava, S., & Gangwar, D. (2022). Examining the role of receptivity to green communication, altruism and openness to change on young consumers' intention to purchase green apparel: A multi-analytical approach. *Journal of Retailing and Consumer Services*, *66*. https://doi.org/10.1016/j.jretconser.2022.102938

Thorpe, A. S., & Roper, S. (2019). The ethics of gamification in a marketing context. *Journal of Business Ethics*, *155*, 597–609. https://doi.org/10.1007/s10551-017-3501-y

Tobon, S., Ruiz-Alba, J. L., & García-Madariaga, J. (2020). Gamification and online consumer decisions: Is the game over? *Decision Support Systems*, *128*. https://doi.org/10.1016/j.dss.2019.113167

Tsou, H.-T., & Putra, M.T. (2023). How gamification elements benefit brand love: The moderating effect of immersion. *Marketing Intelligence and Planning*, *41* (7), 1015–1036. https://doi.org/10.1108/MIP-04-2023-0143

Unurlu, Ç. (2021). The effect of place personality on resident welcoming tourist through positive and negative impacts of tourism. *International Journal of Tourism Research*, *23*(4), 636–651. https://doi.org/10.1002/jtr.2431

Videbæk, P. N., & Grunert, K. G. (2020). Disgusting or delicious? Examining attitudinal ambivalence towards entomophagy among Danish consumers. *Food Quality and Preference*, *83*. https://doi.org/10.1016/j.foodqual.2020.103913

Wang, T., Mai, X. T., & Thai, T. D. H. (2021). Approach or avoid? The dualistic effects of envy on social media users' behavioral intention. *International Journal of Information Management*, *60*. https://doi.org/10.1016/j.ijinfomgt.2021.102374

Wei, Z., Zhang, J., Huang, X., & Qiu, H. (2023). Can gamification improve the virtual reality tourism experience? Analyzing the mediating role of tourism fatigue. *Tourism Management*, *96*. https://doi.org/10.1016/j.tourman.2022.104715

Whittaker, L., Mulcahy, R., & Russell-Bennett, R. (2021). 'Go with the flow' for gamification and sustainability marketing. *International Journal of Information Management*, *61*. https://doi.org/10.1016/j.ijinfomgt.2020.102305

Wong, Y.T., Osman, S., Jamaluddin, A., & Yin-Fah, B.C. (2012). Shopping motives, store attributes and shopping enjoyment among Malaysian youth. *Journal of Retailing and Consumer Services*. *19* (2), 240–248. https://doi.org/10.1016/j.jretconser.2012.01.005

Xi, N., & Hamari, J. (2020). Does gamification affect brand engagement and equity? A study in online brand communities. *Journal of Business Research*, *109*, 449–460. https://doi.org/10.1016/j.jbusres.2019.11.058

Xu, J., Du, H. S., Shen, K. N., & Zhang, D. (2022). How gamification drives consumer citizenship behaviour: The role of perceived gamification affordances. *International Journal of Information Management*, *64*. https://doi.org/10.1016/j.ijinfomgt.2022.102477

Yang, Z., & Peterson, R. T. (2004). Customer perceived value, satisfaction, and loyalty: The role of switching costs. *Psychology and Marketing*, *21*(10), 799–822. https://doi.org/10.1002/mar.20030

Yang, Y., Asaad, Y., & Dwivedi, Y. (2017). Examining the impact of gamification on intention of engagement and brand attitude in the marketing context. *Computers in Human Behavior*, *73*, 459–469. https://doi.org/10.1016/j.chb.2017.03.066

Yu, N., & Huang, Y. T. (2022). Why do people play games on mobile commerce platforms? An empirical study on the influence of gamification on purchase intention. *Computers in Human Behavior*, *126*. https://doi.org/10.1016/j.chb.2021.106991

Yu, X., Roy, S. K., Quazi, A., Nguyen, B., & Han, Y. (2017). Internet entrepreneurship and 'the sharing of information' in an Internet-of-Things context: The role of interactivity, stickiness, e-satisfaction and word-of-mouth in online SMEs' websites. *Internet Research*, *27*(1), 74–96. https://doi.org/10.1108/IntR-02-2015-0060

Zhang, X., Wen, H., & Shao, X. (2024). Understanding consumers' acceptance of edible food packaging: the role of consumer innovativeness. *Journal of Retailing and Consumer Services*, *80*. https://doi.org/10.1016/J.JRETCONSER.2024.103903

Zhou, F., Lin, Y., Mou, J., Cohen, J., & Chen, S. (2023). Understanding the dark side of gamified interactions on short-form video platforms: Through a lens of expectations violations theory. *Technological Forecasting and Social Change*, *186*. https://doi.org/10.1016/j.techfore.2022.122150

Modelling Inherent Risk of Data Intensive Technologies

Quantitatively-differentiated Risk Management Framework Proposal

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Abstract: This study introduces a systematic methodology for risk management in data-intensive systems inside regulated environments, with a special emphasis on European Union scenarios. The framework tackles the distinct issues of reconciling regulatory compliance with the necessity for technical innovation. It delineates a risk trajectory throughout multiple phases of the data pipeline: collection, intake, processing, modelling, and application. Each stage corresponds to certain risk controls, ranging from fundamental validations at lower risk tiers to stringent security and accountability protocols for elevated risks. Organisations can mitigate any negative effects and successfully utilise data-driven insights by implementing appropriate controls at each phase. The suggested approach incorporates a quantitative risk formula that considers data volume, parameter complexity, and sensitive data items to yield a comprehensive risk score. Risk levels are assigned through Monte Carlo simulations, ensuring probabilistic accuracy in risk assessment. To enhance applicability, the framework defines risk thresholds and proposes differentiated controls, enabling organisations to simulate risk scenarios before implementation. This flexible framework seeks to promote the secure and responsible development of data-intensive applications, allowing European companies to enhance their competitiveness globally while upholding ethical and legal standards, such as the EU AI Act, or the EU Digital Services Act.

Keywords: Data-intensive Applications, Risk Management, Regulatory Compliance, Data Management, Risk Modelling

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Introduction

One of the most impactful issues affecting organisational innovation is the restrictive nature of institutional frameworks and bureaucratic constraints. The European Union, as one of the most highly regulated regions in the world, often sees its ambitious start-ups, leading technology firms, and advanced medical organisations struggle to compete. Their counterparts in the U.S. and China, operating under more flexible regulatory frameworks, frequently gain an edge in research and innovation (Feldstein, 2023) on the global stage. The effect of regulations slowing down growth has been well documented over the past decades – 'over-regulation' has always been a relative term to the time regulatory changes were introduced (Kirkegaard *et al.*, 2024), be it 1950s or 2024. Fear of audits and regulatory reprisals leave organisations oftentimes paralysed from attempting to innovate using more complex digital technologies (George & George, 2023). This leaves them lagging behind growing competitors from other, more regulatorily-lax countries. However, these fears most often stem from the lack of resources, capacity or expertise to manage the risks and create safe and compliant applications without losing much (or any) of the advantage the application would bring.

These challenges are addressed by proposing a baseline function for modelling risk specific to data-intensive technologies such as ML/AI models, in highly-regulated environments such as the European Union, where certain regulations in the form of the EU AI Act, or the EU Digital Services Act have to be carefully navigated to ensure compliance, transparency, and accountability of the models. Our model (framework) has three components, with one being the function from which we derive risk levels through simulations. Depending on the risk levels (ranging from one to six, where one is the lowest risk level and six the highest), we have some proposed risk controls based on the data workflow process (data collection, intake, processing, modelling, application). We start by characterising the contemporary data environment and regulatory context that underlie the issue, thus gradually setting the stage for the development of the framework. At the core of this framework is a risk classification system inherent on key dimensions such as the volume of data, complexity in the parameter, and sensitivity that will allow organisations to apply proportional safeguards at each stage of the development pipeline. In the end, risk levels are assigned, thus facilitating proposed implementable controls throughout the development process as mitigation strategies which ensure compliance without unnecessarily stifling innovation. We identify and propose a number of key methods to minimise risk during development, also based on the initial calculated risk level, therefore providing an opportunity to apply proper controls from data collection to final deployment. We ultimately examine the wider ramifications of this

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approach, emphasising its capacity to enable organisations to undertake ambitious data-driven initiatives while ensuring compliance and accountability.

Background

Creating a successful application, akin to many aspects in business, requires the provision of value for the organisation, its customers, or both. Whilst generating the use-case is highly dependent on the organisation, sector of activity, clients, and many more variables, the scope of this paper is focused on the second side of overcoming obstacles. This paper proposes a framework that will enable practitioners to deliver production-level applications that are based on the generation, processing, and general use of large volumes of data, for which the biggest hurdle is often the regulatory overhead that needs to be satisfied.

To navigate this challenge, risk modelling techniques are key in mitigating uncertainty and ensuring compliance in data-intensive applications. There is a wide array of techniques and algorithms that can be used to model risk, such as Deep Neural Networks (DNNs) and ensemble methods like Gradient Boosting Machines (GBMs), which can learn complex nonlinear patterns from large datasets and achieve high predictive accuracy (Peng & Yan, 2021) in risk assessment tasks. Such models can represent intricate patterns that simpler models miss; indeed, when a higher level of complexity is required (beyond what linear functions can provide), deep learning approaches (Paltrinieri *et al.*, 2019) are suggested as suitable solutions. The quantitative approach taken in this paper is not model-driven due to the difficulty in achieving explainability for these models, instead opting for an easier to understand and modify risk function which both business and technical users would be able to utilise.

Methodology

In very recent years many new regulations, directives or other forms of legislation have been implemented to reduce risks associated with dangerous applications of technology, and the common denominator for the most powerful of these technologies is data (Kempeneer, 2021), specifically, big data. The Internet of Things (Greengard, 2021) is the technology that practically enabled the gathering and accumulation of large volumes of data in our present society, and it is still what currently enables some of the biggest breakthroughs in the fields we all hear about – automation, robotics, financial systems, smart – everything. Through large or minute sensors inter-connected via networks as small or large as one can imagine, data captured from natural phenomena, user behaviour, system diagnostics, and more is what has currently become the new gold for those who can leverage it. Blockchains, whilst recently losing ground in terms of public and private interest, still hold potential in niche fields for improvement of operational robustness and transparency (Tyagi *et al.*, 2023), especially in guaranteeing a single source of truth that prevents any possible tampering on the data collected. Lastly, what is ultimately the most advanced and at times least explainable utility of data, creating artificial intelligence models (Car *et al.*, 2019) is where the data truly shines its highest glow.

Whilst not limited specifically to these technologies, this paper aims to create an application-agnostic (generalised) framework to tackle the risk of data-intensive applications of technologies. The level of risk carried by the successive stages of data-handling differ and so the approach differs as well. In order to tackle this issue, the framework we propose differentiates on five increasingly scrutinised levels of risk management, applicable transversally on the data itself, the treatment it receives, and the ultimate use case for which it is required. Figure 1 highlights the high-level data life-cycle components, from collection to treatment to leverage, into which we deep-dive in the following sections and propose potential data-related controls to minimise risk based on the level obtained.

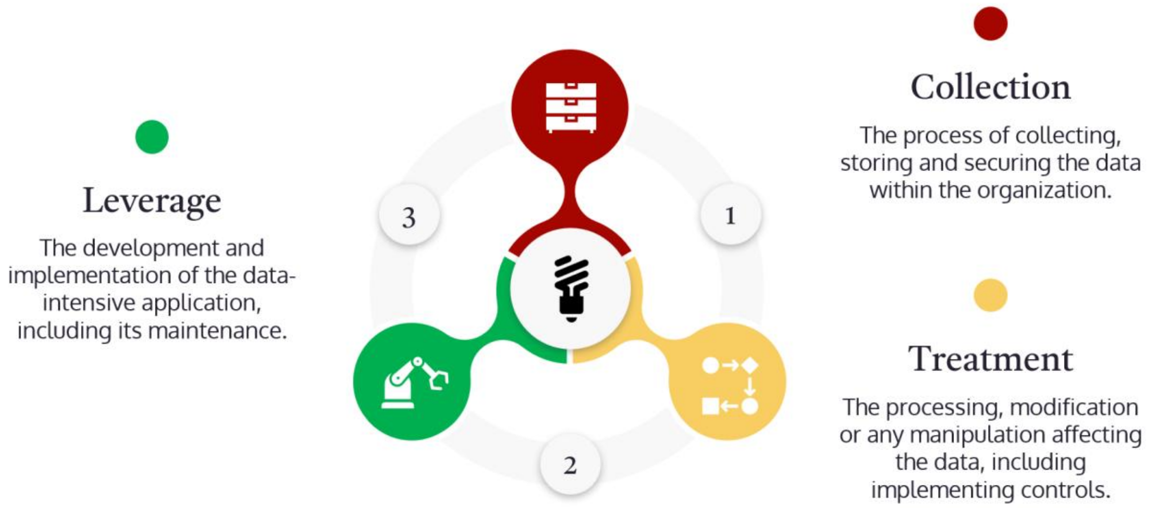

Figure 1: Framework proposal for risk management in data-intensive applications, authors' own elaboration

The data collection and custody process is a critical but often overlooked component of the value chain leading up to a business use case (Janssen *et al.*, 2020) and more often than not it is what makes or breaks the successful implementation of a data-intensive application. Human error, sensor or server malfunctions, and inattentive handling or migrations can all lead to severe deficiencies in what would otherwise become the fuel to powerful engines in an organisation. Data generation and capture has become incredibly varied in recent years due to enabling by IoT technology spreading out to the public (Narayana *et al.*, 2022), although the vast majority of it lies yet unused due to its unstructured nature, missing data capabilities, or organisations simply not prioritising its use and instead simply storing this data for later

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(though not much later, as data importantly has an expiration date as set forth by data retention rules). Figure 2 describes some of the most popular data collection methods (Bavdaž *et al.*, 2020), as well as their drawbacks (Bavdaž *et al.*, 2020; Jatnika *et al.*, 2024), which supports the need for measuring and controlling the deficiencies, or risk, data carries at the very moment it is created:

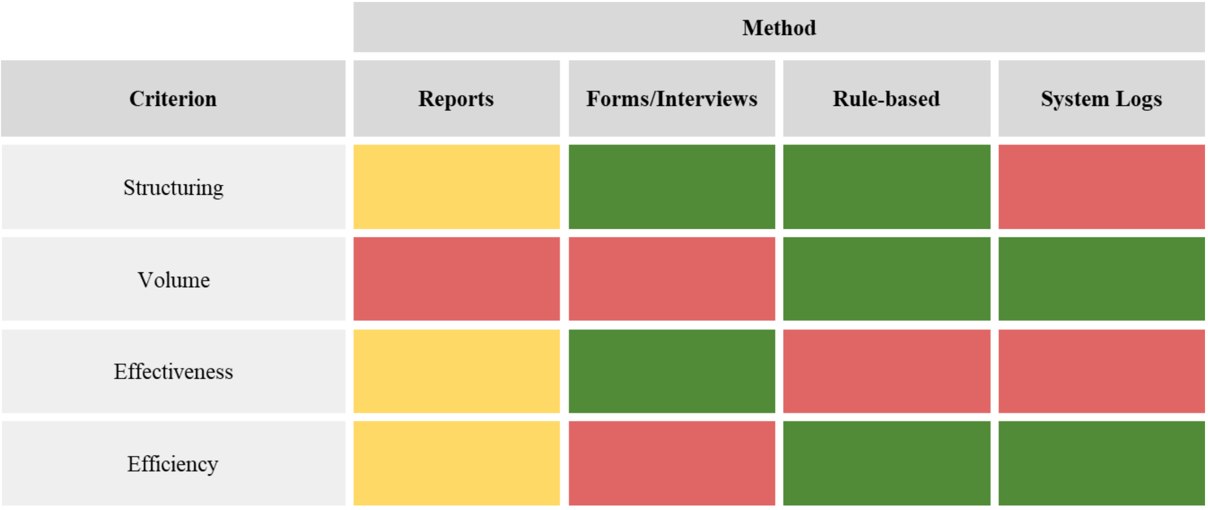

Figure 2: Comparison of data collection methods, authors' own elaboration

Because this first step in the modern data organisation is often the weakest link, controls need to be put in place to steer collection with standards, procedures, technical checks, and more, in order to increase the quality of the data obtained and reduce the effort required to polish and eventually obtain return on investment from it.

The most laborious part of building something with data is being able to transform the information into a usable format, or more laborious yet (Huang & Zhao, 2024), create useful data points out of the gate through manual data labelling. Direct forms of collection such as forms, surveys, or reports are highly useful, but highly laborious to elaborate and distribute (Guest *et al.*, 2013), severely limiting their ultimate impact.

Autonomous collection methods have revolutionised the way we think about data, but making use of it requires expertise and insight into where and how much effort should be exacted to extract the most benefit out of it – system-generated data such as user input, logs, up and downtimes are useful within their own right and incredibly high volume, effectively infinite in nature, but almost always are unstructured and require cleaning and formatting (Zou, 2022) before being at all useful in an organisation. Rule-based systems combine the two, in the sense that business rules are written in terms of typically manually-obtained, empiric, information, which are then used to sift and label certain behaviours observed automatically (Davis & King, 1984), such as financial transactions, user interaction with or within an application, system

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logs, or sensor data if it is at least semi-structured at capture, and much more. That being said, where rule-based systems ultimately fail is their actual effectiveness or correctly classifying behaviours (Waltl *et al.*, 2018). Because phenomena captured as data are almost never static, natural changes almost always render the rules obsolete, and in an attempt to cover more and more possible edge-cases, manually maintaining the rules becomes unsustainable and very costly.

We analyse the most popular data collection methods showcased in Figure 2 based on a set of criteria. In terms of structuring variability, forms/interviews and rule-based collection methods score highly (green) because they provide a reliable means for generating well-organised datasets. On the flip-side, reports are only moderately structured (yellow), as they require additional processing to standardise data. In this category system logs are ranked the lowest (red) due to them often containing unstructured, free-flowing data that needs considerable pre-processing before being useful. Regarding data volume, rule-based systems and system logs aggregate huge volumes of data (green), sparing organisations from the labour of manual extraction. Though, reports and forms/interviews lag (red) because they depend on human input and leak data at a very slow pace. Effectiveness, the third category, varies by method of collection. For example, forms and interviews that require direct involvement of the user excel (green) are specific and precise, whereas reports (yellow), system logs, and rule-based systems (red) clutter with noise, extraneous bits, or fractured records that decrease their usability. The last dimension, efficiency, refers to the practicality of the data collection method. Thus, rule-based systems and system logs dominate (green) through seamless automation, while reports (yellow) and forms/interviews (red) lag since they drain resources, raise costs, and hinder processing workflows.

In order to control for a wider array of issues across the collection-intake-modelling pipeline of application development, we devise a risk function that quantitatively assesses the risk generated for the organisation by developing an application such as a machine learning model, based on its parameters, the volume of data involved, privacy-related sensitivity of the parameters or variables involved, as well as an impact assessment score that can be customised to reflect risk from different areas across the organisation, in a 1 to 5 range. The components of the function are described in detail as follows, before being simulated 100,000 times and generating a Kernel Density Estimation from which we extract the 'risk levels' as quintiles, for 5 levels of risk.

On impact:

The impact component is a manual scoring process performed by the subject matter expert (SME) most familiar with how the data will be obtained, processed and ultimately put into use.

Ranging from 1 to 5, where 5 is the highest level of negative impact on the organisation, the SME, together with risk experts or people who are otherwise familiar with the general risks the organisation is typically facing, have to carve out a few components. The impact scores are simulated using the uniform distribution on the 1 to 5 scale. The impact scores should not be mistaken with the result of the risk function, which provides a numerical but categorical result through Monte Carlo simulations, distributed Uniform (1, 5). The impact metric's only restriction is that it be a quantitative result of a potentially qualitative risk assessment. Before inputting the results of this assessment, if the results are outside the range of this function (1 to 5), they must be scaled to this range before being used as input.

For instance, for a service organisation the risk areas could be defined as potential financial, staffing or reputational losses, while product-oriented organisations would be more concerned with potential interruptions in the production chain, if the application is to be used as a critical component of this process. The number of risk areas possible to be defined is limited at 5 due to the complex nature of determining the risk associated with a single area, and as not all are made equal due to their unique nature stemming from the application, the possible workload required to score more than 5 becomes infeasible.

On parameters:

The number of parameters involved in the creation of an application highly depends on the type of algorithm or model trained to serve as the core component. For instance, traditional machine learning models use relatively few possible parameters, typically into hundreds or lower thousands for the most complex parameters. While the risk model accounts for these scenarios well, there are edge cases in the Natural Language Processing and Computer Vision domains which can have the number of parameters go well into the hundreds of millions, to billions of parameters. The base risk model is not suited nor intended to risk-classify such use cases as they are more often than not trained on unstructured data and on volumes typically not obtainable by the organisations the risk model is defined for. This being said, the formula may be adjusted through scaling

On volumes:

The volume of data is a simple metric to quantify once it has been pre-processed and structured, as the simple sum of data points used during the entire development process of the application. The volume of data is generated based on the Pareto distribution with parameters (α=3, scale=300,000) to observe the nature of data use-cases as being heavy-tailed in low-volume instances, but still having non-negligible probabilities of observing very high values for (V) somewhat regularly regardless of simulation. The Pareto distribution is one of the more prevalent power laws in the risk modelling domain, often appearing in risk functions such as ours to represent components where most of the risk or value is generated by a relatively small number of cases (De Santis *et al.*, 2024). In the Pareto distribution parameters, the higher α term lightens the tail to a low extent. The minimum possible value and the one around which most values will congregate is 300,000, characterising the scenario of data volumes where high values (highly intensive/production-level applications) can still appear, but are not common. This is to say that for machine learning models this includes all training, testing or validation data, and for non-model but algorithmic methods it is simply the sum of input data, for instance graphing algorithms for transaction mapping should have the sum of transactions ultimately graphed as edges.

On the complexity parameter:

The complexity parameter (P/V) is the most dynamic component of the formula. As both (P) and V can take on considerably low or high values, possible combinations of the two end up dominating the results in most instances. This component is created as a ratio due to the complexity brought on by increasing parameters in a model; technically, most data-intensive applications function on a tabular data input, which scales the data volume with the parameters and requires parameter-specific treatment or transformations, processes which introduce and scale risk upwards – the initial parameter form would thus be (P*V), however we must take into account that highly over-fit models lead to false results, which is one of the highest risks when building applications with data at their core. Thus, the volume parameter acts as an anchor for the parameters, decreasing risk when data is abundant in comparison to the parameters, and increasing it should (P) ever be larger than (V).

On sensitive parameters:

Sensitive parameters are defined in the risk model as variables, features or otherwise general input used for the development of the application that carry a sensitive character from a data protection and/or organisational point of view. Processing and using data with such character brings a relatively higher, but still controllable risk to the organisation in the unfortunate event of data loss, breaches, leakage or mishandling due to poor explainability, which is one of the ways the model could possibly be extended with.

Results

Risk classifications in risk management are a versatile method of assessing the potential (negative) impact an initiative could have for the organisation if it was pursued. Risk assessments are typically applicable to all sides of an organisation through customised forms or formulas – which can make them as qualitative or quantitative in nature as required to

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properly assess the risk involved. This framework proposal has at its base a formula that takes into account the most impactful features of data-intensive application development, such as the number of parameters or variables (P), volume of data (V), sensitivity of data, measured through parameters ($P_{sensitive}$) and perceived business impact (I) measured across multiple sectors of the organisation. The resulting formula is as follows, with explanations following it:

$$R = \left(\sum_{d=1}^{D\leq 5} I_d\right) \cdot \frac{P}{V} \cdot \left(1 + \frac{P_{sensitive}}{P}\right) \qquad \textbf{Equation 1}$$

where:

- V ~ Pareto (α=3, scale=300,000): Data Volume, measured as the count of data points used overall (including training, testing);
- P ~ Uniform (50, 10,000): count of application (model) parameters, variables or features, of which:
  - $P_{sensitive}$ ~ Uniform (0, P-1) = count of sensitive variables used;
  - $P_{normal} = P - P_{sensitive}$
- I_d = impact score for risk dimension d, quantified as a facet at risk of the organisation, such as staffing, reputation, financial loss, etc. as a result of untreated risk generated by the application. All risk dimensions have equal weight, the scoring being inherently representative of the impact.
- $1 < D \leq 5$: number of risk areas taken into account; limited to 5 for the purpose of not generating too much complexity in the proposed risk process.
- Parameters-to-Data (P/V) ratio: a complexity parameter, inflating risk whenever V < P due to poor model fitting/development, models should not have the number of parameters exceed the volume of available data; when V > P is true, on the other hand, the complexity parameter effectively becomes a deflating factor.
- Sensitive Data Inflator: the last term of the formula inflates R relative to the proportion of sensitive features present in the usage of data. As $P_{sensitive}$ can only be as high as P-1, the inflator can be very close to double the output R, and take a minimum value of 1.0.

Looking at the sensitivity of R with regards to its individual components, we may look below at Pearson's correlation coefficients for the components, simulated 100,000 times in order to minimise random fluctuations in the variables generated.

Table 1 – Pearson Correlation Coefficient for R components, authors' own calculations

Component	Pearson's correlation coefficient, Component vs R
V	-0.272
P	0.783

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P/V	0.882
$1 + P_{sensitive}/P$	0.261
R	1.000

As we can see, the parameters component mostly controls the formula, as is expected due to its multiplicative nature. Volume decreases risk with low impact, while the complexity parameter combining the two mostly dominates the ultimate (R) value. The sensitive data component is used for fine-tuning values, though at its maximum output it can effectively double the (R) parameter if needed. As all data should be controlled in some way regardless of how sensitive it is, this component's behaviour is as is expected for real-life practical examples and does not serve as a disqualifying factor on its own.

The formula is tested on 500,000 possible combinations, using the ranges and distributions earlier stipulated for each parameter. The resulting kernel density estimator (KDE) plot showcases the distribution of (R) values in Figure 3.

Table 2 – quintile thresholds (±0.005), author's own calculations

Quintile	Threshold
20%	0.094
40%	0.190
60%	0.300
80%	0.448
100%	1.417

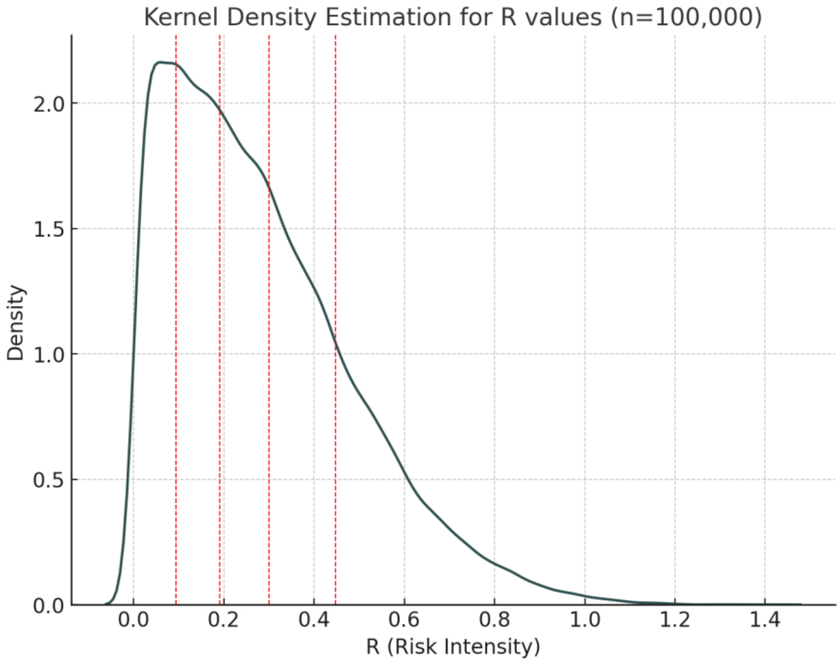

Figure 3 – Kernel Density estimation for R values, with quintiles marked, authors' own elaboration

The red vertical dashed lines in the plot divide the KDE into quintiles, at 20% frequency intervals, namely each vertical 'column' divide of the distribution contains 20% of R values simulated. During other simulations, due to random factors, the thresholds will vary, however for all quintiles except 100% the differences between simulations never exceed 0.005. The last quintile is slightly more volatile due to the nature of outliers, but the differences here do not significantly diverge from the quintile threshold by more than 0.025 in either direction. Given these small variations, risk levels that can be further built into risk management frameworks can be divided as follows:

Table 3 – Risk levels and characteristics, as defined by R quantile thresholds, authors' own elaboration

Risk Level	Thresholds	Characteristics
1	$R < 0.094$	characteristic of small experimental models using low data volume, having low sensitivity and low complexity (most applications)
2	$0.094 \le R < 0.190$	experimental models incorporating sensitive elements
3	$0.190 \le R < 0.300$	extensive proof-of-concept (POCs) models
4	$0.300 \le R < 0.448$	high complexity POCs / lower complexity productionised applications
5	$0.448 \le R < 1.417$	high complexity productionised applications
6	$1.417 \le R$	re-evaluation, should not exceed this threshold

In order to validate the robustness of these components, we test three extreme scenarios in which:

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- the number of parameters range from 5,000 to 100 million;
- all cases have over 80% of the parameters designated as sensitive.

Simulating each of these cases 100,000 times (holding the other distributions equal) we obtain the following quintile thresholds and KDEs:

Table 4: Extreme scenarios testing, authors' own calculations

Quintile	Base Thresholds	5000+ Parameters	80%+ Sensitivity
Q5	0.094	0.260	0.123
Q4	0.190	0.351	0.251
Q3	0.300	0.444	0.391
Q2	0.448	0.570	0.575
Q1	1.417	1.442	1.436

We note in Table 4 the parameters and sensitivity act as expected, inflating the risk up to a point, specifically in the lower-middle quantiles before tapering off around Q4 and Q5. The threshold boundaries are thus fairly robust, especially in the higher-risk categories, which are the most important to assess and treat correctly. The KDE plots may be examined in Appendix A at the end of this paper.

Discussion

Using these calculated boundaries, we are able to define controls for the risk associated with the pipeline-like journey going from collection, through development and finally application of a data-intensive use-case. This is called the risk journey of the use case or application and serves as the crux of most use cases' make or break scenarios.

Table 5 – Risk levels and sample controls across development pipeline, authors' own elaboration

Risk	Data collection	Data intake	Data processing	Data modelling	Application
1	Basic data validation, ensuring completeness	Basic format checks and metadata logging	Standardised processing steps	Basic model validation	Monitoring for application errors
2	Data source verification, initial filtering	Integrity checks, duplicate removal	Automate quality checks on processed data	Model performance testing, documentation	Application logging and alerting setup
3	Compliance checks for data privacy laws	Access control policies, secure transfer	Consistent data quality assurance	Bias and fairness analysis in model	User feedback and usage monitoring

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Risk	Data collection	Data intake	Data processing	Data modelling	Application
4	Advanced data access controls, encryption	Real-time validation, anomaly detection	Continuous validation, secure storage	Robust model validation and auditing	Implement fallback systems, stress testing
5	Multi-level encryption, regular audits	Strong encryption, multifactor access	Redundant processing, disaster recovery plan	Model explainability, accountability measures	Real-time monitoring, fail-safe mechanisms
6	Re-evaluate use case, indicated risk too high				

The process of managing risk throughout the data pipeline commences with the preliminary phases of data collection and intake, where essential validations are required to guarantee data integrity, and some proposed controls can be examined in Table 5. During the data collecting phase, fundamental assessments for data completeness facilitate the identification of any absent entries prior to system integration. As risk escalates, control mechanisms intensify; data acquisition at elevated risk levels necessitates not just verification of data format consistency but also the use of secure transfer methods, such as encryption, to safeguard data during transmission. This configuration reduces the probability of data compromise resulting from unauthorised access or corruption during transmission. The processing stage necessitates consistent data quality assurance due to increasing risk. In low-risk scenarios, regular quality assessments are adequate to avert the transmission of faults throughout the pipeline. In high-stakes settings, redundant processing and disaster recovery strategies are employed to ensure data continuity in the event of system failure. A financial services application may necessitate redundant storage to uphold data integrity, guaranteeing the absence of data loss in the event of a failure within a segment of the processing system. Modelling presents supplementary concerns, especially concerning the equity and openness of machine learning models. For low-risk scenarios, basic model validation is adequate, while higher-risk applications require an extensive investigation of bias and fairness. This guarantees that the model does not yield unintentional discriminatory results. For example, while modelling credit ratings, it is essential to test for biases related to demographic factors to prevent inadvertently disadvantaging specific populations. In the application phase, low-risk applications may necessitate merely fundamental error monitoring, but when risk escalates, advanced controls such as real-time monitoring and fail-safe procedures become essential. This strategy guarantees that, in the event of an unforeseen occurrence, such as an application malfunction or system overload, there are established protocols to sustain operation and reduce interruption.

Data Intake

The data intake process is a fundamental step of any analytical pipeline regardless of an organisation's expertise to put the data to further use – through its existing processes and products, the organisation has to securely store and be able to transfer data when needed, partially or fully, all the while maintaining the technical integrity of the data through technical checks and well-maintained databases. The data intake process stands in stark contrast to user managed environments (UMEs), in terms of the control exerted over the data going from point A to B. In UMEs, downloading, sharing and losing data is an often occurrence and while they provide incredible value and velocity to their users. To better understand the differences between the production/strategic emphasis of data intakes versus the ad-hoc nature of UMEs, the following example may provide insight:

Data Processing

The first step to building a successful use case and obtain sponsoring for development of an application is to provide factual, data-driven insights on the benefits and costs involved, which can only happen if the appropriate understand and assumptions are in place – this requires appropriate processing of the data, in the form of reshaping, extending the database with feature engineering and obtaining actionable insights from the data. The possible issues stemming are limitless – from mismanaging missing values to mistakenly overwriting data with the wrong transformations, processing-related issues can easily end up being passed into the next phase without being caught, ending up in production and producing potentially erroneous results. For illustrative purposes, we may consider the case when a variable has a small amount of missing or otherwise 'null' values – the analyst may make the mistake of dismissing them out of hand if they are in very small proportion, but in doing, so they may easily remove context from the dataset, should those few missing values be stemming from a contextual issue with that variable – if a particular system or sensor is only configured to output positive values according to some conditions, if none of the conditions are met (an edge case), it is possible that it will simply register a null entry. In order to control for this risk, data definitions should be written and put into place, describing the type and legal values of a particular variable, the ranges, and the source of the data therein. The analyst can then use the definition to take a documented decision for imputing the missing data, further investigating, or removing it.

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Data Modelling

Together with data processing, data modelling is what brings the most risk to the organisation out of the entire development pipeline. Due to the very high level of expertise and specialised knowledge required in modelling the data for its final usage, mistakes and issues can appear at every moment, even if appropriate controls have been applied at every step up to this point. One of the major risks involved with this phase is the lack of explainability for how an algorithm used reached a conclusion given its inputs. Accounting for this risk, validation units similar to internal audit teams should be involved in this step and briefed on the phases, steps, controls or assumptions taken to reach the development/production phase of the application, and this particular unit should provide questions, raise issues and resolve them before the application is actually put into use.

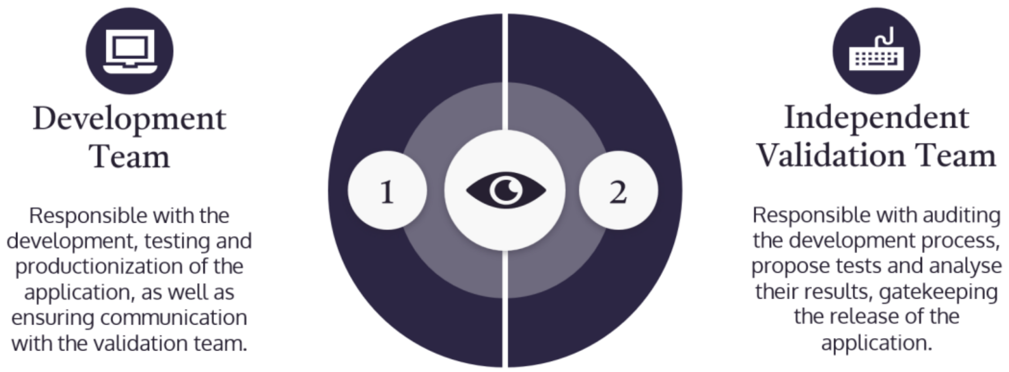

Figure 4: Collaboration and roles in application development and validation, authors' own elaboration

The validation unit should be independent and come from a different hierarchical line, department, or area of the organisation in order to ensure accountability and minimised interference. While they are tasked with ensuring responsible development and preventing issues from arising, the validation team is ultimately working together with the development team members to ensure successful development cycles, as illustrated in Figure 4.

In order to practically demonstrate the implementation of a tag-team validated development with the formula devised previously, we consider the following examples. Reis *et al.* (2018) make use of a 10,000-observation dataset on which they experiment and test certain hypotheses. They devise 15 features, of which they specify 10 are informative, relatively more valuable for modelling, which we assume for the sake of example to also be sensitive. The authors build and test two separate models, a traditional Random Forest and a proposed Probabilistic Random Forest, which can serve as use cases for the validation team to evaluate on. Let us assume on a 1 to 5 scale that they score these as 3 and 5 respectively, given the experimental nature of the latter. This gives us the following formula and risk score:

$$R = \left(\sum_{d=1}^{2}(3,5)\right) \cdot \frac{10}{10000} \cdot \left(1 + \frac{10}{15}\right) = 0.02(Q5) \qquad \textbf{Equation 2}$$

Given the small volume of data and modest number of features, the risk is modelled as being very low, with limited impact and appropriate for an experimental or explorative use case such as the one undertaken by the authors. A more extreme case we may look at is the AlphaZero computerised chess player model. This model can train on millions of chess positions and generate millions of trained parameters to predict with. Silver et al. (2016) describe the model as being trained on 30 million chess positions and reaching ~30 million trained parameters. In cases such as this one, the chess positions are most likely not sensitive and likely public, and with the volume equalling parameters, the risk formula comes down to the impact given by the validation team across a number of scenarios, and the only way in which the risk could ever fall below the highest quintile is if there is a single scenario scored 1, the lowest option given the numerical domain of our impact score. Thus, any model of this magnitude, particularly due to the large parameter count, will have a very high-risk score and hence require a very sophisticated validation and monitoring process throughout all cycles of development in a controlled environment. This being said, the vast majority of such models require extensive computational power and data access, which most organisations do not have or cannot afford, and these are the entities our proposal aims to benefit. For a typical organisation, we may consider the following adjustable approach which is how our contribution should be used. Zhang (2024) trains an XGBoost (eXtreme Gradient Boosting) model, a more powerful tree-based model variant on a credit card transaction dataset with 284,807 observations and 29 variables. Assuming this could be a fraud prevention initiative at a financial institution, all features are likely to be sensitive, and the risk scoring of potential impact should have both breadth and depth – however, there come certain challenges such as data imbalance in such workshops, which result in more difficult modelling processes and need of optimisation. The technical experts in charge can devise a correction to the base formula to account for the imbalance, such as an inverse relationship of the proportion of fraudulent cases, to be detected:

$$R = \frac{\left(\sum_{d=1}^{D\leq 5} I_d\right) \cdot \frac{P}{V} \cdot \left(1 + \frac{P_{sensitive}}{P}\right)}{\frac{Fraudulenttransactions}{Alltransactions}} \qquad \textbf{Equation 3}$$

Assuming a more comprehensive impact scoring, and given the sensitive nature of the data, we may have the following result:

$$\frac{\left(\sum_{d=1}^{D\leq 5} I_d\right) \cdot \frac{29}{284{,}807} \cdot \left(1 + \frac{29}{29}\right)}{\frac{492}{284{,}807}} \Rightarrow \frac{\left(\sum_{d=1}^{D\leq 5} I_d\right) \cdot 0.00020364}{0.0017275} \qquad \textbf{Equation 4}$$

Given that only one model is in production, the Impact scoring can be solely technical at a 5, resulting in R = 0.5894 (Level 5) or breaching into Level 6 when having a more extensive impact assessment. A similar adjustment can be made for churn models, pollution concentration predictors, or clusterisation algorithms, depending on the task at hand and the model metrics to be optimised for the problem.

Conclusions

In this paper, we proposed a potential way of quantitatively measuring/modelling the risk generated by the development journey of data-intensive applications. Through testing and many simulations, we obtain thresholds usable to control risk in a differentiated manner, according to the risk level obtained. The framework level associated with this risk level may be used as a reference for implementing practical controls and not minimise the inherited risk from phase to phase, as well as control the risk inherent to the data from its inception and associated nature.

The proposed risk formulation has some obvious limitations that also serve as opportunities for refinement and extension – for instance, properly accounting for extremely high parameter applications specific to computer vision or natural language processing models is the most immediate challenge that may be tackled. Further adding non-linear components to the formula may also yield valuable advancement to the accuracy of the formula, but what we determine as the most important aspect for the purposes of practical use is that the formula be kept simple enough to be explained and understood by organisational decision-makers. Risk can be modelled with a plethora of advanced techniques and algorithms, but the value generated by these is nil when the person in charge of sponsoring a development proposal does not understand what is happening in terms of uncontrolled risk.

Acknowledgements

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References

Bavdaž, M., Snijkers, G., Sakshaug, J. W., Brand, T., Haraldsen, G., Kurban, B., Saraiva, P., and Willimack, D. K. (2020). Business data collection methodology: Current state and future outlook. *Statistical Journal of the IAOS, 36*(3), 741–756. https://doi.org/10.3233/SJI-200623

Car, J., Sheikh, A., Wicks, P. and Williams, M. S. (2019). Beyond the hype of big data and artificial intelligence: Building foundations for knowledge and wisdom. *BMC Medicine, 17*(1), 143. https://doi.org/10.1186/s12916-019-1382-x

Davis, R. and King, J. J. (1984). The origin of rule-based systems in AI. In B. G. Buchanan & E. H. Shortliffe (Eds.), *Rule-based expert systems: The MYCIN experiments of the Stanford Heuristic Programming Project*. Reading, MA: Addison-Wesley.

De Santis, F., Gubbiotti, S., and Pacifico, M. P. (2024). Distributions of risk functions for the Pareto model. *Open Journal of Statistics, 14*(6), 721–736. https://doi.org/10.4236/ojs.2024.146032

Feldstein, S. (2023). Evaluating Europe's push to enact AI regulations: How will this influence global norms? *Democratization, 31*(5), 1049–1066. https://doi.org/10.1080/13510347.2023.2196068

George, A S; George, A S H. (2023). FMCG's digital dilemma: The consequences of insufficient IT expertise in the fast-moving consumer goods industry. *Partners Universal International Innovation Journal, 1*(3), 46–69. https://doi.org/10.5281/zenodo.8066759

Greengard, S. 2021. *The internet of things*. Cambridge: MIT Press.

Guest, G., Namey, E. E., Mitchell, M. L. (2013). *Collecting qualitative data: A field manual for applied research*. Thousand Oaks, CA: Sage.

Huang, Q; Zhao, T. (2024). Data collection and labeling techniques for machine learning. *arXiv preprint* arXiv:2407.12793. https://doi.org/10.48550/arXiv.2407.12793

Janssen, M., Brous, P., Estevez, E., Barbosa, L. S., & Janowski, T. (2020). Data governance: Organizing data for trustworthy artificial intelligence. *Government Information Quarterly, 37*(3), 101493. https://doi.org/10.1016/j.giq.2020.101493

Jatnika, H., Waluyo, A., Azis, A. (2024). A comparative study on data collection methods: Investigating optimal datasets for data mining analysis. *Journal of Applied Data Sciences, 5*(1), 16–23. https://doi.org/10.47738/jads.v5i1.148

Kempeneer, S. (2021). A big data state of mind: Epistemological challenges to accountability and transparency in data-driven regulation. *Government Information Quarterly, 38*(3), 101578. https://doi.org/10.1016/j.giq.2021.101578

Kirkegaard, J. F., David-Wilp, S., & Tausendfreund, R. (2024). *Keeping Europe Competitive*. German Marshall Fund of the United States. http://www.jstor.org/stable/resrep59184

Narayana, V. L., Rao, G. S., Gopi, A. P., & Patibandla, R. S. M. L. (2022). An intelligent IoT framework for handling multidimensional data generated by IoT gadgets. In F. Al-Turjman & A. Nayyar (Eds.), *Machine Learning for Critical Internet of Medical Things*, 189–210. Springer. https://doi.org/10.1007/978-3-030-80928-7_9

Paltrinieri, N., Comfort, L., & Reniers, G. (2019). Learning about risk: Machine learning for risk assessment. *Safety Science, 118*, 1–10. https://doi.org/10.1016/j.ssci.2019.06.001

Peng, K. & Yan, G. (2021). A survey on deep learning for financial risk prediction. *Quantitative Finance and Economics, 5*(4), 716–737. https://doi.org/10.3934/QFE.2021032

Reis, I., Baron, D., & Shahaf, S. (2018). Probabilistic random forest: A machine learning algorithm for noisy data sets. *The Astronomical Journal, 157*(1), 16. https://doi.org/10.3847/1538-3881/aaf101

Silver, D., Huang, A., Maddison, C. J., Guez, A., Sifre, L., Van Den Driessche, G., Schrittwieser, J., Antonoglou, I., Panneershelvam, V., Lanctot, M., Dieleman, S., Grewe, D., Nham, J., Kalchbrenner, N., Sutskever, I., Lillicrap, T., Leach, M., Kavukcuoglu, K., Graepel, T., & Hassabis, D. (2016). Mastering the game of Go with deep neural networks and tree search. *Nature, 529*, 484–489. https://doi.org/10.1038/nature16961

Tyagi, A. K., Dananjayan, S., Agarwal, D., & Thariq Ahmed, H. F. (2023). Blockchain—Internet of Things applications: Opportunities and challenges for Industry 4.0 and Society 5.0. *Sensors, 23*(947), 1–22. https://doi.org/10.3390/s23020947

Waltl, B., Bonczek, G., & Matthes, F. (2018). Rule-based information extraction: Advantages, limitations, and perspectives. *Jusletter IT*, 2, 4.

Zhang, X. (2024). Machine learning insights into digital payment behaviors and fraud prediction. *Applied and Computational Engineering, 77*, 203–209. http://dx.doi.org/10.20944/preprints202406.1933.v1

Zou, F. (2022). Research on data cleaning in big data environment. In Proceedings of the 2022 International Conference on Cloud Computing, Big Data and Internet of Things (3CBIT) (pp. 145–148). IEEE. https://doi.org/10.1109/3CBIT57391.2022.00037

Appendix A - Extreme Cases – KDE

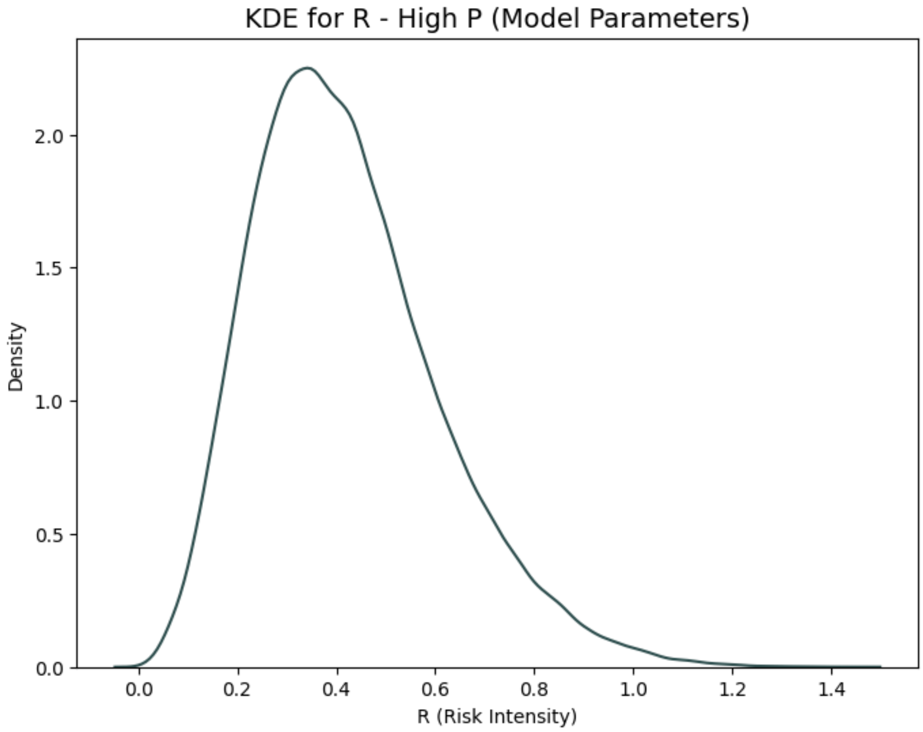

Figure 5 - Kernel Density Estimation for High Parameter counts (5000+)

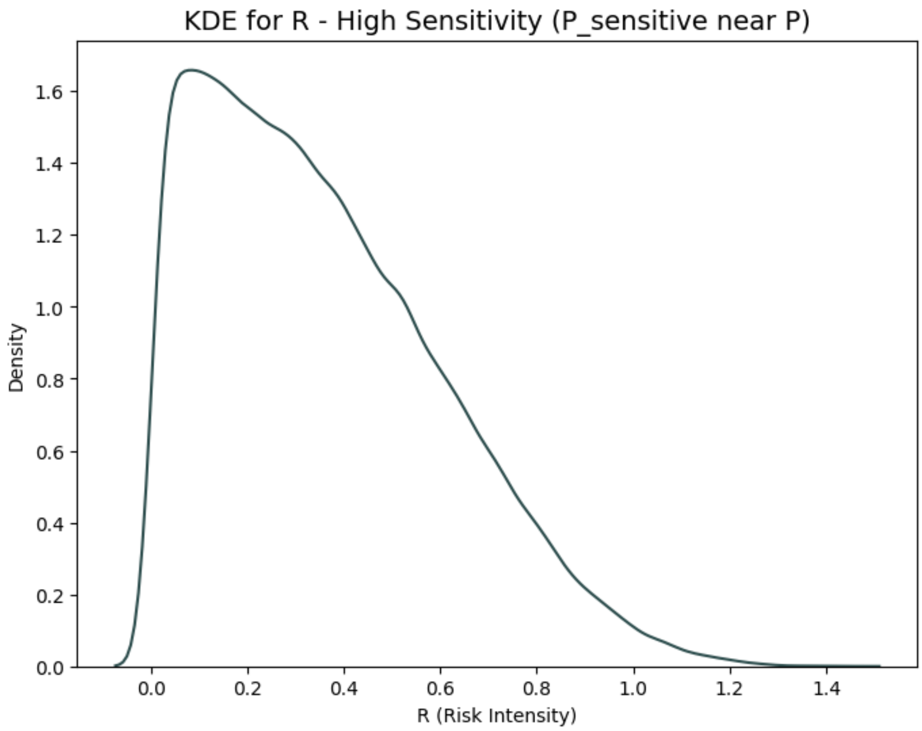

Figure 6 - Kernel Density Estimation for highly sensitive parameters (80%+)

How to Successfully Implement Telework?

A Conceptual Framework Proposition

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Abstract: Teleworking in the Covid-19 pandemic has become a widespread practice adopted by companies worldwide, providing a unique opportunity to experiment with it on a large scale. This study aimed to elucidate the organisational factors facilitating the successful implementation of telework. The primary objective was to identify the organisational and individual prerequisites, as well as the mediating mechanisms, necessary for the successful establishment of telework and measured by the telework outcomes. To do so, we developed a conceptual model to analyse the factors influencing the success of this transition and we tested it on a sample of 171 employees from the banking, IT, and telecommunication sectors. The results indicate that perceived autonomy, management of work-family conflict, and organisational support are key factors in ensuring employee satisfaction, performance, and engagement within this new work framework. However, telework does not have a direct impact on these outcomes without mediating mechanisms.

Keywords: Telework, Organisational Predisposition, Individual Predisposition, Mediating Mechanisms, Outcomes

Introduction

Telework is not a new organisational concept (Meyer *et al.*, 2022) and it remained marginal for a long time. The development of teleworking started in the 1970s around the oil crises of 1973 and 1979 that gave rise to concerns over petrol consumption, long work commutes, and traffic congestion in major metropolitan areas (Pérez *et al.*, 2004). It only began gaining traction in the business world in the early 2000s with the advent of Information and Communication Technologies (ICT). According to a report by the International Labour Organization published in 2017 (Eurofound, 2017), telework is defined as the use of

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information and communication technologies, smartphones, tablets and laptops to perform tasks outside the employer's premises. Initially, telework was limited to jobs where regular in-office presence was optional (Pennequin, 2020). In fact, telework requires specific infrastructure, and, specifically, a different approach to how workplace relationships are managed (Batut, 2020). This explains why many companies struggled to quickly establish a telework model able to maintain the same level of organisational performance as conventional in-office working (Jézéquel, 2021). Moreover, the implementation of telework is considered as an organisational change that requires a solid change-management strategy and some organisational prerequisites to ensure its success (Campbell & Gavett, 2021).

As stated by Baruch & Nicholson (1997), there are four factors that influence telework: individual factors, job factors, organisational factors, and family/home factors. They highlighted that these four factors need to be fulfilled for telework to become feasible and effective. In this regard, it is important to mention that the success of telework implementation is not only measured by its adoption by employees and the organisation, but also by the organisational outcomes that follow. A successful telework adoption by an organisation should be linked to maintaining or enhancing employee satisfaction, engagement and organisational performance. The study of the antecedents that influence the outcomes of telework represent an important research gap (Nguyen, 2021). This leads us to the following research question: What are the organisational factors that favour the successful implementation of telework?

The main objective of this study is to identify the organisational and individual prerequisites, as well as the mediators, for the successful implementation of teleworking as a work organisation mode. In pursuit of this objective, we aim to develop a conceptual model that highlights the various cause-and-effect relationships between the different factors that ensure the successful deployment of telework.

Organisational Prerequisites for Telework Implementing

Organisational predisposition

The concept of organisational predisposition has emerged with the rapid evolution of ICT use in companies (Mutula & Van Brakel, 2006). The most significant definitions consider organisational predisposition as the degree to which an organisation has optimised key attributes necessary for the successful implementation of ICT-based strategies and operational initiatives (Hartman *et al.*, 2000). It is an inherently dynamic concept, primarily based on organisational agility, as it enables effective resource management and enhances competitiveness (Hanafizadeh *et al.*, 2009).

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Organisational predisposition also refers to the commitment of organisational members to change and the organisation's effectiveness in implementing that change (Weiner, 2009). In this context, human resources are considered the most critical organisational predisposition factor and the success factor of any change initiative (Rubel *et al.*, 2020).

Therefore, based on the work of Illegems *et al.* (2001) and Perez et al. (2004), Tokarchuk et al. (2021), who studied the determinants of the decision to implement teleworking, determined that the organisational predisposition of companies is essential in deciding whether to implement telework. The identified dimensions of predisposition can be grouped into three main components: the organisational resources, the individual (human) resources, and the technology resources (Hartman *et al.*, 2000).

Organisational resources

An organisational resource is a rare asset, typically perceived by companies within the same sector as advantageous in terms of performance (Weppe *et al.*, 2013). The resource is considered as an organisational capacity and is defined as an ability to carry out the deployment, combination and coordination of resources and skills across different value streams to implement previously defined strategic objectives (Barney, 1991; Grant, 1991).

The success of a company largely depends on the resources it possesses and controls (Wernerfelt, 1984). Accordingly, these rare organisational resources mainly include leadership style and governance structure. However, the greatest obstacle to the success of telework implementation could be management's mindset, particularly the traditional belief that productivity must be measured by physically seeing workers spending hours at their desks (Donnelly & Thomson, 2015). Therefore, the success of telework implementation depends on a clear understanding of the roles and expectations of both workers and managers (Illegems *et al.*, 2001). Direct supervision becomes less effective because authority can no longer be exercised only through presence. Or managers are familiar with in-person supervision but, while in remote settings, they are unable to physically observe the work being done by their employees. Effective management of the telework environment requires organisational behaviours that emphasise relationship-building and clear, frequent communication to establish or maintain trust in the workplace (Dahlstrom, 2013).

Human resources

Regarding the individual factors, previous research addressed the question related to who could become a teleworker, concentrating on the identification of traits of teleworkers and factors that predict who will telework (Bailey & Kurland, 2002).

The human resources include the skills that determine how an organisation meets market demands or achieves its objectives and addresses the question of what capabilities are required

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to compete and succeed effectively (Hartman *et al.*, 2000). It includes also the ability of managers to implement work organisation by objectives, to resign from supervision and direct control to increase productivity and innovation, and to motivate and coordinate remote workers (Perez *et al.*, 2005).

Technological resources

Research on the effects of ICT on telework has shown a positive relationship between technology and the possibility of teleworking, as technology enables continuous connectivity, allows employees to stay in touch with their professional environment, and ensures availability around the clock. Technology plays a crucial role in moderating potential problems of telework, such as social isolation and communication challenges. Technological tools (e.g., online collaboration tools, web conferencing platforms, workflow management systems, and video conferencing) can be used to enhance collaboration (Bayrak, 2012; Ye, 2012), making it possible to exchange messages between spatially or organisationally separated entities (Barni, 2003).

ICTs facilitate particularly the management of unexpected events and emergencies (Dumas & Ruille, 2014). A lack of maturity in their use can give rise to various risks (informational, privacy intrusion, etc.) (Dumas & Ruille, 2014). Thus, we can hypothesise that organisational predisposition is positively associated with the decision to implement telework (H1).

Individual predisposition

According to Vakola *et al.* (2012), it is important to study individual predisposition because, in the literature, it is not distinguished from organisational predisposition. This lack of conceptual clarity and definition creates confusion in both research and practice. In fact, ignoring the individual perspective predisposition contributes to a partial approach in theoretical and empirical work (Vakola *et al.*, 2012). Individual predisposition for organisational change is indeed a critical success factor; and organisations only change through their members.

In terms of productivity and satisfaction, Feldman & Morris (1997) show that demographic and personality differences play a significant role in determining which types of employees are most suited for telework. In other words, some workers profiles' are better suited for telework arrangements and jobs that typically involve more flexibility, autonomy, and social isolation. This suggests that married people and those with parental responsibilities are likely to find autonomous jobs more attractive, because they provide greater flexibility in balancing work and family demands (Feldman & Morris, 1997).

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Conversely, the social isolation often associated with telework can be problematic for workers without caregiving responsibilities, as they may struggle to replace the social interactions with colleagues (Fachruddin & Mangundjaya, 2012) through interactions with spouses and children. The most studied individual predisposition variables in the context of telework include age (Bosworth & Holden, 1983), gender (Witter *et al.*, 1984), marital status, and the number of children (Hochschild, 1997).

In addition, certain personality dimensions influence the type of worker attracted to telework. Research on personality traits identifies five key dimensions that are critical in understanding work behaviours and attitudes (Barrick & Mount, 1991; Digman, 1980): 1) extraversion; 2) agreeableness; 3) conscientiousness; 4) openness to experience; and 5) emotional stability. Workers who prefer to minimise social interactions are more likely to pursue telework opportunities. Consistent with the literature on personality differences (Digman, 1980), it is expected that individuals scoring high in extraversion will be less inclined toward telework compared to their peers. Furthermore, workers with higher levels of anxiety may seek roles that offer greater opportunities for social interaction, as the physical presence of others can provide a sense of comfort and reassurance (Hackman & Oldham, 1976).

Thus, individual predisposition plays an important role in managerial decisions to implement telework. In other words, situational and personality factors influence the types of telework arrangements and the nature of jobs suitable for telework. Therefore, we can hypothesise that individual predisposition is positively associated with the decision to implement telework (H2).

The decision to implement telework

Many companies have adopted telework as long as their organisational and individual predispositions are adequately leveraged (Pérez *et al.*, 2004). The decision to implement telework can take four main forms:

1. **Full-time vs part-time telework:** This distinction refers to employees who telework full-time and those who only telework part of their work week (Barney, 1991).
2. **Fixed vs flexible schedules:** It is important to differentiate between teleworkers who work fixed hours and those with flexible schedules (Weiss & Cropanzano, 1996).
3. **Working from home vs satellite offices:** Some teleworkers operate alone from home, while others work in satellite stations with fellow teleworkers (Greenhaus & Beutell, 1985).
4. **Organisation-initiated vs employee-initiated telework:** This category distinguishes between telework initiated by the organisation and that initiated by employees to balance work and family demands (Roberts, 1994).

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According to Bailey & Kurland (2002), the decision to implement telework first involves determining the frequency of telework per week and the location, whether at home, in a neighbourhood work centre, at client sites, or in a satellite office. The decision must also specify the level of flexibility in work hours and the degree of formality of the telework program (i.e., formal telework policies versus informal agreements between employees and supervisors), as well as whether telework is initiated by the employee or the organisation. Therefore, a telework implementation decision that takes into account both organisational and individual predisposition, along with the telework modalities offered to employees, can have a direct and positive effect on the outcomes or expected results of such a decision. We can thus hypothesise that the decision to implement telework can have a direct positive effect on outcomes (H3).

Expected outcomes of telework

The primary objective of telework is to achieve the same performance levels compared to on-site work. According to Pradhan *et al.* (2017), the expected outcomes of telework implementation are primarily related to employee performance, satisfaction, and organisational commitment.

- **Employee Satisfaction:** Telework can increase employee satisfaction by providing greater control over work schedules, reducing commuting time and costs, and enabling a better work-life balance. Teleworkers benefit from a relatively uninterrupted work environment and flexible hours, which help them manage both professional and personal responsibilities more effectively.
- **Performance:** Work performance, typically evaluated through performance management, is a key element of effective human resource management. Performance evaluations aim to enhance employee development and are highly valued within human resource portfolios.
- **Organisational Commitment:** Employee commitment is defined by the emotional attachment to the organisation, identification with it, and participation in its activities. Some researchers further conceptualise commitment as an investment in the organisation, where employees feel they would suffer significant loss if they were to leave.

Mediating mechanisms

Mediating mechanisms are psychological processes that influence telework outcomes. According to Gajendran & Harrison (2007), these mechanisms can be categorised into three main variables: **work-family conflict, organisational support,** and **perceived autonomy**.

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Work-family conflict

Work-family conflict is described as 'a form of role conflict experienced when the demands in one role (either work or family) are incompatible with the demands of the other role, making it more challenging to fulfill responsibilities in either domain' (Greenhaus & Beutell, 1985, p. 735). Some researchers argue that telework is a beneficial practice that leads to greater harmony between work and family roles. However, other authors believe that telework exacerbates conflicts by increasing the permeability of professional and family boundaries (Igbaria & Guimaraes, 1999). The permeability of boundaries in telework refers to the extent to which family life or work infiltrates the other domain because they occur in the same physical space, and often simultaneously (Ashforth *et al.*, 2000).

Organisational support

Organisational support refers to employees' perception of their visibility and involvement within the organisational community. Individuals inherently desire to be part of a larger social context (Nardi & Whittaker, 2002). Social connections provide employees with a sense of belonging to a community they can rely on for support and information.

In the context of telework, reduced face-to-face interactions, infrequent and less rich communication between teleworkers and their colleagues or supervisors, and a diminished social presence weaken interpersonal bonds (Nardi & Whittaker, 2002). This lack of direct interaction may result in feelings of isolation and reduced organisational support, potentially affecting employees' sense of belonging and their access to information and resources.

Perceived autonomy

Perceived autonomy is a main characteristic of any work arrangement (Raghuram & Wiesenfeld, 2004). The increased flexibility in scheduling and task execution reinforces employees' perception of autonomy (Hackman & Oldham, 1976). Telework, which allows employees to work from home, provides them with control over various aspects, such as breaks, workspace layout, lighting, and even background music, contributing to an enhanced sense of autonomy (Elsbach, 2003).

Telework is seen as a practice that improves perceived autonomy by offering employees choices regarding where, when, and how they work, since they are physically and psychologically distant from direct supervision. Some researchers also argue that telework promotes greater integration between work and family roles (Raghuram & Wiesenfeld, 2004).

Thus, perceived autonomy, work-family conflict, and the quality of relationships act as **intermediary mechanisms** or partial vectors through which telework affects outcomes. In other words, telework indirectly influences job satisfaction, performance, and other outcomes

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by increasing perceptions of control over the location, timing, and methods of work completion.

We can, therefore, hypothesise that these mediating mechanisms function as **mediating variables** between the decision to implement telework and its expected outcomes (H5). This suggests that successful telework outcomes depend not only on the direct impact of the telework decision (H4) but also on how factors like perceived autonomy, organisational support, and work-family balance are managed within the telework framework.

The Conceptual Model

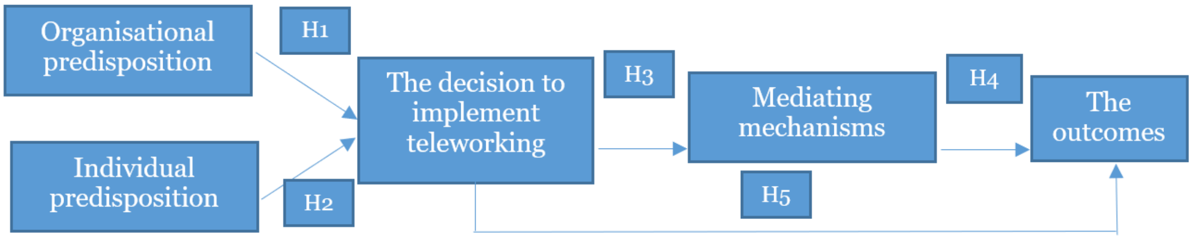

Figure 1. The conceptual model with hypotheses

H1: Organisational predisposition has a direct and positive effect on the decision to implement teleworking.

H2: Individual predisposition has a direct and positive effect on the decision to implement teleworking.

H3: The decision to implement teleworking has a positive direct effect on mediating mechanisms.

H4: The mediating mechanisms are the mediators of the effect of the decision to implement teleworking on the outcomes.

H5: The decision to implement teleworking has a direct positive effect on outcomes.

Methodology

The aim of this research is to understand the organisational factors that ensure the expected outcomes of implementing telework, which can determine its success. To test the research hypotheses of the proposed model and to achieve this goal, we have chosen a structural equation modelling methodology. This method is widely used in management research, particularly in the study of individual employee outcomes (satisfaction, performance, engagement, etc.) (Lacroux, 2011). According to this author, testing research hypotheses that replicate or approximate the complexity of real-life situations requires the construction of models that include a significant number of variables and consist of sometimes complex networks of interactions.

Regarding the model estimation, we opted for the Partial Least Squares (PLS) method, which is one of the most applied modelling methods in the social sciences. It is considered as a 'method for modeling phenomena, capable of defining complex interacting systems' (Jakobowicz & Derquenea, 2007). As emphasised by Chin (1998), the PLS approach can be used to empirically confirm theories, as well as to test the presence or absence of relationships and propose hypotheses for future testing. It is particularly useful when the phenomenon under study is relatively new and the theoretical model or measures are not well established (Chin, 1998).

The choice of the study setting was determined by the specificity of our conceptual model. Our interest focuses on employees who have practiced telework. Companies from the service sector, and, in particular, telematics leisure businesses, energy companies, insurance businesses, banking services, and technological companies are the industries that present higher rates of telework implementation (Belzunegui-Eraso & Erro-Garcés, 2020). Therefore, individuals working in banks, multinational corporations, and the telecommunications sector in Tunisia were included in our sampling target. To collect information from the sample, we administered a questionnaire.

The structure of our questionnaire follows a common format, consisting of three parts: the introduction; the body; and the demographic section. The introduction outlines the research objectives and the topics covered, allowing respondents to become familiar with the subject.

The body is composed of five main sections, each dedicated to the variables of our conceptual model: those related to organisational predisposition, individual predisposition, the decision to implement telework, mediating mechanisms, and outcomes. Each section contains a limited number of statements, each presenting an item in the form of a simple closed-ended question. All items are rated on a Likert scale ranging from 1 to 5. The demographic section, which is the final part of the questionnaire, aims to collect data regarding the respondents' profiles.

We conducted a face-to-face pre-test with five experts who have experience in teleworking prior to administering the questionnaire to confirm its quality and comprehensibility for the respondents. The experts found it clear and comprehensible, which did not result in any modifications to the questionnaire.

Our sample size consists of 171 observations. For the use of the PLS method, the rule for determining the size of a sample consists of multiplying by 10 the number of measurement variables composing the latent variable made up of the largest number of formative indicators, or that dependent on the largest number of independent variables (the largest structural equation) (Chin, 1998). In addition, Chin *et al.* (2003) recommend that, to analyse the effects of interactions, the size of a sample must be at least between 100 and 150 observations.

In this regard, our sample largely meets this condition. It comprises 56.9% men and 43.1% women, with 62.5% aged between 20 and 34 years, 34.7% between 35 and 50 years, and 2.8%

over 50 years. Regarding educational background, the results indicate that 100% of the respondents hold a higher education degree. Additionally, our sample consists of 77.8% middle managers and 20.8% senior managers.

It is remarkable that 75% of the respondents have less than five years of tenure in their current companies, while the remaining 25% have more than five years of experience. Analysing the results, we found that 63.4% of the respondents are single, while 36.6% are married. Additionally, 69% of the respondents do not have children, whereas 15.5% have two children. Furthermore, the percentages of respondents with 1, 3, and 4 children are 9.9%, 2.8%, and 2.8%, respectively. Regarding the living status, 63.9% of the respondents live with their families, while 16.7% are roommates, and 9.7% live alone.

Results and Discussion

The results show that the measurements exceed the reliability threshold. The composite reliability of the various scales surpassed the recommended threshold in the literature (0.707), ranging from 0.735 to 0.972, suggesting that the variables are reliable and acceptable. The composite reliability of the different scales varies between 0.735 and 0.972, which is above the advised value of 0.707 in the literature. This indicates that the variables are considered reliable and acceptable. The results also show that the Average Variance Extracted (AVE) values for the latent variables are greater than the correlations among these same variables, indicating that the latent variables in the model share more variance with their own indicators than with each other. Furthermore, the results demonstrate that there are no issues of multicollinearity, with all Variance Inflation Factor (VIF) values being greater than 1 and less than 10.

Similarly, the R^2 values of the structural model must be sufficiently high to ensure a minimum explanatory power (Urbach & Ahlemann, 2010). According to Chin (1998), the R^2 value should be greater than or equal to 0.19 for accurate variance estimation, while Falk & Miller (1992) sets the minimum acceptable value at 0.10. Thus, the higher the R^2 value, the more valid the model is in explaining the phenomenon under study. In this regard, the R^2 value after bootstrap simulation, with an overall R^2 of 0.337, provides a solid foundation for a relevant and significant interpretation of the results (Table 1).

Table 1. The values R^2 of the explained variance of the dependent variables

Variable	R^2 value
The decision to adopt teleworking	0.337
Mediating mechanisms	0.361
Individual outcomes	0.662

Finally, we examined the structural coefficients to test the model's hypotheses (Figure 2). This indicates that the structural coefficients are significant and exhibit positive signs for all

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structural relationships. Therefore, all tested hypotheses at the structural level are positively confirmed, except for the last hypothesis, which has a p-value of 0.721 (Table 2).

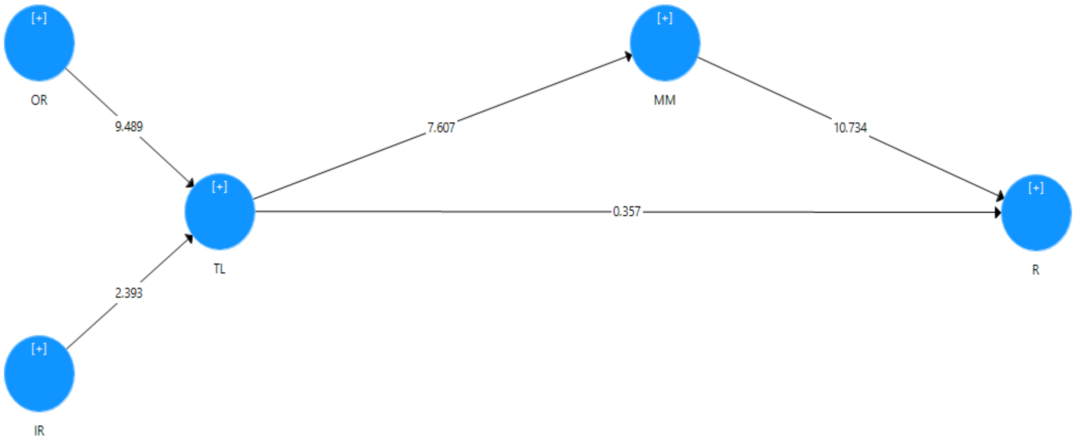

Figure 2. Second-order model

Table 2. Hypothesis test (second-order model)

	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)	P values
IR (individual predisposition) -> **TL** (Telework decision)	0.185	0.193	0.077	2.393	0.017
MM (mediating mechanism)-> **R** (results)	0.810	0.820	0.075	10.734	0.000
OR (organisational predisposition)-> **TL** (Telework decision)	0.540	0.566	0.057	9.489	0.000
TL (Telework decision) -> **MM** (mediating mechanism)	0.596	0.598	0.078	7.607	0.000
TL (Telework decision)-> **R** (results)	0.031	0.028	0.088	0.357	0.721

The Original Sample estimate is the parameter from estimating the model on the original dataset from a normal PLS algorithm estimation. The Sample Mean estimate is the average of the estimates from all the subsamples of the dataset drawn during the bootstrapping procedure.

Positive direct effect of Organisational Predisposition on the Telework Implementation Decision (H1)

The empirical findings confirm that organisational predisposition is a significant precursor to management's decision to implement telework. As previous explained, the empirical study was conducted within banks, multinational companies, and IT service and engineering firms, which not only possess advanced technological resources but also skilled human resources and agile management styles, enabling them to continually seek the development of their organisational resources. In fact, Nguyen (2021) stated that prior experience is an important factor to include when developing and applying telework schemes.

Many companies have adopted telework as their level of organisational predisposition has been adequately leveraged. In many instances, when scholars and companies refer to teleworking, they seek to develop a new way of organising work to support work-life balance or to further improve the integration of several collectives of employees, or just to increase flexibility by facilitating the move from home to work (Belzunegui-Eraso & Erro-Garcés, 2020).

The accumulated capabilities and resources, combined with a certain degree of agility, allow organisations to be more inclined to adapt their operations in response to unforeseen events and to exploit strategic shifts in redefinition (Teece *et al.*, 2016). Thus, telework, as an organisational resource, provided appropriate organisational solutions to the challenges posed by the socio-economic environment during the pandemic. Several experiences in the implementation of teleworking show the use of telework as a new way of organising work that improves conciliation and flexibility (Belzunegui-Eraso & Erro-Garcés, 2020).

Positive direct effect of Individual Predisposition on the Telework Implementation Decision (H2)

The results of our empirical study affirm that individual predisposition is a significant precursor to the decision to implement telework. Considering that telework could disrupt working and management styles, it is conceivable that it might also affect social relationships and, consequently, employees' wellbeing (Domae *et al.*, 2024).

Regarding organisational factors, several scholars identified the operations that can be conducted remotely and sectors where telework is a successful alternative to organise work (Overbey, 2013). Thus, 'white-collar' workers and knowledge-oriented sectors are more likely to use teleworking practices (Mayo *et al.*, 2016). In other words, several worker profiles are better suited to telework arrangements and jobs that typically require more flexibility, autonomy, and social isolation. In IT service and engineering firms, as well as large enterprises, employees are predominantly 'knowledge workers' who prefer to focus on their objectives and are accustomed to use ICT to interact with other members of the organisation, making them more willing to work distantly. In this regard, workers who prefer to avoid social interactions are more likely to seek telework positions, because these jobs allow them to work in relative isolation. Consequently, it is found that highly extroverted workers are less attracted to telework compared to their less extroverted colleagues. Additionally, highly anxious workers are more inclined to pursue jobs that offer more opportunities for social interaction, where they can simply be physically present with others.

Regarding commuting characteristics, longer movement times to work generate stress for workers. Top management has become increasingly aware of this issue and is progressively implementing telework, as it not only helps retain talent but also eliminates commutes that cause stress. As for sociodemographic characteristics, given the prevalence of traditional roles, female employees particularly appreciate the flexibility of balancing their professional and family responsibilities. Since one of the main features of telework is its ability to facilitate better adaptation to both organisational needs and personal or family requirements, these individuals may prefer this form of work. This aligns with what was mentioned by Beatriz *et al.* (2024) concerning the importance of individual predisposition for the decision to implement telework in organisations.

Direct and positive effect of the Telework Implementation Decision on Mediating Mechanisms (H3)

The results of our empirical research affirm this relationship. The mediating mechanism variable in our study comprises perceived autonomy, organisational support, and work-family conflict. Autonomy in the workplace refers to the capacity for initiative, discernment, self-organisation, and even liberty in work. It necessitates intelligence and cognitive capability to react quickly to various unpredictable situations. However, telework may not necessarily enhance autonomy in cases where there is electronic performance monitoring or strictly controlled deadlines. Consequently, increased surveillance and formalisation of telework supervision could reduce perceptions of autonomy (Kinicki *et al.*, 2002).

Moreover, one of the significant purported benefits of telework is its potential to reduce conflicts between work and family roles. Yet, the modalities of telework suggest that, in some cases, teleworkers may experience a greater number of work-family conflicts due to the proximity of family members, particularly dependents, and the blurring of distinctions between work time and family time (Kinicki *et al.*, 2002).

A widely expressed worry by employees regarding telework is the feeling of isolation from the workplace and social contacts. Teleworkers may feel less included in the work environment (Green *et al.*, 2017). Inclusion is defined as the extent to which an individual is physically and psychologically integrated into the organisation (Rousseau, 1989). Given that telework physically removes the teleworker from the workplace, the lack of inclusion can impact employees' investment of time and energy and willingness to make long-term commitments. Isolated employees may not benefit from the informational advantages of social contact and may be less likely to assume exceptional levels of responsibility (Abord de Chatillon *et al.*, 2020). A decreased exposure to colleagues and organisational culture may lead teleworkers to lose sight of their position within workgroups and within the organisation (Brunelle, 2010).

Direct and positive effect of Mediating Mechanisms on Outcomes (H4)

This relationship was affirmed by the results of our empirical research. In fact, autonomy in the workplace is presented as an organisational efficiency and competitiveness lever. It commonly refers to the ability to take initiative, self-organisation, and even liberty in work (Everaere, 1999). Work-family conflict is a form of role conflict, experienced when pressures that arise in one role are incompatible with pressures occurring in the other role. In this context, the requirements associated with work and family are incompatible in certain cases. Recognising this role confusion is a crucial success factor of telework in achieving organisational objectives.

Organisational support refers to the extent to which individuals perceive themselves as central, visible, and involved in the organisational community. Individuals intrinsically desire to be part of a broader social context. Connections with the social context provide employees with a sense of belonging to a community they can rely on for support and information. This support is beneficial for addressing immediate work needs and for establishing a long-term relationship with the organisation. Consequently, organisational support can moderate the negative effects of physical distance from the actual workplace, thereby increasing the likelihood of successful organisational telework outcomes. In this regard, considering these mediating mechanisms in the decision to implement telework would have a direct and positive impact on the expected organisational outcomes resulting from such a decision.

Direct and positive effect of Telework Implementation Decision on Outcomes (H5)

This relationship has not been empirically verified. Therefore, we can assert that employees will only be satisfied, perform well, and remain engaged if they necessarily go through the mediating mechanisms. Perceived autonomy, work-family conflict, and organisational support serve as intermediate mechanisms or partial vectors for the effects of telework on outcomes.

To telework effectively, teleworkers need the heavy use of telecommunications. This explains the findings that persons using the Internet frequently are more likely to telework (Loo & Wang, 2018; Singh *et al.*, 2013) or telework at a higher frequency (Sener & Reeder, 2012). Teleworker teams are heavily reliant on the stability and reliability of IT, which promote collaboration, trust, and transparency. However, communication is more challenging for telework teams than for those working on site. Consequently, workers and managers must make additional efforts to maintain clear and effective communication and a continuous flow of information. To achieve the desired outcomes of telework, it is imperative to establish and clearly communicate the expected results to employees. Clear articulation of these expectations significantly mitigates the risks of ambiguity and misunderstanding, fostering a sense of responsibility and autonomy among teleworkers in the execution of their tasks.

Experienced teleworkers often possess well-defined work identities, established professional networks, and a comprehensive understanding of task demands, all of which contribute to enhancing telework outcomes (Parker, 2014). Furthermore, their advanced time management skills—such as goal setting, task scheduling, and prioritisation—enable them to achieve expected telework outcomes more effectively (Shipp & Cole, 2015). For novice teleworkers, however, the successful implementation of telework requires the integration of mediating mechanisms to facilitate the attainment of target outcomes. These mechanisms may include structured guidance on time management, task prioritisation, and strategies to maintain work-life balance. Social factors must also be carefully considered when designing telework policies (Andreev *et al.*, 2010). Telework has the potential to disrupt traditional management practices and may impact social relationships, which could, in turn, affect employee wellbeing. A significant advantage of working in a conventional office environment is the opportunity for face-to-face interactions and the ability to receive immediate recognition and feedback from colleagues and supervisors. These interactions often contribute to employee satisfaction and enjoyment at work, which may serve as a deterrent to choosing telework (Loo & Wang, 2018).

Conclusions/Recommendations

The aim of our research is to study the impact of organisational factors on the successful implementation of telework and to develop a conceptual framework explaining all variables that can affect expected outcomes. Our theoretical and empirical investigation has not only validated our research model but also affirmed that both organisational predisposition and individual predisposition serve as crucial prerequisites for the decision to implement telework within organisations. In addition, teleworkers will only be satisfied, perform well, or remain engaged in the organisation when mediating or psychological mechanisms are effectively supported by company leaders. It is also worth noting that the best management approach to help teleworkers to reconcile their professional obligations with their personal lives is a management focused on results rather than on tracking the number of hours worked. If employers assign manageable work tasks and realistic objectives, workers can better organise their time and tasks, thereby achieving a balance between their work and personal lives. In fact, it is essential to clearly communicate the expected outcomes to employees, which will significantly reduce the risks of ambiguity and misunderstandings.

Nevertheless, organisations must consider hybrid work arrangements that combine on-site and remote employees within the same work units to mitigate the effects of social isolation on employee engagement and strengthen organisational culture. Thus, hybrid work, alternating between in-person and remote settings, emerges as the future norm of telework. The development of hybrid work must be accompanied by a new way of thinking about

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organisation, meeting formats, and the distribution of tasks, sometimes synchronously and sometimes asynchronously, as well as the modes of participation. At the intersection of these two ways of working, hybrid work demands making informed choices that maximise the benefits of both.

Despite its theoretical and practical contributions, this study also acknowledges certain limitations. Firstly, our findings might not be universally applicable across different cultures and sectors because our analysis focused on industries most predisposed to implementing telework (banking, IT, and telecommunications). Future research must explore the cultural specificity of our model and its applicability in diverse organisational sectors. Secondly, this research did not examine the long-term effects of isolation associated with telework on its implementation outcomes within organisations. Future studies could consider adopting a longitudinal approach to investigate the impact of telework on organisational performance.

References

Abord de Chatillon, E., Lacroux, A., & Richard, D. (2020). Guide de mesure du Bien-être au travail par le SLAC. *Document scientifique de la Chaire Management et Santé au Travail*, Université Grenoble, Alpes. https://www.sphinxonline.com/surveyserver/s/abord/SLAC24/questionnaire.htm

Ama Koffi. C.-E. (2024). Les salariés en télétravail bénéficient de conditions de vie améliorées et d'une meilleure santé, d'après une étude de la Dares. *Challenges*. [online]. https://www.challenges.fr/entreprise/les-salaries-en-teletravail-ont-de-meilleures-conditions-de-vie-et-une-meilleure-sante-selon-une-etude-de-la-dares_910327

Andreev, P., Salomon, I., & Pliskin, N. (2010). Review: state of teleactivities. *Transportation Research Part C: Emerging Technologies*, *18*(1), 3–20. https://doi.org/10.1016/j.trc.2009.04.017

Ashforth, B. E., Kreiner, G. E., & Fugate, M. (2000). All in a day's work: Boundaries and micro role transitions. *Academy of Management Review*, *25*, 472–491. https://doi.org/10.5465/AMR.2000.3363315

Bailey, D., & Kurland, N. (2002). A review of telework research: findings, new directions, and lessons for the study of modern work. *Journal of Organizational Dynamics*, *28*, 383–400. https://doi.org/10.1002/job.144

Barney, J. B. (1991). Firm Resources and Sustained Competitive Advantage. *Journal of Management*, *17*(1), 99–120. https://doi.org/10.1177/014920639101700108

Barni, M. (2003). *Manager une équipe à distance*. Editions d'Organisation. ISBN 978-2-7081-2873-6.

Barrick, M. R., & Mount, M. K. (1991). The Big Five personality dimensions and job performance: A meta-analysis. *Personnel Psychology*, *44*, 1–26. https://doi.org/10.1111/j.1744-6570.1991.tb00688.x

Baruch, Y., & Nicholson, N. (1997). Home, sweet work: requirements for effective home working. *Journal of General Management*, *23*(2), 15–30. https://doi.org/10.1177/030630709702300202

Batut, C. (2020). L'impact du Covid-19 sur le monde du travail: télémigration, rélocalisation, environnement. *Le Grand Continent*. [online]. https://legrandcontinent.eu/fr/2020/05/01/limpact-du-covid-19-sur-le-monde-du-travail-telemigration-relocalisation-environnement/

Bayrak, T. (2012). IT support services for telecommuting workforce. *Telematics and Informatics*, *29*(3), 286–293. https://doi.org/10.1016/j.tele.2011.10.002

Beatriz, M., Beque, M., Coutrot, T., Duval, M., Erb, L., Inan, C., Mauroux, A., & Rosankis, É. (2021, Mai). Quelles conséquences de la crise sanitaire sur les conditions de travail et les risques psycho-sociaux? Dares Analyses, no. 28. Available at https://dares.travail-emploi.gouv.fr/sites/default/files/9bdbcec60416e2944c584578463f5e0a/Dares%20Analyses_Conditions-de-travail_RPS_Consequences-crise-sanitaire.pdf

Belzunegui-Eraso, A., & Erro-Garcés, A. (2020). Teleworking in the Context of the Covid-19 Crisis. *Sustainability*, *12*(9), 3662. https://doi.org/10.3390/su12093662

Bosworth, T. W., & Holden, K. C. (1983). The Role Part-Time Job Options Play in the Retirement Timing of Older Wisconsin State Employees. *Aging and Work*, *6*(1), 31–36.

Brunelle, E. (2010). Télétravail et leadership: déterminants des pratiques efficaces de direction. *Management International*, *14*, 23–35. https://doi.org/10.7202/044657ar

Campbell, S., & Gavett, G. (2021). What Covid-19 Has Done to Our Well-Being in 12 Charts. *Harvard Business Review*. [online]. https://hbr.org/2021/02/what-covid-19-has-done-to-our-well-being-in-12-charts

Chin, W. W. (1998). The partial least squares approach to structural equation modeling. In G. A. Marcoulides (Ed.), *Modern methods for business research* (pp. 295–336). Mahwah, NJ: Lawrence Erlbaum Associates. https://www.researchgate.net/publication/311766005_The_Partial_Least_Squares_Approach_to_Structural_Equation_Modeling

Chin, W. W., Marcolin, B. L., & Newsted, P. R. (2003) A Partial Least Squares Latent Variable Modeling Approach for Measuring Interaction Effects: Results from a Monte Carlo Simulation Study and an Electronic-Mail Emotion/Adoption Study. *Information Systems Research*, *14*, 189–217. http://dx.doi.org/10.1287/isre.14.2.189.16018

Croutsche, J-J. (2002). Etude des relations de causalité. Utilisation des modèles d'équations structurelles (approche méthodologique). *La Revue des Sciences de Gestion*, *198*, 81–97. https://doi.org/10.1051/larsg:2002037

Dahlstrom, T. R. (2013). Telework and leadership style. *Public Personnel Management*, *42*(3), 438–451. https://doi.org/10.1177/0091026013495731

Digman., L. A. (1980). Determining management development needs. *Human Resource Management*, *19*(4). https://doi.org/10.1002/hrm.3930190403

Domae, H., Nakayama, M., Takemura, K., Watanabe, Y., Gobel, M. S., & Uchida, Y. (2023). Antecedents and consequences of telework during the COVID-19 pandemic: A natural experiment in Japan. Preprint submitted to *Humanities and Social Sciences Communications*. Retrieved October 13, 2023 from https://doi.org/10.31234/osf.io/rxn4u

Donnelly, N., & Thomson, P. (2015). Disrupted work: home-based teleworking (HbTW) in the aftermath of a natural disaster. *New Technology, Work and Employment*, *30*(1), 47–61. https://doi.org/10.1111/ntwe.12040

Dumas, M., & Ruille, C. (2014). Le télétravail : les risques d'un outil de gestion des frontières entre vie personnelle et vie professionnelle. *Management & Avenir*, 2014/8, 74, 71–95. https://doi.org/10.3917/mav.074.0071

Elsbach, K. D. (2003). Relating physical environment to self-categorizations: Identity threat and affirmation in a non-territorial office space. *Administrative Science Quarterly*, *48*, 622–654. https://doi.org/10.2307/3556639

Eurofound and the International Labour Office. (2017). *Working anytime, anywhere: The effects on the world of work*. Publications Office of the European Union, Luxembourg, and the International Labour Office, Geneva. https://www.astrid-online.it/static/upload/ef16/ef1658en.pdf

Everaere, C. (1999). Autonomie et collectifs de travail. Collection Points de Repère. https://www.researchgate.net/publication/283346343_Autonomie_et_collectifs_de_travail

Fachruddin. D. F., & Mangundjaya, W. (2012). The impact of Workplace Well-Being and Psychological Capital on Individual Readiness for Change. 4th Asian Psychological Association, Jakarta, Indonesia. https://www.researchgate.net/publication/273461597

Falk, R. F., & Miller, N. B. (1992). *A Primer for Soft Modeling*. University of Akron Press, Akron.

Feldman D. C., & Morris. J. A. (1997). Managing Emotions in the Workplace. *Journal of Managerial Issues*, *9*(3), 257–274. https://doi.org/10.4324/9781315290812

Gajendran, R. S., & Harrison, D. A. (2007). The Good, the Bad, and the Unknown About Telework: Meta-Analysis of Psychological Mediators and Individual Consequences. *Journal of Applied Psychology*, *92*(6), 1524–1541. https://doi.org/10.1037/0021-9010.92.6.1524

Grant, R. M. (1991). The resource-based theory of competitive advantage: implications for strategy formulation. *California Management Review*, *33*(3), 114–135. https://doi.org/10.2307/41166664

Green, N., Tappin, D., & Bentley, T. (2017). Exploring the teleworking experiences of organisations in a post-disaster environment. *New Zealand Journal of Human Resources Management*, *17*(1), 1–19. https://doi.org/10.24135/nzjer.v45i2.19

Greenhaus, J. H., & Beutell, N. J. (1985). Sources of conflict between work and family roles. *Academy of Management Review*, *10*, 76–88. https://doi.org/10.5465/AMR.1985.4277352

Hackman, J. R., & Oldham, G. R. (1976). Motivation through the design of work: Test of a theory. *Organizational Behavior and Human Performance*, *16*, 250–279. https://doi.org/10.1016/0030-5073(76)90016-7

Hanafizadeh, P., Moosakhani, M., & Bakhshi, J. (2009). Selecting the Strategic Best Practices for Business Process Redesign. *Business Process Management Journal*, *15*, 609–627. https://doi.org/10.1108/14637150910975561

Hartman, A., Sifonis, J., & Kador, J. (2000). *Net Ready: Strategies for Success in the Economy*. McGraw-Hill. ISBN 0071352422, 9780071352420

Hochschild, A. R. (1997). *The Time Bind: When Work Becomes Home and Home Becomes Work*. New York: Metropolitan Books. ISBN 9780805044713.

Illegems, V., Verbeke, A., & S'Jegers, R. (2001). The organizational context of teleworking implementation. *Technological Forecasting and Social Change*, *68*, 275–291. https://doi.org/10.1016/S0040-1625(00)00105-0

Jakobowicz, E., & Derquennea, C. (2007). A Modified PLS Path Modeling Algorithm Handling Reflective Categorical Variables and a New Model Building Strategy. *Computational Statistics & Data Analysis*, *51*(8), 3666–3678. https://doi.org/10.1016/j.csda.2006.12.004

Jézéquel, M. (2021). Tendances-Les nouvelles du management. *GESTION*, *45*(4). https://www.academia.edu/122216776/Tendances_Les_nouvelles_du_management

Kinicki, A. J., McKee-Ryan, F. M., Schriesheim, C. A., & Carson, K. P. (2002). Assessing the construct validity of the Job Descriptive Index: A review and meta-analysis. *Journal of Applied Psychology*, *87*(1), 14–32. https://doi.org/10.1037/0021-9010.87.1.14

Lacroux. D. (2011). *Successions: Le guide pratique*. Prat Editions. ISBN-10:2809501963

Loo, B. P. Y., & Wang, B. (2018). Factors associated with home-based e-working and e-shopping in Nanjing, China. *Transportation*, *45*, 365–384. https://doi.org/10.1007/s11116-017-9792-0

Igbaria, M., & Guimaraes, T. (1999). Exploring Differences in Employee Turnover Intentions and Its Determinants Among Telecommuters and Non-Telecommuters. *Journal of Management Information Systems*, *16*, 147–164. https://doi.org/10.1080/07421222.1999.11518237

Mayo, M., Gomez-Mejia, L., Firfiray, S., Berrone, P., & Villena, V. H. (2016). Leader beliefs and CSR for employees: The case of telework provision. *Leadership & Organization Development Journal*, *37*, 609–634. https://doi.org/10.1108/LODJ-09-2014-0177

Meyer, V., Diard, C., & Rost, D. (2022). Télétravail et formes de contrôle émergentes : le cas du secteur bancaire et financier pendant la crise sanitaire de la Covid-19. *Annales des Mines-Gérer et Comprendre*, Septembre, 35–46. https://doi.org/10.3917/geco1.149.0035

Mutula, S. M., & van Brakel, P. (2006). An Evaluation of E-Readiness Assessment Tools with Respect to Information Access: Towards an Integrated Information Rich Tool. *International Journal of Information Management*, *26*, 212–223. https://doi.org/10.1016/j.ijinfomgt.2006.02.004

Nardi, B., & Whittaker, S. (2002). The place of face-to-face communication in distributed work. In P. Hinds & S. Kiesler (Eds.), *Distributed work: New ways of working across distance using technology* (pp. 83–110). Cambridge, MA: MIT Press. https://www.researchgate.net/publication/2389210

Nguyen, M. H. (2021). Factors influencing home-based telework in Hanoi (Vietnam) during and after the COVID-19 era. *Transportation*, *48*(6), 3207–3238, https://doi.org/10.1007/s11116-021-10169-5

Okun, M. A., Stock, W. A., Haring, M. J., & Witter, R. A. (1984). Personal well-being and life satisfaction: a meta-analysis. *Quality of Life Research*, *3*(1), 39–55. https://doi.org/10.2307/1163911

Overbey, J. A. (2013). Telecommuter intent to leave. *Leadership & Organization Development Journal*, *34*, 680–699. https://doi.org/10.1108/LODJ-01-2012-0004

Parker, S. K. (2014). Beyond motivation: job and work design for development, health, ambidexterity, and more. *Annual Review of Psychology*, *65*, 661–691. https://doi.org/10.1146/annurev-psych-010213-115208

Pennequin, N. (2020). L'irruption du télétravail pendant la crise sanitaire liée à la pandémie de Covid 19. *Les Cahiers S.M.T.*, *37*, 1–5. http://www.a-smt.org/cahiers/cahiers/cahier-37/37-1-06-NP.irruption.teletravail.pdf

Pérez, M. P., Sànchez, A. M., de Luis Carnicer., M. P., & Vela Jiménez, M. J. (2004). The environmental impacts of Teleworking: A model of urban analysis and a case study. *Management of Environmental Quality: An International Journal*, *15*(6), 656–671. https://doi.org/10.1108/14777830410560728

Pérez, M. P., Sànchez, A. M., de Luis Carnicer., M. P., & Vela Jiménez, M. J. (2005). The difference of firm resources and the adoption of teleworking. *Technovation*, *25*(12), 1476–1483. https://doi.org/10.1016/j.technovation.2005.04.002

Pradhan, R. K., Kumari, I. G., & Kumar, U. (2017). Human resource flexibility and organisational effectiveness: mediating role of organisational citizenship behaviour. *International Journal of Human Resources Development and Management*, *17*(3/4), 282. https://doi.org/10.1504/IJHRDM.2017.10007452

Raghuram, S., & Wiesenfeld, B. (2004). Work-nonwork conflict and job stress among virtual workers. *Human Resource Management*, *43*, 259–277. https://doi.org/10.1002/hrm.20019

Roberts, B. (1994). Informal economy and family strategies. *International Journal of Urban and Regional Research*, *18*, 6–23. https://doi.org/10.1111/j.1468-2427.1994.tb00248.x

Rousseau, D. M. (1989). Psychological and implied contracts in organizations. *Employee Responsibilities and Rights Journal*, *2*(2), 121–139. https://doi.org/10.1007/BF01384942

Rubel, M. R. B., Hung Kee, D. M., & Rimi, N. N. (2021). High-performance work practices and medical professionals' work outcomes: the mediating effect of perceived organizational support. *Journal of Advances in Management Research*, *18*(3), 368–391. https://doi.org/10.1108/JAMR-05-2020-0076

Sener, I. N., & Reeder, P. R. (2012). An examination of behavioral linkages across ICT choice dimensions: copula modeling of telecommuting and teleshopping choice behavior. *Environment and Planning A*, *44*(6), 1459–1478. https://doi.org/10.1068/a44436

Shipp, A. J., & Cole, M. S. (2015). Time in individual-level organizational studies: what is it, how is it used, and why isn't it exploited more often? *Annual Review of Organizational Psychology and Organizational Behavior*, *2*, 237–260. https://doi.org/10.1146/annurev-orgpsych-032414-111245

Singh, P., Paleti, R., Jenkins, S., & Bhat, C. R. (2013). On modeling telecommuting behavior: option, choice, and frequency. *Transportation*, *40*, 373–396. https://doi.org/10.1007/s11116-012-9429-2

Teece, D. J., Peteraf, M., & Leih, S. (2016). Dynamic Capabilities and Organizational Agility: Risk, Uncertainty, and Strategy in the Innovation Economy. *California Management Review*, *58*(4), 13–35. https://doi.org/10.1525/cmr.2016.58.4.13

Tokarchuk, O., Gabriele, R., & Neglia, G. (2021). Teleworking During the Covid-19 Crisis in Italy: Evidence and Tentative Interpretations. *Sustainability*, *13*(4), 2147. https://doi.org/10.3390/su13042147

Urbach, N., & Ahlemann, F. (2010). Structural Equation Modeling in Information Systems Research Using Partial Least Squares. *Journal of Information Technology Theory and Application*, *11*, 5–40. Available at https://aisel.aisnet.org/jitta/vol11/iss2/2

Vakola, M., Tomprou, M., & Nikolaou, I. (2012). Experiencing organizational change in Greece: the framework of psychological contract. *The International Journal of Human Resource Management*, *23*(2), 385–405. https://doi.org/10.1080/09585192.2011.561223

Weiner, B. J. (2009). A Theory of Organizational Readiness for Change. *Implementation Science*, *4*, 67. https://doi.org/10.1186/1748-5908-4-67

Weiss, H. M., & Cropanzano, R. (1996). Affective Events Theory: A Theoretical Discussion of the Structure, Causes and Consequences of Affective Experiences at Work. In B. M. Staw & L. L. Cummings (Eds.), *Research in Organizational Behavior: An Annual Series of Analytical Essays and Critical Reviews* (pp. 1–74). Greenwich, CT: JAI Press. Available at https://web.mit.edu/curhan/www/docs/Articles/15341_Readings/Affect/AffectiveEventsTheory_WeissCropanzano.pdf

Weppe, X., Warnier, V., & Lecocq, X. (2013). Extending resource-based theory: considering strategic, ordinary and junk resources. *Management Decision*, *51*(7), 1359–1379. https://doi.org/10.1108/MD-05-2012-0392

Wernerfelt, B. (1984). The Resource-Based View of the Firm. *Strategic Management Journal*, *5*, 171–180. https://doi.org/10.1002/smj.4250050207

Witter, R. A., Okun, M. A., Stock, W. A., & Haring, M. J. (1984). Education and Subjective Well-Being: A Meta-Analysis. *Educational Evaluation and Policy Analysis*, *6*(2), 165–173. https://doi.org/10.3102/01623737006002165

Ye, L. R. (2012). Telecommuting: Implementation for Success. *International Journal of Business & Social Science*, *3*(15), 20–29. https://www.canada.ca/content/dam/canada/employment-social-development/migration/documents/journals/Vol_3_No_15_August_2012/4.pdf

Empowering Data Spaces for Future Mobility

Exploring Organisational Roles

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Abstract: Recognising the growing demand for sovereign and interoperable data exchange in advanced mobility services, this paper presents a conceptual framework for developing data spaces within the data economy. Drawing on the Gaia-X initiative, we address the challenges of ensuring data sovereignty and cross-organisational collaboration in complex, diverse data ecosystems. By applying the Institutional Role Model (IRM), we systematically identify and classify 32 distinct organisational roles, organised into eight overarching meta-roles, that are crucial for the successful operation of a data space. Based on expert interviews and the in-depth analysis of two practical use cases, our approach uncovers how technological and economic roles interact to enable the seamless and sovereign exchange of mobility data. The findings enhance theoretical understanding of role-based data space structures and provide insights into data ecosystems' design, governance, and implementation. Stakeholders looking to leverage data space for efficient, sovereign, and innovative mobility services will find these insights highly valuable.

Keywords: Data Ecosystems, Data Spaces, Data Sharing, Organisational Roles, Gaia-X, Digital Economy

Introduction

Data has emerged as a critical asset for companies in this digital revolution to ensure a competitive advantage. According to Gartner, a leading research and consulting company, 'organisations that promote data sharing will outperform their peers on most business value metrics' (Goasduff, 2021). With increased data-sharing initiatives, new data markets and a data economy will emerge, with higher data quantity (Munoz-Arcentales et al., 2020), process improvements, and digital innovations across product and industry boundaries (Yoo *et al.*,

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2010). A structured data-sharing initiative is built on stakeholder collaboration to establish an inter-organisational data ecosystem. We define a data ecosystem as a 'complex socio-technical network that enables collaboration between autonomous actors in order to explore data' (Oliveira *et al.*, 2019, p. 590). However, companies providing data offerings often have concerns about losing control over their data and the fear that competitors and other stakeholders can use data, negatively impacting the data provider (Jussen *et al.*, 2024). To ensure data control, the framework named 'data space' was developed, which can provide data sovereignty (Otto & Jarke, 2019). Although data ecosystems have been widely studied for their role in value creation and innovation, the concept of data spaces with decentralised ownership and governance still needs to be thoroughly explored (De Reuver *et al.*, 2018; Möller *et al.*, 2024; Oliveira *et al.*, 2019). In this context, cloud service providers frequently operate in data markets, offering services built on data without the providing organisations having control over its use. The European Gaia-X initiative addresses these challenges by establishing a technological framework that promotes digital sovereignty and enables trusted, secure data exchanges among the participants (GAIA-X European Association for Data and Cloud, 2022). With the European data strategy, Gaia-X fosters data-driven innovation by fostering transparency, autonomy, and interoperability (Tardieu, 2022).

Our paper investigates the Gaia-X data infrastructure that enables data spaces. Data spaces require a balanced approach integrating technological and economic perspectives to realise practical use cases (Spiekermann, 2019). The collaboration among organisations within data spaces, serving both technological and economic roles, highlights the importance of gaining a deeper understanding of organisational roles and their interactions in these emerging environments where data serves as the central asset for value creation (Janssen *et al.*, 2020; Oliveira & Lóscio, 2018). To explore and enhance our understanding of technological and economic functions and roles, we defined the following research question: Which organisational roles are required to develop a data space for advanced mobility services?' In addressing our research question, we aim to comprehensively understand the organisational roles facilitating sovereign and interoperable data exchange within data spaces. By applying the theory of Institutional Role Models (IRM), we have identified and categorised 32 organisational roles into eight meta-roles through an empirical analysis of two advanced mobility use cases. Our methodological approach involved conducting semi-structured interviews with 12 experts, which provided nuanced insights into the dynamics of role distribution among various actors in the digital economy. These findings illuminate how organisational roles and interactions influence the effectiveness of data spaces, offering theoretical contributions and practical implications for the design and governance of data ecosystems.

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Background

Laursen & Salter (2014) stated the need for companies to open their platforms to foster innovation 'to obtain knowledge, organisations have to reveal some parts of their own knowledge to external actors' (Laursen & Salter, 2014, p. 868). In the information system literature, the term 'data ecosystems' has emerged over the last years as a definition for cross-organisational collaboration for sharing data and digital services, highlighting the need for more research in this area (Curry *et al.*, 2022; Heinz *et al.*, 2022; Legner *et al.*, 2017; Oliveira *et al.*, 2019). The concept of ecosystems originates from the natural ecosystem and was introduced in the business literature by Moore (1993) as business ecosystems. Today, there are different definitions and streams of ecosystems (e.g., innovation, business, digital platforms) in business research and appliances. According to Adner (2017), 'Ecosystem is defined by the alignment structure of the multilateral set of partners that need to interact in order for a focal value proposition to materialise' (Adner, 2017). Business ecosystems are 'several actors that generate multilateral and non-generic complementarities to each other to varying degrees without being subject to complete hierarchical control' (Jacobides *et al.*, 2018, p. 2264). Ecosystems in business research have joined a defined platform owner and autonomous actors collaborating to generate value and possibility for network effects (Hein *et al.*, 2020). Data ecosystems are 'creating, managing and sustaining data-sharing initiatives' (Oliveira & Lóscio, 2018, p. 1) through data-sharing transactions (De Prieëlle *et al.*, 2020). Data sharing allows third parties, for their objectives, to exchange (provide or consume) datasets with other institutions (Jussen *et al.*, 2024). The technological infrastructure to enable data sharing in data ecosystems is named data space. In the following section, we describe the concept of data space.

Creation of data spaces

Data spaces have become pivotal to facilitating secure and sovereign data exchange among institutions. Data spaces address the growing need for entities to collaborate and share data without relinquishing control over their valuable information assets. Data spaces are defined by Möller *et al.* (2024) as 'decentralised data infrastructures designed to enable data-sharing scenarios across organisational boundaries by implementing mechanisms for secure and trustworthy data sharing' (Möller *et al.*, 2024, p. 6). This enables a digital environment where providers and consumers maintain complete control over the use of their data and services. Therefore, institutions can ensure data sovereignty by establishing policies that define and regulate data usage (Otto & Jarke, 2019). Compared to centralised ecosystems, which use centralised data storage, the characteristic of data spaces is decentralised by using data space connectors (Möller *et al.*, 2024). Establishing such data spaces is crucial to increasing the

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economic benefits of data sharing. There are initiatives like Gaia-X and the International Data Spaces Association (IDSA), which provide data sovereignty and fair competition by facilitating data exchange across institutional boundaries through data spaces, thereby fostering innovation and collaboration (Otto & Jarke, 2019; Tardieu, 2022).

Organisational roles for data spaces

Defining explicit organisational roles within data ecosystems is crucial for their structural design, integration, and governance (Bakos, 1998; Gnyawali *et al.*, 2010). Organisational roles are the foundation for aligning participants' actions, ensuring coordination, and fostering trust within data ecosystems. In general terms, roles refer to an individual's relationships within a particular social context (Steimann, 2000). In software systems, including data spaces, these social contexts are intentionally designed and structured (Colman & Han, 2007). We refer to such contexts as organisational roles (Boella & Van Der Torre, 2006). Given that capable and adaptive humans (compared to software entities) need to organise themselves into organisations to achieve complex goals, it seems logical that software entities in complex environments must also be similarly organised to achieve system objectives – even if these software agents are highly capable and autonomous.

Organisation is defined here as the relationships between roles in the system and the processes that maintain the viability of these relationships in response to changing goals and environments. An organisation-centric perspective views roles as nodes in an organisational structure (Colman & Han, 2007). This perspective lays the groundwork for identifying and defining specific roles in data spaces, which is essential for enabling collaboration and integration.

Data sharing enables the primary value proposition in data ecosystems, comprising essential roles defined (De Prieëlle *et al.*, 2020): data providers, data brokers, service providers, application developers, infrastructure, and tool providers. Further essential roles include identity providers, data controllers, and various intermediaries, all contributing to the data spaces' functionality and value generation (Munoz-Arcentales *et al.*, 2020; Nagel & Lycklama, 2022). In the context of data spaces, the coordinated efforts of diverse actors are essential for the ecosystem's architecture and the seamless integration of participants (Otto & Jarke, 2019). Data spaces rely on various actors, from technological providers to market intermediaries, to facilitate secure and sovereign data exchange. Developing new data spaces and integrating actors into existing frameworks are facilitated by a diverse set of generic roles, each characterised by specific actions and responsibilities (Heinz *et al.*, 2022; Otto, 2022; Pullmann *et al.*, 2017).

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Focusing on the functions that actors perform rather than merely their identities can enhance efficiency and clarify the contributions of each participant (Kambil & Short, 1994; Knight & Harland, 2005). Abstracting these roles into broader categories can streamline ecosystem management and facilitate the integration of new participants (Azkan *et al*., 2022; Papert & Pflaum, 2017). Actors can engage in multiple roles simultaneously as data providers and consumers. Establishing clear roles and responsibilities within data spaces is critical for building trust and ensuring interoperability among actors, foundational elements for the success of data spaces (Huppertz & Gieß, 2024). By optimising participant contributions through well-defined organisational roles, data spaces can foster dynamic ecosystems that encourage innovation and technological advancement.

A data space for advanced mobility services

The digital transformation of the mobility sector necessitates innovative data management and sharing solutions to enhance efficiency and safety and foster innovation. Data spaces have emerged as foundational infrastructures that enable decentralised data management practices, facilitating secure and sovereign data exchange among diverse stakeholders (Otto, 2022). By ensuring that data remains at its source and is accessible only when necessary, data space prioritises data sovereignty and promotes semantic integration through linked data principles (Franklin *et al*., 2005). Gaia-X represents a pioneering initiative in developing data space, aiming to create a federated data architecture that integrates data, digital services, and cloud infrastructure (GAIA-X European Association for Data and Cloud, 2022; Tardieu, 2022). Incorporating critical federation services such as identity and trust mechanisms, comprehensive compliance frameworks, and sovereign data exchange Gaia-X enhances interoperability and fosters collaboration across diverse ecosystems. This structured approach ensures data availability and strengthens the autonomy and self-organisation of ecosystem participants. The mobility sector benefits significantly from adopting data space, particularly in advanced mobility services. Trusted data exchange and processing are pivotal enablers for the sector's digitisation and the introduction of novel mobility solutions (Kubach *et al*., 2023; Pretzsch *et al*., 2022). Given the sector's reliance on a wide array of data sources — including traffic infrastructure, vehicle sensors, and fleet operations — there is an imperative need for systems that guarantee data sovereignty, security, and trust. Gaia-X's architecture provides a neutral and secure platform conducive to the impartial exchange of mobility data, facilitating the creation of integrated, efficient, and data-driven services (GAIA-X European Association for Data and Cloud, 2022). As the mobility sector advances toward a more interconnected and data-centric operational model, the role of Gaia-X and similar data space becomes increasingly central, highlighting the necessity for secure and efficient mechanisms for data exchange (Langdon & Schweichhart, 2022).

Building upon the principles of data space and the Gaia-X framework, the 'Gaia-X 4 Advanced Mobility Services' (Gaia-X 4 AMS) project explores two practical use cases to enhance mobility services through advanced technology. The project investigates autonomous driving within the legal framework of Level 4 automation and contributes to establishing a Gaia-X-based data ecosystem for advanced mobility services.

Use Case – Safe Coordination of Autonomous Vehicles: The use case focuses on the safe coordination of autonomous vehicles within their Operational Design Domains (ODD). This use case aims to enhance traffic safety and efficiency by leveraging vehicle sensor data and real-time traffic information, especially at higher automation levels where constant driver supervision is unnecessary. Secure data exchange facilitated by the data space optimises the coordination of autonomous vehicles, leading to improved traffic flow and reduced incidents.

Use Case – Networked and Secure Emergency Corridor: The use case addresses the coordinated utilisation of ODD areas in emergency situations. It integrates disaster management and emergency mobility services to facilitate efficient and safe emergency responses. By building on insights from the first use case, this scenario aims to enable the formation of rescue lanes and optimise routing for emergency vehicles. The data space ensures that sensitive information is exchanged securely, maintaining data sovereignty for all participating entities.

Establishing a data space for advanced mobility services exemplifies how federated data infrastructures can address the mobility sector's complex data sharing and management needs. Through initiatives like Gaia-X and projects like Gaia-X 4 AMS, the sector can leverage data space to enhance service delivery, promote innovation, and maintain data sovereignty. Understanding and defining the critical organisational roles within these data spaces are essential steps toward building trust, ensuring interoperability, and realising the full potential of advanced mobility services.

Data and Method

To explore the emerging concept of data space, we applied a case study methodology (Eisenhardt & Graebner, 2007; Yin, 2013), which is appropriate for examining complex phenomena where existing theories may not sufficiently explain observed difficulties (Ridder, 2017). We integrate the Institutional Role Model (IRM) framework (Schulz & Franck, 2022) into our methodology to organise organisational roles within data spaces. The IRM framework was chosen over alternatives, such as actor-network theory because it provides a system-oriented methodology tailored to the specific needs of dynamic environments like data spaces. This ensures a pragmatic alignment of roles with institutional structures, enhancing governance and operational efficiency. The theory of Institutional Role Models was initially conceptualised to enable firms in the mobility industry to adapt to the dynamic and evolving nature of market systems. This theoretical framework is grounded in Schulz *et al.*'s (2019) work, which provides an in-depth analysis of system dynamics within transportation markets. The IRM emphasises system dynamics and institutional economics, making it suitable for addressing challenges in designing and managing data spaces by providing tools to model and control complex inter-organisational processes. System dynamics allow for analysing feedback loops and time-dependent interactions, essential for adapting data spaces to evolving market demands (Radzicki, 2009). Institutional economics, on the other hand, offers a framework for reducing uncertainties and transaction costs, fostering trust among diverse stakeholders, and ensuring that cooperative behaviours align with shared goals (Schulz *et al.*, 2019).

Data was collected through semi-structured interviews with 12 Gaia-X 4 Advanced Mobility Services project experts. Participants were selected for their extensive experience developing and implementing data spaces within the mobility sector. The use cases provide practical insights into real-world technology utilisation (Orlikowski, 2000), aiding in organising new technologies around user interactions (Jacobson, 2004; Maghazei *et al.*, 2022). These cases are crucial for assessing Gaia-X's potential to drive value creation and innovation in mobility (Kauschke, 2023; Tardieu, 2022).

To develop a structured understanding of technological and economic roles, we conducted a qualitative study using expert interviews guided by a grounded theory approach (Strauss & Corbin, 1990). This methodology is well-suited for capturing complex and evolving social interactions, particularly when existing theories provide limited explanations (Hunger & Müller, 2016). Given its extensive application in qualitative platform research, grounded theory also offers valuable insights for analysing data spaces (Hutterer & Krumay, 2024). Our study aims to systematically identify and categorise previously undefined roles, ensuring a data-driven expansion of knowledge on data spaces while allowing for theoretical flexibility in understanding their organisational dynamics.

Data collection and analysis

We triangulated multiple data sources to ensure the reliability and validity of our findings (Jick, 1979; Yin, 2013). The research process was divided into data collection phases. In the first phase, an extensive literature review was conducted between June and July 2022, involving the analysis of a broad array of scientific publications, practical reports, and internet-based resources. In the second phase, we conducted semi-structured interviews with experts actively involved in the project consortia. Informants were selected based on their substantial engagement in the project and extensive field experience (Graebner, 2004). The interviewees represented a variety of positions across different organisations, ensuring a diverse range of perspectives (see Table 1). Between October and December 2022, data was collected through semi-structured video interviews with 16 experts, each lasting between 14 and 54 minutes, ensuring comprehensive insights into the development of the data space. Each interview involved at least one representative from every participating institution, providing a holistic perspective on the project. All interviews were recorded and transcribed immediately to ensure the accuracy and integrity of the data. The semi-structured interview format allowed a flexible exploration of central topics, which were guided by the following structure:

1. Introduction by the interviewer and the expert introduce its background, organisation, and role in the organisation and project.
2. Definition of technological roles that enable use case-specific data exchange in the data space.
3. Definition of economic roles that enable use case-specific data exchange in the data space.
4. Identify technological roles that could overtake the expert's institution in the data space.
5. Identify economic roles that could overtake the expert's institution in the data space.
6. Assignment of organisational roles (technological and economic) to the use cases.

Table 1. Overview of interviewed experts

ID	Business area of Organisation	Expert Position in Organisation	Organisation size[1]	Interview Duration
1	Research Institute	Research Assistant	Large	0:49 h
2	Research Institute	Research Assistant	Large	0:49 h
3	Research Institute	Research Assistant	Large	0:49 h
4	Research Institute	Research Assistant	Large	0:38 h
5	Research Institute	Research Assistant	Large	0:38 h
6	Research Institute	Research Assistant	Large	0:38 h
7	Engineering Office	Manager Hardware	Large	0:54 h
8	Research Institute	Group Manager Vehicle Function Development	Large	0:54 h
9	IT Consulting	Software Engineer	Large	0:54 h
10	Software Provider	Senior researcher	Large	0:54 h
11	Public Institution	Research Assistant	Large	0:43 h
12	IT Consulting	Manager	Large	0:43 h
13	Engineering Office	Manager Hardware	Large	0:43 h
14	Aircraft Systems Provider	CEO	Middle	0:27 h
15	Research Institute	Research Assistant	Large	0:21 h
16	Software Provider	Senior researcher	Large	0:14 h

Ensuring the reliability of our findings required a systematic approach to addressing potential biases such as information bias, retrospective sense-making, and social desirability bias by

[1] Size according to EU definition, see: https://ec.europa.eu/growth/smes/sme-definition_de (Retrieved 15 July 2024)

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employing a cross-verification process that compared data from the qualitative research phase with findings from the literature review (Ozcan & Eisenhardt, 2009). We ensured a broad spectrum of perspectives by conducting interviews with experts from diverse institutions and professional backgrounds, reducing the likelihood of biased interpretations (Maxwell, 2013). To minimise recall issues and enhance data accuracy, we guaranteed the anonymity of all participants throughout the study (Huber & Power, 1985).

The data analysis was conducted as a comparative case study using case descriptions (see 2.3) for within and cross-analysis (Eisenhardt & Graebner, 2007; Yin, 2013). The coding process started with within-case using a thematic coding structure based on the literature review (Thornberg & Charmaz, 2014). Therefore, we read all the interview manuscripts to find possible patterns. The following two researchers used qualitative data and text analysis software MAXQDA to independently code statements about economic and technological functions, activities, and responsibilities, resulting in a compilation of first-order codes. During the second coding phase, we adopted an iterative process across the cases to refine these first-order codes and generate a set of second-order codes that abstractly grouped the initial codes based on shared characteristics. From these second-order codes, specific roles (third-order codes) were then deducted that accurately reflected the core insights of the data about the current literature. Figure 1 illustrates the resulting data structure, comprehensively representing the hierarchical relationships between meta-roles and specific roles in data spaces.

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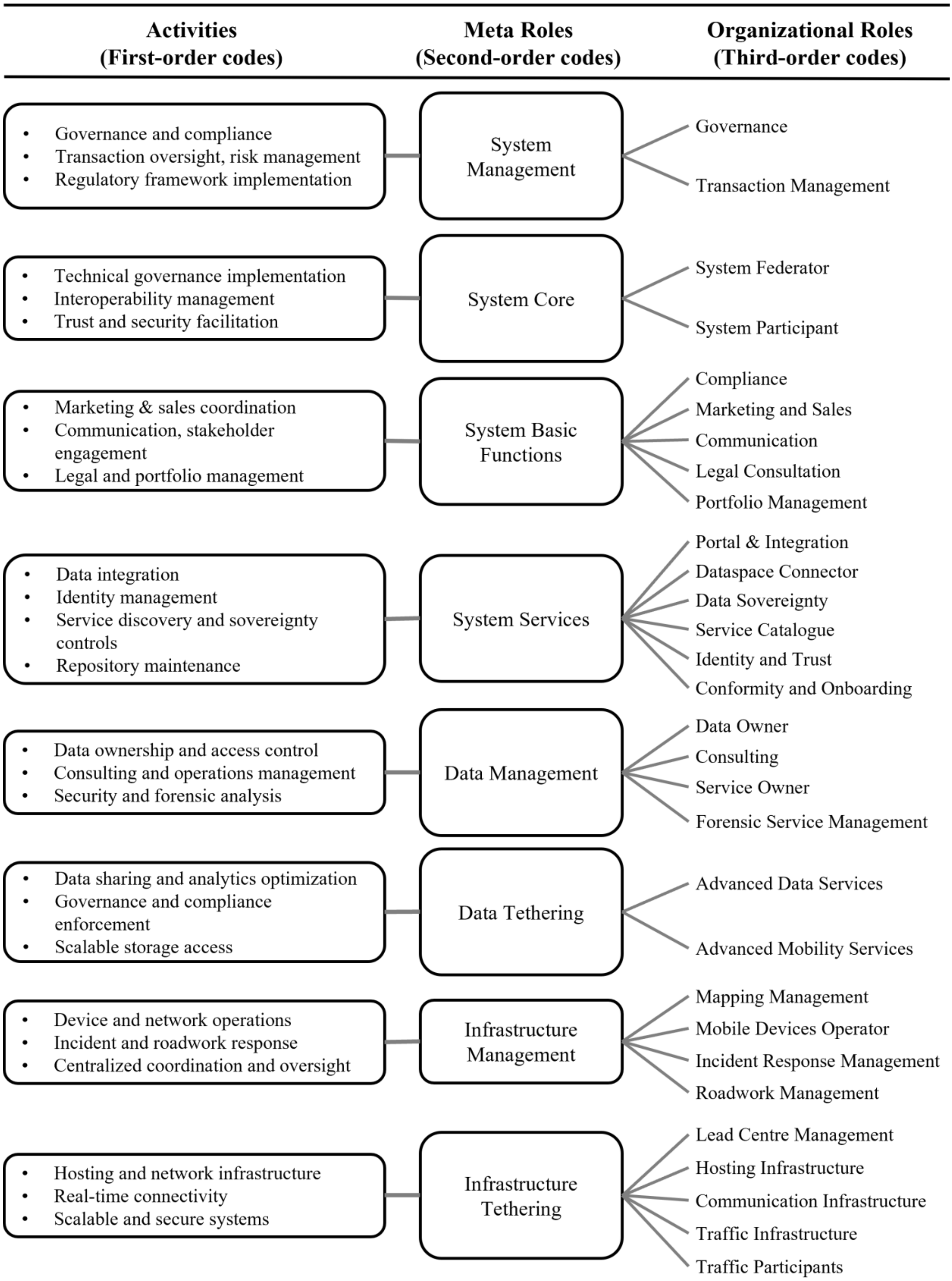

Figure 1. Data Structure

Results

The investigated data space, Gaia-X 4 Advanced Mobility Services, is designed by specific organisational roles to fulfil the requirements of the system architecture and use cases. Our data collection and analyses identified 32 organisational roles clustered into four meta-roles, each in the economic and technological categories. The following two sections describe the technological roles (4.1) and economic roles (4.2) in detail, followed by the role assignment to the use cases (4.3).

Technological roles to design data space

The technological meta-roles **System Core, System Services**, **Data Tethering**, **and Infrastructure Tethering** define the technical system architecture within the data space. These meta-roles are essential for ensuring interoperability, secure data exchange, service integration, and infrastructure reliability, enabling the seamless operation of data spaces.

The meta-role **System Core** forms the operational and participatory backbone of the data space, encompassing governance and core functionalities. It ensures smooth operation and coordination across the federation's services and infrastructure, facilitates secure and sovereign data exchanges, and integrates diverse participants adhering to federation protocols. The *System Federator* is responsible for the operation of the federation services and the federation itself. The role operates as a technological coordinator by ensuring the provision of a data space-wide infrastructure or essential services (system services) that enable the discovery of offers (catalogue), secure (identity and trust), and sovereign (sovereign data exchange) exchange in compliance with rules.

System Services acts as a comprehensive framework for managing secure, efficient, and compliant data exchanges within the federated system. Essential for integrating diverse system services, the role maintains data sovereignty and establishes trust and identity verification processes, orchestrating the data spaces' overall functionality to ensure adherence to established standards and regulatory requirements. *Portal & Integration* uses a graphical user interface to support the data space participants in communication with the system service functions. The role also manages member accounts with profile management and credentials. The institution executing this role instantiates selected services from the catalogue and enables application installation/use and updating. *Data Space Connector* provides data space connectors as executable software components and source code for data space participants to use independently. The role enables data transfer between data space participants, seamlessly merging data from multiple sources into one location, typically a data warehouse. This includes a level of verification, policy enforcement, and contracting control is provided. *Data*

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Sovereignty System helps maintain control over its data by offering services that provide transparency and control over data use in contract negotiations and data exchange. *Service Catalogue* provides offerings and professional services that also enable the operation of a data marketplace (a place where data providers and data consumers can find each other to promote data exchange or access). *Identity and Trust* ensures a secure and trustworthy data exchange within the data space by providing technical support for authentication and authorisation to services/certain information. The role includes decentralised identity management, which enables the data space participants to exchange secure data using digital identities. *Conformity and Onboarding* verify the compliance of shared system services throughout the process and ensure that all participants, resources, and service offerings undergo a validation process before being added to a catalogue.

Data Tethering integrates structured and unstructured data with advanced mobility services, enhancing traffic management and responses to unforeseen events. The role involves data fusion, aggregation, and spatial integration, facilitating effective routing and providing crucial warning messages for comprehensive, data-driven mobility management. *Advanced Data* Services provides services based on mobility data (e.g., weather data, map data). These data are collected, aggregated, or fused to provide higher-quality datasets that are used for the data space. *Advanced Mobility Services* offers mobility services that can optimise traffic routing in case of unforeseen events by calculating and forwarding alternative routes or warning messages to (selected) road users. For this purpose, the mobility service uses data from various data sources and IT services.

Infrastructure Tethering focuses on providing and managing essential infrastructural elements for hosting services and data, enabling communication technologies, and overseeing traffic control systems. The role coordinates traffic participants to ensure optimal traffic management and data exchange, supporting the operational and data needs of the data space. *Hosting Infrastructure* provides the decentralised cloud infrastructure to host Gaia-X System Services, individual service offerings, or simply data of a service. *Communication Infrastructure* enables essential communication by providing communication technologies. *Traffic Infrastructure* operates all relevant traffic control systems involved in traffic management (traffic lights, surveillance cameras, sensors, etc) and is responsible for evaluating traffic data through the traffic control centre, which coordinates actions for optimal traffic control. *Traffic Participants* are road users both on the road and in the air and provide the vehicles that provide and or consume relevant data for advanced data and mobility services.

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Economic roles to design a data space

The economic meta-roles **System Management**, **System Basic Functions**, **Data Management**, and **Infrastructure Management** define the economic system architecture within the data space. These meta-roles are essential for orchestrating strategic operations, market integration, data stewardship, and infrastructure oversight to ensure the federation's holistic and sustainable growth.

System Management is critical in defining strategic processes and organisational structures within the data space. The meta role manages transaction costs, optimises interfaces for efficiency, and ensures compliance with legal and standardisation requirements, thus maintaining system integrity and legality. The role *Governance* is responsible for the design processes of the data space, the actors, and responsibilities concerning the defined goal achievement. This includes the design of a transparent organisational and process structure to establish fair distribution and incentive mechanisms as a basis for sustainable collaboration within the data ecosystem. *Transaction management* identifies and reduces transaction costs at the interfaces of joint work. This simplifies the initiation and execution of transactions within the data spaces (for example, by creating and constantly optimising internal and external interfaces that minimise transaction costs). *Compliance* is ensuring compliance with mandatory regulations and standards. This includes legal requirements, Gaia-X compliance, and standards and requirements within the data space.

System Basic Functions serves as foundational support for data spaces' operations. The meta role involves expanding market reach, facilitating effective communication and coordination, ensuring legal oversight, and managing the service portfolio. It aligns data spaces' offerings with market needs, legal frameworks, and strategic objectives. *Marketing & Sales* is responsible for increasing awareness of the data space and services to achieve market goals. It identifies potential new customers and partners' needs, desires, and requirements to expand the data space. It also coordinates the marketing activities of the individual project parties connected to the project. *Communication* takes over internal communication and project coordination between partners and communication with other relevant data spaces. Furthermore, the role takes over the communication of the interests of the data room with relevant stakeholders. *Legal Consultation* ensures the legal compliance of the data space and the offered services. It ensures legal advice to the institutions within the data space on legal issues (e.g., data protection). The role supports the data space participants in designing the legal framework within the data space and supports the role Governance in the legal conception of the actors and responsibilities. *Portfolio Management* manages and controls the service portfolio within the data space. This includes performance measurement and

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identification of potential opportunities and risks. It identifies potential for optimising the resource allocation to achieve a balanced service portfolio aligned with the strategic goals of the data space.

Data Management encompasses the data lifecycle within the data space, focusing on data quality, authorisation, advising on business models, maintaining service quality, and securing sensitive data. It shapes and maintains data quality, security, and usability, fostering strategic data utilisation. The *Data Owner* is responsible for the data collection, the quality and authorisation of the datasets, and their self-descriptions. *Consulting* analyses the data space participants' existing corporate resources within the data space and identifies potential business models. The role also advises (potential) data space participants on economically viable connections. *The Service Owner* is responsible for a particular service's quality, maintenance, and operation. The role considers the needs of data and service consumers and ensures the continuous improvement of the overall performance. *Forensic Service Management* collects and presents data, enabling eventual evaluation by security and law enforcement authorities. It is responsible for data security – especially protection against manipulation. *Mapping Management* is responsible for the quality of the geodata. The role collects and analyses data from various sources, creating and updating maps and making them accessible to data space participants.

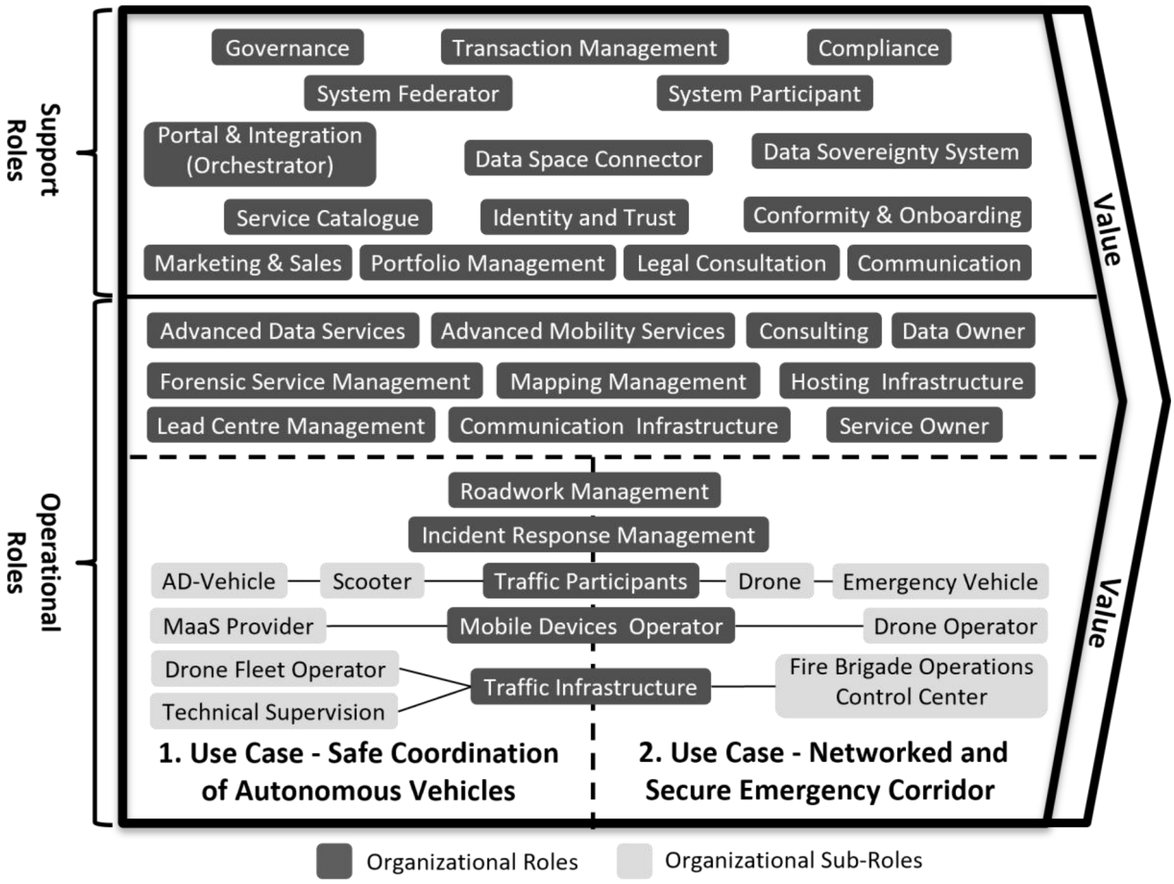
Infrastructure Management involves managing physical and digital infrastructure, including mobile device maintenance and operation, incident response, infrastructure development planning, and the data control centre. The meta role is responsible for seamless operations, safety, and continuous infrastructure improvements within the data space. The *Mobile Device Operator* ensures resource management of the mobile device fleet, including provision, maintenance, and repair. *Incident Response Management is* managing the responses to road accidents and resource allocation, which should minimise the impact of road accidents on other road users. *Roadwork Management* is allocating road construction resources. This includes planning and exchanging information on the timing and location of planned and ongoing road works. *Lead Centre Management* manages the data control centre within the data space, ensuring the data and information exchange.

The technological meta-roles **System Core**, **System Service Provider**, **Data Tethering**, and **Infrastructure Tethering** ensure secure and sovereign data exchanges within the data space by providing essential infrastructure and communication technologies.

Assignment of organisational roles to specific use cases

The effective functioning of data spaces relies on a clear distinction between organisational roles, which is essential for facilitating value creation and maintaining competitive advantage.

Drawing inspiration from Porter's Value Chain framework (Porter, 1985), we categorise these roles into 'operational roles' and 'support roles'. This categorisation clarifies how different roles contribute to the primary activities of delivering data and services within the use cases and how the supporting activities enable and enhance these core functions. Operational roles are involved in creating, processing, and delivering data and services within the data space. These include operational roles such as Advanced Data Services, Data Owner, and Service Owner, integral in both use cases and use case-specific roles like Traffic Participants, Mobile Devices Operator, and Traffic Infrastructure cover distinct organisational sub-roles (see Figure 1). Support roles provide the necessary infrastructure, governance, and compliance mechanisms that ensure the seamless functioning of operational roles. They include infrastructure management, data sovereignty, and security, essential for sustaining trust and maintaining compliance with regulatory standards. This distinction underscores the interdependence between roles. For example, while Data Providers supply the essential inputs for services, Data Sovereignty and Security Management ensures that data is exchanged securely and complies with regulations, thus maintaining trust among participants. Similarly, Service Owners rely on Infrastructure Management to ensure they acquire the necessary technological capabilities to deliver their services effectively. This approach aligns with strategic insights from Porter & Millar (1985), who highlighted how information technology transforms value chains and reshapes industry structures (Porter & Millar, 1985). Institutions within the data space can allocate capabilities more effectively and enhance overall efficiency by defining organisational roles specific to individual use cases and roles engaged in multiple use cases. This approach to role assignment fosters collaboration and enables organisations to leverage information technology for a competitive advantage.



FigFigure 2. Overview of Roles Assignment to Use Cases

Discussion and Limitation

Our study explores the development of organisational structures within data spaces, particularly in the context of Gaia-X and advanced mobility services. As enablers of open and decentralised ecosystems, data spaces are critical for ensuring secure and sovereign data exchange. In the mobility sector, data spaces are a decentralised technological framework that enables sovereign data exchange to foster digital transformation and new mobility services. The roles that various actors assume within these ecosystems are crucial to their successful operation and onboarding of new participants, aligning with institutional roles (Schulz & Franck, 2022). Our findings confirm that role-based structures in data spaces are fundamental for ensuring effectiveness and efficiency. The precise identification and categorisation of roles, especially those responsible for data security, system management, and infrastructure, are critical for optimising processes and allocating resources. These roles enhance the functionality of data spaces and contribute to strategic decision-making. Moreover, these insights are indispensable for process optimisation and strategic planning within a data space, confirming the importance of clearly defined roles in resource allocation (Hein *et al.*, 2020; Otto & Jarke, 2019). However, while the technological roles emerged as uniformly crucial, the relevance of economic roles such as marketing, sales, and system management needed to be clarified. This ambiguity points to the evolving nature of data space governance and highlights the complexity of balancing technological and economic functions. In line with previous research, we found that the prominence of economic roles increases as the ecosystem matures while the initial focus remains on technical governance and infrastructure (Nagel & Lycklama, 2022; Pettenpohl *et al.*, 2022).

Our study has certain limitations. First, the research is based on two use cases within the mobility sector. Future studies should explore data space in other industries, such as healthcare or manufacturing, to better understand how roles might differ across sectors. Additionally, the composition of our expert panel, which predominantly comprised technical experts, may have skewed the findings toward emphasising technological roles over economic ones. A more diverse panel, incorporating management, law, and economics experts, could offer a more balanced perspective on the interaction between technological and economic roles within data space. Future research should aim to bridge this gap by examining how economic roles contribute to the long-term sustainability of data space, especially as they scale across industries. Quantifying the impact of the organisational roles on the overall performance of data space is an area that warrants further investigation. Future studies could develop metrics to assess the effectiveness of these roles, which could be particularly useful for data space governance and strategy (Schulz & Franck, 2022). Future research should explore the dynamics of data space across various sectors to refine the organisational role models and determine which roles are use-case-independent. Additionally, further research is needed to quantify the contributions of individual roles to both technological efficiency and economic success within data spaces. Integrating perspectives from technology, economics, and law, a multidisciplinary approach would provide a deeper understanding of data space governance (Huppertz & Gieß, 2024). Moreover, analysing successful implementations of data spaces in various industries could offer practical insights for designing and managing future data spaces. This would enhance the understanding of the most critical organisational roles within data spaces for improving interoperability, sovereignty, and innovation

Conclusion

This study provides a structured classification of technological and economic roles in data spaces, contributing to the broader discourse on digital ecosystems. By integrating the Institutional Role Model, we offer a systematic framework that enhances role clarity and governance structures within data spaces, addressing coordination, trust, and operational efficiency challenges. Our findings emphasise the interplay between technological and economic roles, highlighting the need for structured governance and interoperability mechanisms to ensure sustainable data-sharing practices. While our study focuses on mobility services, the proposed framework has broader applicability and could be adapted to other domains where federated data sharing is critical. This suggests that healthcare, finance, and energy industries could benefit from similar structured role definitions to enhance collaboration and efficiency.

Building on recent research (e.g., Heinbach *et al.*, 2024; Huber *et al.*, 2022), trust and data sovereignty emerge as key enablers of data space adoption. By defining clear roles and responsibilities, organisations can mitigate data ownership and compliance concerns, strengthening confidence in federated data-sharing models. Furthermore, insights from the Mobility Data Space (MDS) initiative underscore the importance of well-defined governance mechanisms in ensuring cross-platform interoperability and scalability (Pretzsch *et al.*, 2022).

As data spaces evolve, a deeper understanding of organisational roles will be crucial in fostering collaboration, ensuring compliance, and driving innovation. Future research should also examine how AI-driven automation and decentralised decision-making can influence role dynamics within data spaces. By advancing the conceptualisation of roles within data spaces, this study lays the foundation for future research and practical developments in decentralised data ecosystems. Ultimately, the success of data spaces will depend on the ability of stakeholders to balance technological innovation with robust governance frameworks. Ensuring transparency, security, and adaptability will be essential for realising the full potential of these ecosystems, making them a key component of the future digital economy. Addressing economic incentives and governance challenges holistically will be central to ensuring the long-term viability of federated data-sharing models.

Credit author statement

Jens Gessler: conceptualisation, methodology, investigation, data curation, Writing – original draft, visualisation, project administration. **Hanspeter Rychlik:** conceptualisation, methodology, writing – original draft.

Wolfgang H. Schulz: methodology, writing – review and editing, supervision.

Data availability

Data will be made available on request.

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References

Adner, R. (2017). Ecosystem as Structure: An Actionable Construct for Strategy. *Journal of Management*, *43*(1), 39–58. https://doi.org/10.1177/0149206316678451

Azkan, C., Möller, F., Ebel, M., Iqbal, T., Otto, B., & Poeppelbuss, J. (2022, December). *Hunting the Treasure: Modeling Data Ecosystem Value Co-Creation*.

Bakos, Y. (1998). The emerging role of electronic marketplaces on the Internet. *Communications of the ACM*, *41*(8), 35–42. https://doi.org/10.1145/280324.280330

Boella, G. & Van Der Torre, L. (2006). A Foundational Ontology of Organizations and Roles. In M. Baldoni & U. Endriss (Eds.), *Declarative Agent Languages and Technologies IV* (Vol. 4327, pp. 78–88). Springer Berlin Heidelberg. https://doi.org/10.1007/11961536_6

Colman, A. & Han, J. (2007). Roles, players and adaptable organizations. *Applied Ontology*, *2*, 105–126.

Curry, E., Scerri, S., & Tuikka, T. (2022). *Data Spaces: Design, Deployment and Future Directions*. Springer Nature.

De Prieëlle, F., De Reuver, M., & Rezaei, J. (2020). The role of ecosystem data governance in adoption of data platforms by Internet-of-Things data providers: Case of Dutch horticulture industry. *IEEE Transactions on Engineering Management*, *69*(4), 940–950.

De Reuver, M., Sørensen, C., & Basole, R. C. (2018). The Digital Platform: A Research Agenda. *Journal of Information Technology*, *33*(2), 124–135. https://doi.org/10.1057/s41265-016-0033-3

Eisenhardt, K. M., & Graebner, M. E. (2007a). Theory Building from Cases: Opportunities And Challenges. *Academy of Management Journal*, *50*(1), 25–32. https://doi.org/10.5465/amj.2007.24160888

Franklin, M., Halevy, A., & Maier, D. (2005). From databases to dataspaces: A new abstraction for information management. *ACM SIGMOD Record*, *34*(4), 27–33. https://doi.org/10.1145/1107499.1107502

GAIA-X European Association for Data and Cloud. (2022, October 22). *Gaia-X Trust Framework—22.10 Release*. Gaia-X European Association for Data and Cloud AISBL Avenue des Arts 6-9 1210 Brussels www.gaia-x.eu. https://docs.gaia-x.eu/policy-rules-committee/trust-framework/22.10/editorial_information/

Gnyawali, D. R., Fan, W., & Penner, J. (2010). Competitive Actions and Dynamics in the Digital Age: An Empirical Investigation of Social Networking Firms. *Information Systems Research*, *21*(3), 594–613. https://doi.org/10.1287/isre.1100.0294

Goasduff, L. (2021). *Data Sharing Is a Business Necessity to Accelerate Digital Business*. https://www.gartner.com/smarterwithgartner/data-sharing-is-a-business-necessity-to-accelerate-digital-business

Graebner, M. E. (2004). Momentum and serendipity: How acquired leaders create value in the integration of technology firms. Strategic Management Journal, 25(8–9), 751–777. https://doi.org/10.1002/smj.419

Hein, A., Schreieck, M., Riasanow, T., Setzke, D. S., Wiesche, M., Böhm, M., & Krcmar, H. (2020). Digital platform ecosystems. *Electronic Markets*, *30*(1), 87–98. https://doi.org/10.1007/s12525-019-00377-4

Heinbach, C., Gessler, J., Rychlik, H., Stecenko, C., Wieker, H., & Schulz, W. H. (2024). Sharing Business Data Securely: Insights from the European Gaia-X Project on Technical and Economic Roles Enabling Federated Data Spaces. *Journal of Telecommunications and the Digital Economy*, *12*(4), 66–84. https://doi.org/10.18080/jtde.v12n4.1037

Heinz, D., Benz, C., Fassnacht, M., & Satzger, G. (2022a). Past, Present and Future of Data Ecosystems Research: A Systematic Literature Review. *PACIS 2022 Proceedings*. *46*. https://aisel.aisnet.org/pacis2022/46

Huber, G. P., & Power, D. J. (1985). Retrospective reports of strategic-level managers: Guidelines for increasing their accuracy. *Strategic Management Journal*, *6*(2), 171–180. https://doi.org/10.1002/smj.4250060206

Huber, M., Wessel, S., Brost, G., & Menz, N. (2022). Building Trust in Data Spaces. In B. Otto, M. Ten Hompel, & S. Wrobel (Eds.), *Designing Data Spaces* (pp. 147–164). Springer International Publishing. https://doi.org/10.1007/978-3-030-93975-5_9

Hunger, I., & Müller, J. (2016). Barney G. Glaser/Anselm L. Strauss: The Discovery of Grounded Theory. Strategies for Qualitative Research, Aldine Publishing Company: Chicago 1967, 271 S. (dt. Grounded Theory. Strategien qualitativer Forschung, Bern: Huber 1998, 270 S.). In S. Salzborn (Ed.), *Klassiker der Sozialwissenschaften* (pp. 259–262). Springer Fachmedien Wiesbaden. https://doi.org/10.1007/978-3-658-13213-2_59

Huppertz, M., & Gieß, A. (2024). The Interplay of Data-Driven Organizations and Data Spaces: Unlocking Capabilities for Transforming Organizations in the Era of Data Spaces. In *Proceedings of the 57th Hawaii International Conference on System Sciences | 2024* (pp. 4496–4505). https://hdl.handle.net/10125/106925

Hutterer, A., & Krumay, B. (2024). *57th Hawaii International Conference on System Sciences (HICCS), Waikiki Beach Resort, January 3-6, 2024*. University of Hawaii at Manoa.

Jacobides, M. G., Cennamo, C., & Gawer, A. (2018). Towards a theory of ecosystems. *Strategic Management Journal*, *39*(8), 2255–2276. https://doi.org/10.1002/smj.2904

Jacobson, I. (2004). Use cases – Yesterday, today, and tomorrow. *Software & Systems Modeling*, *3*(3), 210–220. https://doi.org/10.1007/s10270-004-0060-3

Janssen, M., Brous, P., Estevez, E., Barbosa, L. S., & Janowski, T. (2020). Data governance: Organizing data for trustworthy Artificial Intelligence. *Government Information Quarterly*, *37*(3), 101493. https://doi.org/10.1016/j.giq.2020.101493

Jick, T. D. (1979). Mixing Qualitative and Quantitative Methods: Triangulation in Action. Administrative Science Quarterly, 24(4), 602. https://doi.org/10.2307/2392366

Jussen, I., Möller, F., Schweihoff, J., Gieß, A., Giussani, G., & Otto, B. (2024). Issues in inter-organizational data sharing: Findings from practice and research challenges. *Data & Knowledge Engineering*, *150*, 102280. https://doi.org/10.1016/j.datak.2024.102280

Kambil, A., & Short, J. E. (1994). Electronic Integration and Business Network Redesign: A Roles–Linkage Perspective. *Journal of Management Information Systems*, *10*(4), 59–83. https://doi.org/10.1080/07421222.1994.11518020

Kauschke, L. (2023). *The transition to smart mobility: Acceptance and roles in future transportation*. Springer Gabler.

Knight, L., & Harland, C. (2005). Managing Supply Networks: *European Management Journal*, *23*(3), 281–292. https://doi.org/10.1016/j.emj.2005.04.006

Kubach, M., Henderson, I., Bithin, A., Dimitrakos, T., Vargas, J., Winterstetter, M., & Krontiris, I. (2023). *A shared responsibility model to support cross border and cross organizational federation on top of decentralized and self-sovereign identity: Architecture and first PoC*. https://doi.org/10.18420/OID2023_08

Langdon, C. S., & Schweichhart, K. (2022). *Data Spaces: First Applications in Mobility and Industry*.

Laursen, K., & Salter, A. J. (2014). The paradox of openness: Appropriability, external search and collaboration. *Research Policy*, *43*(5), 867–878. https://doi.org/10.1016/j.respol.2013.10.004

Legner, C., Eymann, T., Hess, T., Matt, C., Böhmann, T., Drews, P., Mädche, A., Urbach, N., & Ahlemann, F. (2017). Digitalization: Opportunity and Challenge for the Business and Information Systems Engineering Community. *Business & Information Systems Engineering*, *59*(4), 301–308. https://doi.org/10.1007/s12599-017-0484-2

Maghazei, O., Lewis, M. A., & Netland, T. H. (2022). Emerging technologies and the use case: A multi-year study of drone adoption. *Journal of Operations Management*, *68*(6–7), 560–591. https://doi.org/10.1002/joom.1196

Maxwell, J. A. (2013). *Qualitative research design: An interactive approach* (3 edition). SAGE.

Möller, F., Jussen, I., Springer, V., Gieß, A., Schweihoff, J. C., Gelhaar, J., Guggenberger, T., & Otto, B. (2024). Industrial data ecosystems and data spaces. *Electronic Markets*, *34*(1), 41. https://doi.org/10.1007/s12525-024-00724-0

Moore, J. F. (1993). Predators and prey: A new ecology of competition. *Harvard Business Review*, *71*(3), 75–86.

Munoz-Arcentales, A., López-Pernas, S., Pozo, A., Alonso, Á., Salvachúa, J., & Huecas, G. (2020). Data Usage and Access Control in Industrial Data Spaces: Implementation Using FIWARE. *Sustainability*, *12*(9), 3885. https://doi.org/10.3390/su12093885

Nagel, L. & Lycklama, D. (2022). How to Build, Run, and Govern Data Spaces. In B. Otto, M. Ten Hompel, & S. Wrobel (Eds.), *Designing Data Spaces* (pp. 17–28). Springer International Publishing. https://doi.org/10.1007/978-3-030-93975-5_2

Oliveira, M. I. S., Barros Lima, G. D. F., & Lóscio, B. F. (2019). Investigations into Data Ecosystems: A systematic mapping study. *Knowledge and Information Systems*, *61*(2), 589–630. https://doi.org/10.1007/s10115-018-1323-6

Oliveira, M. I. S. & Lóscio, B. F. (2018). What is a data ecosystem? *Proceedings of the 19th Annual International Conference on Digital Government Research: Governance in the Data Age*, 1–9. https://doi.org/10.1145/3209281.3209335

Orlikowski, W. J. (2000). Using Technology and Constituting Structures: A Practice Lens for Studying Technology in Organizations. *Organization Science*, *11*(4), 404–428. https://doi.org/10.1287/orsc.11.4.404.14600

Otto, B. (2022). The Evolution of Data Spaces. In B. Otto, M. Ten Hompel, & S. Wrobel (Eds.), *Designing Data Spaces* (pp. 3–15). Springer International Publishing. https://doi.org/10.1007/978-3-030-93975-5_1

Otto, B., & Jarke, M. (2019). Designing a multi-sided data platform: Findings from the International Data Spaces case. *Electronic Markets*, *29*(4), 561–580. https://doi.org/10.1007/s12525-019-00362-x

Ozcan, P., & Eisenhardt, K. M. (2009). Origin of Alliance Portfolios: Entrepreneurs, Network Strategies, and Firm Performance. *Academy of Management Journal*, *52*(2), 246–279. https://doi.org/10.5465/amj.2009.37308021

Papert, M., & Pflaum, A. (2017). Development of an Ecosystem Model for the Realization of Internet of Things (IoT) Services in Supply Chain Management. *Electronic Markets*, *27*(2), 175–189. https://doi.org/10.1007/s12525-017-0251-8

Pettenpohl, H., Spiekermann, M., & Both, J. R. (2022). International Data Spaces in a Nutshell. In B. Otto, M. Ten Hompel, & S. Wrobel (Eds.), *Designing Data Spaces* (pp. 29–40). Springer International Publishing. https://doi.org/10.1007/978-3-030-93975-5_3

Porter, M. E. (1985). *Competitive advantage: Creating and sustaining superior performance* New York: Free Press.

Porter, M. E., & Millar, V. E. (1985). *How information gives you competitive advantage*. Harvard Business Review, 63, 149-160.

Pretzsch, S., Drees, H., & Rittershaus, L. (2022a). Mobility Data Space: A Secure Data Space for the Sovereign and Cross-Platform Utilization of Mobility Data. In B. Otto, M. Ten Hompel, & S. Wrobel (Eds.), *Designing Data Spaces* (pp. 343–361). New York: Springer International Publishing. https://doi.org/10.1007/978-3-030-93975-5_21

Pullmann, J., Petersen, N., Mader, C., Lohmann, S., & Kemeny, Z. (2017). Ontology-based information modelling in the industrial data space. *2017 22nd IEEE International Conference on Emerging Technologies and Factory Automation (ETFA)*, 1–8. https://doi.org/10.1109/ETFA.2017.8247688

Radzicki, M. J. (2009). System Dynamics and Its Contribution to Economics and Economic Modeling. In R. A. Meyers (Ed.), *Complex Systems in Finance and Econometrics* (pp. 727–737). New York: Springer. https://doi.org/10.1007/978-1-4419-7701-4_39

Ridder, H-G. (2017). The theory contribution of case study research designs. *Business Research*, *10*(2), 281–305. https://doi.org/10.1007/s40685-017-0045-z

Schulz, W. H., & Franck, O. (2022). The Institutional Role Model: A System-Dynamic Approach to Reduce Complexity. *International Journal of Sustainable Development and Planning*, *17*(2), 351–361. https://doi.org/10.18280/ijsdp.170201

Schulz, W. H., Joisten, N., & Arnegger, B. (2019). Development of the Institutional Role Model As a Contribution to the Implementation of Co-Operative Transport Systems. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3421107

Spiekermann, M. (2019). Data Marketplaces: Trends and Monetisation of Data Goods. *Intereconomics*, *54*(4), 208–216. https://doi.org/10.1007/s10272-019-0826-z

Steimann, F. (2000). On the representation of roles in object-oriented and conceptual modelling. *Data & Knowledge Engineering*, *35*(1), 83–106. https://doi.org/10.1016/S0169-023X(00)00023-9

Strauss, A. L., & Corbin, J. (1990). *Basics of qualitative research: Grounded theory procedures and techniques*. Thousand Oaks, CA: Sage.

Tardieu, H. (2022). Role of Gaia-X in the European Data Space Ecosystem. In B. Otto, M. Ten Hompel, & S. Wrobel (Eds.), *Designing Data Spaces* (pp. 41–59). Springer International Publishing. https://doi.org/10.1007/978-3-030-93975-5_4

Thornberg, R., & Charmaz, K. (2014). Grounded Theory and Theoretical Coding. In U. Flick, *The SAGE Handbook of Qualitative Data Analysis* (pp. 153–169). SAGE Publications, Inc. https://doi.org/10.4135/9781446282243.n11

Yin, R. K. (2013). *Case study research: Design and methods* (Fifth edition). Thousand Oak, CA: Sage.

Yoo, Y., Henfridsson, O., & Lyytinen, K. (2010). Research Commentary —The New Organizing Logic of Digital Innovation: An Agenda for Information Systems Research. *Information Systems Research*, *21*(4), 724–735. https://doi.org/10.1287/isre.1100.0322

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Corporate Governance at the Crossroads of AI

Assessing Necessity, Disruption, and Strategic Implementation

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Abstract: Artificial intelligence (AI) is changing corporate governance (CG), creating a lack of consensus among studies regarding its impact. The purpose of this article is to critically explore scholars' perspectives on AI's transformative role in CG, from one side, and suggest the necessary strategies to ensure its responsible and effective integration from another side. The authors have conducted a systematic literature review following the PRISMA flowcharts, analysed 24 indexed journal articles and conference papers using Zotero for reference management, and VOSviewer for bibliometric analysis. The findings start by a double analysis of the AI implementation in CG - 'nice-to-have' or 'must-have' versus 'disruption' or 'integration' - categorising the literature into three groups drawing for scholars: 'enhancers', 'integrators', 'pioneers' and a fourth category perceived by the authors, 'catalysts'. In addition, a set of five strategies for optimising AI use is proposed: ethical frameworks, strengthened governance, skills development, transparency and control mechanisms, and aligning AI with strategic objectives. This study aims to fill two inter-correlated research gaps: exploring how AI is perceived in governance contexts and its potential to integrate with or disrupt traditional structures and establishing a theoretical intersection between *the 'governance of AI'* and *the 'governance by AI'*.

Keywords: Artificial Intelligence (AI), Corporate Governance, Systematic Literature Review, AI Implementation Strategies.

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Introduction

The introduction of artificial intelligence (AI) represents a watershed moment in the world of corporate governance , promising enormous breakthroughs and tremendous progress. The role of AI in corporate governance must also be understood within the broader framework of the digital economy, which refers to economic activities that rely on or are significantly enhanced by digital technologies, particularly the Internet, mobile networks, and data analytics (Bukht & Heeks, 2017). Fenwick *et al.* (2019) believe that the rise of AI and big data analytics in the digital economy has prompted a re-evaluation of traditional corporate governance models, especially in platform companies like Amazon, Apple, and Google, where the traditional shareholder-primacy is no longer adequate. Instead, they require a new 'platform governance' model that aligns with their innovation-driven strategies, that use digital technologies, foster open cultures, and real-time risk management capabilities. This shift reflects the broader trend of digital transformation, that involves leveraging advanced digital technologies like big data, blockchain, and cloud computing (Al-Swidi *et al.*, 2024). As a matter of fact, scholars remain divided, some believe AI should be considered as a management tool, while others argue its integration requires new governance frameworks to address algorithmic accountability and ethical concerns.

According to, Micheler & Whaley (2020) highlight how the digital economy has accelerated the adoption of AI in compliance and monitoring functions, potentially enhancing the effectiveness of corporate governance mechanisms by making regulatory processes more efficient and precise. However, Zetzsche *et al.* (2020) caution that the increasing reliance on AI in corporate decision-making within the digital economy context also introduces new risks and challenges for governance structures, particularly in areas of data privacy, cybersecurity, and algorithmic bias. These issues are situated within a broader context where, as noted by Daidai & Tamnine (2023), the ethical and responsible use of AI becomes an imperative for companies.

In the same vein, Kalkan (2024), AI has the ability to improve decision-making processes by leveraging enhanced analytical capabilities and predictive insights. This promise of increased efficiency is supported by Abdellatif *et al.* (2023), who demonstrate that AI can refine the prediction of the firms' financial performance. However, the incorporation of AI into corporate governance raises new challenges that require the implementation of strong legislative frameworks to address rising concerns such as data privacy and algorithmic bias (Kalkan, 2024).

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Moreover, according to the World Economic Forum (2019), designing a governance system suitable for AI is particularly difficult for three main reasons: first, the diversity of ethical concerns; second, the difficulty in determining the appropriate regulatory instruments; and finally, the complex interactions between technology, economic markets, individuals, and society, as well as the environment, politics, and regulation. These issues underscore the significance of carefully considering the integration or change that AI imposes on corporate governance practices.

In light of these opportunities and challenges raised in previous studies, there is still a lack of consensus among scholars regarding AI's role, with ongoing debates about its impact on corporate governance. For the purposes of this study, this latter refers specifically to the internal mechanisms that guide corporate decision-making, such as the board of directors, ownership structures, internal control and audit systems, and risk management frameworks (Fama & Jensen, 1998; Ouchi, 1979). Our study aims to deeply explore by reviewing and synthesising the literature on 'governance by AI'. We will examine scholars' perspectives on AI's place in corporate governance, while also acknowledging the potential risks and biases of AI tools that may affect governance structures. As part of our analysis, we will propose strategies for the effective implementation of AI to mitigate these negative impacts.

To tackle this complex objective, we break it down into three questions:

- Is AI a 'nice-to-have' or a 'must-have' in corporate governance?
- Does it represent a disruption of traditional governance approaches or a complementary integration?
- What strategies and mechanisms should be implemented to leverage the benefits of AI while minimising its potential risks on governance mechanisms?

These questions arise in a context where, as highlighted by Meiryani *et al.* (2023), the use of Industry 4.0 technologies, including AI, is expected to enhance the transparency and performance of companies. However, this improvement must be accompanied by a thorough reflection on ethics and social responsibility, as advocated by Daidai & Tamnine (2023).

A systematic literature review (SLR) of recently published scientific journal articles, emerges as a relevant methodological approach to grasp the current state of knowledge on this subject, and is particularly suitable for this study because it allows for a structured, methodical approach to identifying, appraising, and synthesising existing studies. This process enables us to draw evidence from a global pool of research and to critically assess the quality and relevance of the findings in relation to our research questions (Munn *et al.*, 2018). The SLR approach helps ensure that our conclusions are based on the most reliable and comprehensive

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evidence available, offering valuable insights to inform both academic understanding and practical implementation in corporate governance (Munn *et al.*, 2018).

The remainder of this paper is structured as follows. First, the theoretical background is presented, highlighting the linkages between AI and corporate governance. This is followed by a description of the research methodology, detailing the protocol for the systematic literature review (SLR). Next, the study's findings are discussed, along with an analysis of the research results. Finally, the paper concludes by summarising the key takeaways, outlining the study's limitations, and providing recommendations for future research.

Theoretical framework

Artificial Intelligence

Artificial intelligence has evolved from a technical concept to a broader dynamic system reflecting a significant progress made in this field, that anticipated in the mid-20th Century (Casares, 2018), as according to Haenlein & Kaplan in their work *A Brief History of Artificial Intelligence: On the Past, Present, and Future of Artificial Intelligence*, stated that:

> '...the roots of AI can probably be traced back to the 1940s, specifically 1942, when the American Science Fiction writer Isaac Asimov published his short story *Runaround*. The plot of *Runaround* – a story about a robot developed by the engineers Gregory Powell and Mike Donavan (2019, p. 2)'.

Furthermore, McCarthy *et al.* (2006) defined AI as the science and engineering of making intelligent machines, emphasising its computational and programmatic nature. As AI progressed, Bostrom (2014) described AI as an artificial system capable of performing tasks that would typically require human intelligence, such as language translation, speech recognition, visual perception, decision-making, and allowing a discovery of the underscored AI's capability to replicate specific human functions, illustrating a shift toward recognising the practical applications of intelligent systems. Kaplan & Haenlein (2019) further refined this by emphasising AI's ability to interpret external data, learn from it, use it and adapt it to achieve goals and tasks.

In a more recent perspective, Russell & Norvig (2021) describe AI as the ability of a computer system capable of learning, reasoning, problem-solving, perception, and understanding language underscoring its role in governance processes. These advancements demonstrate AI's transition from a technical tool to an adaptive system that enhances corporate decision-making, transparency, and strategic foresight.

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Corporate governance

Shleifer & Vishny (1997) defined corporate governance as the ways in which suppliers of finance to corporations assure getting a return on their investment. While in more recent perspectives corporate governance encompasses all the mechanisms that serve to delineate powers and influence the decisions of leaders by defining their discretionary space (Hirigoyen & Poulain-Rehm 2017).

Subsequently, two complementary methods frame corporate governance:

- The disciplinary approach: rooted in agency theory, focuses on information asymmetry and control mechanisms aligning the interests of managers with those of shareholders (Fama & Jensen, 1983; Jensen & Meckling, 1976), and those of other stakeholders (Charreaux, 2007), while minimising agency costs.
- The cognitive approach: introduced, based on the work of Zingales (Rajan & Zingales, 2003; Zingales, 2000), further detailed and studied by Charreaux (2002, 2005), as a
- more contemporary paradigm, highlights decision-making biases, organisational learning, and value creation through innovation and knowledge management.

AI and Corporate Governance: Theoretical Linkages

At the outset, a fundamental distinction must be made between two main distinct fields of study, the 'governance of AI' and the 'governance by AI'. these domains have been examined in isolation, representing a notable gap in the literature.

The 'governance of AI', which has been the predominant focus of existing research (Bareis, 2024; Cihon *et al.*, 2021; Herrmann, 2023; McGovern *et al.*, 2022; Papyshev & Yarime, 2023; Radu, 2021), pertains the regulatory, ethical and legal frameworks that oversee AI's deployment with the objective of ensuring a responsible AI use and mitigating the risks associated to its implementation from cybersecurity to accountability and responsibility (Hanisch *et al.*, 2023).

In contrast, the 'governance by AI' - the application of AI in the corporate governance functions (Kingsly, 2024) - remains a relatively new context and an under-explored area of research. Which creates a second significant gap as there is limited understanding of how AI technologies are perceived in governance contexts and the extent to which they can redefine or seamlessly integrate with traditional governance mechanisms (board of directors, audit committees, internal controls, etc.). Addressing this gap, our study first examines how AI-driven tools are perceived by scholars.

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Beyond this, we seek to bridge the first gap by, for the first time to the best of our knowledge, establishing a theoretical intersection between the 'governance of AI' and 'governance by AI'. By doing so, we propose a strategic framework for organisations to harness AI in corporate governance while mitigating its associated risks. This dual approach not only advances academic discourse, but also highlights new gaps, inviting reflection on the need for more actionable insights to support firms in navigating the complexities of AI-driven governance.

In practice, AI is already being integrated into corporate governance through various technologies, each contributing to different governance mechanisms. The most frequently mentioned AI technologies in corporate governance are machine learning, virtual assistants, followed by predictive algorithms, graph networks, and voice assistants (Rane *et al.*, 2024; Yankovskiy, 2023). As corporate governance relies on various mechanisms to regulate corporate activities and ensure accountability, the integration of those different AI tools introduces new theoretical dimensions, fundamentally transforming and reshaping those mechanisms and decision-making frameworks.

First, AI enhances the contractual mechanisms, such as the board structure (Ma *et al.*, 2024), executive incentives and compensation (Kingsly, 2024) and internal audits and regulatory compliance systems (Cui *et al.*, 2022; Hanisch *et al.*, 2023), by improving transparency, minimising information asymmetry, and automating compliance monitoring (Hanisch *et al.*, 2023). For instance, AI-driven automation minimises administrative burdens and enhances decision-making efficiency (Kingsly, 2024).

Second, AI's capacity in vast data processing and predictive analytics supports cognitive mechanisms by reducing biases (Ma *et al.*, 2024), enabling real-time decision-making (Cui *et al.*, 2022), and optimising strategic choices (Gouiaa & Huang, 2024). AI augments cognitive governance by providing enhanced risk assessment and adaptive learning frameworks, much like the board members' learning process with AI-driven learning systems that refine governance mechanisms, added to audit committee knowledge accumulation with machine learning models that enhance risk detection, shows how AI reinforces the relationship between board capabilities, financial oversight, and decision-making by integrating automated governance alerts and adaptive monitoring frameworks, according to Shipilov *et al.* (2024).

By exploring these transformations, this study aims to provide a structured understanding of AI's evolving role in corporate governance. The insights generated will contribute to both theory and practice, offering a roadmap for organisations seeking to harness AI's benefits while addressing its governance challenges.

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Research method

To address our multidimensional issue and explore in depth how AI can be optimised to enhance corporate governance, while navigating the challenges and opportunities it presents, we have chosen a rigorous methodological approach: a systematic literature review (Tranfield *et al*., 2003).

The systematic review of the literature offers, by consequence, several advantages for our study, as in contrast to narrative review, the systematic review follows a methodical, scientific, and transparent process that seeks to reduce bias by searching the literature for relevant studies and by documenting every step of the review process (Linnenluecke *et al*., 2020).

Subsequently, it allows us to approach our issue in a holistic manner, integrating diverse perspectives from multiple disciplines and contexts. Furthermore, this methodological approach ensures scientific rigor in the collection and analysis of data, thereby reducing potential biases and increasing the reliability of our conclusions. Finally, it offers us the opportunity to identify not only current knowledge but also gaps in research, thereby paving the way for future investigations in this crucial area of corporate governance in the age of AI (Briner & Denyer, 2012).

Data sources

Our research relied on a wide range of academic and scientific databases. The main sources used include Scopus and Web of Science, recognised for their extensive coverage in management sciences and technologies. We also consulted other commercial publishers - such as SpringerLink, Taylor & Francis Group, as well as the Science Publishing Group databases - to ensure comprehensive coverage of the relevant literature.

Selection criteria

We have applied strict filters to refine our selection of articles:

- Filter by date: Only articles published between 2022 and 2024 were selected, thus ensuring the relevance and timeliness of our analysis. Our decision to focus on this timeframe is based on the publication trends observed in the Scopus ‘Analyze results’, which highlights a significant rise in scientific output starting in 2022. Scopus was chosen as the primary database for our analysis due to its broad coverage, that according to Chadegani *et al*. (2013, p. 13) ‘Scopus provides 20% more coverage than Web of Science’, making it an indispensable source for academic research. The publication trend shows a sharp increase in studies from 2022 onward, with only 10 papers in 2020 and 13 in 2021, compared to 23 in 2022, 39 in 2023, and 56 in 2024.

Given this substantial growth, earlier years had a limited number of studies, making it difficult to establish robust trends and extract meaningful insights. Therefore, given this substantial growth in research output from 2022 onward focusing on 2022-2024 ensures a comprehensive and up-to-date review of the literature (See Figure 1). In addition to this reason, we also noticed that the majority of the articles published before 2022 were discussing the public governance rather than the corporate governance.

- Type of document: Our focus has been exclusively on peer-reviewed journal articles and conference papers, ensuring a high level of academic rigor, basically articles from well ranked journals (ABS Journal Ranking, 2021).
- Languages: The articles in English have been included, allowing for an international perspective.

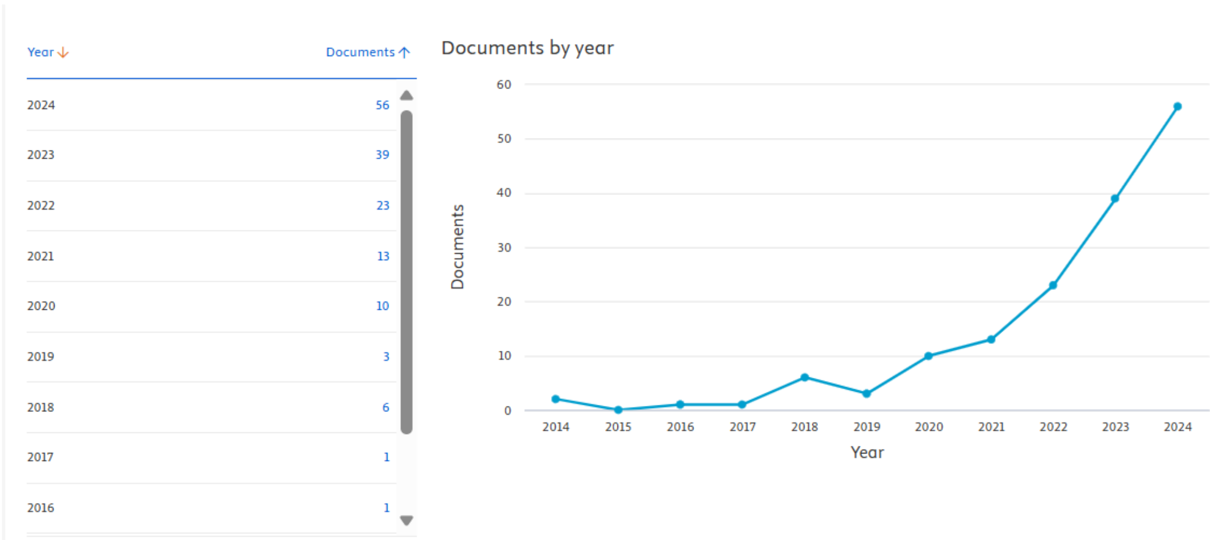

Figure 1. Trends in AI and Corporate Governance Publications (Source: Scopus Analyze results)

Research Strategy

We have developed a keyword research strategy combining the following keywords: ('Artificial Intelligence' OR 'Machine Learning' OR 'New Technologies' OR 'Technological Innovation' OR 'Digital Transformation') AND ('Corporate Governance ' OR 'Board of Directors' OR 'Corporate Performance' OR 'Artificial Governance'), with the subject area limited to Business, Management and Accounting and Social Sciences (See Figure 2).

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TITLE-ABS-KEY ("Artificial Intelligence" OR "Machine Learning" OR "New Technologies" OR "Technological Innovation" OR "Digital Transformation") AND TITLE-ABS-KEY ("Corporate Governance" OR "Board of Directors" OR "Corporate Performance" OR "Artificial Governance") AND PUBYEAR > 2021 AND PUBYEAR < 2025 AND (LIMIT-TO (OA , "all")) AND (LIMIT-TO (DOCTYPE , "cp") OR LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (SUBJAREA , "BUSI") OR LIMIT-TO (SUBJAREA , "SOCI"))

Figure 2. Database Query and Literature Search Parameters (Compiled by Authors)

Selection process

The selection process for the articles followed several rigorous steps according to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram. As Page *et al.* (2021, p. 6) state, PRISMA 'allows readers to assess the appropriateness of the methods, and therefore the trustworthiness of the findings'.

Accordingly, the first stage of the selection process involved identification, where relevant references were retrieved from three major academic databases: Scopus, which yielded 108 articles; Web of Science (WoS), which contributed 28 articles; and the aforementioned publishers, from which 11 relevant articles were collected. This initial search resulted in a total of 147 references. Following identification, the screening phase commenced, during which duplicate records and ineligible studies were removed using Zotero software. After this step, 109 unique records remained. These were then subjected to an initial assessment based on a review of their titles and abstracts to determine their relevance to the research focus (See Figure 3).

In the eligibility phase, a full-text evaluation was conducted to refine the selection further. At this stage, 38 articles were excluded due to misalignment with the research scope, primarily because their titles or abstracts did not directly relate to the study's objectives. Furthermore, 28 additional articles, which did not cover the 'governance by AI', nor the 'governance of AI', were also removed. As a result, 43 references were retained for a more in-depth review.

Finally, during the inclusion phase, a final selection process was undertaken based on the study's specific research questions. At this stage, 19 additional articles were excluded, as they did not provide sufficient insights relevant to the sub-questions of the study. Ultimately, a total

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of 24 articles were included in this systematic review, forming the foundation for the subsequent analysis and discussion.

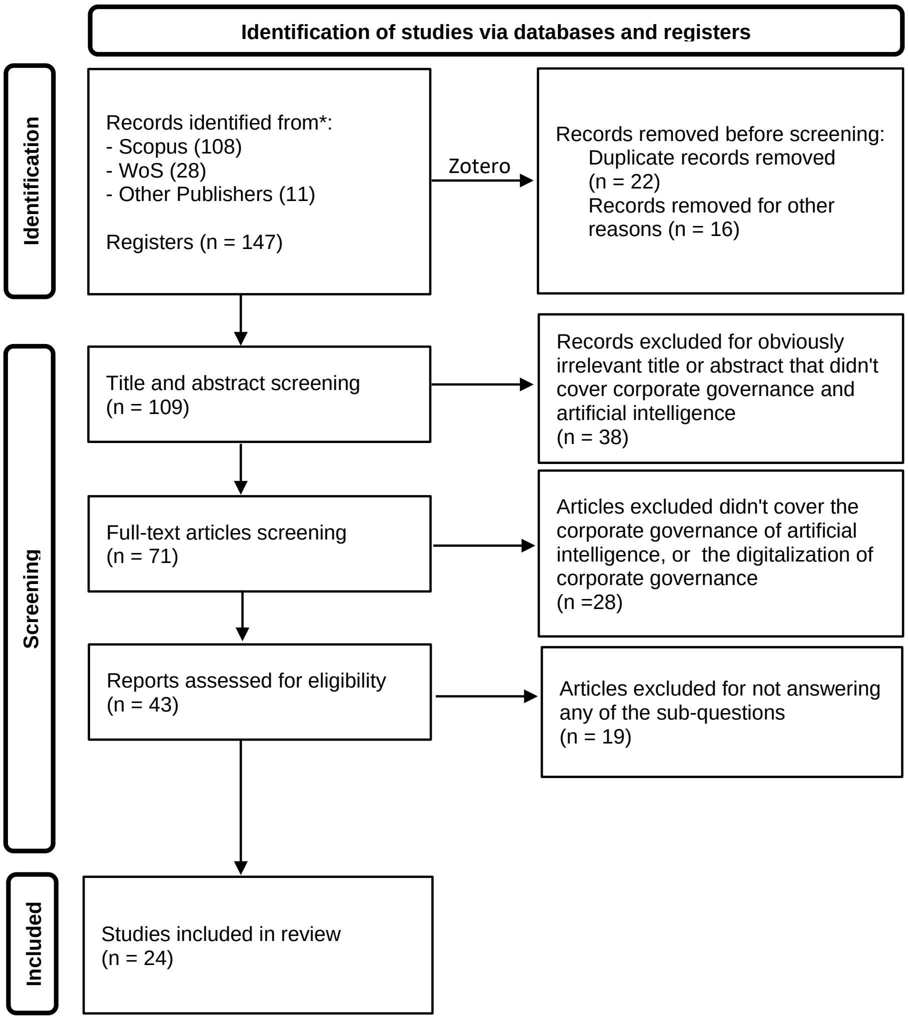

Figure 3. PRISMA Flow Diagram from Page *et al*. (2021) (Authors)

Main findings

General overview of empirical research on AI and CG

An analysis of the co-occurrence provides a structured overview of the empirical research landscape on AI and corporate governance, highlighting themes studied previously interconnections. The findings reveal that the literature is concentrated around three main research streams, AI-driven corporate governance, digital transformation, and sustainability (See Figure 4). The dominant cluster highlights AI's integration into governance frameworks, focusing on board decision-making, risk management, and corporate strategy. The presence of terms like 'board of directors' and 'firm performance' underscores AI's growing role in corporate oversight and leadership dynamics. This reflects a shift towards data-driven governance, enhancing decision-making and accountability. The second cluster links AI with digital transformation, emphasising its role in enterprise performance and operational efficiency. The limited direct connections between AI and governance transformation suggest an underexplored area in current research. And the third cluster connects AI-driven governance with sustainability and ESG strategies, particularly in emerging economies. The co-occurrence of terms like 'corporate social responsibility' and 'sustainability' indicates a growing interest in AI's ethical and regulatory implications. The thematic clusters identified in the literature reflect the evolving role of AI in corporate governance and their alignment with our research questions.

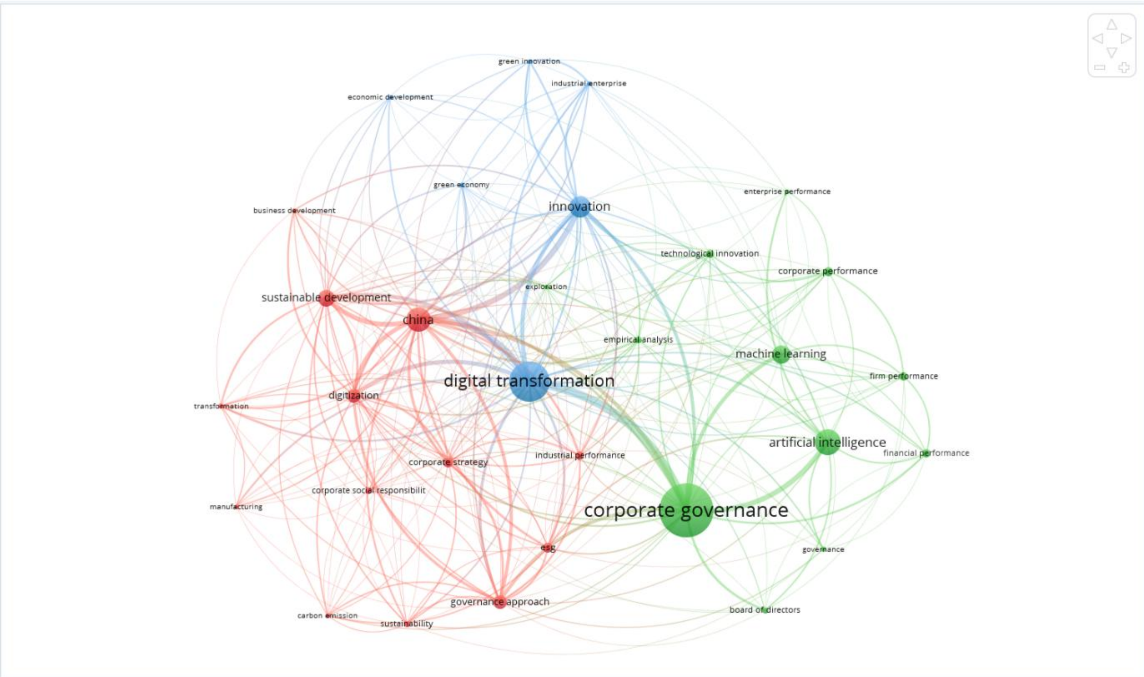

Figure 4. Keyword Co-occurrence Word Map (Source: VOSviewer)

AI: A 'nice-to-have' or a 'must-have' in corporate governance?

One of the major points of divergence in the literature concerns the question of whether AI should be considered as a simple optional asset or as an element that has become indispensable in governance practices. On the one hand, and especially between the years 2022 and 2023, several authors see AI as an auxiliary tool, allowing to improve decision-making processes, without being an essential component of governance (for example, in contexts where the complexity of decisions does not justify complete automation) (Bruner, 2022; Gow *et al.*, 2022; Novelli *et al.*, 2023). These studies highlight AI as a facilitator of innovation and efficiency, but often with a view to complementing human tools and processes.

On the other hand, a growing trend considers AI as an essential element for modern businesses. This perspective is particularly reflected in the 2024 work on digital transformation, where AI is seen as a necessity to ensure competitiveness, transparency and speed of decisions in the era of big data. For these researchers, AI is becoming an essential lever, and no longer optional, to ensure efficient governance in the face of complex and uncertain environments (Albalawee & Fahoum, 2024; Kampmann, 2024), which is aligned with the results of Cihon *et al.* (2021) and Hilb (2020) (See Table 1).

AI: A disruption or a simple integration of traditional approaches to governance?

The second key point revealed by this literature review concerns the impact of AI on pre-existing governance approaches. The central question here is whether AI marks a real break with traditional governance models or whether it simply fits as a new tool within already established frameworks.

Only a limited number of studies consider AI as a transformative force that fundamentally challenges traditional paradigms of corporate governance . By automating part of the decision-making processes, AI redefines the role of boards of directors, changes the relationships between shareholders and managers, and complicates the notions of responsibility and ethics (Cui *et al.*, 2022; Kampmann, 2024). This approach emphasises the idea that AI ushers in a new era of governance, characterised by the autonomy of intelligent systems and data-driven decision-making.

Most authors, on the other hand, perceive AI as a simple extension of traditional governance tools. For these researchers, AI is not a disruption, but rather a complementary integration, serving to improve existing practices without fundamentally transforming governance principles (Albalawee & Fahoum, 2024; Bruner, 2022; Eroğlu & Karatepe Kaya, 2022; Khan *et al.*, 2022; Praful, 2023; Wang *et al.*, 2023). It allows, for example, to increase transparency, refine financial predictions or improve risk assessment, but it remains subordinate to human decision-making frameworks (See Table 1).

We decided that whether a study perceives AI as a 'nice-to-have' or 'must-have', by the following vocabulary and terms like 'essential', 'indispensable,' 'crucial', 'necessary', and 'key mediator' suggest AI is a **must-have**, while terms like 'valuable', 'unlikely to replace', and 'not yet indispensable' suggest AI is a **nice-to-have**.

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Table 1. Comparative Analysis Of 14/24 Studies on AI In Corporate Governance (Authors' Compilation)

Author(s)	**Journal**	**AI: desirable or essential asset?**	**Disruption or complementary integration?**
Eroğlu & Karatepe Kaya (2022)	European Business Organization Law Review	Must-have	While AI enhances efficiency, it supports rather than replaces human decision-making.
Bruner (2022)	Journal of Corporate Law Studies	Nice-to-have	AI enhances oversight and compliance but cannot replace the nuanced decision-making of human boards.
Cui *et al.* (2022)	Frontiers in Environmental Science	Must-have	AI transforms governance methods by integrating machine learning and neural networks.
Khan *et al.* (2022)	Frontiers in Environmental Science	Must-have	It enhances firms' ability to monitor and control performance while complementing traditional methods.
Shen (2022)	Frontiers in Psychology	Must-have	Complementary integration: AI improves existing governance systems by using techniques such as transfer learning to balance rules and decision-making.
Meiryani *et al.* (2023)	Foresight and STI Governance	Nice-to-have	AI adoption varies by organisation size and industry, suggesting a gradual integration rather than a radical transformation of governance structures.
Novelli *et al.* (2023)	AI & Society	Nice-to-have	AI strengthens existing processes by improving monitoring and reporting without replacing traditional methods.
Praful (2023)	American Journal of Artificial Intelligence	Must-have	While AI supports informed decision-making and adaptability, it complements rather than replaces traditional governance.
Wang *et al.* (2023)	Applied Sciences (Switzerland)	Must-have	AI improves transparency and efficiency in management while supporting sustainable development, serving as a complementary integration.
Ziniuk *et al.* (2022)	Financial and Credit Activity: Problems of Theory and Practice	Must-have	Digital transformation in CG enhances existing processes and creates new ones, ensuring effective management and stakeholder interaction.
Rane *et al.* (2024)	Studies in Economics and Business Relations	Must-have	AI's ability to quickly analyse financial data and automate risk management and compliance signals a shift in governance paradigms
Ma *et al.* (2024)	Heliyon	Must-have	AI strengthens CG by enhancing transparency and decision-making.

Kalkan (2024)	Journal of Corporate Finance Research	Must-have	The study frames AI as an evolving force that reshapes governance rather than replacing traditional structures entirely.
Albalawee & Fahoum (2024)	Cogent Business & Management	Must-have	AI helps navigate the challenges of digital transformation while respecting existing legal frameworks and improving governance practices.

Based on the analysis of selected articles on AI and corporate governance, and taking into account the diverse perspectives and suggestions from the authors in this field, we propose a categorisation derived from this dual analysis.

This taxonomy, developed from the observed divergences and convergences between the selected studies, offers a conceptual framework to better understand the varying perspectives on the impact of AI on corporate governance (See Figure 5). It categorises AI's role as either a 'must-have' or 'nice-to-have' in governance and evaluates whether it is seen as a disruption to traditional governance mechanisms or simply an integration.

- The first category, **Enhancers**, considers AI as a 'nice-to-have' tool, that integrates harmoniously into existing approaches to corporate governance. Referred to as 'improvers', these scholars consider AI to be a potentially valuable, though non-essential, technology. They believe AI can optimise governance processes without fundamentally changing them. For these authors, AI serves as an auxiliary tool designed to enhance efficiency, while traditional governance models remain fundamentally intact. Their focus is on incremental improvements rather than systemic transformations, with an emphasis on maintaining the human element in decision-making, where AI plays a supportive role (Bruner, 2022; Meiryani *et al.*, 2023; Gow *et al.*, 2022; Novelli *et al.*, 2023).
- The second, and the more widely held, category is **Integrators**, perceives AI as a 'must-have', a crucial element for modern corporate governance. However, they believe that its use fits into the framework of traditional approaches to governance, improving and strengthening them without fundamentally disrupting them. To sum up, the authors of this category, referred to as 'adapters', believe that integrating AI as essential to gaining a competitive edge, encourage major but limited adjustments to governance procedure, concentrate on integrating AI into current structures in a smooth manner, and they emphasise the importance of board members and executives having an understanding of AI (Albalawee & Fahoum, 2024; Eroğlu & Karatepe Kaya, 2022; Kalkan, 2024; Khan *et al.*, 2022; Ma *et al.*, 2024; Praful, 2023; Shen, 2022; Wang *et al.*, 2023).
- The third category, **Pioneers**, also finds AI as a 'must-have' but takes a more radical stance, viewing its application as a complete overhaul of governance models. These 'reinventors' believe AI will fundamentally redefine the way companies are run and controlled.

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Lastly, this category of authors advocates for AI-centric governance models, while they envision AI taking on key decision-making roles, propose radical restructuring of board compositions and functions, and they emphasise the need for new regulatory frameworks to accommodate AI governance (Cui *et al.*, 2022; Rane *et al.*, 2024; Ziniuk *et al.*, 2022).

This refined categorisation offers a more nuanced view of the different perspectives on the impact of AI in corporate governance. It sheds light not only on the degree of importance given to AI (nice-to-have versus must-have), but also on the depth of its perceived impact on existing internal governance structures (integration versus disruption). Notably, no authors have considered AI as a nice-to-have for corporate governance with a strong disruption with old corporate governance approaches models. We introduce a new category, here, **Catalysts**, for whom artificial intelligence is viewed as a 'nice-to-have' technology that has the power to drastically alter and upend established inner corporate governance structures. Artificial intelligence (AI) can spur innovation and fresh perspectives on governance without being a necessary prerequisite.

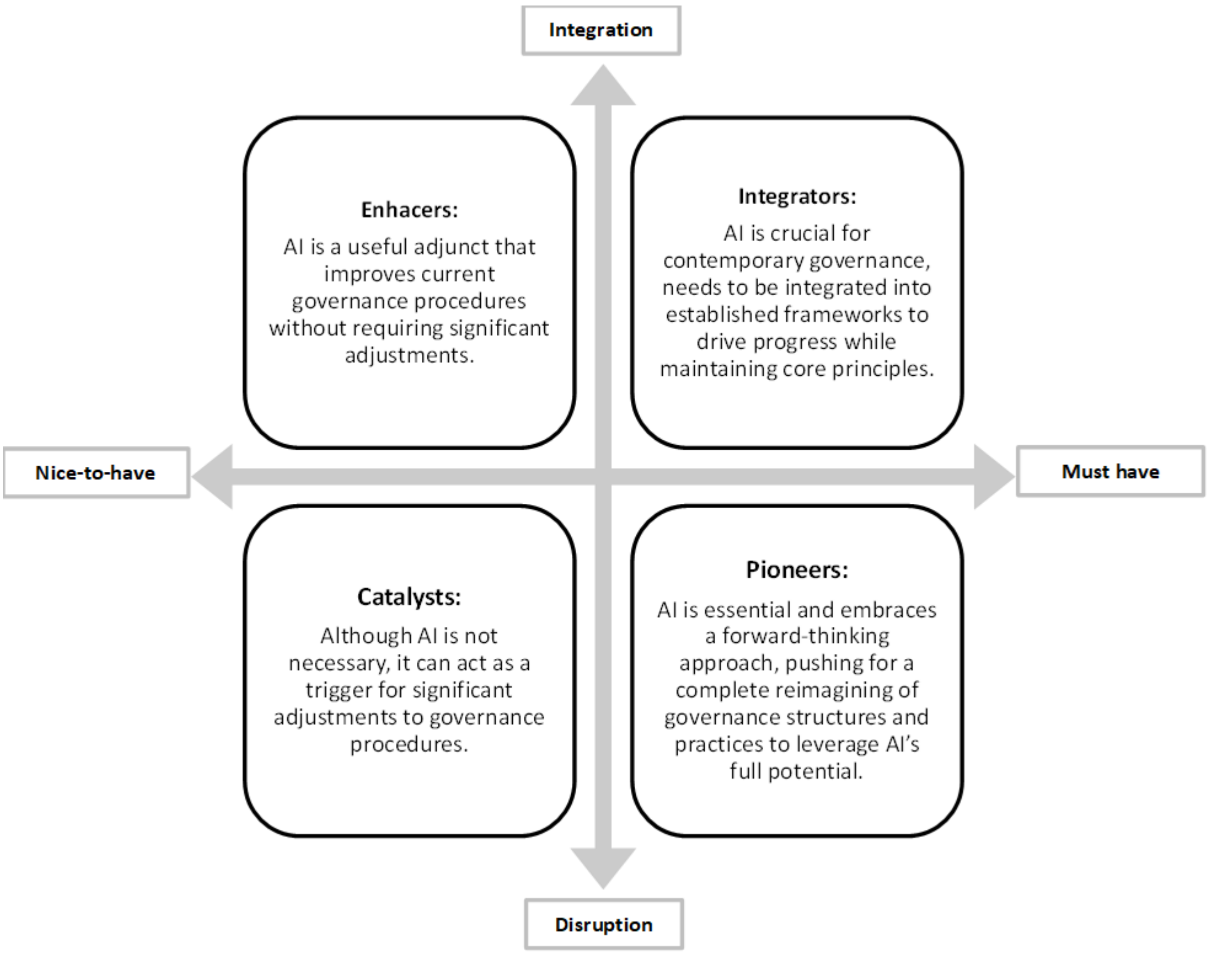

Figure 5. Categorisation Matrix of Perspectives on AI Integration in Corporate Governance (Authors' Contribution)

Overall, this approach provides a better understanding of the current issues and debates around AI in corporate governance, highlighting the different visions of its role and transformative potential. It thus offers a richer framework to analyse and discuss the future implications of AI in this field.

A set of strategies for AI governance optimisation

The integration of artificial intelligence (AI) into corporate governance represents both a major opportunity and a complex challenge. This governance must, therefore, be supported by continuous monitoring mechanisms of AI systems, as suggested by Kalkan (2024), to ensure their alignment with business objectives and societal values. This is why he advocates the redefinition of governance models to include ethical and transparency considerations and recommends the adoption of transparent practices in the use of AI.

Recently, several studies (Abdellatif *et al.*, 2023; Ali *et al.*, 2023; Binh, 2024; Daidai & Tamnine, 2023; Meiryani *et al.*, 2023; Simion & Kelp, 2023; Wang *et al.*, 2023) have proposed strategies and mechanisms aimed at optimising the benefits of AI while mitigating its potential risks. These recommendations are structured around five interdependent axes, forming a holistic framework for responsible and effective 'governance of AI', presented as follows:

1) Establishing a robust ethical framework: At the heart of any AI integration strategy is the need to establish a robust ethical framework. This involves developing clear policies and ethical guidelines for the use of AI, aligned with corporate values and applicable regulations (Ali *et al.*, 2023; Simion & Kelp, 2023). This ethical framework serves as the foundation for all other AI-related initiatives and decisions within the organization (Herrmann, 2023; Kingsly, 2024).
2) Strengthening governance and oversight structures: To ensure that the ethical framework is effectively implemented, it is crucial to establish appropriate governance and oversight structures, 'The stronger the individual board characteristics, the more attention it will pay to the development of AI, and the stronger its promotion effect on innovative activities. Vice versa' (Gouiaa & Huang, 2024, p. 45). This includes establishing dedicated AI oversight committees composed of multidisciplinary experts (Wang *et al.*, 2023), as well as strengthening the role of independent boards of directors (Binh, 2024). These structures play a key role in the continuous assessment of the ethical and operational impacts of AI, thus ensuring coherence between established policies and their practical application.
3) Skills development and awareness: The effectiveness of the ethical framework and governance structures largely depends on the understanding and buy-in of all

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stakeholders. This is why training and awareness-raising of employees and managers on the implications of AI are essential (Ali *et al.*, 2023; Binh, 2024). These continuous training programs must cover not only the technical aspects of AI, but also its ethical and operational implications, thus creating an organisational culture aware of the challenges of AI.

4) Implementation of transparency and control mechanisms: To complete this system, it is necessary to put in place concrete transparency and control mechanisms. This involves adopting audit and control technologies specific to AI systems, using technologies such as blockchain to ensure transparency of transactions (Wang *et al.*, 2023), and conducting regular assessments of ethical, operational, and strategic risks (Binh, 2024). These mechanisms not only help detect and correct potential deviations but also strengthen stakeholders' trust in the company's use of AI.
5) Strategic alignment and value creation: The use of AI must be aligned with the company's strategic objectives. Daidai & Tamnine (2023) highlight the potential of AI to improve efficiency and decision-making, while Abdellatif *et al.* (2023) highlight the need for digital transformation to remain competitive. Finally, Meiryani *et al.* (2023) add an important dimension by advocating the integration of Corporate Social Responsibility (CSR) and sustainable development practices into the use of AI. This approach not only optimises the benefits of AI, but also ensures that its use is ethical and beneficial to society as a whole.

The interconnection of these five axes creates an AI governance ecosystem where each element reinforces the others. The ethical framework guides the governance structures, which in turn oversee the implementation of policies. Training and awareness-raising ensure that all actors understand and adhere to these principles, while transparency and control mechanisms allow the effectiveness of the entire system to be verified and adjusted as needed. By adopting this integrated approach, companies can not only optimise the benefits of AI in their governance, but also build a sustainable and responsible model of AI use, aligned with their values and long-term objectives.

Conclusion/Recommendations

This systematic review of the literature on the impact of artificial intelligence (AI) in corporate governance has revealed a complex and rapidly evolving landscape. Our findings highlight the diverse perspectives on the role and importance of AI in modern governance practices.

First, the perception of AI in governance reveals a spectrum of opinions ranging from AI as a mere 'nice-to-have' enhancement tool to a now 'must-have' element for effective governance in the digital age.

Second, opinions diverge as to whether AI represents a fundamental break with existing governance models or whether it fits as a complementary tool within established frameworks.

This first dual analysis allowed us to propose a taxonomy of the authors' perspectives (Bruner, 2022; Cui *et al*., 2022; Eroğlu & Karatepe Kaya, 2022; Khan *et al*., 2022) - '**Enhancers**', '**Integrators**', and '**Pioneers**'. However, we introduce a fourth category**, 'Catalysts',** as our own conceptual contribution. This category arises from our reflection on an inherent contradiction: it would be inconsistent for an author to portray AI as merely an incremental tool while simultaneously arguing for its disruptive impact on corporate governance structures. Finally, it was crucial to define some strategies for implementing AI in corporate governance practices, in order to benefit from its operational optimisation while being wary of potential risks. The study highlighted the importance of establishing, first, a robust ethical framework (Simion & Kelp, 2023), second, strengthened governance structures (Binh, 2024), third, a training and skills development program (Ali *et al*., 2023), and fourth, transparency and control mechanisms for an optimal and responsible use of AI (Binh, 2024; McGovern *et al*., 2022).

The study proposes that companies must navigate between optimising their operations through AI and managing the potential risks associated with its use. The diversity of perspectives identified underscores the need for a nuanced and adaptive approach. Organisations must assess their own context and objectives to determine the optimal place of AI in their governance, whether it is an incremental improvement or a radical transformation. In addition to these research implications, several research avenues emerge to deepen our understanding, including empirical studies on the long-term impact of AI on corporate performance and ethics, comparative analysis of emerging regulatory frameworks for AI governance, and exploration of industry-specific challenges in adopting AI for governance.

Finally, as with any research endeavour, this study has certain limitations. First, the findings are primarily theoretical, as they are based on a literature review rather than empirical validation. Second, the scope of the study is influenced by the time frame of the selected literature, which may exclude some important studies prior to 2022. Third, the inclusion and exclusion criteria for article selection may have shaped the scope of the review and, consequently, its conclusions. In conclusion, although this study provides an important theoretical basis, further research is crucial to empirically validate these results and develop practical strategies for corporate governance in the era of Artificial Intelligence.

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References

Abdellatif, E. M., Saleh, S. A. F., & Hamed, H. N. (2023). Corporate Financial Performance Prediction Using Artificial Intelligence Techniques. In Magdi, D., El-Fetouh, A.A., Mamdouh, M., Joshi, A. (Eds.) *Green Sustainability: Towards Innovative Digital Transformation. ITAF 2023. Lecture Notes in Networks and Systems*, *753*, Singapore: Springer. Scopus. https://doi.org/10.1007/978-981-99-4764-5_3

ABS Journal Ranking 2021. (n.d.). Journal Ranking Portal. https://journalranking.org/

Albalawee, N. & Fahoum, A. A. (2024). A novel legal analysis of Jordanian corporate governance legislation in the age of artificial intelligence. *Cogent Business and Management*, *11*(1). Scopus. https://doi.org/10.1080/23311975.2023.2297465

Ali, K., Alzaidi, M., Al-Fraihat, D., & Elamir, A. M. (2023). Artificial Intelligence: Benefits, Application, Ethical Issues, and Organizational Responses. In Nagar, A.K., Singh Jat, D., Mishra, D.K., Joshi, A. (Eds.) *Intelligent Sustainable Systems. Lecture Notes in Networks and Systems*, *578*. Singapore: Springer. Scopus. https://doi.org/10.1007/978-981-19-7660-5_62

Al-Swidi, A. K., Al-Hakimi, M. A., Al Koliby, I. S., Hasan, M. B., & Abdul-Talib, A.-N. (2024). The role of digital transformation in boosting CSR-driven green innovation among Yemeni manufacturing SMEs. *Discover Sustainability*, *5*(1). Scopus. https://doi.org/10.1007/s43621-024-00506-w

Bareis, J. (2024). The trustification of AI. Disclosing the bridging pillars that tie trust and AI together. *Big Data & Society*, *11*(2). https://doi.org/10.1177/20539517241249430

Binh, N. T. T. (2024). An application of artificial neural networks in corporate social responsibility decision making. *Intelligent Systems in Accounting, Finance and Management*, *31*(1). Scopus. https://doi.org/10.1002/isaf.1542

Bostrom, N. (2014). Superintelligence: Paths, Dangers, Strategies. Oxford University Press.

Briner, R. B., & Denyer, D. (2012). Systematic review and evidence synthesis as a practice and scholarship tool. In The Oxford handbook of evidence-based management (pp. 112–129). Oxford University Press.

Bruner, C. M. (2022). Artificially intelligent boards and the future of Delaware corporate law. *Journal of Corporate Law Studies*, *22*(2), 783–805. Scopus. https://doi.org/10.1080/14735970.2022.2153965

Bukht, R., & Heeks, R. (2017). Defining, Conceptualising and Measuring the Digital Economy. https://research.manchester.ac.uk/en/publications/defining-conceptualising-and-measuring-the-digital-economy

Casares, A. P. (2018). The brain of the future and the viability of democratic governance: The role of artificial intelligence, cognitive machines, and viable systems. *Futures*, *103*, 5–16. https://doi.org/10.1016/j.futures.2018.05.002

Chadegani, A. A., Salehi, H., Yunus, M. M., Farhadi, H., Fooladi, M., Farhadi, M., & Ebrahim, N. A. (2013). A Comparison between Two Main Academic Literature Collections: Web of Science and Scopus Databases. *Asian Social Science*, *9*(5), p18. https://doi.org/10.5539/ass.v9n5p18

Charreaux, G. (2002). L'actionnaire Comme Apporteur de Ressources Cognitives. *Revue Française de Gestion*, *141*(5), 77-107. https://www.cairn.info/revue-francaise-de-gestion-2002-5-page-77.htm

Charreaux, G. (2005). Pour une gouvernance d'entreprise « comportementale ». Une réflexion exploratoire... *Revue Française de Gestion*, *31*(157), 215–238. https://doi.org/10.3166/rfg.157.215-238

Charreaux, G. (2007). La valeur partenariale: Vers une mesure opérationnelle...: Comptabilité Contrôle Audit, *Tome 13*(1), 7–45. https://doi.org/10.3917/cca.131.0007

Cihon, P., Schuett, J., & Baum, S. D. (2021). corporate governance of artificial intelligence in the public interest. *Information (Switzerland)*, *12*(7). Scopus. https://doi.org/10.3390/info12070275

Cui, X., Xu, B., & Razzaq, A. (2022). Can Application of Artificial Intelligence in Enterprises Promote the Corporate governance? *Frontiers in Environmental Science*, *10*. Scopus. https://doi.org/10.3389/fenvs.2022.944467

Daidai, F., & Tamnine, L. (2023). Artificial intelligence and corporate governance. In Koranteng F.N., Baghaei N., & Gram-Hansen S.B. (Eds.), *CEUR Workshop Proceedings*. *3474*. 18th International Conference on Persuasive Technology, Eindhoven, Netherlands, 19-21 April 2023. Scopus. https://www.scopus.com/inward/record.uri?eid=2-s2.0-85173563256&partnerID=40&md5=cf630a302cd1855504f9f619de30d3f5

Eroğlu, M., & Karatepe Kaya, M. (2022). Impact of Artificial Intelligence on Corporate Board Diversity Policies and Regulations. *European Business Organization Law Review*, *23*(3), 541–572. Scopus. https://doi.org/10.1007/s40804-022-00251-5

Fama, E. F., & Jensen, M. C. (1983). Agency Problems and Residual Claims. *The Journal of Law and Economics*, *26*(2), 327–349. https://doi.org/10.1086/467038

Fama, E. F., & Jensen, M. C. (1998). Separation of Ownership and Control. SSRN Scholarly Paper 94034. https://doi.org/10.2139/ssrn.94034

Fenwick, M., McCahery, J. A., & Vermeulen, E. P. M. (2019). The End of 'Corporate' Governance: Hello 'Platform' Governance. *European Business Organization Law Review*, *20*(1), 171–199. https://doi.org/10.1007/s40804-019-00137-z

Gouiaa, R., & Huang, R. (2024). How do corporate governance , artificial intelligence, and innovation interact? Findings from different industries. *Risk Governance and Control: Financial Markets and Institutions*, *14*(1), 35–52. Scopus. https://doi.org/10.22495/rgcv14i1p3

Gow, I. D., Larcker, D. F., & Zakolyukina, A. A. (2022). How Important is Corporate governance? Evidence from Machine Learning. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.4231644

Haenlein, M., & Kaplan, A. (2019). A Brief History of Artificial Intelligence: On the Past, Present, and Future of Artificial Intelligence. *California Management Review*, *61*(4), 5–14. https://doi.org/10.1177/0008125619864925

Hanisch, M., Goldsby, C. M., Fabian, N. E., & Oehmichen, J. (2023). Digital governance: A conceptual framework and research agenda. *Journal of Business Research*, *162*. Scopus. https://doi.org/10.1016/j.jbusres.2023.113777

Herrmann, H. (2023). What's next for responsible artificial intelligence: A way forward through responsible innovation. *Heliyon*, *9*(3). https://doi.org/10.1016/j.heliyon.2023.e14379

Hilb, M. (2020). Toward artificial governance? The role of artificial intelligence in shaping the future of corporate governance. *Journal of Management and Governance*, *24*(4), 851–870. https://doi.org/10.1007/s10997-020-09519-9

Hirigoyen, G., & Poulain-Rehm, T. (2017). Approche comparative des modèles de gouvernance: Une étude empirique. *Revue Française de Gestion*, *43*(265), 107–129. https://doi.org/10.3166/rfg.2017.00144

Jensen, M. C., & Meckling, W. H. (1976). Theory of the Firm: Managerial Behaviour, Agency Costs and Ownership Structure. SSRN Scholarly Paper 94043. https://doi.org/10.2139/ssrn.94043

Kalkan, G. (2024). The Impact of Artificial Intelligence on Corporate governance. *Journal of Corporate Finance Research*, *18*(2), 17–25. Scopus. https://doi.org/10.17323/j.jcfr.2073-0438.18.2.2024.17-25

Kampmann, D. (2024). Venture capital, the fetish of artificial intelligence, and the contradictions of making intangible assets. *Economy and Society*, *53*(1), 39–66. https://doi.org/10.1080/03085147.2023.2294602

Kaplan, A., & Haenlein, M. (2019). Siri, Siri, in my hand: Who's the fairest in the land? On the interpretations, illustrations, and implications of artificial intelligence. *Business Horizons*, *62*(1), 15–25. https://doi.org/10.1016/j.bushor.2018.08.004

Khan, M. A., Mazliham, M. S., Alam, M. M., Aman, N., Malik, S., Urooj, S. F., & Taj, T. (2022). An empirical mediation analysis of technological innovation based on artificial intelligence in the relationship between economic development and corporate governance mechanism. *Frontiers in Environmental Science*, *10*. Scopus. https://doi.org/10.3389/fenvs.2022.999096

Kingsly, K. M. (2024, October 2). The Intersection of Corporate Governance and Artificial Intelligence. https://doi.org/10.2139/ssrn.4974386

Linnenluecke, M. K., Marrone, M., & Singh, A. K. (2020). Conducting systematic literature reviews and bibliometric analyses. *Australian Journal of Management*, *45*(2), 175–194. https://doi.org/10.1177/0312896219877678

Ma, Y., Binti A. Rahim, N. S., Bt Panatik, S. A., & Li, R. (2024). Corporate governance , technological innovation, and corporate performance: Evidence from China. *Heliyon*, *10*(11). Scopus. https://doi.org/10.1016/j.heliyon.2024.e31459

McCarthy, J., Minsky, M. L., Rochester, N., & Shannon, C. E. (2006). A Proposal for the Dartmouth Summer Research Project on Artificial Intelligence, August 31, 1955. *AI Magazine*, *27*(4), Article 4. https://doi.org/10.1609/aimag.v27i4.1904

McGovern, A., Ebert-Uphoff, I., Gagne, D., & Bostrom, A. (2022). Why we need to focus on developing ethical, responsible, and trustworthy artificial intelligence approaches for environmental science. *Environmental Data Science*, *1*. https://doi.org/10.1017/eds.2022.5

Meiryani, M., Warganegara, D. L., & Andini, V. (2023). Big Data, Machine Learning, Artificial Intelligence and Blockchain in Corporate governance . *Foresight and STI Governance*, *17*(4), 69–78. Scopus. https://doi.org/10.17323/2500-2597.2023.4.69.78

Micheler, E., & Whaley, A. (2020). Regulatory Technology: Replacing Law with Computer Code. *European Business Organization Law Review*, *21*(2), 349–377. https://doi.org/10.1007/s40804-019-00151-1

Munn, Z., Peters, M. D. J., Stern, C., Tufanaru, C., McArthur, A., & Aromataris, E. (2018). Systematic review or scoping review? Guidance for authors when choosing between a systematic or scoping review approach. *BMC Medical Research Methodology*, *18*(1), 143. https://doi.org/10.1186/s12874-018-0611-x

Munn, Z., Stern, C., Aromataris, E., Lockwood, C., & Jordan, Z. (2018). What kind of systematic review should I conduct? A proposed typology and guidance for systematic reviewers in the medical and health sciences. *BMC Medical Research Methodology*, *18*(1), 5. https://doi.org/10.1186/s12874-017-0468-4

Novelli, C., Taddeo, M., & Floridi, L. (2023). Accountability in artificial intelligence: What it is and how it works. *AI & Society*, *39*, 1871–1882. https://doi.org/10.1007/s00146-023-01635-y

Ouchi, W. G. (1979). A Conceptual Framework for the Design of Organizational Control Mechanisms. *Management Science*, *25*(9), 833–848. http://links.jstor.org/sici?sici=0025-1909%28197909%2925%3A9%3C833%3AACFFTD%3E2.0.CO%3B2-L

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., … Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ*, 71. https://doi.org/10.1136/bmj.n71

Papyshev, G., & Yarime, M. (2023). The state's role in governing artificial intelligence: Development, control, and promotion through national strategies. *Policy Design And Practice*, *6*(1), 79–102. https://doi.org/10.1080/25741292.2022.2162252

Praful Bharadiya, J. (2023). A Comparative Study of Business Intelligence and Artificial Intelligence with Big Data Analytics. *American Journal of Artificial Intelligence*, *7*(1), 24-30. https://doi.org/10.11648/j.ajai.20230701.14

Radu, R. (2021). Steering the governance of artificial intelligence: National strategies in perspective. *Policy And Society*, *40*(2), 178–193. https://doi.org/10.1080/14494035.2021.1929728

Rajan, R. G., & Zingales, L. (2003). The great reversals: The politics of financial development in the twentieth century. *Journal of Financial Economics*, *69*(1), 5–50. Scopus. https://doi.org/10.1016/S0304-405X(03)00125-9

Rane, N. L., Choudhary, S. P., & Rane, J. (2024). Artificial Intelligence-driven corporate finance: Enhancing efficiency and decision-making through machine learning, natural language processing, and robotic process automation in corporate governance and sustainability. *Studies in Economics and Business Relations*, *5*(2), 1–22. https://doi.org/10.48185/sebr.v5i2.1050

Russell, S., & Norvig, P. (2021). *Artificial Intelligence: A Modern Approach*, Global Edition. Pearson Higher Ed.

Shen, W. (2022). Analysis of the application of artificial intelligence technology in the protection of corporate governance rights and interests. *Frontiers in Psychology*, *13*. Scopus. https://doi.org/10.3389/fpsyg.2022.966689

Shipilov, A., Ahn, Y., Greve, H., & Rowley, T. (2024). The impact of governance practices on firm outcomes: A machine-learning exploration. *Journal of Organization Design*, *13*(2), 45–64. https://doi.org/10.1007/s41469-024-00165-1

Shleifer, A., & Vishny, R. W. (1997). A Survey of Corporate governance. *The Journal of Finance*, *52*(2), 737–783. https://doi.org/10.1111/j.1540-6261.1997.tb04820.x

Simion, M., & Kelp, C. (2023). Trustworthy artificial intelligence. *Asian Journal of Philosophy*, *2*(1), 8. https://doi.org/10.1007/s44204-023-00063-5

Tranfield, D., Denyer, D., & Smart, P. (2003). Towards a Methodology for Developing Evidence-Informed Management Knowledge by Means of Systematic Review. *British Journal of Management*, *14*(3), 207–222. https://doi.org/10.1111/1467-8551.00375

Wang, J., Song, Z., & Xue, L. (2023). Digital Technology for Good: Path and Influence—Based on the Study of ESG Performance of Listed Companies in China. *Applied Sciences (Switzerland)*, *13*(5). Scopus. https://doi.org/10.3390/app13052862

World Economic Forum. (2019). *Moving First on AI Has Competitive Advantages and Risks, New Report Helps Navigate*. https://www.weforum.org/press/2019/10/moving-first-on-ai-has-competitive-advantages-and-risks-new-report-helps-navigate/

Yankovskiy, R. M. (2023). Introduction of Information Technologies and Artificial Intelligence in Corporate Governance Practices in Russia: A Quantitative Study. SSRN Scholarly Paper 4652653. Social Science Research Network. https://doi.org/10.2139/ssrn.4652653

Zetzsche, D., Arner, D., Buckley, R. P., & Tang, B. W. (2020, February 1). Artificial Intelligence in Finance: Putting the Human in the Loop. CFTE Academic Paper Series: Centre for Finance, Technology and Entrepreneurship, no. 1., University of Hong Kong Faculty of Law Research Paper No. 2020/006. https://ssrn.com/abstract=353171

Zingales, L. (2000). In search of new foundations. *Journal of Finance*, *55*(4), 1623–1653. Scopus. https://doi.org/10.1111/0022-1082.00262

Ziniuk, M., Dyeyeva, N., Bogatyrova, K., Melnychenko, S., Fayvishenko, D., & Shevchun, M. (2022). Digital transformation of corporate governance . *Financial and Credit*

Activity: Problems of Theory and Practice, *5*(46), 300–310. Scopus. https://doi.org/10.55643/fcaptp.5.46.2022.3807

Integration of Non-Terrestrial Network for 5G IoT and Future 6G

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Abstract: The exponential growth of the Internet of Things (IoT) has spurred the need for robust and extensive connectivity solutions. In response to the market and use-case requirements, the Third Generation Partnership Project (3GPP) introduced Narrowband IoT (NB-IoT). The latest NB-IoT integration with Non-Terrestrial Network (NTN) aims to bridge the coverage gaps in challenging terrains and address capacity issues in dense urban environments through the utilisation of satellites and Unmanned Aerial Vehicles (UAVs). This research paper explores the potential of NTN systems to complement and enhance the capabilities of 5G NB-IoT and 6G technologies. Through a combination of academic research and simulation, it seeks to evaluate the advantages of NTN, such as extended coverage and improved signal quality, for massive IoT device connectivity. Our simulation results demonstrate a trade-off between coverage and network capacity: while higher UAV altitudes provide extensive coverage by reaching more receivers, they also suffer from reduced signal strength and capacity due to increased path loss. This paper provides an overview of technical specifications and challenges related to NB-IoT and NTN, an assessment of NB-IoT NTN performance in a real-world scenario, and an analytical framework with simplified graphical representations for evaluating NTN integration into NB-IoT.

Keywords: NB-IoT, Non-Terrestrial Network, NTN, UAV, Satellite

Introduction

Recent years have witnessed an explosive growth in Internet of Things (IoT) services, with a projected global connection of 35 billion IoT devices by 2028 (Ericsson, n.d.). While the mobile industry was considered late in the IoT market compared to other Low-Power Wide

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Area Network (LPWAN) technologies, such as Sigfox and LoRaWAN, the standardization of LTE-M and Narrowband Internet of Things (NB-IoT) in 2016 by the 3rd Generation Partnership Project (3GPP) ensued their rapid growth, due to its reliable licensed spectrum and ease of deployment. According to the latest Ericsson mobility report, 124 service providers globally have launched NB-IoT networks and 57 have launched LTE-M/Cat-M (Ericsson, n.d.). The number of devices connected via these technologies reached nearly 500 million by the end of 2022, with expectations of reaching 2 billion by 2028 (Ericsson, n.d.). Among the two cellular IoT technologies, NB-IoT stands out for its support of extended network coverage, massive deployment capabilities, prolonged device lifespan, and seamless integration with existing infrastructure, making it a key enabler of the massive IoT ecosystem.

As 5G deployments rapidly expand worldwide and 6G is on the horizon, the scope of the mobile network ecosystem continues to grow and diversify. In parallel to the rollout of 5G, NB-IoT has become the dominant choice for LPWAN applications; its number of connected devices has outpaced other LPWAN technologies with a 47% market share (C&T RF Antennas Inc, 2021). In 3GPP's Release 16, NB-IoT was included as the standard for 5G's massive machine-type communications (mMTC; massive IoT) and was seamlessly integrated into the 5G New Radio (NR) frequency band (5G Americas, 2012). This integration is expected to further expand its use-case portfolio with an exponential increase of supported devices, data rate, and performance.

The continued growth of IoT relies on critical factors, including ubiquitous coverage and the ability to handle the magnitude of connections and data rates required for future IoT applications. In 2022, 3GPP adapted the NB-IoT protocol for Non-Terrestrial Networks (NTNs) as part of 5G's Release 17 specifications. NTN is considered vital to meet the escalating demands of 5G IoT and future 6G services, especially in challenging geographical terrains and dense urban environments.

By exploring current academic findings and utilising simulation, the research project aims to explore how the NTN systems can complement and enhance the capabilities of 5G NB-IoT and 6G technologies. The scope of the project focuses on evaluating the advantages of employing NTN in dense urban area scenarios, particularly in terms of coverage extension, improved signal quality, and support for massive IoT device connectivity. In dense urban areas, where terrestrial Base Stations (BSs) face limited spectral resources, Unmanned Aerial Vehicles (UAVs) have emerged as a promising solution for IoT and cellular communication. UAVs offer mobility, deployment flexibility, and the ability to establish Line-of-Sight (LOS) links. However, previous studies on UAV altitude and position optimisation often rely on mathematical models and open-space assumptions, overlooking real-world environmental

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factors and signal propagation effects. Additionally, these studies usually involve complex algorithms with limited visual representation of coverage and performance.

This project addresses these research gaps by developing a simplified and realistic framework to examine the downlink coverage probability in dense city areas. The simulation will utilise the MATLAB software with Ray-Tracing propagation model to provide a more relevant and visually comprehensible performance analysis.

This paper:

- Provides an overview of technical specifications and challenges for NB-IoT and NTN systems in general;
- Assesses the performance of NB-IoT NTN based on a real-world scenario using UAVs as base stations in terms of coverage area, supported connections and throughput capacity;
- Offers an analytical framework with simplified graphical representations for evaluating the integration of NTN into NB-IoT.

The rest of the paper is arranged as follows. The next section will present an overview of the 5G NB-IoT standard. The following section will show a literature review on NB-IoT state-of-the-art coverage design and the integration of NTN. Next, the system model will be presented, followed by the results and discussion. Finally, there is a conclusion.

5G NB-IOT NTN Standard and Technical Overview

Background/Overview

A generic IoT architecture consists of three layers: the Sensing layer, the Network/Communication layer, and the Application layer. The Sensing layer, consisting of sensors and actuators, is responsible for interacting with the physical environment, conducting measurements, collecting data, or carrying out actions based on the IoT applications (Domínguez-Bolaño *et al.*, 2022). The network/communication layer enables communication and data exchange between devices and IoT platforms, providing physical access and backhaul connections for IoT applications. Most IoT applications employ wireless communication technologies, such as 3GPP NB-IoT, LoRaWAN and Sigfox, for wide-area network access. The application layer consists of IoT platforms and application servers, providing control, data processing, storage, and a management interface between users and IoT systems. Figure 1 shows the architecture of an IoT system using NB-IoT technology.

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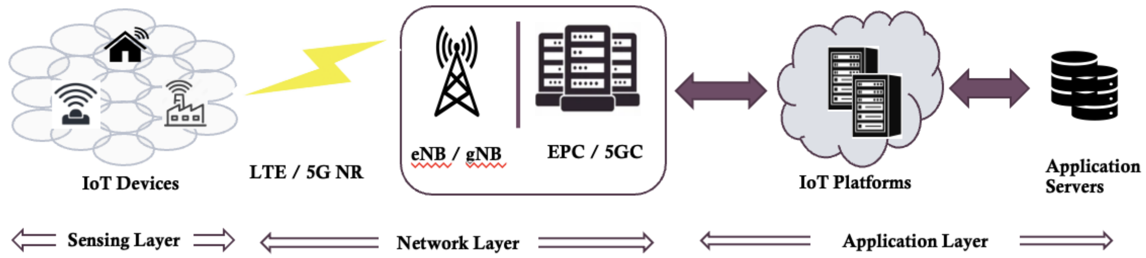

Figure 1. IoT System Architecture using NB-IoT

NB-IoT, a 3GPP-standardised cellular LPWAN protocol, was introduced in 2016's Release 13 and included in 5G's massive IoT standard in Release 16. Designed for mMTC, it supports numerous low-cost devices with reduced data rates and long battery life. NB-IoT employs a carrier bandwidth of just 180 kHz within a licensed spectrum band, allowing it to support billions of devices with reliability as required in 5G mMTC. Compared to other LPWAN technology such as LoRa, its wide coverage range and robust penetration make it well-suited for providing reliable connectivity in complex urban environments, making it ideal for large-scale IoT deployments like smart cities. The deployment of NB-IoT devices as smart city solutions also showed increase demand from governmental and regulatory authorities for public safety purposes. Another key advantage of NB-IoT is its ability to utilise existing LTE infrastructure, reducing deployment costs and facilitating faster adoption by both mobile network operators (MNOs) and customers, providing an economy of scale for current mobile chipset vendors, such as Qualcomm or Meditak.

NTN, defined in 3GPP, is a kind of network partially or fully operating for communication purposes through an airborne vehicle, such as a UAV or high altitude platform, or spaceborne vehicle, including geostationary earth orbit (GEO), medium earth orbit (MEO), and low earth orbit (LEO) satellites. These systems have garnered significant attention as solutions to overcome coverage limitations of Terrestrial Networks (TNs) and to enhance network performance. They operate above traditional ground-based infrastructure, providing a unique vantage point for extending coverage to remote and under-served areas. Table 1 summarises the comparison between NTN and TN.

Table 1. Technical comparison between TN and NTN (Azari *et al.*, 2022)

Feature	Terrestrial Network	Non-Terrestrial Network
Coverage	Up to 100 km	Up to 3500 km (GEO)
Path loss	138 dB	190 dB
Propagation delay (RTT)	Up to 0.67 ms	0.67 ms (UAV) up to 540 ms (GEO)
Doppler shift	1 kHz (UE in Train with 2GHz carrier frequency)	48 kHz (LEO with 600 km altitude and 2 GHz carrier frequency)

Three main objectives and use cases for NTN integration of 5G NB-IoT (Azari *et al.*, 2022) are:

- Service Ubiquity: Provide connectivity for user equipment (UE)/sensors deployed in remote and unserved/under-served areas or disaster-hit regions. Examples of ubiquity use cases are IoT (e.g., agriculture, asset tracking, metering) and public safety (i.e., emergency networks).
- Service Continuity: Combination of TN and NTN to provide continuous connectivity to devices in areas where TN fails to reach, such as in maritime vessels, aircraft and trains.
- Service Scalability: Throughput enhancement, on-demand complement to ground IoT base stations when relatively high data rate is needed. Use cases leverage the large coverage area of satellites or flexibility of UAVs and contribute to off-loading traffic from terrestrial networks during the busy hours.

While the deployment of UAVs as temporary relay nodes and aerial Evolved Node B (eNB) has been substantially tested and employed in various use-case scenarios due to their low cost and flexibility, the commercial deployment of satellites for 5G NB-IoT is still in its early stages after Release 17 in 2022. Various MNOs and manufacturers have collaborated with satellite communications providers to leverage the extended coverage. For instance, Apple's iPhone began supporting satellite connections using Globalstar's network for emergency calls in 2022 with the release of the iPhone 14. Last year, T-Mobile US also partnered with Starlink to provide satellite connectivity using part of T-Mobile's 2.5 GHz spectrum, potentially accelerating an MNO's integration of satellite-based NTN services to expand its 5G network to remote locations (Meyer, 2023).

5G NB-IoT — Technical overview

NB-IoT, based on 3GPP LTE specifications, uses existing LTE components to speed up market entry for MNOs. NB-IoT is designed to support low-cost, low device complexity, and provide extensive coverage while enabling long battery life; it is also engineered for deployment flexibility.

In NB-IoT's physical layer, the downlink uses Orthogonal Frequency Division Multiplexing (OFDM) and QPSK modulation with a minimum bandwidth of 12 subcarriers at 15 kHz each. The uplink employs single-carrier FDMA (SC-FDMA), where single-tone transmission schemes can be adopted for low rate and less power consumption with 3.75 kHz and 15 kHz of sub-carrier spacing, while a multi-tone option can adopt 15 kHz of sub-carrier spacing (Sharma, 2021). The flexibility allows eNBs to support a large number of users in parallel (Zayas *et al.*, 2017). To maintain low device complexity, the downlink transport block size is capped at 680 bits (Liberg, Sundberg *et al.*, 2019). Additionally, devices are only required to support half-duplex operation, eliminating the need for simultaneous transmission and reception. 3GPP Release 14 added a lower device power class with maximum 14 dBm transmit power, enabling smaller batteries with lower peak current and reducing device cost. Table 2 summarises the main physical parameters of NB-IoT.

Table 2. NB-IoT Physical Layer Specifications (Tabbane, 2017)

Parameters	Uplink	Downlink
Transmission scheme	SC-FDMA	OFDMA
Subcarrier	Single-tone – 3.75 kHz Multi-tone – 15 kHz	15 kHz
Modulation	BPSK, QPSK	QPSK
Repetition factor	Up to 128	Up to 2048
Maximum Coupling Loss	64 dB	64 dB
Channel	NPUSCH, NPRACH	NPDSCH, NPBCH, NPDCCH
Bandwidth	180 kHz	180 kHz
Peak Data rate	Up to 200 kbps	144 kbps

One of the crucial aspects of NB-IoT is the coverage enhancement (CE), where signal repetitions are used to maintain reliable communication in remote or challenging locations. By iterating Layer 3 (RRC, NAS) messages a predefined number of times, known as the repetition factor (RF), it increases the chance of accurate reception at the receiver side (Tsoukaneri *et al.*, 2018). Three CE Levels are defined, with each CE Level dictating the number of times the messages can be repeated to reach devices in poor coverage areas aiming for a maximum coupling loss (MCL) of 164 dB, thus improving coverage by up to 20 dB compared to LTE, which operates at 144 dB:

- CE Level 0: +0dB (normal coverage);
- CE Level 1: up to +10dB (moderate coverage);
- CE Level 2: up to +20dB, 128 repetitions (bad coverage).

Regarding deployment flexibility, NB-IoT can operate in three modes (Figure 2): standalone mode with dedicated GSM spectrum channel; in the guard-band of an LTE carrier; or in-band mode using a physical resource block (PRB) with an LTE carrier. These options allow the re-farming of a portion of the GSM spectrum for NB-IoT, offering flexible spectrum migration options for mobile operators. This flexibility also facilitates the deployment of NB-IoT alongside the 5G NR (Liberg, Sundberg *et al.*, 2019).

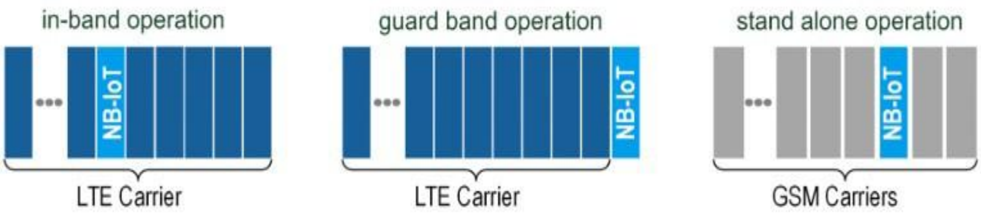

Figure 2. NB-IoT — Deployment modes (5G Americas, 2019)

In 3GPP Release 16, 5G NR reserves radio resources for NB- IoT within an NR carrier. In this context, there are also three deployment models: NB-IoT can be operated in NR in-band, NR guard-band and NR-Standalone mode (5G Americas, 2012). This means the NB-IoT UE and NB-IoT radios can be connected to the 5G core directly via the 5G N1 NAS signalling, allowing service providers increased flexibility of deployment (5G Americas, 2019).

One of the main characteristics of 5G NR is the support of multiple spectrum ranges from below 1 GHz up to above 40 GHz (5G Americas, 2012). 5G NB-IoT, with the advantage of operating in a higher frequency band compared to LTE, can provide broader bandwidths with high-speed channels (5G Americas, 2019). Since both NR and NB-IoT utilise OFDM-based modulation and share support for 15-kHz subcarriers, the downlink can achieve interference-free orthogonality without the need for guard-bands between the two systems (Liberg, Bergman *et al.*, 2019). This coexistence further enhances the versatility and effectiveness of NB-IoT within the 5G landscape, supporting its seamless integration.

NTN architecture

NTNs are designed to provide connectivity in areas that are typically hard to reach or lack terrestrial infrastructure. These areas may include remote locations, vessels or aeroplanes, where establishing traditional ground-based networks are either economically infeasible or physically impossible. The spaceborne and airborne categories with various types of network components enable this unique connectivity capability. The traditional GEO satellites, at 35,786 km altitude, offer wide coverage but have longer latency. Lower-altitude satellites, MEOs and LEOs, also known as non-geostationary (NGSO) satellites, have lower latency but higher Doppler shift effect due to their high velocity relative to the earth. The airborne UAVs offer limited coverage but are more flexible and cost-effective, with lower latency and higher throughput at the expense of a smaller footprint, suitable for rapid deployment needs. Table 3 summarised some of the parameters and characteristics of the three common NTN components.

Table 3. Parameters for the common NTN types (Giuliano & Innocenti, 2023)

NTN Type	Altitude	Footprint Size	Max RTT (Delay)	Characteristics
GEO	35,786 km	200–3500 km	Up to 541.46 ms (service and feeder links)	Large coverage, High delay, High cost, Low flexibility
LEO	300–1500 km	100–1000 km	25.77 ms (600 km) 41.77 ms (1200 km)	Less delay, Lower cost, Higher flexibility compared with GEO, High Doppler shift
UAV	1–10 km	1–50 km	< 67 µs (service and feeder links)	Less coverage size, Low cost, highly flexible

A terrestrial network for mobile service typically features the following system elements: 1) user equipment (UE)/IoT device; 2) base station (eNB/gNB), which provides the access/service link to the UEs; 3) core network that provides control functionalities including authentication, session management etc.; and 4) the data network, which handles data forwarding between networks and endpoints.

Figure 3 illustrates the integration of various NTN components into the current terrestrial architecture. The UE is able to transparently connect to a terrestrial node, as well as to the NTN platform, which acts as a NodeB through the service link. The NTN is then connected via a feeder link to the NTN gateway/ground station, which is connected to the operator's core and data network. The NTN platform can also serve as a relay between a NodeB and the core network, facilitating backhaul services with high-speed data rate connectivity. It is also possible to have multi-hop connectivity through an inter-satellite link (ISL) with one of the NTNs (i.e., satellite, UAV or HAP). This generic mechanism allows NTN to extend connectivity to remote or challenging-to-reach areas seamlessly.

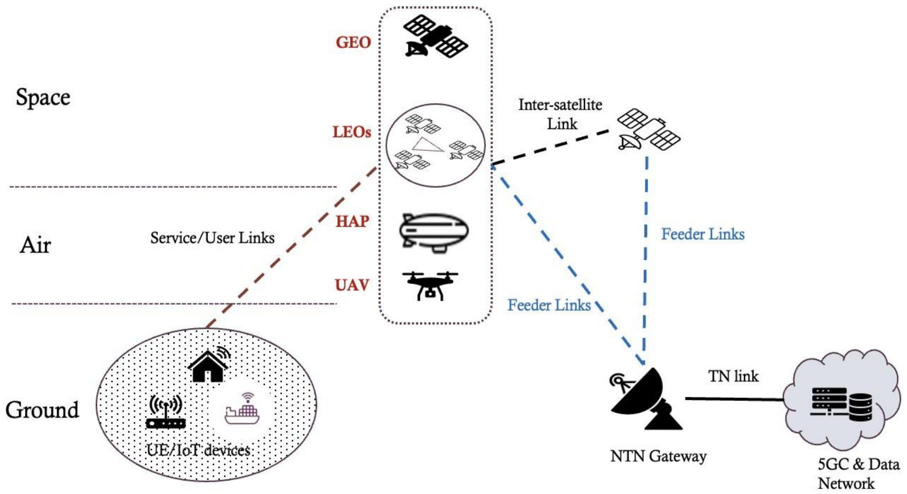

Figure 3 NTN — Architecture overview

3GPP specified two options in detail for satellite deployment in Releases 17 and 18 (Figure 4). The 'Transparent Mode' architecture was standardised in Release 17. The eNB/gNB is located at the ground, the UE's service link initially passes through a satellite, which acts as a radio-frequency repeater without any processing on-board, then forwards the signal through a feeder link to the NTN Gateway/NodeB. The satellite only repeats the NR-Uu radio interface from the service link to the feeder link and vice versa (5G Americas, 2012). For the other option of 'Regenerative Mode', eNB/gNB is implemented as a payload on the satellites; satellites can perform encoding/decoding, modulation/demodulation and routing tasks.

In the context of NB-IoT, the 3GPP Release 17 TR 36.763 study specifically identifies scenarios that are applicable to NB-IoT and proposes necessary changes to support NB-IoT over satellite. Regarding frequency band usage, according to the TS 38.821, NTN can operate in both FR1 (450 MHz to 6 GHz) and FR2 (24.25 GHz to 52.6 GHz) (5G Americas, 2012). For

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NB-IoT, it is assumed that the bands used are sub-6GHz (Merias, 2020). Additionally, satellite constellation orbits can be either LEO or GEO and the transparent payload mode should be used. For the service link between the IoT devices and the satellites, it is recommended to use Earth-fixed tracking areas for cell coverage. In the case of NTN LEO, the objective is to minimize the ping-pong effect of tracking area updates required by the devices due to satellite motion. To achieve this, the tracking area is configured to remain fixed on the ground. When a satellite beam enters a new planned tracking area, the network updates the broadcast tracking area code (TAC). If a device detects that it has entered a tracking area that is not on its list of previously registered tracking areas within the network, it initiates a mobility registration update procedure (Merias, 2020).

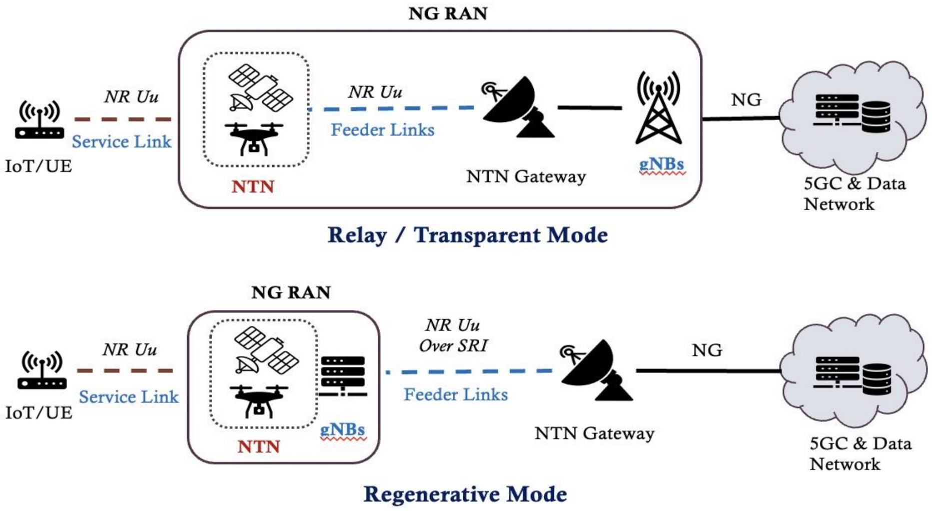

Figure 4. Two main NTN architecture modes

To address the high round-trip time (RTT) delay and Doppler shift effect in NTN satellite links, the primary solutions proposed in 3GPP studies involve leveraging Global Navigation Satellite System (GNSS) capabilities in conjunction with satellite ephemeris data. GNSS enables devices to determine their precise location, while NTN ephemeris data calculates the relative velocity and the RTT between the device and the satellite. These measures can compensate for Doppler shift effects and ensure accurate synchronisation of time and frequency (Liberg *et al.*, 2020).

Literature Review

5G NB-IoT — The-state-of-the-art coverage design

Extensive research has focused on the coverage and performance of NB-IoT since its introduction by 3GPP in 2016. Recent integration of NB-IoT into 5G NR frequency bands has drawn new studies on how 5G NR technology can enhance the potential of NB-IoT, while thorough performance analysis is limited in this early stage. One of the main coverage improvement aspects of NB-IoT is the adaptation of repetition rate. The study in Abusabah *et al.* (2022) shows that the increase of repetition counts can reduce the block error rate across different transmitter density scenarios. On the other hand, the study in Tsoukaneri *et al.* (2018) reveals that the coverage improvement achievable through signal repetitions is limited by the quality of channel estimation and the coherence time of the channel for low-powered devices operating in extreme coverage conditions.

The study in Gbadamosi *et al.* (2020) highlighted that the operation of 5G NR in higher frequency bands offers wider channels and higher speeds beyond 1 GHz for IoT service. Technologies such as Multiple-Input Multiple-Output, macro-assisted small cells, and licensed shared access can enhance spectrum utilisation and network performance. Furthermore, integrating licensed and unlicensed spectrum in 5G will increase network capacity and service performance.

While these technologies enhance system coverage and network capacity, there is limited analysis of the trade-offs between coverage and performance. Additionally, there is a lack of research on the practical integration of NB-IoT with NTN for real-world IoT deployments.

NTN — Technical review

The standardisation and industrial interest due to market potential has drawn a substantial academic research effort to explore and review the state-of-the-art NTN architecture proposed by the 3GPP. In Zhou *et al.* (2019), a mathematical model is introduced to assess the coverage and the accessible capacity of devices in a LEO satellite network under various scenarios. It concluded the coverage degree to the ground is vital for evaluating the satellite communication capabilities. The research in Manzoor *et al.* (2022) evaluated the relationship between Line-of-Sight (LoS) probability, frame repetitions, and satellite coverage to propose a framework to optimise repetition strategies based on satellite availability and geographical variations. They found that devices with lower LoS probability or larger zenith angles require more repetitions for successful data transmission.

Sørensen *et al.* (2021) provided a link-level analysis between LEO satellites and IoT devices, considering geometry, Doppler effects, propagation time, and link budget. The study showed that nanosatellites could effectively serve as base stations in an NTN NB-IoT cellular infrastructure with a reduced cell size of approximately 560 km. This demonstrates the feasibility of using nanosatellites to extend NB-IoT services to challenging areas.

These studies highlight the importance of optimising coverage and signal reliability under various geographical and environmental conditions. However, further research is needed to

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explore these challenges in the context of different NTN systems, such as UAVs, to ensure performance in various real-world scenarios.

Integration of NTN in mobile services

The integration of NTNs, including UAVs, high-altitude platforms and satellites, into wireless networks is of increasing interest due to the promise of extending coverage and enhancing network capacity.

In the context of UAV use cases, research in Song *et al.* (2020) and Hao *et al.* (2022) utilises UAVs as aerial relays or eNBs, equipped with caching capabilities. This enables them to efficiently boost and transmit received signals between user IoT devices and eNBs. Additionally, a full-duplex scheme proposed in Samir *et al.* (2019) illustrates how UAVs can alleviate wireless network congestion by gathering data from time-sensitive IoT devices and securely transferring it to a ground gateway with guaranteed performance levels.

Prior works in UAV-based NTN focus on height optimisation to maximise coverage area and the number of IoT devices served, as well as optimising UAV trajectories to minimise IoT device energy consumption. Rahimi *et al.* (2021) proposed a mathematical model and an iterative algorithm to determine the optimal altitude for the UAVs to effectively cover IoT nodes. Sobouti *et al.* (2020) introduced complementary heuristic methods, including meta-heuristic algorithms and mathematical programming techniques, to ascertain both the number and positions of the UAVs. Chetlur & Dhillon (2017) analysed downlink coverage, finding that while increasing UAV numbers boosts network capacity, it also increases interference, and reduces overall coverage probability. Most research primarily develops mathematical models for optimal UAV numbers and positions in 2D or 3D open space, often neglecting environmental factors.

The research in Cluzel *et al.* (2018) explored extending IoT coverage using a LEO satellite constellation. It proposed a system architecture where each satellite digitises and stores the targeted spectrum until it can be relayed to a ground station. The study also introduced a detection algorithm designed to mitigate Doppler drift effects on demodulation performance.

The paper in Kodheli *et al.* (2019) focused on the implementation of beam-forming techniques within NGSO constellations to enhance NB-IoT performance. The results revealed that the performance with minimum mean square error beamforming surpasses that of the non-beamformed scenario, with Signal to Interference and Noise Ratio (SINR) values over 10 dB higher in the beamformed scenario.

Research studies in both Sørensen *et al.* (2021) and Conti *et al.* (2020) have conducted system-level performance analyses of NB-IoT NTN deployment. While Sørensen *et al.* (2021)

emphasises the assessment of system performance indicators, such as device density, coverage area, and connection handling capabilities, considering various operational configurations and traffic characteristics, Conti *et al.* (2020) focuses on evaluating access delay and access success probability within an NB-IoT NTN system. Additionally, Sørensen *et al.* (2021) outlines a modelling framework for scenarios employing nanosatellites. The results not only demonstrate the technical feasibility of the model system, but also highlight the trade-offs existing between system configurations and performance.

While studies reveal significant advances in integrating NTNs with NB-IoT, various research gaps remain, particularly regarding the practical deployment of NTN systems in real-world environments. Factors such as geography, mobility, and spectrum resource availability, especially within urban settings, have not been fully addressed and examined. Current research on UAV positioning often overlooks environmental factors such as building obstructions and reflections, which can have significant impact on coverage and network performance. Limited work has also been conducted on addressing interference issues and the challenges of dynamic positioning in practical UAV scenarios. Moreover, as 5G NR can offer greater capacity and flexibility, there is a need for research regarding end-to-end performance evaluations of NTN integration (e.g., UAVs and LEO satellites) leveraging 5G NR for NB-IoT services.

System Model

Use-case scenario

NB-IoT has emerged as the preferred solution by city governments and organisations as the primary smart city technology, due to its reliability, extended coverage and excellent penetration capabilities. The NTN platform UAV, with its low cost and flexibility, is ideal for temporary deployments. In this study, we consider Melbourne CBD and a telecom operator developing a robust backup and disaster recovery plan for its ongoing NB-IoT smart city deployment in the CBD. This plan addresses unexpected emergency situations, ranging from terrestrial base station damage, system outages or congestion to special crowd events and emergency device updates. NB-IoT devices, like emergency alert systems and monitoring sensors, require uninterrupted connectivity for crucial updates. The plan involves deploying a UAV platform equipped with NB-IoT eNB at the intersection of Lonsdale and Swanston Streets to facilitate downlink transmissions and extend coverage.

In this simulation, we will compare the coverage and reachability between the existing terrestrial eNB and the eNB mounted on UAVs positioned at varying heights. The goal is to determine the optimal UAV height that can provide the best possible coverage while maintaining sufficient signal strength.

Unlike previous research efforts that relied on numerical or mathematical approaches, this paper utilises ray-tracing propagation models in MATLAB for a more comprehensive analysis. Figure 5 illustrates the simulation scenario. The parameters for the simulations are summarised in Table 4.

Table 4. Simulation parameters: UAV downlink to NB-IoT devices

Parameters	Values
Transmit power (Tx)	1 0 Watts (30 dB)
eNB height (Tx)	TN-BS – 16m UAV 1 - 120m UAV 2 – 250m
UE/IoT device height (Rx)	1.5m
Frequency	2600 MHz
Bandwidth	180 kHz
Repetition factor	32
Noise Temperature	290 K
Noise Figure (Rx)	8 dB

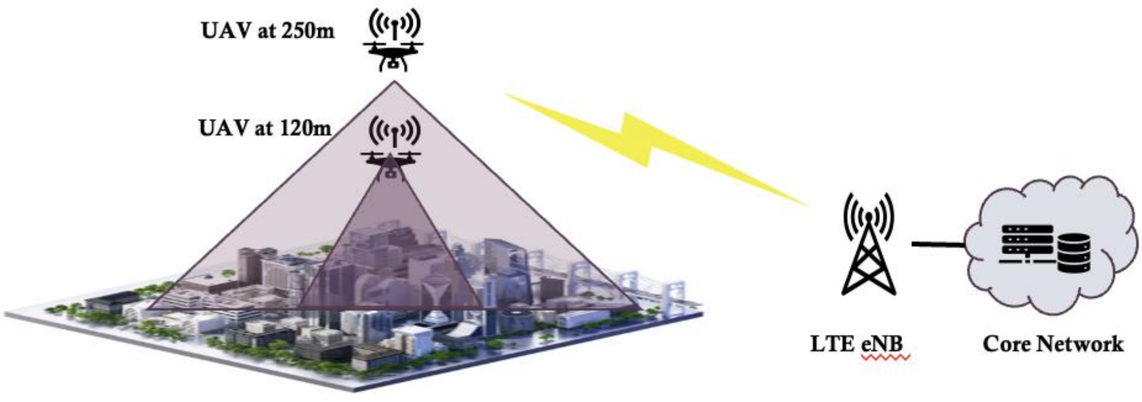

Figure 5. NTN — UAV performance analysis simulation scenario

Simulation method

We have chosen to employ the ray-tracing model for its ability to deliver precise coverage forecasts, particularly in dense urban settings characterised by multifaceted structures. This model excels in considering the unique geometry and attributes of the environment, making it well-suited for application in city areas adorned with buildings. The ray-tracing model accommodates both line-of-sight and non-line-of-sight scenarios, accounting for environmental interactions, such as reflection, diffraction and scattering, resulting in more authentic outcomes. The software tool can effectively simulate the performance of wireless access systems at the physical layer by tracing the propagation paths of rays originating from transmitters as they traverse the three-dimensional terrain (MathWorks, n.d.).

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QoS parameters and formulas

Quality of Service (QoS) parameters and formulas that will be used in the project are defined as follows.

3GPP has established a specific technique for estimating errors at the physical layer known as the block error rate (BLER). Within NB-IoT, data is transmitted in blocks with a specific number of bits. BLER calculates the ratio of incorrectly received transport blocks to the total number of blocks transmitted across a certain number of frames. It is used to evaluate a device's physical-layer performance and is crucial for assessing receiver sensitivity. The coverage boundary will be defined using the signal-to-noise ratio (SNR) threshold based on a target BLER 5% value, where:

$$\text{BLER} = \text{Number of Successful Block Transmissions} / \text{ Total Number of Blocks Transmitted}$$

By using MATLAB's LTE Toolbox, we could obtain the BLER vs SNR for different repetition rates as shown in Figure 6.

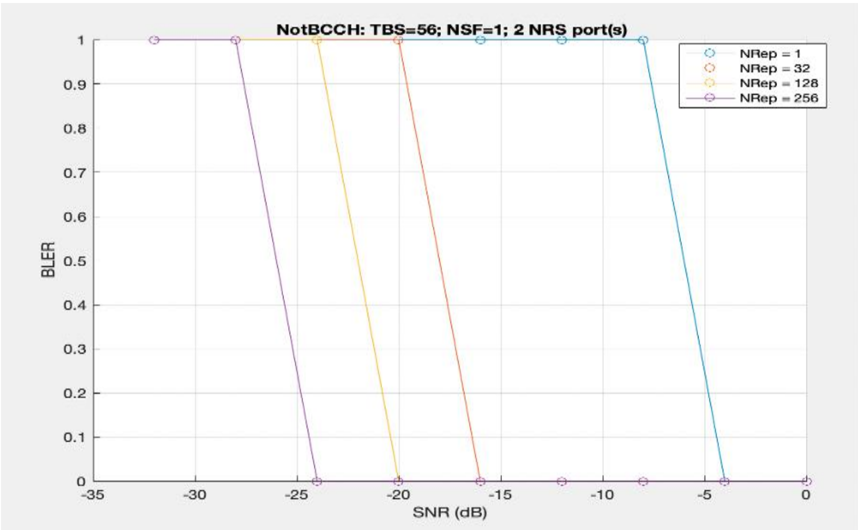

Figure 6. Block error rate (BLER) for different repetition rates

The Signal to Interference and Noise Ratio ($SINR$) is the ratio between the Received Signal Strength (RSS) in Watts and the interference power (I) from external sources, as well as the effective noise power (N) (Sun, 2014),

$$\text{SINR} = \frac{RSS}{(I+N)}. \tag{1}$$

Based on the site map from the Radio Frequency National Site Archive (RFNA) that shows the location of different ground base stations in the city area (Figure 7), by using the ray-tracing simulation we could extract the interference and use it to calculate the resultant SINR.

Figure 7. Assumed Interferers-Tx 1 to Tx 4

The total interference (I) is obtained by assuming the worst-case scenario and summing the signal strengths (ss) received from Tx 1 to Tx 4 (Figure 7) using the formula (Sun, 2014):

$$I = \sum_{i \in \{interferers\}} I_i \ . \tag{2}$$

The obtained total interference = -25.5dB.

The Noise Power (N) calculation formula is (Sun, 2014):

$$N = k \times T \times B \times F, \tag{3}$$

where $k = 1.38 \times 10^{-23}$ is Boltzmann's constant, T is the noise temperature, B is the data bandwidth, F is the noise figure of the receiving devices, using the values in Table 4. The obtained noise power is $N = -143.4\ dB$.

By using the SNR threshold value, obtained from BLER vs SNR with 5% BLER and a repetition rate of 32, and the Interference (I) and Noise power (N) obtained in equations 1 and 2, we can calculate the RSS threshold:

$$RSS\ Threshold = SNR\ Threshold + 10 \log_{10}(1 + N)\,. \tag{4}$$

The RSS threshold (receiver sensitivity) represents the lowest allowable input power level at which the receiver can identify a signal with an acceptable error rate (BLER).

Shannon Capacity is the maximum data capacity that can be sent over any channel; it defines the correlation between the bandwidth (B), signal-to-noise power ratio (SNR) and maximum capacity/transmission rate (C).

The Shannon Capacity formula is (Sun, 2014):

$$\mathrm{C} = \mathrm{B} \log 2\ (1 + \mathrm{SNR}). \tag{5}$$

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Results

Based on the provided use-case scenario, we selected a Telstra 4G/5G base station location and its height from RFNA, representing the terrestrial NB-IoT eNB. We then compared it with an eNB mounted on a 120 m UAV positioned at the same intersection of Lonsdale and Swanston Streets. Figure 8 illustrates two coverage contours, one for the UAV at a height of 120 m and the other for the ground TN BS. These contours were generated using the 32 repetition rate. We can see the coverage area for UAV-120m is much larger than the TN's BS.

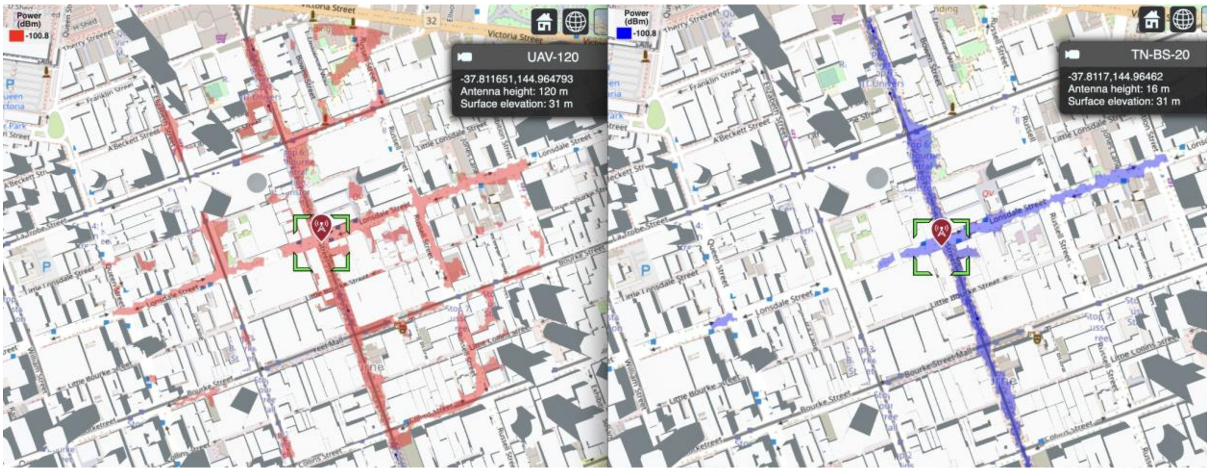

Figure 8. Coverage boundary-UAV-120 m and TN-BS-16 m

To assess the approximate number of IoT receivers that can be covered with acceptable performance, we included receivers in this simulation. We distributed 200 IoT receivers evenly across various main roads in the CBD. By utilising the MATLAB Ray Tracing model, we obtain and compare the coverage area, RSS/SINR for each receiver, and the number of receivers reached, while maintaining a minimum RSS threshold.

Figure 9. TN-BS-16m case, number of covered receivers = 37/200

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Figure 9 displays the Ray-tracing simulation result of TN-BS where only 37 devices can be covered out of 200. A UAV at 120 m (Figure 10) can cover 115 receivers; a UAV at 250 m (Figure 11) can cover up to 156 receivers.

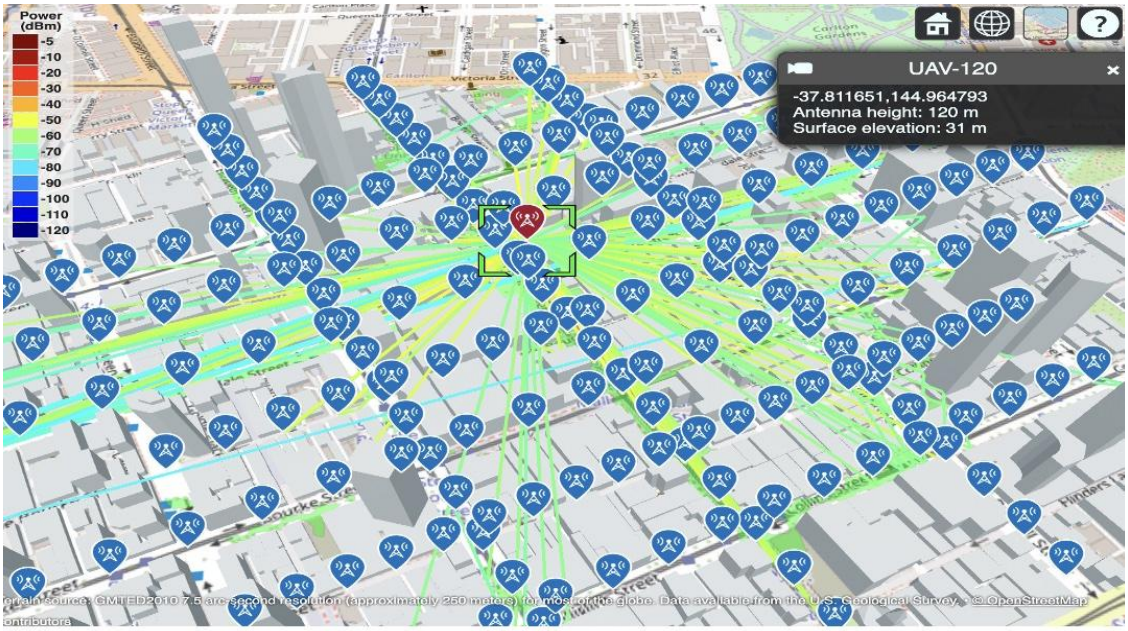

Figure 10. UAV-120m case, number of covered receivers = 115/200

Figure 11. UAV-250m case, number of covered receivers = 156/200

Based on the received signal strength (RSS) of each receiver obtained from the simulation, we plotted the cumulative distribution function (CDF) diagram using the Shannon Capacity formula (5). The CDF result of Shannon Capacity (Figure 12) illustrates the performance trends for UAVs at different altitudes and a traditional ground base station (BS at 16 m). At higher altitudes (UAV at 250 m), the UAV can reach a greater number of receivers. However, its data rate per Hz capacity saturates earlier compared to the UAV at 120 m, indicating performance degradation for some receivers. This degradation suggests increased path loss and signal attenuation at higher altitudes, leading to a decrease in signal strength and overall network capacity.

The Figure also indicates that a ground base station (BS at 16 m) covers the fewest receivers and achieves the lowest capacity. This result highlights the limitations of ground-based stations in urban environments, where obstructions and limited line-of-sight coverage reduce reachability and signal quality.

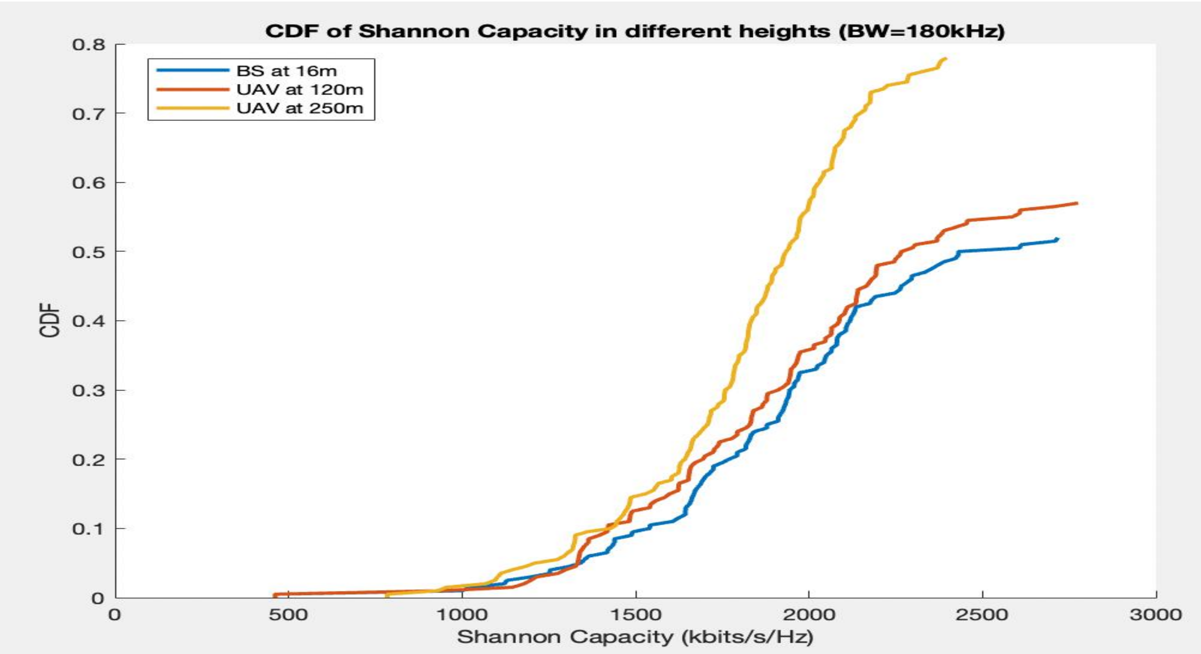

Figure 12. CDP of Shannon Capacity in different heights (BW-180 kHz)

The results demonstrate a trade-off between coverage and data rate capacity. When determining the optimal altitude for UAV-based NB-IoT deployment, it is essential to consider the specific use-case requirements. If extensive coverage is the primary goal and latency or low data rates are not a concern (e.g., utility meters, air quality sensors), UAVs at higher altitudes are preferable. However, for applications requiring reliable performance and higher data rates (e.g., emergency alerts, public safety services), as demonstrated in our simulated case scenario, lower UAV altitudes (e.g., 120 m) provide a more balanced solution.

Conclusion

In this paper, through a comprehensive review of existing literature on NB-IoT within the framework of 5G NG (Next Generation) and the NTN architecture, we presented the state-of-the-art of the technologies and integration mechanisms, exploring the potential use cases, capabilities and limitations. The work also presented the methodology of the simulation based on a use-case scenario involving the deployment of UAVs as eNBs in a city area. By utilising ray-tracing propagation models in MATLAB and incorporating various QoS parameters, we successfully generated preliminary results with graphical representations. The results from the simulation demonstrate the potential of leveraging UAVs as an NTN system for NB-IoT deployment, compared to traditional terrestrial base stations in urban environments. The findings highlight a trade-off between coverage and data rate capacity, emphasising the importance of selecting the appropriate UAV altitude based on the specific use-case scenario and environmental constraints.

Although field testing may still be needed to account for uncertainties, such as interference effects on SINR, this study provides a practical estimation of optimal coverage for a real-world scenario using software simulation tools and a propagation model. Future work could explore the integration of machine learning and artificial intelligence techniques to further enhance the accuracy of coverage estimations and interference predictions in dynamic urban environments.

References

5G Americas. (2012). *3GPP Releases 16 & 17 Beyond* [White paper]. https://www.5gamericas.org/wp-content/uploads/2021/01/InDesign-3GPP-Rel-16-17-2021.pdf

5G Americas. (2019, July). *5G: The Future of IoT* [White paper]. https://www.5gamericas.org/wp-content/uploads/2019/07/5G_Americas_White_Paper_on_5G_IOT_FINAL_7.16.pdf

Abusabah, A. T., Rahman, M. A., Oliveira, R., & Flizikowski, A. (2022). The importance of repetitions in ultra-dense NB-IoT networks. *IEEE Communications Letters*, *26*(5), 1199–1203. https://doi.org/10.1109/LCOMM.2022.3151324

Azari, M. M., Solanki, S., Chatzinotas, S., Kodheli, O., Sallouha, H., Colpaert, A., Montoya, J. F. M., Pollin, S., Haqiqatnejad, A., Mostaani, A. & Lagunas, E. (2022). Evolution of non-terrestrial networks from 5G to 6G: A survey. *IEEE Communications Surveys & Tutorials*, *24*(4), 2633–2672. https://doi.org/10.1109/COMST.2022.3199901

C&T RF Antennas Inc. (2021, October 25). *NB-IoT and LoRa of LPWAN market analysis in 2022*. https://lcantennas.com/nb-iot-and-lora-of-lpwan-market-analysis-in-2021/

Chetlur, V. V., & Dhillon, H. S. (2017). Downlink coverage analysis for a finite 3-D wireless network of unmanned aerial vehicles. *IEEE Transactions on Communications*, *65*(10), 4543–4558. https://doi.org/10.1109/TCOMM.2017.2722500

Cluzel, S., Franck, L., Radzik, J., Cazalens, S., Dervin, M., Baudoin, C., & Dragomirescu, D. (2018, June). 3GPP NB-IoT coverage extension using LEO satellites. In *2018 IEEE 87th Vehicular Technology Conference (VTC Spring)* (pp. 1–5). IEEE. https://doi.org/10.1109/VTC-Spring.2018.8417723

Conti, M., Andrenacci, S., Maturo, N., Chatzinotas, S., & Vanelli-Coralli, A. (2020, June). Doppler impact analysis for NB-IoT and satellite systems integration. In *ICC 2020-2020 IEEE International Conference on Communications (ICC)* (pp. 1–7). IEEE. https://doi.org/10.1109/ICC40277.2020.9149140

Domínguez-Bolaño, T., Campos, O., Barral, V., Escudero, C. J., & García-Naya, J. A. (2022). An overview of IoT architectures, technologies, and existing open-source projects. *Internet of Things*, *20*, 100626. https://doi.org/10.1016/j.iot.2022.100626

Ericsson. (n.d.). *Ericsson mobility visualizer*. Retrieved September 18, 2023, from https://www.ericsson.com/en/reports-and-papers/mobility-report/mobility-visualizer

Gbadamosi, S. A., Hancke, G. P., & Abu-Mahfouz, A. M. (2020). Building upon NB-IoT networks: A roadmap towards 5G new radio networks. *IEEE Access*, *8*, 188641–188672. https://doi.org/10.1109/AC-CESS.2020.3030653

Giuliano, R., & Innocenti, E. (2023). Machine learning techniques for non-terrestrial networks. *Electronics*, *12*(3), 652. https://doi.org/10.3390/electronics12030652

Hao, C., Chen, Y., Mai, Z., Chen, G., & Yang, M. (2022). Joint optimization on trajectory, transmission and time for effective data acquisition in UAV-enabled IoT. *IEEE Transactions on Vehicular Technology*, *71*(7), 7371–7384. https://doi.org/10.1109/TVT.2022.3166237

Kodheli, O., Maturo, N., Andrenacci, S., Chatzinotas, S., & Zimmer, F. (2019). Link budget analysis for satellite-based narrowband IoT systems. In *Ad-Hoc, Mobile, and Wireless Networks: 18th International Conference on Ad-Hoc Networks and Wireless, ADHOC-NOW 2019, Luxembourg, Luxembourg, October 1–3, 2019, Proceedings 18* (pp. 259–271). Springer International Publishing. https://doi.org/10.1007/978-3-030-31831-4_18

Liberg, O., Bergman, J., Höglund, A., Khan, T., Medina-Acosta, G. A., Rydén, H., Ratilainen, A., Sandberg, D., Sui, Y., Tirronen, T., & Wang, Y. E. (2019, September). Narrowband Internet of Things 5G Performance. In *2019 IEEE 90th Vehicular Technology Conference (VTC2019-Fall)* (pp. 1–5). IEEE. https://doi.org/10.1109/VTCFall.2019.8891588

Liberg, O., Löwenmark, S. E., Euler, S., Hofström, B., Khan, T., Lin, X., & Sedin, J. (2020). Narrowband Internet of Things for Non-Terrestrial Networks. *IEEE Communications Standards Magazine*, *4*(4), 49–55. https://doi.org/10.1109/MCOMSTD.001.2000004

Liberg, O., Sundberg, M., Wang, E., Bergman, J., Sachs, J., & Wikström, G. (2019). *Cellular Internet of Things: From Massive Deployments to Critical 5G Applications*. Academic Press.

LightReading (2020, July 30). NB-IoT Officially Recognized as a 5G Standard, Driving IoT Development. Informa Tech. https://www.lightreading.com/iot/nb-iot-officially-recognized-as-a-5g-standard-driving-iot-development

Manzoor, B., Al-Hourani, A., & Al Homssi, B. (2022). Improving IoT-over-satellite connectivity using frame repetition technique. *IEEE Wireless Communications Letters*, *11*(4), 736–740. https://doi.org/10.1109/LWC.2022.3141831

MathWorks (n.d.). *Ray tracing propagation model*. The MathWorks, Inc. Retrieved September 18, 2023, from https://au.mathworks.com/help/comm/ref/rfprop.raytracing.html

Merias, P. (2020). Study on Narrow-Band Internet of Things (NB-IoT)/enhanced Machine Type Communication (eMTC) support for Non-Terrestrial Networks (NTN). (3GPP Reference No: 36.763, Rel-17). https://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=3747

Meyer, D. (2023, June 1). What role will satellite play in the 5G? SDxCentral. https://www.sdxcentral.com/articles/analysis/what-role-will-satellite-play-in-the-5g-story/2023/06/

Pons, M., Valenzuela, E., Rodríguez, B., Nolazco-Flores, J. A., & Del-Valle-Soto, C. (2023). Utilization of 5G technologies in IoT applications: Current limitations by interference and network optimization difficulties—A review. *Sensors*, *23*(8), 3876. https://doi.org/ 10.3390/s23083876

Rahimi, Z., Sobouti, M. J., Ghanbari, R., Seno, S. A. H., Mohajerzadeh, A. H., Ahmadi, H., & Yanikomeroglu, H. (2021). An efficient 3-D positioning approach to minimize required UAVs for IoT network coverage. *IEEE Internet of Things Journal*, *9*(1), 558–571. https://doi.org/10.1109/JIOT.2021.3084521

Samir, M., Sharafeddine, S., Assi, C. M., Nguyen, T. M., & Ghrayeb, A. (2019). UAV trajectory planning for data collection from time-constrained IoT devices. *IEEE Transactions on Wireless Communications*, *19*(1), 34–46. https://doi: 10.1109/TWC.2019.2940447

Sateliot. (n.d.). *Everywhere connected*. Retrieved September 18, 2023 from https://sateliot.space/

Sharma, L. (2021). NB-IoT for 5G: How 5G Aligns With NB-IoT. In S. K. Routray & S. Mohanty (eds), *Principles and Applications of Narrowband Internet of Things (NBIoT)* (pp. 352–372). IGI Global. https://doi.org/10.4018/978-1-7998-4775-5.ch015

Sobouti, M. J., Rahimi, Z., Mohajerzadeh, A. H., Seno, S. A. H., Ghanbari, R., Marquez-Barja, J. M., & Ahmadi, H. (2020). Efficient Deployment of Small Cell Base Stations Mounted on Unmanned Aerial Vehicles for the Internet of Things Infrastructure. *IEEE Sensors Journal*, *20*(13), 7460–7471. https://doi.org/10.1109/JSEN.2020.2973320

Song, K., Zhang, J., Ji, Z., Jiang, J., & Li, C. (2020). Energy-efficiency for IoT system with cache-enabled fixed-wing UAV relay. *IEEE Access*, *8*, 117503–117512. https://doi.org/10.1109/ACCESS.2020.3004843

Sørensen, R. B., Møller, H. K., & Koch, P. (2021). 5G NB-IoT via low density LEO Constellations. In *35th Annual Small Satellite Conference* (pp. 1–9). https://doi.org/10.48550/arxiv.2108.06172

Sun, Z. (2014). *Satellite networking: Principles and protocols*. Chicheter, West Sussex, England: Wiley.

Tabbane, S. (2017, December). *IoT Long Range Technologies: Standards*. ITU. https://www.itu.int/en/ITU-D/Regional-presence/AsiaPacific/SiteAssets/Pages/Events/2017/Nov-IOT/NBTC–ITU-IoT/IoT-standards.pdf

Tsoukaneri, G., Condoluci, M., Mahmoodi, T., Dohler, M., & Marina, M. K. (2018). Group communications in narrowband-IoT: Architecture, procedures, and evaluation. *IEEE Internet of Things Journal*, *5*(3), 1539–1549. https://doi.org/10.1109/JIOT.2018.2807619

Zayas, A. D., & Merino, P. (2017, May). The 3GPP NB-IoT system architecture for the Internet of Things. In *2017 IEEE International Conference on Communications Workshops (ICC Workshops)* (pp. 277–282). IEEE. https://doi.org/10.1109/ICCW.2017.7962670

Zhou, H., Liu, L., & Ma, H. (2019, May). Coverage and capacity analysis of LEO satellite network supporting Internet of Things. In *ICC 2019-2019 IEEE International Conference on Communications (ICC)* (pp. 1–6). IEEE. https://doi.org/10.1109/ICC.2019.8761682

When the Known Well May Sell

The Interaction of Familiarity and Choice Numeracy on Satisfaction with a Streaming Video on Demand Recommendation Interface

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Abstract: While Streaming Video on Demand (SVOD) consumers may express a desire for unlimited new and novel choices, excess choice can cause anxiety and choice overload. Further, familiarity can also influence perceptions of available choices. Addressing a gap in the literature on familiarity's interaction with choice numeracy in an SVOD recommendation environment, this 2x2 experiment examines effects of choice-set size of TV sitcoms on potential use/perceptions of SVOD platforms and to what extent familiarity with the choices interacts with those perceptions through examining differences and interactions between small vs large choice sets, and familiar vs non-familiar shows. Familiarity tends to override potential choice overload effects and non-familiarity tends to exacerbate negative effects associated with too much choice, which has implications for purveyors of not only SVOD systems but other digital applications with similar recommendation systems, such as music streaming and podcasts, to emphasise choices that are likely to have familiarity to consumers, especially when interfaces themselves may be unfamiliar.

Keywords: Choice Overload, Choice Familiarity, Streaming Video on Demand, Digital Platforms, Recommendation Systems

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Introduction

The post-digital age has seen the growth of various content platforms, and Streaming Video on Demand (SVOD) services are no exceptions. With services such as Netflix, Amazon Prime Video, Disney+, Apple TV, YouTube TV, Hulu, Paramount+, Peacock, and nearly countless others, there has never been so much content immediately available to consumers. With so much content, SVOD services have designed user interfaces to attractively recommend viewing choices to their users in order to compete for those precious minutes consumers have to devote to watching streamed programming.

Consumer choice research has been widely studied since the mid-20th century. Research suggests that offering consumers a large variety of options to choose from can both benefit and hinder choice (Misuraca *et al.*, 2024; Chernev *et al.*, 2015). On the one hand, greater choice increases the likelihood that consumers will find a closer match to their purchase goals. On the other hand, excess choice can cause anxiety and choice overload effect; fewer choices can actually increase the likelihood that an actual purchase is made (Misuraca *et al.*, 2024; Iyengar & Lepper, 2000).

In addition, familiarity has an effect on perceptions (Afonso *et al.*, 2024) and processing (Abreu *et al.*, 2023) of choices at hand. For example, if a given idea is more familiar to a person, they are more likely to rate that idea as better and more likely to perform well in practice vs a new, previously unconsidered idea (Greul *et al.*, 2023). Similarly, if an item is readily perceived so that it seems to 'jump out' from the page, it is more likely to be judged as having been seen, and thus remembered (Jacoby & Dallas, 1981). Perceptual fluency theory was posited by Jacoby & Dallas (1981) as a way to explain the ease of processing familiar words. Processing fluency positively impacts a subject's perceptions of aesthetic pleasure: the more fluently perceivers can process an object, the more positive their aesthetic response (Reber *et al.*, 2004). In addition, subjective judgments of fluency affect liking more than objective ones (Forster *et al.*, 2013).

For this study the researchers focused on the influence the size of data sets can have on viewing choices of SVOD platforms and to what extent familiarity with choices offered affect those decisions. This study is a mixed experimental design combining a within-subjects (low choice vs high choice) factor and a between-subjects (familiar vs non-familiar shows) factor of television situational comedies. Using perceptual fluency theory (Jacoby & Dallas, 1981), mere exposure effect (Zajonc, 1968), and utilising Reutskaja *et al.*'s (2020) cost-benefit model, perceived factors, such as choice difficulty, satisfaction, regret, risk, and expertise, were measured to gauge consumer attitudes as well as examine the cognitive mechanisms that may influence a choice overload effect within an SVOD environment.

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Literature Review

Choice overload effect

The choice overload effect, in general, posits that increasing the number of attractive suggestions to choose from leads to negative impacts, such as a decrease in attractiveness and satisfaction of options (Iyengar & Lepper, 2000), an increase in regret about the decision (Schwartz 2004), and decision difficulty (Peterson & Cheng, 2020). This effect has been conceptualised and labelled in various ways, including 'overchoice effect' (Gourville & Soman, 2005; Misuraca *et al.*, 2016), the 'tyranny of too much' (Beneke, 2015), and 'hyperchoice' (Mick *et al.*, 2004). This variety is often incorporated into the 'Choice Overload Hypothesis' (Misuraca *et al.*, 2024; Scheibehenne *et al.*, 2010). In an oft-cited field study on the effect of choice numeracy (six, or 'limited,' vs 24, or 'extensive') on eventual purchase of jam, Iyengar and Lepper (2000) found that 'choice overload' can negatively affect consumers' propensity to purchase, as purchase levels for the limited set were 10 times those of the extensive set. In a follow-up experiment, they also found that given a choice set of six or 30 topics, more students chose to write a two-page essay for a small amount of class extra credit when given the smaller set (74%) versus the larger set (60%) of potential essay prompts. Choice overload effect has also been compared with choice deprivation, when there are fewer choices available than desired; a curvilinear relationship has thus been found between choice level and satisfaction where consumers seek a 'Goldilocks zone' of sorts of choice level (Reutskaja *et al.*, 2022; Matysek & Tomaszczyk, 2022)

The underlying cognitive mechanism of the choice overload problem has been explained in various ways by researchers. For example, the increased level of choice environment may incur confusion, anxiety and conflict (Festinger, 1957). Reutskaja *et al.* (2020) posited a 'cost-benefit' model to explain the mechanism underlying the cognitive activity at play, though some research has shown increased cognitive activity associated with greater levels of choice could contribute to greater storage and recall (Wise *et al.*, 2008). Within the limited asset of cognitive processing, stimulus overload would undermine the value of having a large choice array (Misuraca *et al.*, 2024). Since the Iyengar & Lepper (2000) study, the choice overload hypothesis has been researched across domains including careers (e.g., Launspach *et al.*, 2016), consumer products (Chernev, 2003), media (Wise *et al.*, 2008), and algorithm applications (Bollen *et al.*, 2010). The most popular area using the choice overload approach is consumer behaviour (e.g., Chernev *et al.*, 2015; Scheibehenne *et al.*, 2010), but digital economy scholars have also adopted choice overload as an explanation for effects of today's barrage of information in everyday communication (e.g., Wise *et al.*, 2008).

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Graham (2018) stated that choice is the nature of contemporary life; a greater flow of options from digital web-based platforms reinforces the potential paradox of the benefits of choice numeracy. He thus proposed digital platforms should consider radical reconfiguration of choices to users. Accordingly, the puzzle of overloaded choices situated in a hyperchoice digital media setting arises as one that media, digital economy, and marketing communication scholars should attempt to solve.

Video streaming platform recommendation studies

The surge of popularity in video streaming services encouraged computer science researchers to test the effectiveness of the recommendation algorithms of websites and platforms. There are several studies of experiments to examine the users' evaluations of recommendation sets resulting from various types of algorithms. Utilising a choice overload hypothesis to consider the users' evaluation about the algorithm and investigated the optimal level of choice set in video streaming platform sites, Bollen *et al.* (2010) found that larger choice did not produce better performance in users' perception of a movie recommendation. Similarly, Willmensen *et al.* (2016) found that small and diverse options increased users' satisfaction and attractiveness of the items, rather than the traditional Top-N recommendation design in movie sites.

In a meta-analysis of the choice overload literature, Chernev *et al.* (2015) proposed four key factors that influence choice overload when it comes to a number of choices, or 'assortment size': two extrinsic, or objective, factors, namely 'choice set complexity' and 'decision task difficulty', and two intrinsic, or subjective, factors: 'preference uncertainty' and 'decision goal'. The extrinsic factors are those that are not particular to the decision-maker and would be more or less constant regardless of the particular person involved in making the decision, whereas the intrinsic factors would be more dependent on the individual. They identified time constraints, decision accountability (requiring justification of a given choice), number of attributes or dimensions involved (e.g., colour, size, length, genre), and presentation format (are choice sets presented in an organised fashion or not?) as being factors influencing 'decision task difficulty'. Thus, no time limits, no justification, a low number of competing attributes and a well-organised set of choices in a platform would lower perceived choice difficulty. For 'choice set complexity', presence of a dominant option, the overall attractiveness of choice options (smaller choice sets are preferable when options are attractive), commonality of features among the options and complementarity of the options presented (i.e., are the features among presented choice sets complementary versus disparate?) can ameliorate overload effects. Thus, an attractive dominant option, smaller choice sets and commonality of the choices presented would theoretically lower choice difficulty.

Among the intrinsic factors, they proposed product-specific expertise, that is, 'knowledge about the attributes and attributed levels describing the available alternatives' (Chernev *et al.*, 2015, p. 338) as influencing 'preference uncertainty', with unfamiliarity having a positive relationship with choice deferral/overload. For 'decision goal', decision intent, decision focus, and level of construal were identified as relevant factors. Decision intent refers to 'whether they approach the decision task with the explicit goal of making a choice' versus 'merely to consider the available alternatives' (p. 339), with browsing more associated with less choice overload. Similarly, decision focus has to do with whether the choice involves merely choosing a smaller set of alternatives, or narrowing, versus a particular item, where narrowing is less likely to result in choice overload, and 'larger assortments are more likely to lead to choice overload when the goal involves choosing an option from an assortment rather than choosing among assortments' (p. 339), and level of construal — is the decision process 'a high-level, abstract, and distant process or a low-level, concrete and proximate process'? (p. 339) — can influence consumers, with more proximate decisions being associated with greater propensity for choice overload.

Choices made among SVOD platforms may vary among these factors depending on the situation. As mentioned, in terms of psychological processes that explain underlying cognitive mechanisms, Reutskaja *et al.* (2020) posited a 'cost-benefit' model: if the set of choices is too complex to give consideration, people will prefer a smaller set of choices because the cognitive cost of consideration will more likely equal the perceived benefit.

Other lines of studies in designing an effective recommendation system put emphasis on the features of the recommendation algorithm. Ekstrand *et al.* (2014) used three common collaborative filtering algorithms and found novelty decreases and diversity increases user satisfaction. Additionally, recommendation variety and quality have been shown to mediate user experience perceptions (Knijnenburg *et al.*, 2012). Thus, a consumer's subjective experience with the recommendations is critical to predict their perception of choice difficulty and affective evaluation, such as satisfaction and attractiveness.

Familiarity and choice

Familiarity is one of the main factors that may affect the choice overload effect. If a person is familiar with the set of choices or has a clear preference, they will be less likely to struggle with choices and therefore the choice-overload effect may be minimised (Chernev *et al.* 2015). For example, Mogilner *et al.* (2008) found that the number of choices only mattered with less familiar cases. Similarly, Misuraca *et al.* (2019) discovered in their four experiments comparing brand cues or no cues that exposure of the brand name increased satisfaction and confidence and decreased regret and difficulty.

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In addition, there is extensive literature on the effect of familiarity on choice and preferences in general. Generally, familiarity positively affects choice. Greul *et al.* (2023) found that participants who were exposed to 'novel ideas' which they had previously seen tended to rate the quality and potentiality of those ideas higher than those presented with completely new, previously unseen options. Afonso *et al.* (2024) demonstrated that greater levels of trustworthiness and friendliness perceptions resulted from the use of a more familiar handwritten script. Ward *et al.* (2014) looked at radio use and song preferences. Despite subjects generally agreeing that they preferred new, novel music, their study showed that songs that were more familiar (as well as those that participants claimed to be more 'sick of') were more likely to be chosen. Their regression showed familiarity predicted choice even more so than liking. In a study of Swedish investors, Massa & Simonov (2006) posited that, rather than engaging in classic hedging behaviour to balance risk, individuals in the dataset tended to purchase stocks they were more familiar with, that is, those that the investor was geographically or professional close to, or those that they had held for a long period of time. Overall, there is support for lower perceptions of risk when choices are familiar.

Underpinning these mechanisms with regard to familiarity, Zajonc (1968) documented the so-called 'mere exposure effect', wherein simply exposing people to various stimuli (e.g., nonsense words, Chinese characters, photographs) tends to result in more positive perceptions the higher the frequency of exposure, and that any physical fear or avoidance reaction associated with novel stimuli tended to wane after seven or eight exposures, as measured by galvanic skin responses. Jacoby & Dallas (1981) posited perceptual fluency theory to explain ease of processing familiar stimuli—when something is familiar it is recognised more readily and utilises fewer cognitive resources. The related uncertainty reduction hypothesis has also been suggested as a mechanism behind the positive affect associated with familiar stimuli, as familiar items do not create a sense of anxiety (Bornstein, 1989). Connecting these concepts, Reber *et al.* (2004) showed that processing fluency positively impacts subjects' perceptions of aesthetic pleasure, while Forster *et al.* (2013) demonstrated that subjective judgments of fluency affect liking more than objective ones. Similarly, Abreu *et al.* (2023) showed that cognitive processing improves for the familiar, such that more overall accompanying information is processed when faces are familiar.

Hypotheses and Research Questions

Chernev *et al.*'s (2015) meta-analysis provided support for the proposition that increases in choice set complexity, preference uncertainty and 'a more prominent effort-minimizing goal' (p. 346) are associated with greater choice overload. Additionally, the literature is fairly consistent in finding that familiarity positively affects choice satisfaction, with processing fluency theory a workable theoretical framework. When familiarity and overload effects are combined, there is some evidence of familiarity possibly reducing levels of choice overload, though this interaction has not been previously studied in this context.

Taken together, this leads to the following hypotheses:

H1a: The familiar cue will increase attitude toward the brand, attractiveness of the recommendations, and the intent to use the platform versus the unfamiliar cue.

H1b: The familiar cue will decrease perceived choice difficulty, perceived regret, perceived time-loss risk and perceived risk of service use versus the unfamiliar condition.

H2a: The low choice environment will result in higher levels of attitude toward the brand, the attractiveness of the recommendations, and intent to use the platform than the high choice environment.

H2b: The low choice environment will show a lower level of choice difficulty, perceived regret, perceived time-loss risk, and risk of service use than the high choice environment.

Research Questions: What are the interaction effects of familiarity and level of choice on (a) perceived choice difficulty, (b) attractiveness of the recommendations, (c) perceived risk of time loss, (d) perceived regret, (e) attitude towards the brand, (f) intent to use, and (g) risk of service use?

Method

Design

The study was a mixed design combining a within-subjects (low choice vs high choice) factor and a between-subjects (familiar vs non-familiar shows) factor. Half the sample was exposed to screens of high-choice and low-choice familiar shows, and the other half were exposed to stimuli of unfamiliar shows in both high- and low-choice conditions. The familiarity condition was randomly assigned by the Qualtrics platform. Similarly, choice level (high and low) stimuli were then presented in random order. The stimuli were presented in the form of a theoretical new SVOD service ('U-TV') user interface (see Figures 1 and 2). Following Wise *et al.*'s (2008) use of within-subjects design for a study on effects of level of choice, the researchers also utilised a between-subjects design for the familiarity manipulation, following Reeves & Geiger's (1994) direction to test between subjects when using alterations of the same message to create treatment variance (show lists were either real shows or fake shows with similar message attributes).

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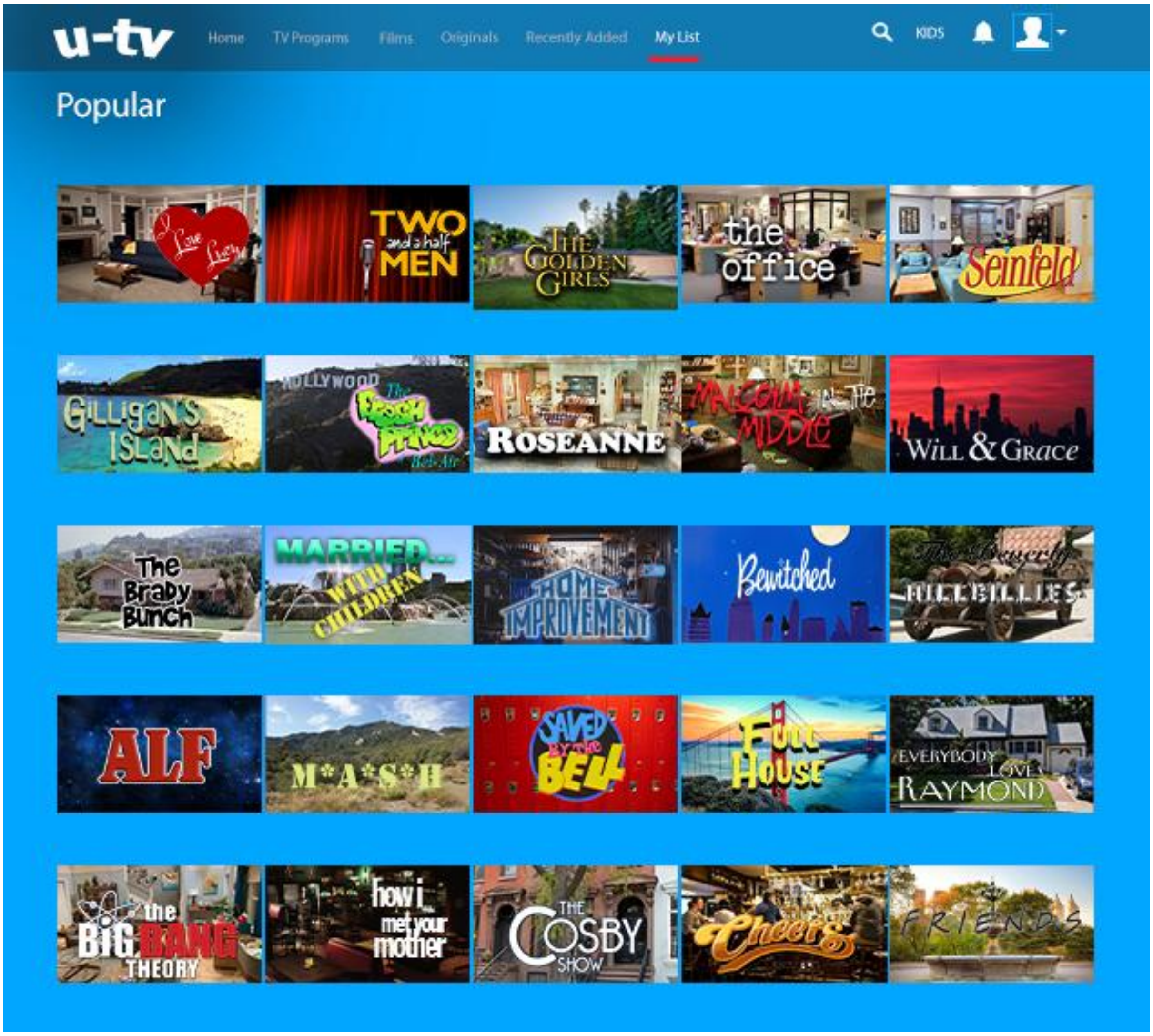

Figure 1. Sample Stimuli: High choice/Familiar

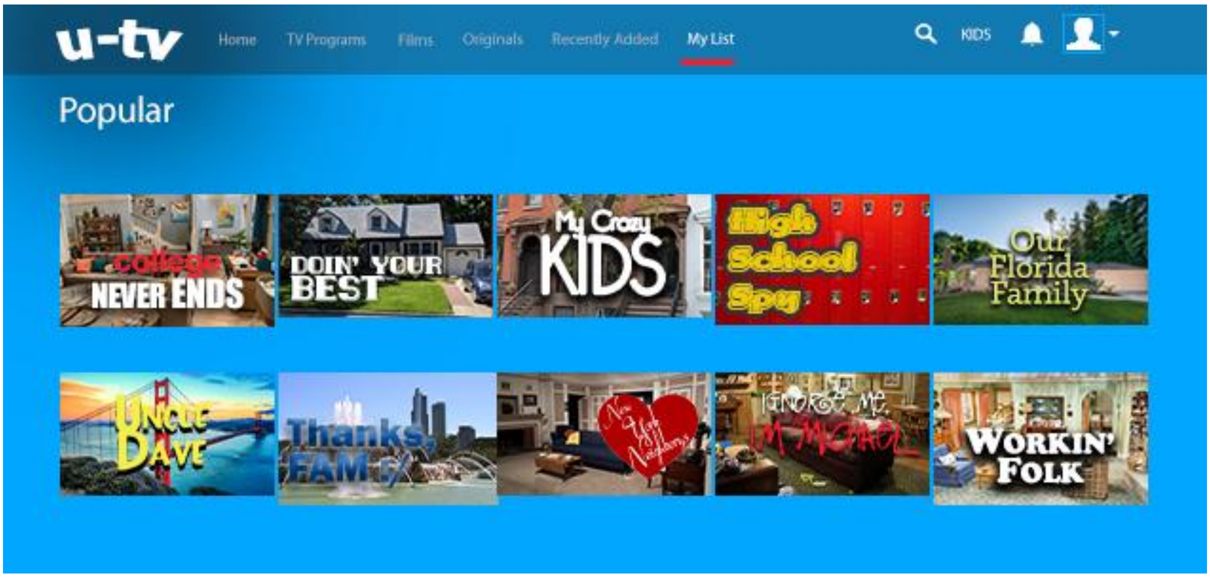

Figure 2. Sample Stimuli: Low choice/Unfamiliar

Participants

An a priori power analysis was conducted to assess an appropriate sample size. Given the relatively small (yet significant) Beta of the effect of familiarity on choice (.1) in the Ward *et al.* (2014) study on music, using Lenhard & Lenhard's (2016) Beta effect size calculator provides an estimated effect size of .15. G-Power 3.1 for Mac (Faul *et al.*, 2009) advised a total sample size of 351 from a p-value of .05, power of .8, four groups and one covariate (numerator *df* = 1). However, as this is a combination between- and within-subjects design, the study produces at least the same power with only 176 total participants (in total there were 352 measures for each dependent variable (DV) since participants provided answers after seeing two stimuli each). Thus, the researchers aimed for at least 88 participants in each of the groups.

Based on the power analysis outputs and after ethics approval for the study, recruitment and online consent process, the researchers sent emails inviting participation in an online experiment to a random sample of 4000 students at a large public university in the United States, asking them to participate in market research for a new Streaming Video on Demand Service that may soon launch, 'U-TV'. Participants were incentivised by the inclusion of a drawing for a $50 gift card taken from among those who completed the experiment and left their email address. The invitations initially resulted in a total of 186 completes; however, after removing those who opted out of inclusion in the dataset (the U-TV brand does not exist), the final cleaned dataset had a total of 181 participants (90 in the familiar condition, 91 in the non-familiar). Thus, the final response rate was 4.5%. SPSS was utilised to analyse results; figure visualisations below were built in Google Slides.

Stimuli

Since familiarity is of interest, a list of familiar TV sitcoms was generated by taking YouGov.com's ranking of 'The most famous all-time TV shows in America', defined as 'the [percentage] of people who have heard of an all-time TV show' (YouGov.com, 2021) and taking the first 25 sitcoms listed. These shows were used as the basis of the stimulus materials. A typical user interface for an SVOD service was created in Photoshop using a fictitious 'U-TV' brand to avoid confounds with existing brands or interfaces. For the familiar set of shows, representative photos of show locations or sets were chosen without identifiable actors included so as to avoid possible confounds due to celebrity identification or popularity. Show logos were then sourced from the Internet and placed appropriately over the image. For the non-familiar set, titles were created by the researchers with use of similar fonts and graphic treatment so as to avoid potential confounds caused by changes in typography.

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For the low-choice condition, two rows of shows were presented (10 shows). For the high-choice condition, five rows of shows were presented (25 shows). Though prior research has operationalised low-choice conditions utilising five or six choices (Wise *et al.*, 2008; Iyengar & Lepper, 2000; Bollen *et al.*, 2010), one row of shows is not consistent with a typical user experience, which would at least present two rows 'above the fold' when offerings are shown in a landscape format. As one row may cause ecological validity issues, two rows is our low-choice format, and five is our high-choice operationalisation (25 shows) following Iyengar & Lepper's 26 choices (2000) and slightly more than Bollen *et al.* (2010) used (20 choices) and Wise *et al.*'s (2008) 15 choices.

To ensure message variance, the researchers created multiple stimuli by randomisation of show thumbnails and order, with nine different possible versions of each of the four conditions, so as to avoid confounds due to order effects or particular shows or title cards eliciting some particular strong feeling or response in the participants. Thus, participants were randomly assigned to both condition and order. See Figures 1 and 2 for representative examples of each condition.

Measures

Adopting an approach from prior research (Bollen *et al.*, 2010; Ekstand *et al.*, 2014; Willmensen *et al.*, 2016), choice difficulty was measured via 4 items (e.g., 'I would probably change my mind several times before making a show choice from among these recommendations') (Cronbach's *alpha* [α]= 0.79) and choice satisfaction was also measured with 4 items (e.g., 'I am satisfied with the recommendations') (α= 0.95). Perceived risk of time loss was measured by two items (e.g., 'I would be afraid of wasting my time of choosing a show among these recommendations') (α= 0.75), developed from Roselius (1971).

Regret was measured by asking 'how much do you think you might regret your choice if you picked something from the screen you just saw?' (1=not at all, 7=very much). Attitude towards the SVOD brand (α= 0.95) and subscription intention (α= 0.97) were each measured by a five-item, seven-point semantic differential scale (Spears & Singh, 2004). Lastly, the researchers measured the risk of using the service by 4 items with a 5-point Likert-type scale (e.g., 'I believe there could be negative consequences from using this service') (α= 0.91) derived from Corretore *et al.* (2005).

TV show expertise as a control variable was measured following previous studies (Bollen *et al.*, 2010; Longo & Baiyere, 2021; four items, 7-point Likert-type) (α= 0.90, Mean *[M]*= 3.38, Standard Deviation [*SD]* = 1.47). SVOD use experiences and demographic variables (age, gender, education [school classification level], and race) were measured for control variables as well.

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Results

Sample description and demographics

As mentioned, the final sample contained data from 181 participants. Gender was reported as 43.4% male (n = 75), 56.7% female (n = 98) and 4.5% (n= 8) reported 'other' or 'prefer not to say.' The mean age was 23.7 years (*SD* = 8.47). Reflecting the ubiquity of SVOD service use, 95.6% of the sample reported currently having a subscription to a streaming video on demand service (n = 173) vs 4.4% (n = 8) reporting no current subscription, and a mean of 5.42 (*SD* = 1.60) was reported when asked how often those services were used on a scale from 1 to 7, where 1 was 'never' and 7 was 'all the time'. See sample characteristics/demographics in Table 1.

Table 1. Demographics and Sample Characteristics

Item/Measurement	Mean	Standard Deviation
Age	23.7 years	8.47
	Proportion	**Number**
Male	43.4%	75
Female	56.7%	98
Other gender/ prefer not to say	4.5%	8
White	69.6%	126
Black	6.6%	12
Hispanic or Latino	11%	20
Asian	15.5%	28
American Indian or Alaskan Native	7.2%	13
Native Hawaiian or Other Pacific Islander	.6%	1
Other ethnicity	3.3%	6
Currently have an SVOD subscription	95.6%	173
No current SVOD subscription	4.4%	8
	Mean	**Standard Deviation**
How often are current SVOD subscription services used?	5.42	1.6
Perceived TV show expertise	3.38	1.47

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Main effects of Familiarity

To test H1a, a number of calculations were carried out. To assess the main effect of familiarity on attitude toward the brand, a repeated-measures analysis of co-variance (ANCOVA) was performed with race as a covariate included (dummy coded as white = 1, non-white = 0) due to a significant correlation with race and attitude toward the brand in the high-choice condition (Pearson's r = .16, p = .04). Simple main effects analysis showed that the familiar cue (M = 4.44, SD = 1.38) increased attitude toward the brand versus the unfamiliar cue (M= 3.75, SD = 1.37) to a statistically significant degree (F(1, 177) = 11.21, p < .001, partial eta squared = .059). For the main effect of familiarity on the attractiveness of the recommendations, a repeated-measures ANCOVA was performed with race as a covariate included, due to a significant correlation between race and the attractiveness scale in the high-choice condition (r= .17, p= .025). The familiar cue (M= 4.2, SD=1.40) was more attractive than the unfamiliar (M= 3.5, SD=1.41) to a statistically significant degree (F(1,177)= 12.91, p < .001). For the main effect of familiarity on intent to use the platform, ANCOVA was performed with race and TV sitcom expertise, due to significant correlations with race on the high choice condition and with expertise in both choice conditions (r = .204, p = .006; r = .272, p < .001; r = .255, p < .001, respectively). Results showed a significant effect (F(1,176) = 9.99, p = .002, partial eta squared = .054) for familiarity, where familiar shows again resulted in higher intention to use (M = 4.08, SD=.85) versus non-familiar shows (M = 3.67, SD=.86). Thus, H1a is supported.

To assess H1b, a repeated-measures ANCOVA was performed with perceived choice difficulty as the DV with race and sitcom expertise as covariates, due to significant correlations with race in both conditions and expertise in the high-choice condition (r = .18, p = .015; r = .183, p = .014; r = .158, p = .033, respectively). Non-familiar shows resulted in a greater level of perceived choice difficulty (M = 3.85, SD=1.06) versus familiar shows (M = 3.19, SD=1.06) to a statistically significant degree (F(1,177) = 19.204, p < .001, partial eta squared = .089); this was in the hypothesised direction. A repeated-measures ANCOVA was then performed with sitcom expertise as a covariate and regret as the DV, due to a significant correlation between expertise and regret in the high-choice condition (r = .16, p = .03). Non-familiar shows resulted in a greater level of regret (M = 3.86, SD=1.45) than familiar shows (M = 2.81, SD=1.45) to a statistically significant degree (F(1,178) = 23.685, p < .001, partial eta squared = .12). For time-loss risk, sitcom expertise was included as a covariate, due to a significant correlation with the high-choice condition (r = .25, p < .001). ANCOVA revealed a significant difference (F(1,178) = 9.87, p = .002, partial eta squared = .053), where the familiar show condition resulted in lower perceptions of time-loss risk (M = 3.25, SD=1.27) than in the non-familiar condition (M = 3.85, SD=1.27). For overall risk perceptions, a repeated subjects

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analysis of variance (ANOVA) revealed no significant differences in the non-familiar (M = 3.11, SD=1.15) versus the familiar (M = 2.86, SD=1.14) condition ($F(1,179)$ =2.195, p = .14). Taken together, non-familiarity tends to result in higher levels of risk and potential regret, thus, H1b is supported. See Table 2.

Table 2. Main Effects of Familiarity: DV Means and Standard Deviations (Adjusted)

Mean (SD)	Attitude-brand	Attractive-ness	Intention to Use	Choice Difficulty	Potential Regret	Time-Loss Risk	Risk of Service Use
Familiar	4.44** (1.38)	4.20** (1.40)	4.08* (0.85)	3.19** (1.06)	2.81** (1.45)	3.24* (1.27)	2.68 (1.14)
Non-familiar	3.75** (1.37)	3.45** (1.41)	3.67* (0.86)	3.86** (1.06)	3.86** (1.45)	3.85* (1.27)	3.11 (1.15)

* $p<.05$, ** $p<.01$

Main effects of Choice Level

Similarly, to assess H2a, beginning with the main effect of choice level on attitude toward the brand, a repeated-measures ANCOVA was performed with race as a covariate included (dummy coded as white = 1, non-white = 0), due to a significant correlation with race and attitude toward the brand in the high-choice condition. Simple main effects analysis showed that the difference in attitude toward the brand in the low choice condition (M = 4.06, SD=1.49) and the high choice condition (M = 4.13, SD=1.54) were not statistically significant (p = .40). For attractiveness of the recommendations, the high-choice level was greater (M = 3.95, SD=1.65) than the low-choice (M = 3.71, SD=1.57) to a statistically significant degree (p = .02), in contradiction to expected direction. For intention to use the platform, differences in the high-choice (M = 3.90, SD=1.00) and low-choice (M = 3.85, SD=1.00) conditions were not significant ($F(1,176)$ = .925, p = .34). Thus, H2a was not supported.

To assess H2b, an ANCOVA with race and sitcom expertise as covariates showed a significant difference on choice difficulty between the high- (M = 3.66, SD=1.41) and low- choice (M = 3.38, SD=1.22) conditions ($F(1,177)$ = 5.99, p = .015, partial eta squared = .033); this difference was in the hypothesised direction with more choice difficulty evident for the high-choice condition. For regret, an ANCOVA with sitcom expertise as the covariate was performed; means for the high-choice condition were lower (M = 3.28, SD=1.71) than the low-choice condition (M = 3.40, SD=1.68), but the difference was not significant ($F(1,178)$ = 1.58, p = .21). For time-loss risk, no significant differences ($F(1,178)$ = 1.298, p = .26) were found in perceived time loss when in the low-choice (M = 3.59, SD = 1.57) versus the high-choice condition (M = 3.51, SD = 1.48). For overall risk, no conventionally significant differences (F(1,179) = 3.59, p = .06) were found in the low-choice (M = 3.06, SD=1.32) versus the high-choice condition (M

= 2.91, *SD*=1.21), though the marginally significant results trended in the opposite of the predicted direction. Thus, there was weak support found for H2b. See Table 3.

Table 3. Main Effects of Choice Level: DV Means and Standard Deviations (Adjusted)

Mean (SD)	Attitude-brand	Attractive-ness	Intention to Use	Choice Difficulty	Potential Regret	Time-Loss Risk	Risk of Service Use
Low Choice	4.06 (1.49)	3.71* (1.57)	3.85 (1.00)	3.38* (1.22)	3.40 (1.68)	3.36 (1.57)	3.06 (1.32)
High Choice	4.12 (1.54)	3.95* (1.65)	3.90 (1.00)	3.65* (1.41)	3.28 (1.71)	3.51 (1.48)	2.91 (1.21)

* p<.05, **p<.01

Interaction effects of Familiarity and Level of Choice

There were no significant interaction effects on attitude toward the brand ($F(1,178) = .92$, $p = .34$); however, there were significant interaction effects on attractiveness of the recommendations ($F(1,177) = 4.8$, $p = .03$, partial eta squared = .026).

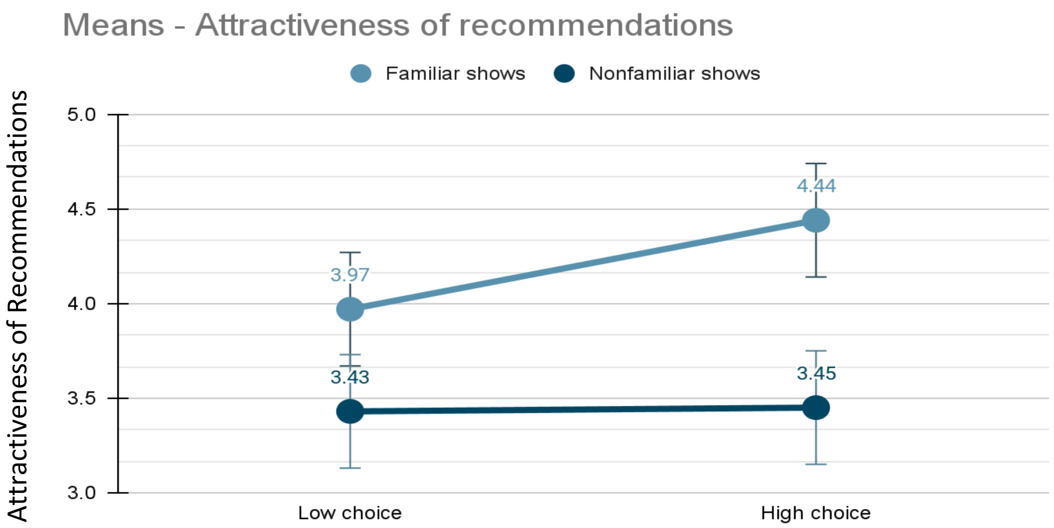

Figure 3. Interactions – Attractiveness of Recommendations

Further examination showed a significant difference between attractiveness of familiar shows (M =4.44, *SD*=1.56) versus unfamiliar (M = 3.45, *SD*=1.57) in the high-choice condition ($p < .001$); the differences between means in the low-choice conditions were also significant ($p = .02$) in the same direction (M = 4.0, *SD*=1.56 ; M= 3.44, *SD*=1.57). Familiarity is an advantage when it comes to recommendation attractiveness. There were no significant interaction effects found for behavioural intention to use the platform ($F(1, 176) = .806$, $p = .37$). See Figure 3.

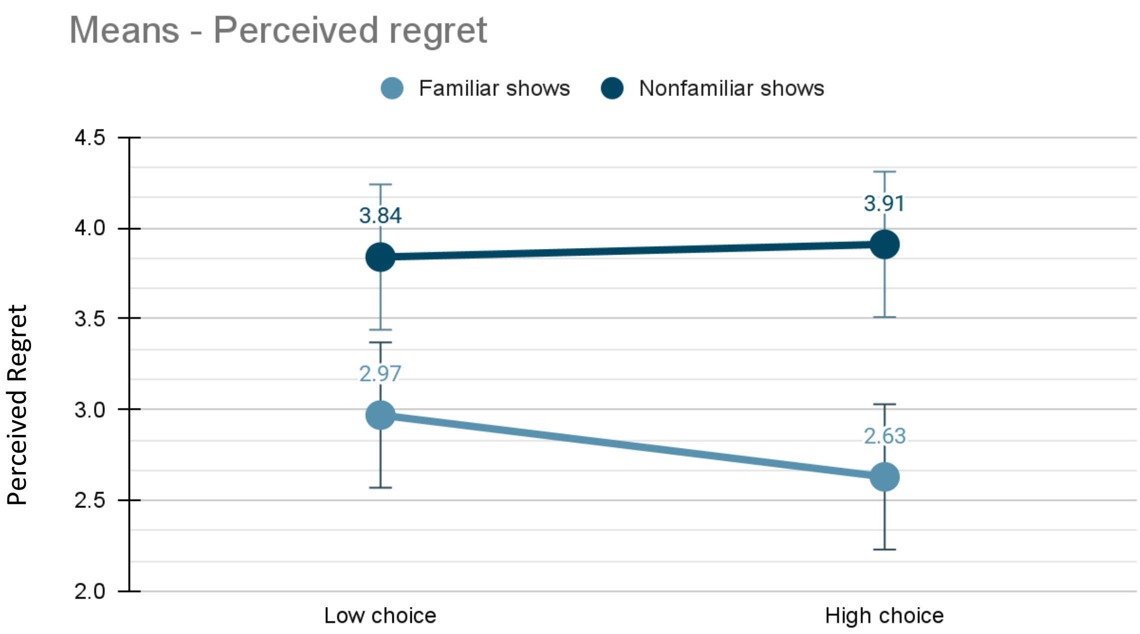

Figure 4. Interactions – Perceived Regret

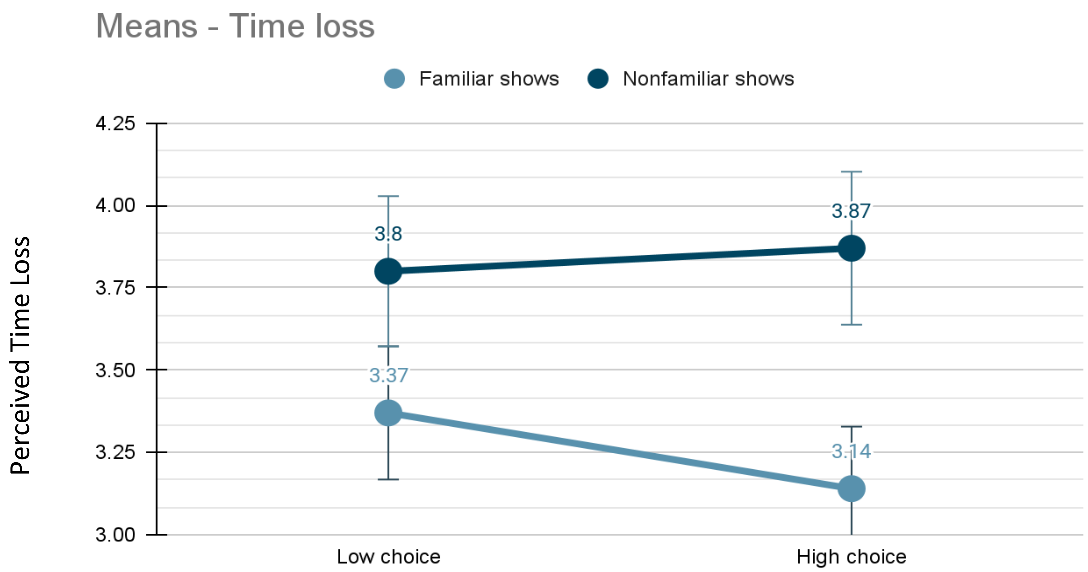

Figure 5. Interactions – Perceived Time Loss

There were no significant interaction effects found on perceived level of choice difficulty (F(1,177) = 1.47, p = .225). There were significant interactions found on perceived regret (F(1,178) = 3.91, p = .050, partial eta squared = .021). Further examinations revealed significant differences between familiar and non-familiar shows at both high- and low-choice levels (both at the p < .01 level), though the difference was greatest at the high-choice level; that is, familiarity tends to ameliorate potential negative effects of choice overload when it comes to regret perceptions. Mean differences were .85 at the low-choice level (p < .001, familiar regret M = 2.98, SD=1.62; non-familiar regret M = 3.83, SD=1.62) but were 1.25 at

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the high-choice level (p < .001, familiar regret M = 2.65, SD=1.58; non-familiar regret M = 3.90, SD=1.58). See Figure 4.

Though mean differences were significant in both low- and high-choice conditions for non-familiar versus familiar shows, no significant interaction effects were found on time-loss risk, but the mean differences again were significantly (p < .001) greater in the high-choice condition (.73) when comparing non-familiar (M = 3.87, SD=1.40) vs familiar shows (M = 3.14, SD=1.39) than in the low-choice condition (mean difference = .45, p = .05, non-familiar M = 3.82, SD=1.55; familiar M = 3.37, SD=1.56), again showing that more choice exacerbates perceived time-loss risk when choices are unfamiliar, as familiarity tends to override perceived time-loss risk. For overall risk, no significant interaction effects were detected (F (1,179) < .001, p = .992). See Figure 5.

Discussion

Despite consumers often expressing preferences for what's new and less familiar (e.g., Greul at al., 2023; Ward *et al.*, 2014), hypotheses regarding the positive effect of familiarity in choice sets were supported, with attitude toward the brand, attractiveness of the set of recommendations, and intention to use significantly higher for the familiar set of shows vs the unfamiliar set, and perceived difficulty in making choices, regret, and potential risk of time loss significantly lower for the familiar vs non-familiar set. This is in line with previous research on familiarity and choices. Ward *et al.* (2014) postulated that familiarity is especially relevant when making choices when the need for stimulation and accompanying cognitive load were low; the present results may corroborate that if considering sitcom viewing an activity that does not require large amounts of cognitive load.

The interaction effects also show how familiarity can alleviate potential choice overload. Wise *et al.* (2008) found that higher choice levels resulted in more cognitive resources being allocated in a study of online news headlines; the headlines and associated stories were again probably unfamiliar to the study participants and thus exacerbated any potential effects associated with greater levels of choice, and those conditions may be at play here as well. This mirrors to a degree the phenomenon detailed in the Iyengar & Lepper (2000) study, where shoppers were faced with what were presumably previously unfamiliar jams as well as a presumably unfamiliar brand; the lower choice levels resulted in more purchases. Kim *et al.* (2023) recently found that consumers actually preferred more choices vs fewer over an AI-generated chat interface vs one purportedly from a human: if consumers have the idea that a familiar AI tool is being used to feed recommendations, they may be less sensitive to the potential effects of choice overload.

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Accordingly, for choice overload, main effects were not quite as clear. While choice difficulty perceptions did increase significantly in the high-choice condition vs the low-choice condition in line with the overall tenets of choice overload theory, perceptions of the attractiveness of the recommendations also increased as well, while non-significant differences were found among the other perceptual variables measured on a global level. This pattern does seem to fall in line somewhat with other previous research on choice. For example, Chernev *et al.*'s (2015) meta-analysis found that choice set complexity and decision task difficulty were main objective, extrinsic factors that seemed to moderate potential choice overload effects. In our experiment, the choices were neither complex (e.g., the presented choice sets were complementary and had 'align ability', that is, there were common features among the choices) and it can be presumed the perceived task difficulty (that is, the lack of time constraints, the low number of overall attributes and dimensions, familiar presentation format, and lack of necessary justification for opinions) is quite low. Additionally, an intrinsic factor Chernev *et al.* (2015) identified as having a moderating relationship with choice overload, decision goal, would also perhaps ameliorate choice overload effects, as browsing as a decision goal was associated with less negative overload.

Conclusions/Recommendations

In terms of takeaways for industry, practitioners should utilise familiar/famous choices in recommendations when possible, in contrast to stated consumer preferences for the new and novel. The effect on attractiveness, intention to use, perceived difficulty in making choices, potential regret and time loss are all powerful. Consumers overall tend to prefer more choice in an SVOD environment; however, regret and time loss are enhanced when looking at unfamiliar choices in higher choice environments. Thus, the results show some evidence of choice overload effect in a sense when choices are unfamiliar. Therefore, in cases where new and potentially unfamiliar shows are exclusively proffered, practitioners should utilise less choice. As our results suggest choice overload effect is more evident in conditions where choices are more unfamiliar than familiar, it seems familiarity can trump most potential choice overload effects in an SVOD recommendation environment due to lessening the cognitive resources involved in processing. Alternatively, SVOD providers could work to make the recommendations agents themselves familiar, thus ameliorating potential choice overload effect, as noted above.

This study was limited to popular situational comedies in the United States only. Future research should include other locales and genres, such as drama, action, or horror. In addition, this study was limited to college students with a mean age of 23 years. While popular in their day, unfamiliarity with some of the shows could be attributed to them being older than the participants in the study. Future studies should include a more age-diverse population and more age-relatable content.

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References

Abreu, A. L., Fernández-Aguilar, L., Ferreira-Santos, F., & Fernandes, C. (2023). Increased N250 elicited by facial familiarity: an ERP study including the face inversion effect and facial emotion processing. *Neuropsychologia*, *188*, 108623. https://doi.org/10.1016/j.neuropsychologia.2023.108623

Afonso, H. M., Keizer, A., Biľak, P., & Beier, S. (2024). Familiarity effect in the perception of handwriting: Evaluating in-group/out-group effect among readers of the Latin script. *Journal of Writing Research*, *16*(2), 203–222. https://doi.org/10.17239/jowr-2024.16.02.01

Beneke, J. (2015). Are consumers really bewildered by overchoice? An experimental approach to the tyranny of "Too much". *Journal of Food Products Marketing*, *21*(1), 90–101. https://doi.org/10.1080/10454446.2013.843490

Bollen, D., Knijnenburg, B. P., Willemsen, M. C., & Graus, M. (2010, September). Understanding choice overload in recommender systems. In *Proceedings of the fourth ACM conference on Recommender systems* (pp. 63–70). https://doi.org/10.1145/1864708.1864724

Bornstein, R. F. (1989). Exposure and affect: Overview and meta-analysis of research, 1968–1987. *Psychological Bulletin*, *106*(2), 265–289. https://doi.org/10.1037/0033-2909.106.2.265

Chernev, A. (2003). Product assortment and individual decision processes. *Journal of Personality and Social Psychology*, *85*(1), 151. https://doi.org/10.1037/0022-3514.85.1.151

Chernev, A., Bockenholt, U., & Goodman, J. (2015). Choice overload: A conceptual review and meta-analysis. *Journal of Consumer Psychology*, *25*(2), 333–358. https://doi.org/10.1016/j.jcps.2015.07.001

Corretore, C. L., Marble, R. P., Wiedenbeck, S., Kracher, B., & Chandran, A. (2005). Measuring online trust of websites: Credibility, perceived ease of use, and risk. *AMCIS 2005 Proceedings*, Paper 370. https://asset-pdf.scinapse.io/prod/46967924/46967924.pdf

Ekstrand, M. D., Harper, F. M., Willemsen, M. C., & Konstan, J. A. (2014, October). User perception of differences in recommender algorithms. In *Proceedings of the 8th ACM Conference on Recommender systems* (pp. 161–168). https://doi.org/10.1145/2645710.2645737

Faul, F., Erdfelder, E., Buchner, A., & Lang, A.-G. (2009). Statistical power analyses using G*Power 3.1: Tests for correlation and regression analyses. *Behavior Research Methods, 41*, 1149–1160. https://doi.org/10.3758/BRM.41.4.1149

Festinger, L. (1957). *A Theory of Cognitive Dissonance* (Vol. 2). Stanford University Press.

Forster, M., Leder, H., & Ansorge, U. (2013). It felt fluent, and I liked it: subjective feeling of fluency rather than objective fluency determines liking. *Emotion, 13*(2), 280–289. https://doi.org/10.1037/a0030115

Gourville, J. T., & Soman, D. (2005). Overchoice and assortment type: When and why variety backfires. *Marketing Science*, *24*(3), 382–395. https://doi.org/10.1287/mksc.1040.0109

Graham, T. (2018). Platforms and hyper-choice on the World Wide Web. *Big Data & Society*, *5*(1), 2053951718765878. https://doi.org/10.1177/2053951718765878

Greul, A., Schweisfurth, T. G., & Raasch, C. (2023). Does familiarity with an idea bias its evaluation?. *Plos one*, *18*(7), e0286968. https://doi.org/10.1371/journal.pone.0286968

Iyengar, S. S., & Lepper, M. R. (2000). When choice is demotivating: can one desire too much of a good thing? *Journal of Personality and Social Psychology, 79*(6), 995–1005. https://doi.org/10.1037/0022-3514.79.6.995

Jacoby, L. L., & Dallas, M. (1981). On the relationship between autobiographical memory and perceptual learning. *Journal of Experimental Psychology: General, 110*(3), 306–340. https://doi.org/10.1037/0096-3445.110.3.306

Kim, J., Kim, J. H., Kim, C., & Park, J. (2023). Decisions with ChatGPT: Reexamining choice overload in ChatGPT recommendations. *Journal of Retailing and Consumer Services*, *75*, 103494. https://doi.org/10.1016/j.jretconser.2023.103494

Knijnenburg, B. P., Willemsen, M. C., Gantner, Z., Soncu, H., & Newell, C. (2012). Explaining the user experience of recommender systems. *User Modeling and User-Adapted Interaction*, *22*, 441–504. https://doi.org/10.1007/s11257-011-9118-4

Launspach, T., van der Deijl, M., Spiering, M., Heemskerk, M. M., Maas, E. N., & Marckelbach, D. (2016). Choice Overload and the Quarterlife Phase: Do Higher Educated Quarterlifers Experience More Stress?. *Journal of Psychological and Educational Research*, *24*(2), 7–16. http://www.marianjournals.com/files/JPER_articles/JPER_24_2_2016/Launspach_et_all_JPER_2016_25_2_7_16.pdf

Lenhard, W. & Lenhard, A. (2016). *Calculation of Effect Sizes*. Retrieved from https://www.psychometrica.de/effect_size.html. Dettelbach (Germany): Psychometrica. https://doi.org/10.13140/RG.2.2.17823.92329

Longo, C., & Baiyere, A. (2021). So, what should I watch? Choice overload among SVOD users. In *ISPIM Conference Proceedings* (pp. 1–15). The International Society for Professional Innovation Management (ISPIM). https://research.cbs.dk/en/publications/so-what-should-i-watch-choice-overload-among-svod-users

Massa, M., & Simonov, A. (2006). Hedging, familiarity and portfolio choice. *The Review of Financial Studies, 19*(2), 633–685. https://doi.org/10.1093/rfs/hhj013

Matysek, A., & Tomaszczyk, J. (2022). In quest of goldilocks ranges in searching for information on the web. *Journal of Documentation*, *78*(2), 264–283. https://doi.org/10.1108/JD-01-2021-0019

Mick, D. G., Broniarczyk, S. M., & Haidt, J. (2004). Choose, choose, choose, choose, choose, choose, choose: Emerging and prospective research on the deleterious effects of living in consumer hyperchoice. *Journal of Business Ethics*, *52*(2), 207–211. https://doi.org/10.1023/b:busi.0000035906.74034.d4

Misuraca, R., Ceresia, F., Teuscher, U., & Faraci, P. (2019). The role of the brand on choice overload. *Mind & Society*, *18*, 57–76. https://doi.org/10.1007/s11299-019-00210-7

Misuraca, R., Nixon, A. E., Miceli, S., Di Stefano, G., & Scaffidi Abbate, C. (2024). On the advantages and disadvantages of choice: future research directions in choice overload and its moderators. *Frontiers in Psychology*, *15*, 1290359. https://doi.org/10.3389/fpsyg.2024.1290359

Misuraca, R., Teuscher, U., & Faraci, P. (2016). Is more choice always worse? Age differences in the overchoice effect. *Journal of Cognitive Psychology*, *28*(2), 242–255. https://doi.org/10.1080/20445911.2015.1118107

Mogilner, C., Rudnick, T., & Iyengar, S. S. (2008). The mere categorization effect: How the presence of categories increases choosers' perceptions of assortment variety and outcome satisfaction. *Journal of Consumer Research*, *35*(2), 202–215. https://doi.org/10.1086/588698

Peterson, N., & Cheng, J. (2020). Decision experience in hyperchoice: the role of numeracy and age differences. *Current Psychology*, *41*, 5399–5411. https://doi.org/10.1007/s12144-020-01041-3

Reber, R., Schwarz, N., & Winkielman, P. (2004). Processing fluency and aesthetic pleasure: Is beauty in the perceiver's processing experience? *Personality and Social Psychology Review, 8*(4), 364–382. https://doi.org/10.1207/s15327957pspr0804_3

Reeves, B., & Geiger, S. (1994). Designing experiments that assess psychological responses to media messages. In A. Lang (Ed.), *Measuring Psychological Responses to Media Messages* (pp. 165–180). Lawrence Erlbaum Associates, Inc.

Reutskaja, E., Cheek, N. N., Iyengar, S., & Schwartz, B. (2022). Choice deprivation, choice overload, and satisfaction with choices across six nations. *Journal of International Marketing*, *30*(3), 18–34. https://doi.org/10.1177/1069031X211073821

Reutskaja, E., Iyengar, S., Fasolo, B., & Misuraca, R. (2020). Cognitive and affective consequences of information and choice overload. In R. Viale (Ed.), *Routledge Handbook of Bounded Rationality* (pp. 625–636). Routledge.

Roselius, T. (1971). Consumer Rankings of Risk Reduction Methods. *Journal of Marketing*, *35*(1), 56–61. https://doi.org/10.1177/002224297103500110

Scheibehenne, B., Greifeneder, R., & Todd, P. M. (2010). Can there ever be too many options? A meta-analytic review of choice overload. *Journal of Consumer Research*, *37*(3), 409–425. https://doi.org/10.1086/651235

Schwartz, B. (2004). The Tyranny of Choice. *Scientific American*, *290*(4), 70–75. https://doi.org/10.1038/scientificamerican0404-70

Spears, N., & Singh, S. N. (2004). Measuring attitude toward the brand and purchase intentions. *Journal of Current Issues & Research in Advertising*, *26*(2), 53–66. https://doi.org/10.1080/10641734.2004.10505164

Ward, M. K., Goodman, J. K., & Irwin, J. R. (2014). The same old song: The power of familiarity in music choice. *Marketing Letters, 25*(1), 1–11. https://doi.org/10.1007/s11002-013-9238-1

Willemsen, M. C., Graus, M. P., & Knijnenburg, B. P. (2016). Understanding the role of latent feature diversification on choice difficulty and satisfaction. *User Modeling and User-Adapted Interaction*, *26*(4), 347–389. https://doi.org/10.1007/s11257-016-9178-6

Wise, K., Bolls, P. D., & Schaefer, S. R. (2008). Choosing and reading online news: How available choice affects cognitive processing. *Journal of Broadcasting & Electronic Media*, *52*(1), 69–85. https://doi.org/10.1080/08838150701820858

YouGov.com. (2021). The Most Famous All-time TV Shows (Q3 2021). YouGov US. https://today.yougov.com/ratings/entertainment/popularity/all-time-tv-shows/all

Zajonc, R. B. (1968). Attitudinal effects of mere exposure. *Journal of Personality and Social Psychology, 9*(2, pt2), 1–27. https://doi.org/10.1037/h0025848

Remembering Keith Barnes and the Saudi Project

A Tribute to Keith Barnes (1932–2025) and Recollecting the Saudi Project

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Abstract: Keith Barnes died at age 92 on 3 January 2025. He devoted his whole working life to PMG and Telecom. He rose from the ranks in the Queensland State Administration to become Chief Planning Engineer in Telecom Headquarters. Keith did it his way, but his story is broadly typical of many others who contributed to the great infrastructure-building era of telecommunications in the post-war era. What is not typical is Keith's last major assignment, which was to lead the in-country team from Telecom Australia to provide a wide range of professional advice and support to Saudi Telecom. The assignment was unique, big and challenging. In this article the authors pay tribute to Keith and the team, and reflect upon the Saudi project itself.

Keywords: Keith Barnes, PMG, Telecom Australia, Telecom Australia (International), Saudi Arabia

Introduction

Keith Barnes' journey in Australian telecommunications was similar to many others, in that he started at the bottom and, through perseverance and effort, he worked his way to senior ranks. The Postmaster-General's Department (PMG) and Telecom Australia have many such stories. What sets Keith Barnes apart is that he became Telecom's Chief Planning Engineer and, uniquely, challenged himself late in his career to take on a completely new and unique assignment as Telecom's senior representative on the ground in Saudi Arabia.

Keith's death in January 2025 provides an opportunity to reflect on his career and his contribution to Australian telecommunications, and also to recall the times and the context in which the Saudi project was conceived and implemented.

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Early career

Keith was born on 11 December 1932 in Ipswich, Queensland to Alexander and Louise Barnes. He was the eldest of six children. Alex Barnes was a storeman in Ipswich at the time. The family later moved to Brisbane.

Keith spent his childhood years in Brisbane. With the help of a scholarship, he attended the Industrial High School in Fortitude Valley in 1947, 1948 and 1949 (Hoskins, 2025). He left school at the end of 1949 and joined the PMG's Queensland Administration as a trainee technician. He spent the period from 1949 to 1966 in PMG Queensland, where he was, in turn, a technician-in-training, technician, senior technician, technical instructor, a cadet engineer, and, finally, an engineer.

Keith graduated as a Bachelor of Science at the University of Queensland in 1961 and became a member of the Institute of Engineers (Australia) in 1962 (Barnes, 1990). He was known even then for his rigorous preparation before undertaking any task and being as ready to handle whatever might arise in doing so; good qualities for training and technical instruction, and for his next assignments in engineering planning.

PMG Headquarters, Melbourne

In 1966, Keith moved with his growing family to Melbourne, and joined PMG Headquarters, where he honed his expertise in the growing field of data (or, initially, non-voice) communications. This involved a promotion to the next level — at that stage, he was an Engineer, Class 2 in Subscriber Equipment, Telegraph and Power Branch (Barnes, 1990).

From 1974 to 1977, he was a data communications expert with the National Telecommunications Planning Group. He was a key member of the team that produced the *Telecom 2000* report (Australian Telecommunications Commission, 1975). That project has been described in articles published in this journal and its predecessor, the *Telecommunication Journal of Australia* (Newstead, 2000). The aim of the project was to provide analysis on how telecommunications demand, technology and markets might develop in Australia over the following 25 years (notionally up to the year 2000) and to provide guidance for Telecom Australia's priorities and investment strategies for the medium and longer term.

Keith himself noted that the work of the team and its *Telecom 2000* report were 'applauded by other long-term planning groups around the world' and recognised as 'a significant contribution to the methodology of long-term planning' (Barnes, 1990). Unfortunately, recognition closer to home was less forthcoming, and the report was effectively shelved fairly soon after its release. The new Telecom senior management had more pressing shorter-term matters to consider. The mid to late 1970s were themselves times of great change, with widespread industrial disputes over the introduction of new switching technology that required significantly fewer staff; capital rationalisation; increasing threats of network competition; and unprecedented demands for new and traditional services from all sectors.

In 1977, Keith was appointed to the position of Superintending Engineer, Telephone Switching Design, Customer Networks and Data Networks, covering engineering responsibility for all aspects of product management of the telegraph, telex and public telegram services (Barnes, 1990). At that time, telegram services were starting to decline, and this decline became much more marked over the next decade. Telex services, on the other hand, were growing and the challenge for Telecom was to source exchange equipment and customer terminals to keep pace with the demand (Australian Telecommunications Commission, 1979).

Over the five years from 1983 to 1988, Keith had very senior engineering roles in the Telecom Network Engineering organisation, including Chief Transmission Engineer, Chief Planning Engineer, Chief Switching Engineer, and Chief Forward Network Planning Engineer. In these roles, he was responsible for all of the planning, design and construction of the Australian inter-exchange network. During that period, external pressures increased, requiring Telecom to be transformed into a commercial enterprise, capable of successfully operating in an increasingly competitive marketplace. However, it was also an organisation that relied on proven, reliable and modern electronic engineering and its technical expertise was its traditional strength. Keith was in the engine room at that critical time. On occasion, he acted as General Manager, Engineering (Barnes, 1990).

Figure 1. Keith Barnes at the VIIIth CCITT Assembly of the ITU in Torremolinos in October 1984

International telecommunications developments and standards were critical inputs for Telecom's planning and procurement, and Telecom played a significant role in contributing to the work of the International Telecommunication Union and shaping the outputs of its many study groups and other working parties. Keith's role in Engineering Planning meant that he and his team needed to attend many of these forums. He led the Australian delegations at some very important international meetings, such as the VIIIth Plenary Assembly of the CCITT[1] in Malaga-Torremolinos, Spain in October 1984 (Figure 1).

Telecom was a large organisation, and many people contributed to its planning, designing, constructing and operating the infrastructure and systems that sustained its services to the nation. Keith Barnes was a key member of the engineering leadership of the organisation during those years and made an outsized contribution to the progress that was made.

Colleagues who worked with Keith during this period unfailingly refer to the rigorous approach that he had to preparation for important meetings, and to ensuring that decisions were taken on the basis of the best evidence available. He was tough on himself, and he expected the same of others. Those same colleagues also point out that Keith was scrupulously fair, encouraging and supportive of his staff.

There was surprise in some quarters when Keith made it clear in 1988 that he was available for a new and different challenge for the last years of his working life. He was 55 at that stage and had intended to retire around 60. The specific challenge that caught his attention was the Saudi Project.

The Saudi Project

Background

In the early 1980s, major telecommunications companies around the world were establishing specific-purpose vehicles to enable them to undertake planning, construction and operation of telecommunications networks in other countries, in many cases with support from national aid programs that were focussed on developing export markets for their countries' telecommunications equipment manufacturing industry.

As a strategic initiative, by the mid-1980s, Telecom Australia had established its own international vehicle, Telecom Australia (International) Ltd (TA(I)), seeking to capitalise on the success of the PMG in building relationships through the Colombo Plan Program, which exposed Australia's telecommunications talent to countries in the Asia-Pacific Region in the 1950s, 1960s and early 1970s (Loughnan, 2025).

Within a few short years, TA(I) had won contracts, mainly smaller ones, in many countries from Norway to Fiji and followed a corporate strategy based on trying to win some of the very large international contracts (Loughnan, 2025).

The world's largest telecommunications service contract at the time was to assist in the planning and operations of the Saudia Arabian network. The project was opened for tenders in 1987. This contract had been held by the international arm of Bell Canada for eleven years and there was a general view at the time that the Canadians were well entrenched and almost certain to be awarded the contract again (Rasmussen, 2025).

TA(I) bids for Saudi

After discussions with a potential Saudi partner, NESMA Corporation, who had won a contract in a joint venture with the Port of London authority to operate the ports in Saudi Arabia, TA(I) decided to bid for this internationally prestigious contract and established a high-powered bid team comprising Telecom specialists in engineering planning, design and operations, along with representatives from customer service, marketing and finance (Loughnan, 2025).

Competition for the Saudi contract was fierce. Apart from the Canadians, other bids were supported by the United Kingdom and Germany. All bids were supported by their respective governments. Saudi Telecom was (and remains) a government-owned enterprise, headed by a governing council chaired by the Minister.

By mid-May 1988, the *Australian Financial Review* was speculating that 'Telecom is poised to win a A$125m telecommunications contract in Saudi Arabia. The bid is the lowest of the three short-listed tenders. The tender, for the planning, expansion and management of Saudi Arabia's telephone & data network for the next three years, is considered the most prestigious telecommunications contract on offer in the world' (Neales, 1988).

After much negotiation with the Saudis, TA(I) was awarded the contract in September 1988. The contract was for an initial period of three years and could be extended by agreement for further similar periods.

Keith Barnes signals his interest

Keith Barnes had been on the periphery of the bid process early in 1988 and was attracted to an exciting opportunity to be involved in what was emerging as a landmark international telecommunications contract.

Ken Loughnan was then Executive Director (and, later, Managing Director) of TA(I) and had the task of establishing the senior team for the project, who would, in turn, identify and recruit the highly skilled staff required. He recalls:

> 'I was conscious that the bid process for this contract was tying up a lot of high-quality Telecom resource, but everyone was so enthusiastic about this novel opportunity that there were no grumbles from the top Telecom management team … and then I received a call from Keith Barnes. Thinking our luck had changed, I took the call. To my amazement Keith wasn't making contact to complain about resources, he was calling to confidentially express interest in leading the project in Saudi should we be successful – a person with far greater experience, status and respect than I could have imagined we would be able to recruit to the key leadership role – little did we realise how important Keith's attributes were going to be to the success of the project' (Loughnan, 2025).

Keith joined the project team and departed Melbourne for Saudi with the advance party on 1 October 1988. Some TA(I) staff, including Alan Dubberley, a senior member of the team, were already in Saudi Arabia sorting out preliminary arrangements and logistics for undertaking the contract.

The Saudi challenge

There had been a strong bond between Saudi Telecom and Bell Canada (who had bid well over double the TA(I) bid price), particularly at the top level. TA(I) needed to establish equally strong bonds in a short time. TA(I)'s Saudi partner, NESMA Corporation, under its then President, Sheikh Saleh Al Turki, was critically important in forging these links (Loughnan, 2025).

TA(I) was given a very demanding timeframe to have its advisors on the ground in the Saudi Arabia. Alan Dubberley was later to relate: 'Even after we took over the contract, I heard stories of Bell Canada promoting a recovery team to replace us 'once we failed' – such was the environment' (Dubberley, 2025). TA(I)'s Saudi partners were experienced in dealing with multi-national teams and provided every assistance in relation to logistics, accommodation, travel, medical and dental care.

The contract called for 130 expert advisors in various engineering, technical, commercial and administrative roles to be recruited and in place in Saudi Arabia by specified times. They were to be located mainly in Riyadh, with smaller operational teams in Abha (South Region), Damman (East Region) and Jeddah (West Region), and other smaller outposts, reflecting the regional structure of Saudi Telecom. The initial challenge was to recruit these experts and to expedite their arrival. In the event, even though the contract was amended to an average of 130 over the three years of the contract, 141 expert advisors were recruited in the first year (Rasmussen, 2025).

Keith Barnes' role

Keith's role was formally styled as Senior Advisor. He was the head of the Australian team in Saudi and responsible for all in-country dealings with the Saudi administration.

As noted above, Saudi Telecom was structured as a government department, the Ministry of Posts, Telephones and Telegraphs. Below the Minister in the structure was the Deputy Minister, Fouad Abu Mansour, and the Assistant Deputy Minister, Muhammad Jamil Ahmad Mulla. The Deputy Minister was Keith's counterpart (Figure 2), and the Assistant Deputy Minister was his day-to-day contact (Dubberley, 2025).

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Figure 2. Saudi Deputy Minister, Fouad Abu Mansour, and Keith Barnes, circa 1990. (Regrettably, the author has not been able to unearth details of this occasion.)

Quoting Ken Loughnan again:

> 'Keith was a very special person — he made a major contribution to the Saudi project, leading our Telecom Team, developing and maintaining an outstanding relationship with our partners in the NESMA group as well as Saudi Telecom. His was a novel challenge — no-one in our leadership group at Telecom had ever been given the task of managing a large diverse multi-functional group of Telecom professionals and their families over a long period of time in a foreign country with different customs and practices, while twinning another Telco. And he did a masterful job — from oversighting Saudi's national network planning, design and operation to the development of modern customer service, accounting and back-office functions, through to kids' education and dental care and local transportation, to ensuring adequate amenities and sporting facilities for each of our families — I will be forever grateful to have received that telephone call from Keith in early 1988' (Loughnan, 2025).

The recruitment task was ongoing throughout the contract period. The initial staff contracts were typically for two years in the case of advisors with families, and for one year for advisors without families. Advisors needed to be replaced as their contracts expired, or if they needed to return to Australia before expiry.

Several hundred senior and mid-level Telecom staff and their families have also been grateful to Keith for forging TA(I)'s initial presence in the Kingdom. As one of the senior members of the team, Kevin Currie, was later to relate: 'Keith had a great instinct for balancing the needs of the Saudis, the company and the team. Due to his sense of diplomacy, fair play and just the right touch of discipline and flexibility, the project got off to a good start. We really missed his finesse and judgement when he finally left the project' (Loughnan, 2025).

Another senior member of the team, Murray Rasmussen, referred to the challenges of running the major compound for the Australian team and their families in Riyadh, and of the issues that inevitably arose (Rasmussen, 2025). Alan Dubberley recalled that 'it was like running a small country town' (Dubberley, 2025).

Keith handled personnel issues very well, with the help of his senior team. But Keith's main task was to manage the in-country relationship with his Saudi Telecom counterparts, and he did that extremely well, with 'finesse and judgement', as noted by Ken Loughnan above, and with a lot of hard work and rigorous preparation.

Many of the Australians in Saudi Arabia used their spare time to complete courses remotely or to learn Arabic — but Keith did something unique. Although he grew up close to the Queensland coast, he had not learned to swim. Keith's villa was amongst a cluster of executive villas built around their own swimming pool. Keith arranged lessons to take advantage of the opportunity. He learned to swim, in the middle of a vast desert. (Dubberley, 2025; Rasmussen, 2025)

What was achieved in Saudi Arabia

Telecom staff were able to advise on the introduction of new services to Saudi Arabia, and to assist in their implementation. For example, prior to TA(I)'s presence, there had been no free-call services and no packet-switched data services in Saudi Arabia. These services were established or well advanced in planning by the time the project concluded in 1994. An Ericsson public mobile phone service operating in Saudi Arabia when TA(I)'s contract started was limited to 1000 services and very limited coverage. The Australian team was able to use Australian experience in mobile telephony to organise for tenders for the supply and deployment of GSM digital services, which by-passed the analogue cellular mobile technology altogether. Murray Rasmussen recalls that the Australian team also initiated the first fibre connection along the causeway between Saudi Arabia and Bahrain; and assisted in solving heat propagation problems affecting transmission and service in the desert, using experience with the same issues in Australia (Rasmussen, 2025).

The Saudi project enabled many Telecom personnel to broaden their experience and expertise in ways that may not have been possible had they remained throughout that same period in Australia. In particular, knowledge transfer skills, dealing with a range of new circumstances, and effectively engaging with professionals in a different culture, were important. This experience and expertise were of value in Australia, where, as a result of industry restructure

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and imminent competition, the ground was shifting and there was a premium on adaptation and agility.

The Saudi project comes to an end

The Saudi project ended for TA(I) in 1994. It did not get a third term.

There were many reasons for that, not the least being a very competitive bidding process. However, Telecom Australia had merged with the Overseas Telecommunications Corporation in 1992 and Telstra Corporation had been formed as a result. Telstra's new senior management team had different priorities to the senior management that had embarked on the Saudi project six years before. Ken Loughnan had left TA(I) and Telstra's overseas interests were heavily focussed on Asia and the Pacific. Telstra's prime focus was to transform itself and meet the competitive challenges in Australia.

Keith Barnes – Post-Saudi and Recognition

Keith ceased in his role as Senior Advisor, Australian Saudi project team and returned to work in Telecom Australia in December 1990. He took on the role of Director, Business Development in the Corporate Strategy Directorate, and retired in 1993.

The Director of Corporate Strategy, Dennis Flentje, recalls that Keith's deep technical knowledge and practical experience in telecommunications operations were extremely valuable in assessing strategies and options in those uncertain times (Flentje, 2025).

Keith moved back to Queensland with his partner, Judy, and, later, they moved to Victoria. Keith had a long and fulfilling retirement and was very much involved in breeding and racing thoroughbred horses (Ward, 2025).

He died on 3 January 2025. He is survived by his children, Garry, Karen, Geoffrey and Ross.

Keith had a long and successful career in Australian telecommunications and, through his involvement in planning and operations, made a strong contribution to an important era of infrastructure building. It is appropriate to record his two years in Saudi Arabia at the end of his career as his final achievement, but certainly not the only one. The Saudi project was a unique assignment that called for the exercise of all of the skills and expertise that he had developed beforehand, and is worthy of special attention for that reason.

The recognition of his peers and colleagues in PMG/Telecom is implicit in the comments quoted above. Sheikh Saleh Al Turki, then President of the NESMA Corporation and TA(I)'s partner in Saudi Arabia, is today mayor of both the Red Sea City of Jeddah and the Holy City of Makkah. On receiving news of Keith's passing, he messaged: 'I am saddened to learn of

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Keith's passing. May God bless his soul. Please pass on my condolences to the family' (Loughnan, 2025).

Keith Barnes and the Journal

It would be incomplete not to mention Keith's contributions to the Telecommunications Society and to its *Journal*.

In 1966, Keith wrote an article entitled *ARM 50 Crossbar Transit Exchange* (Barnes, 1966). At the time, he was introduced as Engineer, Class 2, Subscribers Equipment, Telegraph and Power, Headquarters. The article reflects the extent to which technical knowledge was shared across the industry in the *Journal* at that time.

In 1984, Keith was Chairman of the Council of Control of the Telecommunications Society of Australia. He was also Telecom's Chief Planning Engineer. As Chairman, he wrote the editorial for the first issue of the *Journal* for 1984 (Barnes, 1984).

Acknowledgements

The author appreciates the contribution to this reflection on Keith Barnes' career and contribution to Australian telecommunications from his family and many friends and former colleagues. I am indebted to his son, Ross, for access to papers and documents, and to Don Hoskins for his information about Keith's early years in Brisbane. I acknowledge also the substantial assistance received from Keith's former colleagues and associates, who shared their recollections or prepared notes for this tribute. They include Peter Clifton, Alan Dubberley, Barry Evans, Dennis Flentje, Peter Frueh, Peter Keating, Dr Ken Loughnan AO, Murray Rasmussen and Graeme Ward.

References

Australian Telecommunications Commission. (1975). Telecom 2000: An exploration of the long-term development of telecommunications in Australia, National Telecommunications Planning Branch, Planning Directorate, Australian Telecommunications Commission, Melbourne.

Australian Telecommunications Commission. (1979). Annual Report of Telecom Australia, 1978-79 (Canberra), pp. 57–59 in relation to telex and telegram services.

Barnes, K. (1966). ARM 50 Crossbar Transit Exchange. *Telecommunication Journal of Australia*, *16*(2), 105-109.

Barnes, K. A. (1984). Editorial. *Telecommunication Journal of Australia*, *34*(1), 2.

Barnes, K. A. (1990). CV (unpublished), a copy of which was provided by Ross Barnes to the author.

Dubberley, A. (2025, February). Recollections of Keith Barnes and the Saudi Project, in conversation with the author, 5 February 2025.

Flentje, D. (2025, February). Recollection of Keith Barnes, in conversation with the author, 13 February 2025.

Hoskins, D. (2025, February). Recollections, as a childhood friend and PMG colleague of Keith Barnes, in conversation with the author, 29 February 2025.

Loughnan, K. (2025, February). Notes for a tribute to Keith Barnes (unpublished), provided to the author, 8 February 2025.

Neales, S. (1988). Telecom Tipped for $125M Saudi Deal. *Australian Financial Review*, 17 May 1988. https://www.afr.com/companies/telecom-tipped-for-125m-saudi-deal-19880517-k2s88

Newstead, I. A. (2000). Telecom 2000 – In Retrospect. *Telecommunication Journal of Australia*, *50*(3), 11–18.

Rasmussen, M. (2025). Recollections as a colleague of Keith Barnes in Saudi Arabia, in conversation with the author, 3 February 2025 and 13 March 2025.

Ward, G. B. (2025, March). Recollections as a Telecom colleague and co-member of various horseracing consortia with Keith Barnes, in unpublished email to the author, 11 March 2025.

End Note

[1] Consultative Committee for International Telephony and Telegraphy of the ITU, which, since the reorganisation of the ITU in 1993, has been known as the ITU-T (for telecommunications).

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Ninety Years of the Journal

Simon Moorhead
Telecommunications Manager

Abstract: The *Journal* revisits several historic papers from 1935, 1938 and 1939 that reflect on the formation of the Society and its associated Journal.

Keywords: History of Australian Telecommunications, The Telegraph Electrical Society of Melbourne, The Postal Electrical Society of Victoria, The *Telecommunication Journal of Australia*.

Introduction

In 2025, TelSoc (the Telecommunications Association Inc.) celebrates 90 years of publishing the *Telecommunication Journal of Australia* and its successor, the *Journal of Telecommunications and the Digital Economy*.


The Telecommunication Journal of Australia

No. 1 JUNE, 1935

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THE POSTAL ELECTRICAL SOCIETY OF VICTORIA

Figure 1. The first issue of the *Telecommunication Journal of Australia*, June 1935.

This is one of several papers to be published in 2025 covering this significant anniversary in the evolution of the Society. The first Journal was published in June 1935 and comprised only 24 pages. The original Australian journal was modelled after the success of the UK *The Post Office Electrical Engineers' Journal* (published from 1908), which was probably the premier telecommunications journal at the time.

The foreword to the first Australian journal (Crawford, 1935) states that *The Post Office Electrical Engineers' Journal*:

> 'also started from small beginnings and from a sense of the need which British Post Office Engineers were then feeling of some vehicle by which they could pool and share their engineering knowledge and experience. For the true Scientist and Engineer is never selfish or exclusive. He [*sic*] is glad to bring his contribution into the common

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> hive of knowledge and place his observed data at the disposal of his fellow-workers, whether they be workers in the realm of inductive thought, research or practical engineering. The value of a Journal of this kind to our Engineers is emphasised in another article in these pages, but may I stress one vital truth—it is only possible to achieve success in a Journal of this kind by widespread and consistent support!' (Crawford, 1935, p. 1).

This theme of sharing knowledge and observed data seems naïve today with the realities of commercial competition and the need to keep some developments confidential for reasons of competitive or national advantage.

Our December 2024 issue contained nearly 200 pages and credit must go to the contributors and editors (both past and present) who have been able to produce this outstanding journal for so long and in recent times, when competitive pressures have influenced the material available for publication.

The two historic papers, Credlin (1938) and McMahon (1939), detail the early history of the Postal Electrical Society of Victoria and the Telegraph Electrical Society of Melbourne . These were the forerunners of the Telecommunications Society of Australia.

In 1874 (and two years before Dr Alexander Graham Bell invented the telephone) (Credlin, 1938, p. 2), several like-minded telegraph workers and country postmasters formed the Telegraph Electrical Society in Victoria. The purpose was for mutual discussion of day-to-day telegraph problems and the advancement of their technical and practical knowledge. The proceedings of the Society were published on a quarterly basis and lecture pamphlets were reproduced in newspapers of the day. Details of the early Society were 'scanty' when the first paper was written. This paper includes a photograph of the committee members in 1908 (Credlin, 1938, p. 2), as well as a photograph of the welcome that Dr Alexander Graham Bell received at the Melbourne Central Exchange, taken in 1910 (Credlin, 1938, p. 3).

Through the courtesy of the then Superintendent of Mails in Sydney, copies of the transactions of the Telegraph Electrical Society were subsequently made available, which led to the second paper (McMahon, 1939) eight months later.

This paper provides much more detail on the committee membership, subscription fees and the papers that were given to members and the public. It mentions a talk on electric telegraphy that was given as an introduction to an exhibition of Electric Telegraphy for members at the Athenæum Club in 1875 (McMahon, 1939, p. 166). The paper also highlights a number of milestones in its transactions, such as the laying of an undersea cable between Sydney and New Zealand (McMahon, 1939, p. 167). It notes that, in an 1877 edition of the Society's journal, there was discussion of Dr Alexander Graham Bell's invention of the telephone. It was stated that:

> 'By means of his telephone the human voice (or any other sound) is carried by magnetic currents along a telegraphic wire and reproduced at the stations on the lines.... It has been seen by Sir William Thomson and pronounced by him to be 'the greatest by far of all the marvels of the Electric Telegraph,' and the Telegraphic Journal, London, states that so many proofs have been given of the authenticity of the invention that its reality can no longer be a matter for doubt' (McMahon, 1939, p. 168).

The Telecommunications Society of Australia celebrated its centenary in 1974 and several other historic papers from this time will be revisited later in this series. Since the formation of the Telegraph Electrical Society in Victoria in 1874, we have seen an explosion in the rate of development of telecommunications and the social changes that this has facilitated. These key developments will also be covered in later papers in this series.

References

Crawford, J. M. (1935, June). Foreword. *Telecommunication Journal of Australia, 1*(1), 1.

Credlin, E. J. (1938). The Early History of the Postal Electrical Society of Victoria. *Telecommunication Journal of Australia, 1*(2), 2–4.

McMahon, B. (1939). The Early History of the Telegraph Electrical Society, Melbourne. *Telecommunication Journal of Australia, 3(*2), 166–170.

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Crawford (1935)

FOREWORD

THE purpose of a foreword in a venture of this kind is, I suppose, to send it forth with every initial good wish—a sort of literary breaking of a champagne bottle on the prow of this our Victorian Technical Argosy as she takes the water for her maiden voyage. If that be so, then very sincerely do I contribute my word of Good Luck and Bon Voyage.

I well remember, as Secretary of the Institution of Post Office Electrical Engineers, helping to launch a Journal which, at its inception, was equally modest, and which we sent forth with equal trepidation. Its first issue was on All Fools' Day, 1908, and there were some who facetiously connected the date with the venture; but to-day the Journal is probably the premier Telecommunication Journal of the World—"The Post Office Electrical Engineers' Journal." It also started from small beginnings and from a sense of the need which British Post Office Engineers were then feeling of some vehicle by which they could pool and share their engineering knowledge and experience. For the true Scientist and Engineer is never selfish or exclusive. He is glad to bring his contribution into the common hive of knowledge and place his observed data at the disposal of his fellow-workers, whether they be workers in the realm of inductive thought, research or practical engineering. The value of a Journal of this kind to our Engineers is emphasised in another article in these pages, but may I stress one vital truth—it is only possible to achieve success in a Journal of this kind by widespread and consistent support!

So, just as 64 years ago the Society of Telegraph Engineers in London founded the great Institution of Electrical Engineers with its world-wide membership and authoritative Journal, and 27 years ago the Engineers of the British Post Office founded the Post Office Electrical Engineers' Journal, which to-day has also a world-wide circulation, so may our Victorian venture be a prelude to an All-Australian Communication Journal, which in due time will increase in value and become the authoritative record of the steady progress of Communication Engineering in Australia.

J M Crawford

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Credlin (1938)

THE EARLY HISTORY OF THE POSTAL ELECTRICAL SOCIETY OF VICTORIA

E. J. Credlin

Even in the embryonic days of Telegraph and Telephone Engineering in Australia, those directly associated with this important communication industry realized the importance and advantages of a society, embracing officers who controlled and operated the service, to facilitate the interchange of technical knowledge and its practical application.

Thus as early as 1874—even before the advent of the telephone—the first Electrical Society was formed in Victoria by the then comparatively few Telegraph Society workers, who apparently realized that even in those early stages of the development of the telegraphic engineering art, their day to day problems would be lessened and simplified by mutual discussion, and that this society would provide an avenue for the advancement of their technical and practical knowledge.

Unhappily the records of the activities and progress of this foundation body are very scanty. As far as can be ascertained, the subscription was 10/- per annum, and the activities were conducted, during the inception period, by some half a dozen members, who arranged for the issue of a journal, and the preparation, printing, and distribution of technical papers. The subscription fees were intended to provide the funds for this purpose. It is interesting to note that the membership comprised a large proportion of the country postmasters. Presumably, however, the papers issued by the society were of such an abstruse character that they were not always suited to the needs of the general members and as the years progressed the enthusiasm of its sponsors was not maintained. Although it had remained primarily a Telegraph Society, it lost much of its punch, although there were periodic revivals. It was eventually superseded in 1908 by the Postal Electrical Society, which comprised both Telegraph and Telephone Branches, including members of the Traffic Section, who were officers of the Engineering Branch, under the organization existing at that time.

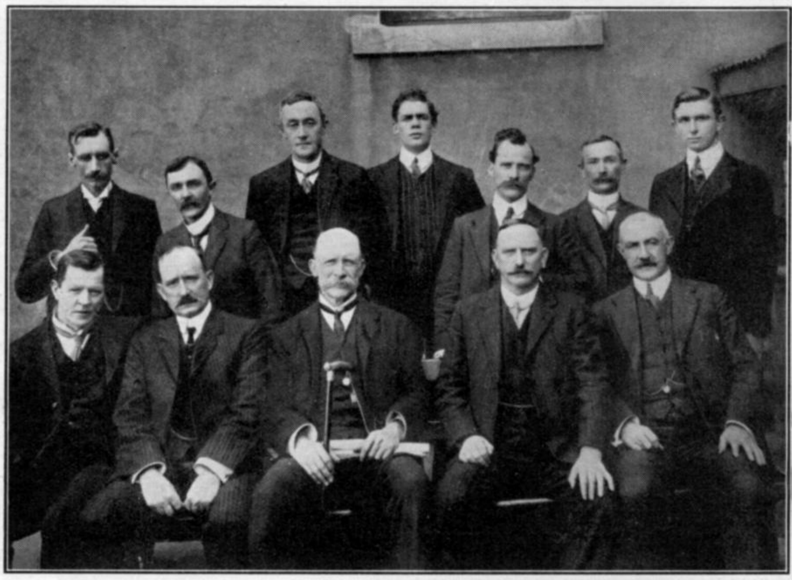


Fig. 1.—Committee—Back row: E. S. Howson, W. J. Dawson, H. J. Rutherford, G. H. Bussell, F. Prior, O. A. Junck, E. A. Batty. Front row: M. J. Fitzgerald, G. H. Morgan, H. W. Jenvey, C. E. Bright, T. Howard.

The inaugural meeting of the new society, viz., the Postal Electrical Society, was held in the old Telegraph Office, located in the Elizabeth Street Post Office—then the General Post Office—on the 11th November, 1908.

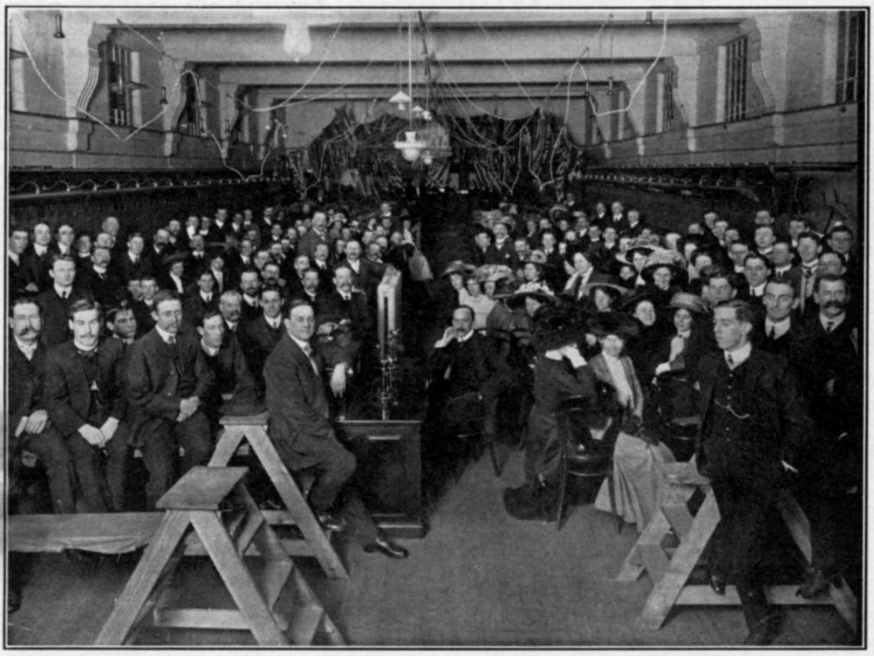
The prime movers in the formation of the new society were Messrs. O. Junck and H. Rutherford. Mr. H. W. Jenvey, Electrical Engineer, Victoria, was elected the first President, while the Vice-Presidents were Messrs T. Howard and M. Fitzgerald. Mr. Rutherford was the first Secretary and was succeeded by Mr. Batty. The Patrons included Mr. C. E. Bright, the Deputy

Postmaster-General, and Mr. J. Hesketh, the Chief Electrical Engineer.

The photograph published shows the members of the first committee, and should be of particular interest to at least the older members, providing as it does, such a tangible link with the early history of the society.

The object of the society was the advancement of Postal Electrical Engineering in all its phases, and for the instruction of members on relative matters of a technical nature. Any officer of the Service was eligible for membership. These objectives were fittingly outlined by the President (Mr. Jenvey) in the following extract from his inaugural address:—

"We have to consider what is really the object of forming a P. & T. Society. In the first place there must be solid co-operation in order to keep it alive. Members should prepare papers and present them for discussion at the meeting. They should also make it a point to attend the meetings regularly and give encouragement to those who contribute papers. The motive of the Society should be to improve the knowledge of the officers—there is ample scope for study in our business without going outside the telegraph and telephone service. The field of study is not only electrical. It is too often thought that knowledge of electricity and electrical laws is sufficient to fit an officer of this branch for his duties—but that is not the case—that fact is becoming more widely recognized in all electrical engineering concerns, whether private or Governmental. Before a person can deal satisfactorily with, and solve electrical engineering problems, whether telegraph or telephone, he must be fortified with sound general knowledge. Knowledge of electrical laws itself is not sufficient, he must have a knowledge of things which are taught in schools and universities—without that knowledge he will always find himself deficient."



Flashlight photograph of welcome to Dr. Graham Bell, at Melbourne Central Exchange, 17.8.1910. Given by Postal Electrical Society of Victoria.

As an indication of the comprehensiveness of the original membership, it included many non-technical officers, in fact, practically the whole of the administrative staffs of the Engineering Branch, Victoria, and those of the Chief Electrical Engineer's Branch.

Meetings were held once a month at the G.P.O., and arrangements were made for a paper, technical in nature, to be read at each meeting. Occasionally, refreshments were arranged for. The early lecturers included Messrs. Junck, Powell, Rutherford, and Howard. Special visit nights were also arranged, and the programme included visits to the Central C.B. Exchange, then in course of installation, the Metropolitan

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Fire Station, the 'Age' office, and engineering works.

Although endeavours were made to establish a technical library, this phase of the society's early efforts did not meet with very great success. As an aid to this proposal, the P.M.G.'s Department was approached for a donation of £10/10/- which, however, was refused.

In 1910, Dr. Graham Bell visited Melbourne and inspected the Central C.B. Exchange during its installation. He honoured the society as its guest at a function held in the Exchange just prior to the formal opening. The photograph published shows the members of the party on this occasion. Dr. Graham Bell and other distinguished personages on the platform, however, have not been kindly treated by the photographer, and identification requires the use of a magnifying glass.

The growth and development of the society, and its progressive activities, particularly over the last few years, must surely serve as a splendid testimonial to the original sponsors of this society, whose aims and objectives were so idealistic, but are nevertheless now within the limits of achievement.

[Editor's Note.—As it is desired to compile as complete a history as possible of the early years of the society, members are specially invited to furnish any additional information that may be in their possession. In particular, a complete copy of Mr. Jenvey's inaugural address and early papers published by the society would be welcome.

We are indebted to Messrs. R. F. Archer, E. A. Batty, and H. J. Rutherford, for kindly furnishing the information on which these notes have been based, and for the loan of the photographs.]

McMahon (1939)

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THE EARLY HISTORY OF THE TELEGRAPH ELECTRICAL SOCIETY, MELBOURNE

B. McMahon, D.P.A., A.M.I.E. (Aust.)

In the June, 1938, issue of the "Telecommunication Journal of Australia," Mr. E. J. Credlin, in writing of the inauguration of the Postal Electrical Society in 1908, referred to the formation of the first Electrical Society in Victoria in 1874. Through the courtesy of Mr. F. R. Bradley, Superintendent of Mails, Sydney, copies of the transactions of this Society have been made available.

The transactions were first published in a bound volume issued in 1875, from which it is learnt that the first Ordinary General Meeting was held on Wednesday, 12th August, 1874. On one of the introductory pages it is advertised that the Society was established "for the promotion of the knowledge of electricity, especially as connected with telegraphy." The Society arranged to meet for the transaction of business at the Melbourne Athenæum on the second and fourth Wednesdays of each month at 8 p.m.

The first Committee of Management comprised Mr. G. Smibert, Mr. D. Mickle, Mr. D. J. McGauran and Mr. H. W. Jenvey. The Honorary Secretary and Treasurer was Mr. L. S. Daniel. Throughout the first volume of transactions, Messrs. McGauran and Daniel were frequent contributors, and apparently their work and enthusiasm contributed greatly to the successful establishment of the Society. The subscription was £1 per annum for town members and 10/- per annum for corresponding (or country) members. In the early volume no mention is made of a President, and the transactions show that there was a different Chairman at each meeting, Mr. D. J. McGauran occupying the chair at the first meeting, followed by Mr. C. W. Miller, Mr. D. Mickle and Mr. George Smibert.

There were 48 members and 61 corresponding members, and at the inception of the Society membership was restricted "for the present" to officers of the Post and Telegraph Department. On September 9th, 1874, however, it was resolved "that any gentleman intimately connected with the practice of telegraphy in this or the neighbouring colonies shall be eligible for membership of this Society." Apparently no provision was made for female, or perhaps in the spirit of the age I should say lady members, for Rule No. 12 provided eligibility for membership for no others than "any gentleman intimately connected with the practice of telegraphy. . . ."

We can admire the broad outlook of the founders of this Society, who so soon after its inception made membership available to telegraph workers in the neighbouring colonies, a quarter of a century before Australia became a Federation. In 1875 the telegraphic art was more or less a mystery to the general public, if not to many members of the Department, and in this respect it is interesting to read that a short elementary lecture on electric telegraphy was given by Mr. L. S. Daniel as an introduction to the Exhibition of the Electric Telegraph at a public entertainment which was given by the members of the Society at the Melbourne Athenæum on Monday, 1st February, 1875. The entertainment, which was presided over by Mr. Turner, the then Deputy Postmaster-General of Victoria, "was very successful, and the Melbourne Press was unanimous in pronouncing it one of the most interesting lectures ever given in the city."

In recent times there has been much discussion on the use of proper functional designations for professional and technical occupations, and some of the words around which the discussion has turned are "Mechanic," "Electrician" and "Engineer." Those who now lean to the word "Electrician" are perhaps unconsciously following a precedent established as far back as 1874, when Mr. H. W. Jenvey, in his paper on "Electrical Resistance," wrote "and here I will introduce a fundamental law of electrical measurement named after an **Electrician** who put it into form. It is, 'That the quantity of electricity passing a given point in a circuit in a given time is equal to the electro-motive force, or original and natural power of the battery, divided by the resistance of the circuit.' This is called Ohms Law, and Mr. Culley, **the Electrician,** calls it 'the basis of all the mathematical laws of electric currents' —a very important definition."

That these Electricians of the past were no less human than the Mechanics, Linemen, Electricians and Engineers of to-day may be gathered from the observations of Mr. L. S. Daniel at the first Ordinary General Meeting of the Society. Mr. Daniel, in submitting that the object of members was to gain knowledge, which was power, put it that "If our value be increased, we may naturally expect a tangible recognition of this improvement." He is rather diffident in mentioning this aspect, and confesses that he "would never have thought of putting the matter in such plain language as he finds it in the Journal of the Telegraph Engineers' Society of London, where he came across the following passage in a lecture on the Advantages of Scientific Education, delivered by Mr. W. H. Preece, C.E." Mr. Preece, afterwards Sir William Preece, Chief Engineer of the British Post Office, said, "There is no doubt that a knowledge of the technical details of telegraphy will eventually lead to an increase of the emoluments of those who are now engaged in the Department."

The Society continued to prosper in its first year, and we find that, by July, 1875, the membership had increased to 49, with 78 corresponding members. Though Rule No. 12 making "any gentleman" eligible for membership apparently remained unaltered, we find in the Progress Report for the quarter ending the 30th April, 1875, that the Society had a number of lady members, donations towards the printing fund of the Society having been received from "the following members:—Miss F. A. Dobson, Telegraph Office, Dandenong, 10/-; Mrs. S. E. Kinahan, of Terang, 10/-; Miss E. Allison, of Sorrento, 5/-." The report states that, "These donations are the more gratifying that they have been quite unsolicited."

For the information of its members, the Society published in its transactions a reference to "telegraphing the St. Leger, 1874." Over the four days' race meeting the total number of messages transmitted "reached the astounding figure of 16,500." On the same page a reference is made to working speeds of morse instruments. From New York came two instances of fast transmission of ordinary messages, viz., 330 messages in 6 hours, 30 minutes, 50.7 per hour, and 136 messages in 2 hours, 68 per hour. It is then recorded that, on the occasion of the last Melbourne Cup race (1874) 216 messages were sent from the racecourse to Melbourne, on one of the wires, in 1 hour and 58 minutes, being at the rate of 109.8 per hour, while at the Cup of the previous year the rate was 124.5 per hour. It is explained that, on account of the frequent occurrence of the same names, abbreviations could be used to a great extent, and it is then added that, "As a matter of swift penmanship on the part of the receiving operator, these performances could not easily be surpassed." It is clear that our pioneer members did not intend to be outdone by any reports from America.

Even in the first year of its life the Society did not lack recognition overseas, for it is reported that Mr. H. W. Jenvey's paper on "The Adjustment of the Morse Instrument," which was read before the Society in October, 1874, was published in the London Telegraphic Journal of July 1st, 1875.

Reading on through the transactions, we are brought nearer to the present day by seeing a name at present well known in telegraph and telephone engineering circles in Victoria, for on the 22nd September, 1875, "Mr. H. Quarry described and illustrated Wheatstone's Alphabetical Instrument by taking to pieces and showing the construction and mechanism of its different parts." In the same issue we find the Society attempting to lighten the tedium associated with reading heavy technical matter by including a paragraph culled from the "Electrical News," which read: "The practice of hanging linen to dry on the telegraph wires has, according to the Pall Mall Gazette, lately become general in Armenia, and revealed the hitherto unknown fact that the peasantry of that country are in the habit, occasionally, of washing their clothes . . . ."

The march of time in the affairs of nations is brought vividly before us in reading the report of the International Telegraphic Conference which was held at St. Petersburg. We no longer hear this city so named, but surely all engaged in the business of telecommunication will derive some satisfaction from the thought that, for three-quarters of a century, representatives of all nations have gathered together for a common purpose and discussed amicably and with such wonderful results the problems which have arisen in telecommunication affairs throughout the world. Another matter of interest in the same issue is an extract from the "Queensland Times" of March, 1875. The editor of this paper often wondered how it was that a proper word had not been invented to express the name of a message sent by the submarine wire, without pedantry. He affirmed that the word "Cablegram" was simply execrable, both in sound and linguistic propriety. He then suggests, "Why not use the euphonius word 'Calogram,' which is from the Greek word 'Calos'—a cable? . . ." and to think that, in 1939, we are still using "Cablegram."

In the transactions for the year ending July 31st, 1875, is published an extract from the "Sydney Morning Herald" of January 11th regarding the submarine cable to connect the Colony of New South Wales with New Zealand. "The Herald" article reported that the first portion of the cable arrived in the steamship "Edinburgh," which was the first cable ship that had then visited this part of the world. On this account the arrival of the ship created great interest in Sydney. She carried a 240-mile length of the New Zealand cable, the remainder being on board the "Hibernia," which was expected in Sydney in another few weeks. It was reported also that the "Edinburgh" on the same trip brought from England a short cable "about 35 miles in length, which she laid near Adelaide, across what is known as the Back Passage, to connect the telegraph line between Western and South Australia." South Australian members might know what has become of this cable.

That the same friendly spirit which now characterises the association of technical officers of the telecommunication services was in existence to just the same extent in the early days of telegraph societies may be gleaned from a report of a gathering held on Tuesday evening, 7th March, 1875, at 9 p.m. About 60 officers of the Department assembled at Clement's Café (Does any member remember it?) to make a presentation of a silver tea and coffee service to Mr. D. J. McGauran. The report relates that, "It having transpired early in March that the New South Wales Government had secured the services of Mr. D. J. McGauran, Operator, of the Melbourne Office, and a member of the Committee of Management of this Society, it was immediately and unanimously resolved not to allow him to leave the Department in which he had for so many years been so deservedly popular, without some souvenir from his fellow-telegrahists." The Chairman was Mr. T. R. James, who referred to his amusement at receiving a letter from a country member complaining that "New South Wales was gobbling up all the plums." Mr. James added that "the sister Colony had now gobbled up our choicest plum. (Hear, hear.)"

A separate paragraph in the report relates that "Champagne and other refreshments being now introduced, the Chairman called upon the meeting to drink Mr. McGauran's health, which was done amid great applause." It is not known what effect the refreshments had on the gathering, but it is naively reported later that, "The official portion of the proceedings having now terminated, **the remainder of the evening was spent in a most pleasant manner.**" (The black type is ours.) The report concludes, "Some astonishment was subsequently excited at the Hobson's Bay Railway Terminus by the larger portion of the meeting accompanying Mr. McGauran to the St. Kilda 11 p.m. train, and saluting him as the train moved off, with hearty cheers." It may be a fair inference that the last train in those days departed at 11 p.m.

Those members who are particularly concerned with the telephone side of telecommunication will be interested in a report headed "Novel Telegraphy in Canada." It includes an extract from the "Brantford Expositor," which relates that a number of gentlemen interested in scientific matters recently assembled at the office of the Dominion Telegraph Company to witness some very wonderful experiments on an apparatus invented by Mr. A. Graham Bell, son of Professor A. M. Bell, of Tutelan Heights. "This gentleman claims to be able to transmit musical sounds over a telegraph wire." Members are aware of the rapid progress made in the years immediately following, and the photograph published in the June, 1938, issue of the welcome to Dr. Graham Bell at Melbourne Central Exchange on the 17th August, 1910, will now be of special interest.

From 1874 to 1876 the proceedings of the Telegraph Electrical Society were published as "transactions." In the next issue covering the period March to July inclusive, 1877, the title "Journal" is used, and as the only other copy of the proceedings which is available is for the January to December period of 1881, when the term "Journal" is still used, it may be assumed that the "transactions" permanently gave way to the "Journal of the Telegraph Electrical Society, Melbourne."

In the 1877 Journal further reference is made to Professor Graham Bell's telephone. "The most wonderful of these telephones is that invented by Professor Graham Bell. By means of his telephone the human voice (or any other sound) is carried by magnetic currents along a telegraphic wire and reproduced at the stations on the lines. . . . It has been seen by Sir William Thomson and pronounced by him to be 'the greatest by far of all the marvels of the Electric Telegraph,' and the Telegraphic Journal, London, states that so many proofs have been given of the authenticity of the invention that its reality can no longer be a matter for doubt."

That this confidence in the report was not shared by the editors of the Melbourne Journal may be gathered from the comment just a little later in the report. It reads: "What we are called upon to believe about this invention is of such a nature as to make a personal inspection of it almost essential, in order to destroy all doubt of its reality." After a reference to the method of working the report goes on: "This is hard enough to believe, but when we have to add to this that the vibrations are produced in the first instance by the human voice, and that the vibrations produced on the plate at the other end of the line **are made to reproduce the articulate sounds of the human voice,** surely it is no wonder that there are to be found persons of no small scientific attainments who, in the absence of ocular demonstration, have declared the so-called invention to be 'a physical impossibility.'" (Reference July, 1877.)

However, the editors were not without a broad outlook on general matters, and during 1875 an article was published on the "Typewriter." It said that, although this clever invention was not directly connected with electricity nor with telegraphy, the art of **fast writing** was so important a feature of the latter that it was considered the accompanying article (from "The Times" of April 25th) would not be out of place in the Journal. One of these instruments was reported to be in the possession of the New South Wales Telegraph Department, and the Committee of Management of the Victorian Society indicated that it would be glad to have a practical opinion of the estimation in which it was held there.

In "The Times" article the reporter states that, "The typewriter more nearly resembles in outward appearance a sewing machine than anything else. . . . The uses of this ingenious contrivance are so obvious and so numerous that we may content ourselves by observing that the only work to which it cannot be applied is that of bookkeeping or writing in books."

In the Journal for the period ending July, 1877, is published an account of the first steps in electric telegraphy in England, being an extract from the inaugural address by Mr. C. V. Walker, F.R.S., on the 12th January, 1876, on being elected President of the Society of Telegraph Engineers. Mr. Walker referred to the deep debt of gratitude owed to electric telegraphs by the Railways, but he remarked that the debt was not all on one side. He quoted remarks published as early as March, 1850, that "The electric telegraph is greatly indebted to the Railways, if not for its existence, at least for the friendly hand they have held out to it, and indeed for the protecting care with which they have guarded it. . . . This little line of telegraph (Great Western Railway) was then one of the sights of London. Well do I remember in 1845 paying my shilling to see it. It was made known by handbills to passers-by." Present members will be interested in the reprint of the handbill published on this page.

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It is of interest to note the comparatively wide range of technical discussion and study covered in the early years of the Society, despite the limited membership and the restricted facilities. Following are titles of some of the lectures delivered between 1874 and 1877, following the inaugural lecture by Mr. L. S. Daniel on "The objects, use and working of the Telegraph Electrical Society":—

By Mr. Geo. Smibert:
- Electricity.
- Origin of the Voltaic Current.
- Magnetism and Electro-Magnetism.
- Arrangement of Circuits and Commutators in the Chief E.T.O., Melbourne.

By Mr. D. J. McGauran:
- Duplex Telegraphy (with demonstration).
- On the Transmission of two messages in the same direction at the same time on one wire.
- An auto-translator for closed circuits.

By Mr. H. W. Jenvey:
- Electrical Resistance.
- The Adjustment of Morse Instruments.

By Mr. H. Quarry:
- Wheatstone's Alphabetical Instrument.

By Mr. S. Deverell:
- Sea-water Battery.

By Mr. P. R. Challen:
- Statical Electricity and a brief discussion of the means of producing it.

Mr. L. S. Daniel, in addition to lecturing on "The Morse Instrument," read an extract entitled "Aldini's Bovine Battery" dealing with electricity in the bodies of human and other animals.

Mindful of the interests of its members, the Society in 1875 set out to provide a course of instruction, and there are printed four papers on "Galvanic Batteries" read by Mr. D. J. McGauran, "being part of the course of instruction which it has been determined to pursue." During the visit of the cable ship "Duke of Edinburgh" the opportunity was taken to invite the ship's Chief Electrician to read a paper on "Interference Between Lines."

The Journal for March to July, 1877, was devoted largely to "giving members some account of the instruments at present exciting much interest in Telegraphic circles, and which, from their power of conveying sound, are called telephones." In addition to reports of Bell's lectures and demonstrations in U.S.A., reference was made to Reiss' telephone and Gray's instrument. The trend towards telephony continued, for the 1881 Journal opened with "Modern Forms of the Telephone," by James Doyle, M.S.T.E., though the remainder of this issue dealt with telegraphy, and in September, 1881, we see the first reference to quadruplex in a "Note on the working of the Quadruplex between Sydney and Melbourne," by Mr. D. J. McGauran.

The last reference in the 1881 volume is a re-

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view of the Report of the Adelaide Observatory for 1879, presented to the Society by C. Todd, Esq., C.M.G. Mr. Todd, who was then P.M.G. and Superintendent of Telegraphs in South Australia, later became Sir Charles Todd, a name prominently associated with the building of the overland telegraph line between Adelaide and Darwin.

This 1881 volume is the last printed record we possess of the proceedings of the Telegraph Electrical Society between the time of its inception in 1874 and its revival as the Postal Electrical Society in 1908. The enthusiasm of its founders and early members has left us this record of their splendid work for the first eight years.