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Editorial

Expanding the Digital Economy

Leith H. Campbell
Managing Editor

Abstract: This editorial comes in two parts: some remarks on barriers to the further expansion of the digital economy; and a brief introduction to the papers in this issue.

Keywords: Digital economy, Barriers to participation, Editorial

Expanding the Digital Economy

When the founders of TelSoc re-established this journal, after the demise of the *Telecommunication Journal of Australia*, they wisely included “Digital Economy” in the title. Indeed, the “Digital Economy” section of the *Journal* has become one of its busiest, with a steady stream of submissions. In this issue, we publish three papers in that section describing careful studies on the progress and reception of the digital economy in different countries. While experience varies widely, it is no surprise that perceived benefits and ease of use figure highly in motivations to adopt digital-economy applications.

For a long time now, workers in the telecommunications industry have been aware that there is a much larger industry – Information Technology (IT) – surrounding their own. Still, it is startling to discover that one IT company, Apple Inc., is now approaching a valuation of 3,000 billion (3×10^{12}) US dollars on the stock market ([Reuters, 2021](https://www.reuters.com/article/technology-apple-valuation/apple-valuation-reaches-3-trillion-idUSKCN240184)), a value larger than the Gross Domestic Product of most countries. It is just one indicator of the importance of the digital economy to the economy and society in general.

With great influence should come great responsibility. Now that governments and many businesses have moved to make online access to their services the easiest, the most practical, or the only approach, it becomes even more important that the telecommunications and IT industries strive to make their products accessible by everyone. One barrier to access – affordability – is described in a summary provided in this issue of a forum organized by TelSoc’s Broadband Futures Group. It is pointed out that the telecommunications and IT

industries can do more to make their products accessible to the least well off; it is not just an issue for governments.

The rapid growth of the digital economy is set to continue. The COVID-induced step change to online applications has demonstrated the resilience of most current networks to surges in demand, but it has exposed many weaknesses in current services. There is a clear need for better and more consistent support for online education and telehealth consultations, for example, as well as improved human factors for less error-prone interactions with mobile phones and other IT devices. The current situation in which users must continually “learn” new interfaces and systems in order to participate in the digital economy and society will likely become a barrier to participation – and hence to further growth.

The IT industry should recognize that “innovation” is not always beneficial for users. Why, for example, should it be that answering a voice call requires the user to “swipe right” on some devices or in some applications, while it requires a “swipe up” on others, or clicking on a button on yet others? This is a barrier to usage for unskilled users – which, necessarily, is most of them. Competition often leads to beneficial advances, but useless “innovation” can just be a nuisance.

There is a role for government too. The EU regulations on data privacy, for example, have led to more uniform and improved data handling across much of the world. Government intervention will become more likely if barriers to usage are seen to affect significant numbers of citizens. The Australian ([Wilding, 2021](#)) and Indonesian ([Hidayat & Mahardiko, 2020](#)) governments have intervened in social media content, for example.

The expansion of the digital economy and digital society to include everyone is not a given. Full inclusion should be a goal, however, for all major participants. It will require co-operation between business (especially application developers), standards bodies and governments to bring it about.

In This Issue

As always, our latest issue contains a wide variety of content – from public policy, through the digital economy and telecommunications, to a historical reprint.

Continuing our series of outputs from TelSoc’s Broadband Futures Group, we publish a Special Interest Paper, *Assessing Australia’s Progress towards a National Broadband Strategy at December 2021*, on the Group’s recent assessment of progress towards a National Broadband Strategy for Australia.

In the Public Policy section, there are two papers. *State Control by Stealth in the Big Data Era – From WeChat to the Social Credit System in China* describes the rise of the social credit

system and the role of WeChat. This is an important account that deserves to be widely read. The other paper, *The Broadband Futures Forum: Affordability of Broadband Services*, summarizes the recent forum on affordability and inclusion.

In the Digital Economy section, we publish three papers from widely different countries. *The Evolution of Digital Capital in Organizations: A Quantitative Assessment* describes the evolution of the digital economy in Russian business. *Determinants Affecting the Adoption of E-commerce and Its Impact on Organisational Performance of SMEs in Sri Lanka* is a study of the take-up of e-commerce and the factors driving it. *Factors Determining the Use and Acceptance of Mobile Banking in Colombia* studies the take-up of mobile banking.

In the Telecommunications section, we publish two papers. *Iterative Interference Cancellation for Multi-Carrier Modulation in MIMO-DWT Downlink Transmission* considers transmission enhancement in a cellular wireless channel. *Predictions from an Empirical Study in the Turkish Mobile Telecommunications Market on the Determinants of Mobile Customer Churn* reports on a study of factors causing customers to change mobile providers. We also include a Technical Note, *A Predictive Algorithm for Handover Decisions between LTE and LTE-A Networks*, providing some results on cellular handover decisions.

In the History of Telecommunications section, *Revisiting the Power Co-ordination Challenges of the Original Snowy Mountains Scheme* reprints a paper from the *Telecommunication Journal of Australia* on co-ordinating power transmission and telecommunications networks in a major engineering project.

As always, we encourage you to consider submitting articles to the *Journal* and we welcome comments and suggestions on which topics or special issues would be of interest.

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The Evolution of Digital Capital in Organizations: A Quantitative Assessment

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Abstract: This study analyzed the evolution of resources in organizations towards digital capital using the example of Russia, by analyzing data on the development of technological infrastructure. It concluded that, over the past decade, there were moderately favourable conditions in terms of technological orientation in the Russian Federation. However, only a third of Russian organizations have mastered digital transformation in the context of digital interaction in the online environment using relatively simple information technologies. At the same time, a downward trend was noted for the pace of digitization of business processes and management decisions through dedicated software, reducing the global competitiveness of such organizations. The quantitative assessment of the evolution of digital resources demonstrated that Russian organizations have only a basic level of mastery of digital technologies, with some additional capabilities. This level is characterized by the use of relatively simple digital technologies and standard software. Thus, Russian economic entities in almost all areas use information and communication technology as a component of digital capital for the production of added value, but within limited professional competencies. The study results can be used by organizations' management for meso-level research and by policymakers for evaluating the digital economy.

Keywords: digital capital, ICT, knowledge economy, global information networks, digital resources

Introduction

The ubiquitous use of digital technologies in a chaotic business environment amid the COVID-19 crisis plays a key role in dealing with the aftermath of the pandemic. The measures introduced to contain the coronavirus infection (movement limitations, social distance, and

wearing masks) required a new way of interaction from the business sector in the form of remote work and using digital platforms and technologies for video conferencing and going online. In this environment, information and communication technology (ICT) has helped alleviate the impacts of the pandemic, with uneven degrees of mitigation. This concerns, first of all, connectivity limitations (access, use, and speed), social inequalities, industrial heterogeneity, low organizational competitiveness, and limited access to data and information management, especially in developing countries ([Bárcena, 2021](#); [Romanyuk, Sukharnikova & Chekmareva, 2021](#)).

However, as technology advances, new governance challenges constantly emerge: the importance of cybersecurity steadily increases (each innovation in technology carries the potential for new types of cyber threats); the business environment becomes more variable (technology introduction contributes to the update of economic relations and the structure of business models); environmental aspects of digitalization undergo changes (new digital devices, applications, and data transfers increase energy consumption, contribute to climate change, and generate large amounts of electronic waste) ([UN, 2021](#)). The transformation of organizations in terms of digitalization in Russia is of particular relevance today because, over the past decade, digital technology has evolved from the tactical level, focused on attracting consumers through enhanced access to information services, to the strategic level – the full-fledged formation of the digital economy ([Romanyuk, Sukharnikova & Chekmareva, 2021](#); [Abdimomynova, 2021](#)).

The present study is divided into five parts. The next section introduced the concept of Digital Capital and provides the rationale for the study. There follows a short section on research methodology. A Results section describes the outcomes of the study and is followed by a discussion, where the collected findings are compared with those presented in other similar studies. A Conclusion summarizes the research findings, practical implications, and a description of further work directions.

Literature Review

The use of digital technology has now become global due to the mass distribution and availability of information in an online environment. This trend encourages organizations to undertake digital transformation to better their overall activity by means of improving the quality of service, optimizing internal operations, and creating business models suitable for the digital economy ([Bárcena, 2021](#)). In order to digitalize products, services, and business processes, organizations need to adopt the latest digital technologies, particularly software. With its help, every function (especially those related to marketing, customer service, human resource management, and production) will contribute to the comprehensive digital

transformation of the organization ([Khin & Ho, 2018](#)). In view of this, combining technology with business, the available models will play a significant role in building a future digital ecosystem.

In the current environment, technological infrastructure and modern management embody the capital, resource, and management tools of the organization ([Romanyuk, Sukharnikova & Chekmareva, 2021](#)). Effective human interaction with technological environments was examined by Park ([2017](#)). He found that technology users can benefit greatly from a digital society through technology adoption and free access to it. In addition, Park introduced the concept of digital capital (DC) as a resource that can be used to obtain benefits for the individual, organization, or community that owns it. It is accumulated over time and can be mobilized to create added value. As such, DC exists in physical objects, like products or buildings, or in intangible forms, like knowledge or wisdom. In other words, it exists either in objectified forms that have material properties or as embodied states ([Park, 2017](#)).

During the “pre-digital” era, researchers distinguished between five types of capital or resources (5C): financial, natural, produced, social, and human. While not itself productive, financial capital promotes economic production through a system of ownership or control over physical capital. Natural capital is made up of the resources and ecosystem services of the natural world. Produced capital consists of physical assets generated by applying human productive activities to natural capital and capable of providing a flow of goods or services. Social capital, the most difficult to measure, includes such intangible concepts as shared values, socially significant knowledge, mutual understanding, and trust. Human capital refers to the productive capacities of an individual that can be inherited and acquired through education, training, and experience ([Goodwin, 2003](#)). Even though a wide range of data is available, to date, the question of the existence of human capital has not yet been finally resolved by researchers since, unlike others, this capital type is not alienable ([Piketty, 2014](#)).

In the digitalization era, a new, digital form of economic circulation has emerged. It presupposes that ideas, knowledge, labour, and rights to use seemingly idle assets are transferred between geographically dispersed but connected and interactive online communities. This dissemination is evident in a number of digital economic environments such as social media, online marketplaces, crowdsourcing, crowdfunding, and other manifestations of the sharing economy ([Langley & Leyshon, 2017](#)).

The widespread use of smartphones and digital platforms has led to a new type of digital power. At the micro-level, this digital power tends to rule the behaviour of actors and users of digital networks and is likely to turn the traces of their activities into Big Data networks. However, at the macro-level, the Big Data network, consisting of user behaviour traces, has

become the third form of capital, which surpasses industrial and financial capital – the digital one. Today, a considerable number of companies linked to digital technologies and the Internet are making profits in ways ranging from simple sales of software and applications to direct dominance over large Big Data networks ([Jiang, 2019](#)). The rapid development of the Internet and emergence of novel digital solutions in the last two decades (e.g., cloud and mobile services, artificial intelligence) have increased the deep penetration of the Web in ICT and production, and made a notable contribution to shaping the Internet of Things community and developing a digital economy ([Tou et al., 2018](#)).

Park ([2017](#)) defines DC as an ecosystem of digital technologies of an individual (organization, community) that shapes and guides the way a user interacts with digital solutions. DC embraces the preconditions for effective digital interaction necessary for an individual (organization, community) to thrive in a digital society ([Park, 2017](#)). According to Bughin & Manyika ([2018](#)), DC represents the resources underlying the key processes to developing new products and services for the digital economy. Traditionally, DC takes two forms. The first covers tangible assets (servers, routers, online shopping platforms, and basic Internet software) displayed as capital investments in the company's books. In turn, the second encompasses intangible assets that represent a significant and growing share of what drives today's digital economy ([Bughin & Manyika, 2018](#)).

DC is not separated from traditional 5C capital types. It allows them to be effectively used in the digital environment and contributes to their development, reproducing profit offline. DC transforms offline activities (shaped by 5C) into digital activities (time spent online, information and knowledge found, acquired resources and skills, types of activities performed) converted into externally visible social resources (better job, wages, knowledge; larger social network; and the like benefits). This new capital interacts with every single traditional capital type, and the fruits of this interaction have implications both for digital and social contexts ([Ragnedda, 2018](#)). According to Calderon Gomez ([2020](#)), cultural capital transforms into DC through the techno-socialization of people, whereas social capital changes into DC by dint of social practices and social support. DC can be retransformed into each of the three main capital forms: to an economic one by means of professional networking and access to goods; to a cultural one through access to knowledge; and into a social one by the differential management of social ties ([Calderon Gomez, 2020](#)). Perez, Sokolova & Konate ([2020](#)) managed to allocate a new capital type from DC called digital social capital (websites, social networks, etc.), which can influence financial capital through the cryptocurrency market and the rank of the initial coin offering according to the market capitalization.

Along with the rapid development of ICT, the traditional agricultural and industrial society is being replaced by post-industrialism and a new digital economy type. This economy is based

upon knowledge and ICT and is characterized by the importance of acquiring and processing information for the sustainable development of the whole country and its competitive advantages ([Digilina & Lebedeva, 2020](#)). In our new knowledge-intensive society, the organization is likely to be grounded on networks through which information flows. Hence, high-tech manufacturing is organized around two groups that do not necessarily have any geographical proximity to each other. One of them is usually a highly skilled research and development centre with qualified personnel in a core industrial high-tech area. The other is most often represented by a large assembly facility with sufficiently qualified workers, but which could well be located on another continent and tightly linked to the innovation centre via global information networks ([Jafari & Moharrami, 2019](#)). The data above confirm that the transition to the digital economy is accompanied by the dramatic evolution of the role of economic resources. In industrial societies, the main drivers of economic development are largely represented by labour and financial resources, whereas, in digital economies, these are knowledge, people, and technologies (DC) ([Popkova, 2019](#)). Concurrently, unlike traditional types of resources (5C), which can be quantitatively measured, DC does not have direct quantitative characteristics and cannot be the object of complex quantitative analysis. The same applies to assessing the effectiveness of DC in the activities of organizations ([Clermont, 2017](#)).

As a process and result of gaining experience of using digital technologies in a digital environment by a business entity, DC can be viewed at several levels: the macro-level (characteristic of digitalization and digital transformation of the state), the meso-level (use of digital technologies by organizations), and the micro-level (as an individual characteristic). The state level concerns primarily demographic properties and characteristics of education, culture, and healthcare. For organizations, DC has value in the form of professional characteristics or digital competencies. In this context, digital resources make the organization more informatized primarily from the perspective of a technology management policy aimed at constructing and developing a telecommunications infrastructure that integrates geographically distributed production, material, and intellectual resources through a single information space. At the personal level, DC is represented by the accumulated experience of interaction in the digital environment, which is effectively used to generate income ([Bannykh, 2020](#); [Khitskov et al., 2017](#)).

A rather successful attempt to measure DC of an individual was undertaken by Ragnedda, Ruiiu & Addeo ([2020](#)) through exploratory factor analysis and a representative sample survey of 868 residents of the United Kingdom. Researchers have developed a Digital Capital Index that shows linkages between DC and socio-economic and socio-demographic patterns such as age, income, educational background, and place of residence ([Ragnedda, Ruiiu & Addeo,](#)

[2020](#)). A similar methodology was used by Gladkova, Vartanova & Ragnedda ([2020](#)) in a study on the ethnic diversity of eight federal districts of Russia and their technological development. They surveyed 398 Internet users from the Russian Federation and used the Digital Capital Index comprising data on the level of digital access and digital competence. The results of this investigation showed the absence of a universal correlation between the ethnic composition of the regions and the level of their technological advancement. Lissitsa, Chachashvili-Bolotin & Bokek-Cohen ([2017](#)) have examined the digital divide between Israel's Jewish majority and two ethnic minorities: Israeli Arabs and immigrants from the former Soviet Union. They found that, beyond the impact of classic socio-demographic factors, DC is an essential resource contributing to the growth of income and professional prestige of people. Apart from this, DC was defined as a promising mobility channel for smaller ethnic groups in achieving social and economic equality with the ethnic majority in a country or region ([Lissitsa, Chachashvili-Bolotin & Bokek-Cohen, 2017](#)).

Exploring the specifics of building a digital economy, Benčič *et al.* ([2019](#)) came to the conclusion that, in developed states, the foundation of digital competitiveness of the economy is designated by the high level of integration of ICT and novel devices, while the barrier to the effective use of DC is the low interest of businesses in digital modernization. A diametrically opposite situation characterizes developing countries – their efforts to assure the integration of ICT and devices are far from satisfactory, but the interest in digital modernization from businesses is high ([Benčič et al., 2019](#)). Adarov & Stehrer ([2020](#)) emphasize the critical importance of building an ICT infrastructure to ensure the required DC level and state that its effective use increases the competitiveness of both separate organizations and the whole country.

The review of academic sources on the matter has shown that previous works are mainly devoted to studying the DC of the individual, while resource evolution and quantitative assessment of DC formation in organizations are practically not touched upon. The Russian Federation, with its resource-dependent economy, attaches a special significance to the formation of the DC as the basis of the digital economy. Particularly, this evidence represents the reason for choosing Russia as a case study.

The scientific novelty of the study resides in estimating the contribution of meso-level digitalization in the digital economy based on standardized information on the implementation of digital technology as a ground for the diversification of the production system.

The practical novelty of the study lies in the proposed marketing strategy aimed at transforming organizations through digital solutions relying on resources and capabilities in an ICT context.

The ultimate goal of this research is to investigate the evolution of resources of various organizations towards DC as the basis for economic activity, using the example of the Russian Federation.

The research objectives are as follows:

- 1) Analyze data characterizing the level of formation of the technological infrastructure of organizations in the Russian Federation over the past decade;
- 2) Monitor and evaluate the effectiveness of digital transformation in organizations of the Russian Federation;
- 3) Quantify the evolution of digital resources of organizations by means of economic dynamics modelling and a conceptual approach.

Materials and Methods

This study used a quantitative approach for two purposes: (1) to track the evolution of digital resources in the organization by analyzing the Federal State Statistics Service data ([Rosstat, 2020](#)) that reflect the formation of ICT as a component of the organization's DC (for 2009-2019); and (2) to demonstrate the results of the assessment through a conceptual model. The theoretical basis of this paper was represented by the works of Bughin & Manyika ([2018](#)), Khitskov *et al.* ([2017](#)), Bannykh ([2020](#)), and Romanyuk, Sukharnikova & Chekmareva ([2021](#)). The unit of analysis was the organization, and the selection criterion was organizations located on the territory of the Russian Federation. (This choice was based on the fact that this state strives to form a digital economy). Hence, an overview of the level of development of the digital economy in the country was provided by the example of Russian organizations.

The methodological tools used within this research were analysis, monitoring, quantitative assessment, and modelling. The visualization of the results was realized in the form of figures and tables.

The study process was divided into three stages.

The first stage presupposed the collection and analysis of indicators that characterize the technological infrastructure at the meso-level over the past decade on the basis of such data as:

1. Share of Russian organizations benefiting from:
 - a) personal computers (PCs);
 - b) server hardware;

- c) local area networks;
 - d) electronic mail;
 - e) global information networks.
2. Share of Russian organizations using global information networks (by type of economic activity);
 3. Share of Russian organizations with a personal web page (by type of economic activity);

The preliminary analysis showed a positive trend in the development of technological infrastructure at the organization level over the past ten years, but with the restrained interest of businesses in digital modernization.

The second stage intended to monitor and evaluate the effectiveness of digital transformation in Russian organizations over the past ten years on the basis of the following data:

1. Share of Russian organizations using dedicated software;
2. Distribution of Russian organizations' expenses on ICT (by type);
3. Number of PCs in organizations.

Monitoring and assessment results showed that only one-third of Russian organizations mastered the specialized digital development level in terms of building digital interaction online, which does not assume the availability of professional competencies for making digital decisions based on engineering marketing knowledge.

In the third stage, a conceptual scheme for a quantitative assessment of the evolution of digital resources of an organization was modelled by aggregating weighted average growth data on individual ICT items (share of Russian organizations benefiting from PCs, server hardware, local area networks, electronic mail, global information networks, web pages; share of Russian organizations using dedicated software). In total, these data allowed an assessment of the current state of development of the organization's digital resources. To describe the conceptual model, three levels of digital development of the organization were used:

1. Basic – implies such a technological infrastructure of the organization, where workers do not require professional competencies based on engineering marketing knowledge;
2. Specialized – grounded on the technological orientation of the basic level and special capabilities of traditional digital technologies while referring to the readiness of the organization for digital interaction in the online environment;

3. Advanced – assumes that business processes are automated using advanced digital technologies while relying on the technological infrastructure of the organization and special capabilities of digital technologies.

The result of the quantitative assessment showed that the factor responsible for the effectiveness of digital transformation on the part of business process automation in Russian organizations has a negative trend. This indicates that organizations of the Russian Federation are not able to make digital decisions that are based on knowledge of engineering marketing and can hardly be called competitive in the global market.

The research was limited to the ICT component of DC and made no assessment of such DC segments as human capital and knowledge. Future studies could fruitfully explore this issue further by their in-depth examination.

Results

In modern realities, the technological infrastructure of an organization reflects both the general evolution of information systems in DC and the technological implementations that are used to solve the everyday needs of the organization. The analysis of the technological infrastructure formed in Russian organizations over the past ten years (2009–2019) revealed that the portion of entities using server hardware in their activities grew to 54% (against 16% in 2009). Thus, the technologization increase at the meso-level was 38.0% or 3.8% per year, indicating restrained growth dynamics and relatively weak business interest in digital modernization.

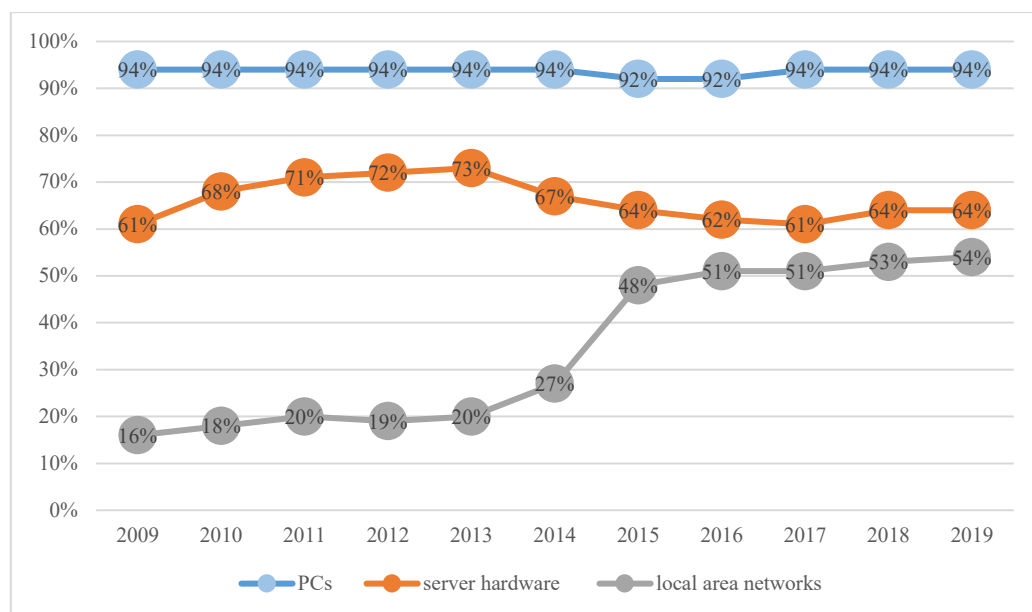


Figure 1. Share of organizations in the Russian Federation taking advantage of PCs, server hardware, and local area networks, for 2003-2019.

Source: developed by the authors based on data retrieved from the Federal State Statistics Service of the Russian Federation ([2020](https://rosstat.gov.ru)).

As can be seen in Figure 1, 61% of organizations used local area networks in their activities in 2009. Their purposes were marked with great diversity: from creating a single network of service PCs in order to connect with the office equipment and access the Internet; to the performance of other more complex tasks, e.g., production automation and the use of customer relationship management (CRM), enterprise resource planning (ERP), and supply chain management (SCM) systems. In 2019, this indicator remained almost the same (64%). The rise in the share of organizations taking advantage of local area networks was 3% (from 61% in 2009 to 64% in 2019). This fact can be caused by difficulties with integrating several new systems simultaneously (like concurrent ICT introduction and Internet expansion).

Almost identical dynamics were observed for the transition of Russian organizations to digital business models based on the use of ICT, in which a particular role is assigned to electronic mail, global information networks, and personal web pages (Figure 2).

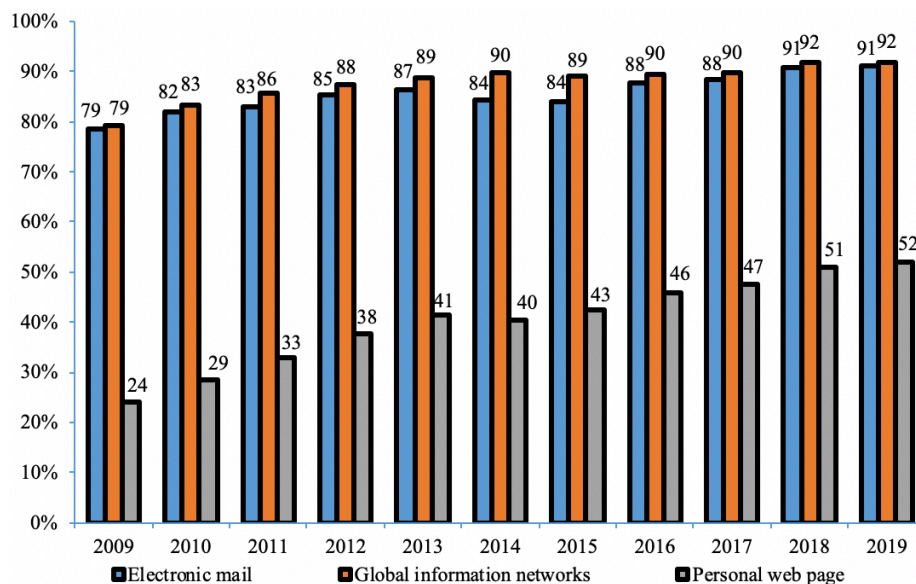


Figure 2. Share of organizations in the Russian Federation taking advantage of electronic mail, global information networks, and having personal web pages, for 2003-2019.

Source: developed by the authors based on data retrieved from the Federal State Statistics Service of the Russian Federation (2020).

As seen in Figure 2, despite the frequent use of global information networks and e-mail services in their activities, only a little more than half of the Russian organizations (52%) had a web page in 2019. That is, 48% of companies, enterprises, and other entities and organizations were using traditional channels of communication with consumers, clients, sponsors, etc. Notwithstanding this, it should be noted that the demand of the information society and business sector for digital communication through the Internet was quite high during the investigated period (it increased by 28 percentage points, from 24% in 2009 to 52% in 2019).

The outcomes of monitoring of the effectiveness of digital transformation by economic activity types in the Russian Federation and in terms of the use of global information networks and Internet web pages are presented in the Appendix (Tables A1 and A2). These data indicate that the largest proportions of organizations using global information networks in 2019 (96%) are in information and communication, finance and insurance, public administration and military and social security, and health and social services industries. The latter is also noticeable for active use of web pages simultaneously with the global information network (81%), which improves the effectiveness of such organizations in the external environment (Appendix, Table A2).

With increasing digitalization, the introduction of ICT is becoming a prerequisite for a successful organization's operation and development. The use of dedicated software can surely be called an important tool in the digital world, as it facilitates building the professional competencies of the staff to be able to make optimal digital solutions based on engineering marketing knowledge. Over the period from 2009 to 2019, though, the share of organizations in the Russian Federation utilizing dedicated software in their activities (not standard software supplied with a PC) decreased by 3%, from 89% to 86% (Table 1), which indicates the lack of stimulation for the information and technology sector development at the meso-level.

Table 1. Monitoring of the effectiveness of digital transformation in Russian organizations, for 2009-2019

Share of organizations using dedicated software	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
	%										
Total share of organizations using dedicated software	89	89	90	86	85	86	85	85	84	86	86
Software for organizational, managerial, and business tasks	61	60	60	60	60	56	52	53	52	55	55
Software for financial calculations	60	60	61	61	61	57	55	55	55	56	57
Other software	41	42	43	38	37	32	33	30	28	29	29
Software providing Internet access to databases	24	28	28	29	31	31	32	31	30	32	32
Software for automated production, technological processes	15	18	18	17	17	16	15	15	15	17	17
Educational software	17	19	19	22	18	15	14	14	14	17	16
Design software	11	12	12	12	12	12	11	11	11	13	13
Software for editorial and publishing activity	5	9	7	6	6	7	5	5	5	7	7
Research software	3	3	3	3	3	4	4	3	3	5	5

Share of organizations using dedicated software	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
	%										
Legal reference software	56	54	55	57	55	54	52	52	51	53	53
ERP, CRM, SCM software	6	8	10	10	10	14	15	16	17	20	21
Procurement software	0	0	36	36	39	36	38	38	36	38	39
Sales software	0	0%	24	23	23	20	22	22	22	26	26

Source: developed by the authors based on data retrieved from the Federal State Statistics Service of the Russian Federation ([2020](#))

Note: “Other software” indicator covers systems for automated banking, trade, ordering, library management, translation, and other specialized tasks.

As of 2019, only 5% of dedicated software was used for scientific research and 7% for editorial and publishing activities. The largest portion of dedicated software users required special programs to conduct financial calculations (57%), to solve organizational, managerial, and business tasks (55%), and to access legal information (53%).

The development of ICT is reflected in organizational expenditures on providing the resource base (Figure 3). During the analyzed period, it reduced for almost all ICT types: telecommunication services and Internet access by 16%, purchase of software by 1.7%, ICT-related employee training by 0.9%, purchase of telecommunications equipment by 0.3%, other costs by 2.4%. The only exception was the cost of ICT services outsourcing and overall software purchase costs – the growth was 7.6% and 1.7%, respectively.

As shown in Figure 3, from 2009 to 2018, the distribution of organizations’ costs for various types of ICT decreased by an average of 4.2% due to the rise in expenditures (by an average of 4.6%) on delegating internal ICT-related tasks to an outside contractor (to a greater degree) and purchasing standard software (to a lesser degree).

Overall, in 2019, most of the companies’ ICT costs fell on the purchase of digital-related machinery and equipment, as well as their maintenance, modernization, and repairs performed by the organization’s own resources (33.9%) and the purchase of standard software, with subsequent adaptation and adaptation to the organization’s business model (21.1%) (Figure 4).

It is important to note that with the digitalization of the economy, the number of PCs in the organizations of the Russian Federation from 2009 to 2019 increased 1.5 times (from 8.744 million to 13.817 million PCs), and the number of PCs with access to global information networks rose 2.4 times. This fact testifies to the development of new technological trends and compliance with mandatory requirements of modern development and operation of organizations in the digital economy era (Figure 5).

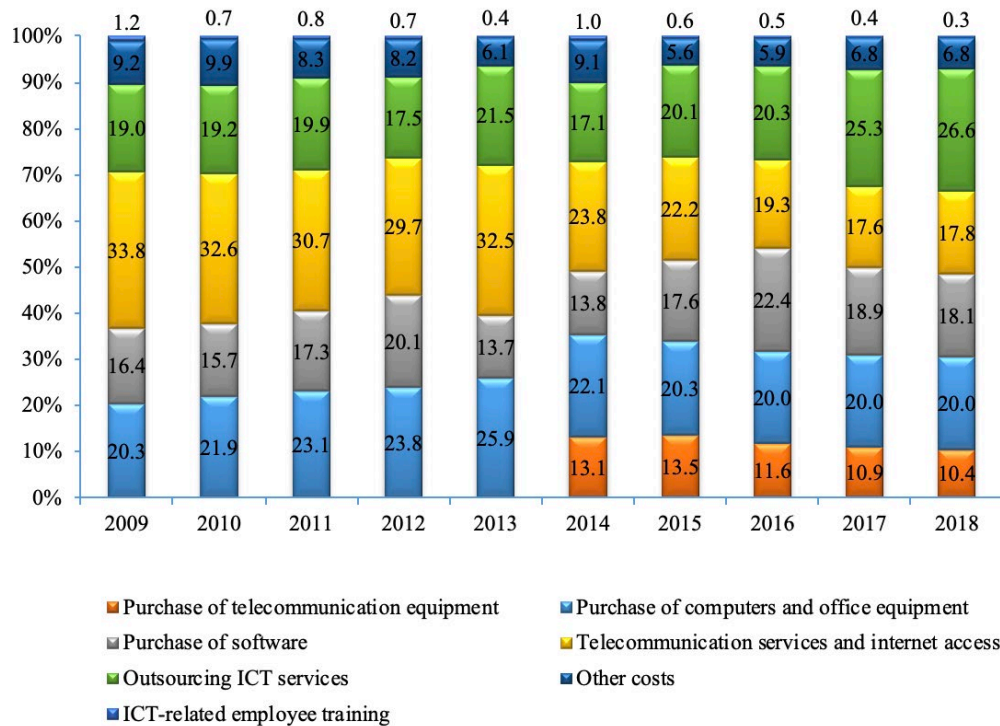


Figure 3. Distribution of Russian organizations' expenditures on ICT by type, for 2009-2018 (as % of total).

Source: developed by the authors based on data retrieved from the Federal State Statistics Service of the Russian Federation (2020)

Note: The presented data cover the period until 2018 since this year, the Federal State Statistics Service revised cost allocation parameters to reflect changes more drastically. The distribution of ICT costs as of 2019 is shown in Figure 7.

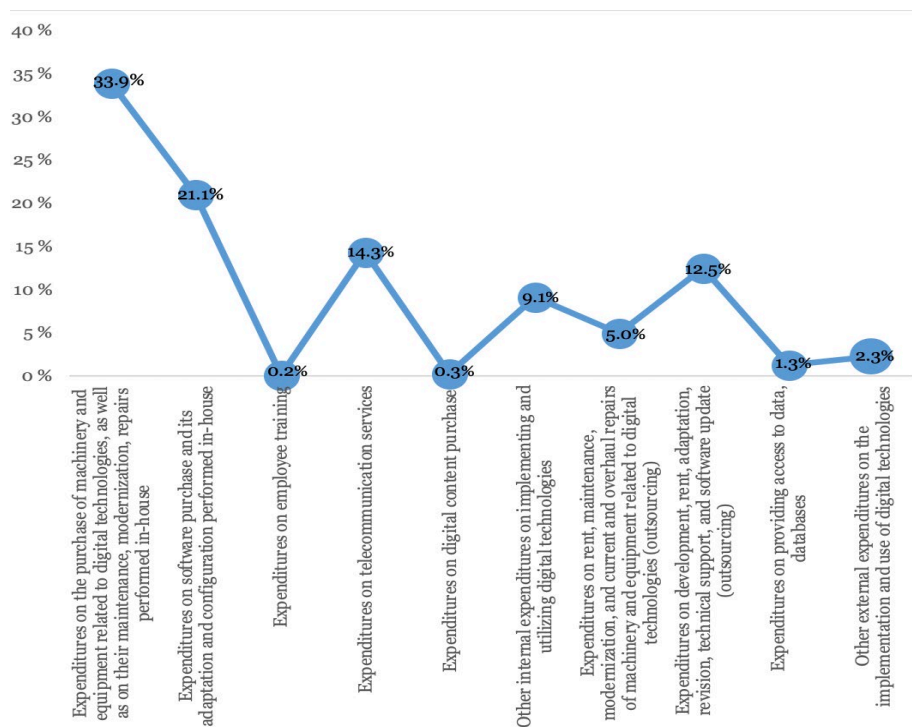


Figure 4. Distribution of Russian organizations' expenditures on ICT by type, for 2019 (as % of total).

Source: developed by the authors based on data retrieved from the Federal State Statistics Service of the Russian Federation (2020).

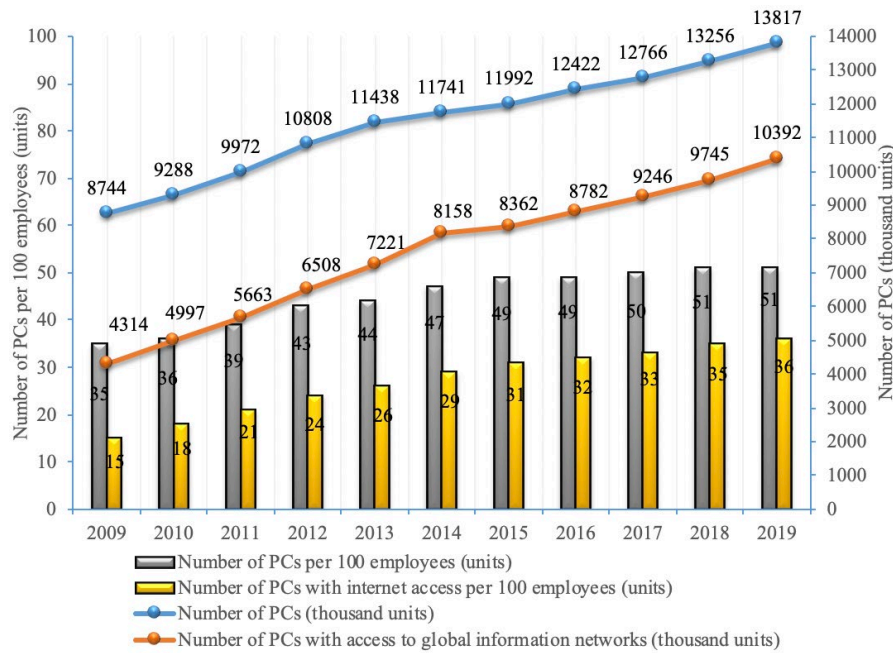


Figure 5. Number of PCs in the organizations of the Russian Federation, for 2009-2019.

Source: developed by the authors based on data retrieved from the Federal State Statistics Service of the Russian Federation (2020).

As can be seen from Figure 5, the number of PCs per 100 employees grew with the saturation of companies with computer equipment. Similarly, the number of PCs with Internet access per 100 employees was noted to be in direct dependence on the number of PCs connected to global information networks.

Given the data obtained, one can conclude that the development of digital resources of organizations of the Russian Federation, regardless of the field of activity, use the following ICT components for the production of added value: computing equipment, server and telecommunications equipment, local and global information networks, new communication channels (electronic mail, web pages), and dedicated software. A quantitative assessment of the evolution of digital resources of Russian organizations in the context of economic dynamics modelling and conceptual approach is presented in Figure 6.

To describe the quantitative assessment of the evolution of the organization's digital resources in the context of economic dynamics (Figure 6), it is proposed to use three levels of organizational development:

- Basic level – describes the organization's technological infrastructure where workers do not require professional competencies based on engineering marketing knowledge;
- Specialized level – grounded on the technological orientation of the basic level and special capabilities of relatively simple digital technologies; it defines the readiness of the organization for digital communication in an online environment;

- Advanced level – designates the automation of business processes using advanced digital technologies.

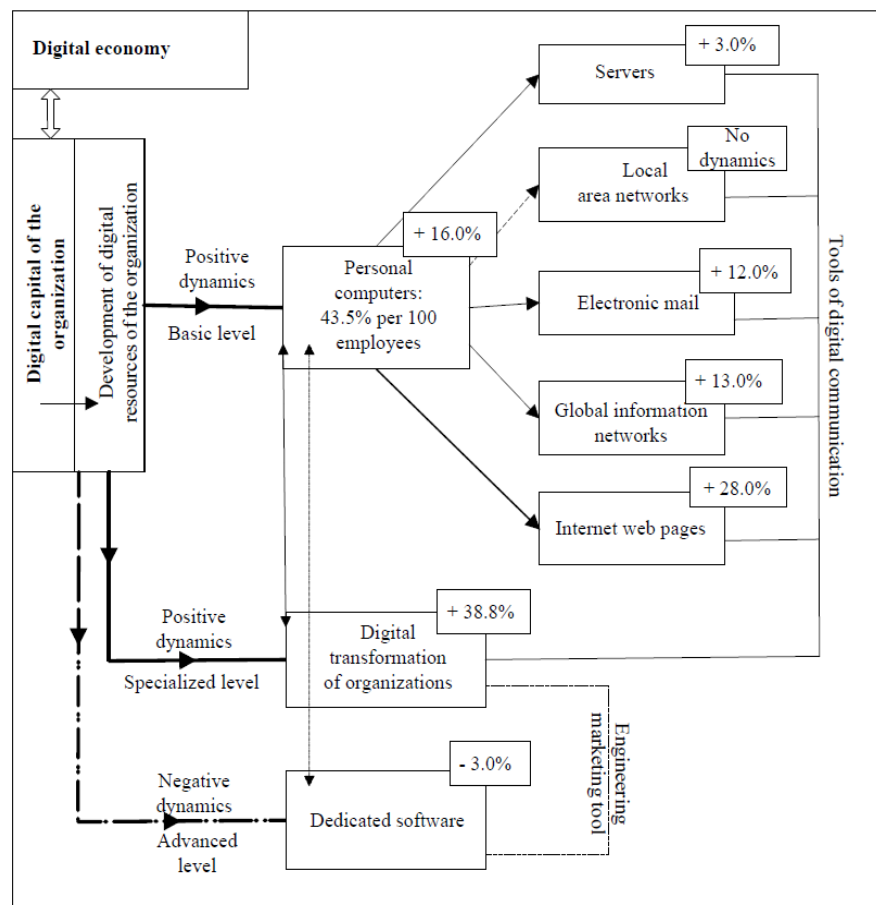


Figure 6. Conceptual model of a quantitative assessment of the evolution of organization's digital resources in the context of economic dynamics (on the example of the Russian Federation)

Note: “ $\longleftrightarrow$ ” unit of measure for the digital economy; “ $\cdots$ ” negative dynamics; “ $\longrightarrow$ ” organization's development level.

Source: developed by the authors based on data from Rosstat (2020).

The result of the quantitative assessment based on the aggregation of data on the evolution of Russian organizations' digital resources over the past decade showed that the organizations have the basic level of digital transformation with a moderate technological orientation growth (+16%). At the same time, they mastered specialized capabilities using relatively simple digital technologies (+38.8%). The best results in terms of simple digital technologies were noted for the use of web pages (28%), global information networks (13%), and electronic mail (12%), with, however, rather negative dynamics of the use of advanced digital technologies, particularly, of dedicated software. Such a digital development progression suggests a gap in the DC of Russian organizations in the form of low interest in the modernization and automation of business processes, which does not allow them to follow the demands of the global market on the part of the business sector.

Discussion

An organization's DC is based on a combination of knowledge and ICT, which complicates a comprehensive assessment of its level and impact on economic activity efficiency (Clermont 2017). Ragnedda, Ruiu & Addeo (2020), Gladkova, Vartanova & Ragnedda (2020), and Lissitsa, Chachashvili-Bolotin & Bokek-Cohen (2017) have analyzed DC through the prism of digital access and digital competence of individuals inhabiting one or another region but fail to assess the development of the ICT component of the DC in the corporate segment. In this regard, the present study is unique as it quantitatively assessed the formation of DC through the analysis of data characterizing the technological infrastructure at the meso-level and through monitoring the digital transformation in organizations. The examination of the development of technological infrastructure revealed the restrained growth of technological orientation in the organizations of Russia. Moreover, the dynamics associated with the use of ICT indicators showed that, in ICT development and DC formation, increased attention is paid to digital communication. In this respect, an increase in the number of organizations connected to global information networks, holding enough computer and server equipment, and having personal web pages was noted. The investigation outlined that the highest rates of using global information networks were recorded in public administration, military and social security, healthcare and social services, and higher vocational education. Aside from this, organizations operating in healthcare and social services, as well as in the field of higher vocational education, were defined as the first in terms of the number of personal web pages. This suggests a fairly high DC development degree in Russia at the level of the state (Bannykh, 2020). No less important is also the fact that internal and external costs for software procurement and adaptation are decreasing (their average share was 27.5% in the year 2019), and a growing share of organizations is now likely to outsource ICT services.

Similar to this research, Adarov & Stehrer (2020) studied productivity drivers at the meso- and macro-levels with a focus on capital accumulation and organizational structure. They deduced that ICT and intangible DC play a significant role in productivity growth. Ragnedda, Ruiu & Addeo (2020) characterize DC as the accumulation of digital competencies and digital technologies and argue that its development is related to the country's socio-economic and socio-demographic development patterns. The contribution of ICT to the economic performance of organizations was also confirmed by Bughin & Manyika (2018), who found that the spending on intangible assets (software, employees' training, and access to data and databases) has almost equalled with costs spent on tangible assets (computer and server equipment, their maintenance and repair) (Bughin & Manyika, 2018). In sum, the transition of the ICT component of DC to an immaterial state indicates a change in the role of economic

resources used by organizations towards knowledge, people, and technologies, which is inherent to a developing digital economy ([Popkova, 2019](#)).

The findings obtained in the current paper are corroborated by those of Benčíč *et al.* ([2019](#)). In particular, the statement that developing countries have a rather low digital modernization level was confirmed by the quantitative assessment results for 2019 – subdued technology-oriented growth in meso-level (1.6% per year), reduced spending on specialized software (-3%), and insufficient research (5%). Tou *et al.* ([2018](#)) argue that the intensification of the research and development sector creates new opportunities for global competition and compliance with the digital economy's demands. The results of building a conceptual model based on the evolution of digital resources of Russian organizations that link digital orientation and digital capabilities showed that the transformation of organizations in terms of digital orientation is moving towards digital stakeholder collaboration, while in terms of digital capabilities, there is a decline in outsourcing of engineering marketing tasks. In sum, the collected results demonstrate that Russian organizations have mastered the basic level of digital development using special capabilities of relatively simple digital technologies to interact and communicate in a digital environment while reducing the factors influencing the elaboration of digital solutions that organizations need to enter global markets.

Conclusions

Taken together, the findings of this work show that, over the past ten years, the development of technological orientation of Russian organizations in the field of ICT has evolved from the technologization of the working environment to full-fledged digitalization. The analysis of data characterizing the technological infrastructure and monitoring the use of ICT in Russian organizations revealed that only one-third of organizations, regardless of the field of activity, has a business model for the digital economy. Apart from this, it was found that the DC of the organization depends on the level of the development of its digital resources. The quantitative assessment of the evolution of the organization's digital resources in the context of economic dynamics and conceptual approach demonstrated that a growth trend is now present at only two levels of digital development: the one aimed at mastering basic technologies and the other implying the use of relatively simple digital technologies for interaction in the digital environment. Concurrently, it was noted that there is a negative tendency for the use of advanced digital technologies, in particular dedicated software. This indicates that the majority of Russian organizations experience difficulties in optimizing their business processes using digital technologies, taking a cost-saving approach to material and time resources, and improving the efficiency of strategic management and the quality of the output product/service due to low digital transformation rates. From this it follows that Russian

organizations can hardly be deemed competitive in the globalized market. The country's central digital capital development focus is set on public administration, military and social security, health and social services, and higher vocational education.

The methods and results of this work can be exploited by the management of organizations in developing strategies, tactics, concepts, and programs for DC development in the digital economy. Besides, the present findings may have important implications for policymakers while analyzing the digital needs of organizations.

Further research is recommended to be concentrated on studying the current state of engineering marketing within the organizational structure of the Russian Federation.

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Appendix

Table A1. Monitoring of the use of the global information network by economic activity types in the Russian Federation, for 2009-2019

Economic activity type	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Mining	90%	91%	92%	91%	93%	94%	92%	93%	89%	86%	86%
Processing/manufacturing	92%	94%	94%	95%	95%	96%	96%	96%	95%	93%	93%
Construction	90%	92%	93%	92%	92%	92%	91%	91%	87%	84%	83%
Production and distribution of electrical power, gas, and water	73%	77%	82%	85%	87%	88%	88%	90%	92%	91%	94%
Wholesale and retail trade, auto repairs	84%	88%	89%	90%	92%	94%	95%	96%	94%	94%	93%
Hotels and catering services	73%	78%	81%	84%	85%	87%	87%	84%	86%	85%	87%
Transport and storage	87%	89%	89%	90%	90%	91%	88%	86%	92%	91%	92%
Information and communication	96%	95%	96%	96%	97%	97%	95%	95%	96%	95%	96%
Finance and insurance	93%	94%	95%	95%	95%	94%	92%	92%	92%	95%	96%
Real estate	75%	77%	79%	80%	80%	80%	77%	77%	63%	84%	86%
Research and development	94%	95%	95%	95%	95%	96%	95%	95%	95%	92%	92%
Public administration, military and social security	77%	85%	89%	91%	93%	94%	94%	96%	95%	95%	96%
Higher vocational education	96%	97%	98%	98%	98%	98%	96%	97%	97%	95%	95%
Healthcare and social services	90%	93%	95%	96%	97%	97%	96%	96%	95%	96%	96%
Recreation and entertainment, culture and sports	52%	57%	63%	70%	74%	79%	81%	82%	85%	86%	88%
Other activities	84%	89%	90%	92%	94%	94%	94%	93%	91%	91%	91%

Source: developed by the authors based on data retrieved from the Federal State Statistics Service of the Russian Federation (2020)

Note: 1) green colour designates an increase in indicators, yellow marks years of stabilization, red denotes a decline; 2) "Other activities" embrace agriculture, forestry, hunting, fishing and fish farming, as well as other types of services.

Table A2 Monitoring of organizations in the Russian Federation having a personal web page, by type of economic activity, for 2009-2019

Economic activity type	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Mining	25%	28%	30%	33%	37%	35%	37%	41%	40%	37%	40%
Processing/manufacturing	46%	51%	53%	57%	58%	56%	58%	62%	64%	62%	63%
Construction	28%	31%	34%	37%	39%	37%	40%	41%	39%	38%	39%
Production and distribution of electrical power, gas, and water	17%	24%	29%	34%	36%	34%	39%	42%	48%	48%	51%
Wholesale and retail trade, auto repairs	29%	36%	36%	40%	44%	49%	53%	54%	53%	59%	55%
Hotels and catering services	25%	29%	32%	35%	37%	38%	42%	44%	45%	43%	46%
Transport and storage	27%	31%	32%	35%	37%	36%	37%	38%	37%	36%	38%
Information and communication	60%	63%	66%	65%	68%	64%	62%	61%	62%	60%	63%
Finance and insurance	52%	55%	57%	62%	63%	61%	62%	65%	67%	69%	69%

Economic activity type	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Real estate	23%	26%	29%	31%	32%	30%	30%	32%	19%	32%	33%
Research and development	61%	64%	65%	68%	69%	64%	67%	69%	70%	67%	66%
Public administration, military and social security	19%	25%	31%	38%	42%	39%	41%	45%	47%	48%	52%
Higher vocational education	74%	77%	79%	83%	82%	77%	79%	81%	88%	83%	85%
Healthcare and social services	13%	18%	32%	41%	51%	53%	59%	65%	73%	75%	81%
Recreation and entertainment, culture and sports	13%	15%	19%	23%	27%	28%	32%	37%	42%	45%	50%
Other activities	7%	8%	11%	14%	17%	17%	17%	19%	20%	20%	23%

Source: developed by the authors based on data retrieved from the Federal State Statistics Service of the Russian Federation ([2020](#))

Note: 1) green colour designates an increase in indicators, yellow marks years of stabilization, red denotes a decline; 2) “Other activities” embrace agriculture, forestry, hunting, fishing and fish farming, as well as other types of services.

Determinants Affecting the Adoption of E-commerce and Its Impact on Organisational Performance of SMEs in Sri Lanka

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Abstract: The Internet has become the best innovative driver in the fourth industrial revolution, transforming businesses into a technological era with speed and cost-effectiveness. E-commerce is one of the modern business strategies used by many companies to expand their market without limiting its geographical boundaries. This business strategy was initially used by companies in developed countries and eventually adopted by developing countries. Sri Lanka is a developing country and e-commerce penetration is far below other countries in the region. Perceived benefits, transformational leadership, and competitive pressure are the influencing factors of e-commerce adoption. The Technology-Organization-Environment and Diffusion of Innovations theories were used as the base of this research, and 350 samples were collected from the senior managers of SMEs. All factors significantly influenced e-commerce adoption and that positively affected the organisational performance of SMEs in Sri Lanka.

Keywords: Adoption of E-commerce, Influencing Factors, Determinants of e-commerce, e-Business Adoption

Introduction

In the fourth industrial or technology revolution, organisations have changed their growth strategies with innovative technological adoptions (Fonseka *et al.*, 2020). The Internet has transformed the offline business environment into online businesses, which has reduced time,

cost, and distance. This new instrument facilitates communication across the globe cost-effectively and super-fast. It opened the door to a unique aspect of trade without limiting it to geographical boundaries ([Hidayati, Permatasari & Fajry, 2019](#)). It is called "electronic commerce", which refers to exchanging goods and services between parties via computer networks ([Wen & Guy, 2019](#)). E-commerce is the modern trending art of trading method in the 21st century, and it is one of the effective growth strategies in business. Išoraitė & Miniutienė ([2018](#)) have explained that e-commerce is a business in which an online platform is used to enhance profitability through its activities and communicate with many individuals and entities at the same time. This trending platform creates opportunities for business owners and individuals to tap untapped markets within a short period of time and cost-effectively.

With the expansion of smart-device usage, people are addicted to using online platforms for their day-to-day lives and, as a result, e-commerce penetration has gone up globally ([Chmielarz & Parys, 2018](#)). This innovative adoption utilized by many organisations globally has significantly affected the global economy by increasing cross-border revenue. The COVID-19 outbreak has accelerated the growth of e-commerce globally ([UNCTAD, 2021](#)). Statista ([2021](#)) indicates the global picture of e-commerce revenue, which reached 2.38 trillion US Dollars in 2017. The forecasted global e-commerce revenue is 6.54 trillion US Dollars for the year 2024. It is an enormous growth of 175% revenue within six years.

Furthermore, the highest annual expected e-commerce revenue growth (2019-2023) rate of 17.8% in the Asian region is indicated by India, and the lowest rate of 9.1% is by Sri Lanka ([Statista, 2021](#)). The level of e-commerce usage is lagging behind in developing countries compared to developed countries. Developed countries initially adopted e-commerce, and they are harvesting the real benefit of it, more than developing countries ([Xuhua, Chosniel Elikem & Akaba, 2019](#)). The developing countries faced many issues when adopting e-commerce, such as the lack of resources, the management perception, lack of government support, or industry pressures, which are issues common to many developing countries ([Dahbi & Benmoussa, 2019](#)). The e-commerce penetration of Sri Lanka is shallow in the region since the country is still in the developing stage.

Previous researchers have described SMEs as the backbone of any economy ([Kuruwitaarachchi et al., 2020](#)). The Ministry of Industry and Commerce of Sri Lanka has highlighted that more than 75% of the enterprises are SMEs and that they contribute more than 52% to the Gross Domestic Product (GDP) of the country. The service sector is the most significant contributor to the national GDP, which is nearly 60%. The major contributors in the service sector are banking and finance, tourism, telecommunication, IT and related services, and retail sectors ([Department of Census and Statistics, 2020](#)).

The statistics revealed that Sri Lankan entrepreneurs are still reluctant to adopt e-commerce for their businesses. This is one of the biggest issues that Sri Lankan SMEs are currently facing when competing in the global market. This strategic weakness was highlighted with the COVID-19 outbreak in Sri Lanka. Therefore, the adoption of e-commerce by SMEs is extremely important in developing countries like Sri Lanka. Previous researchers have found many factors influencing the adoption of e-commerce in different contexts, but transformational leadership is not widely studied in such studies. Thus, this study is important for entrepreneurs to understand the significance of e-commerce adoption, and for regulatory bodies to amend their policies where necessary, to encourage SMEs to adopt e-commerce. Hence this study aims to address the following research questions:

- a. What is the most influencing factor which affects the adoption of e-commerce by SMEs?
- b. How does the adoption of e-commerce impact the organisational performance of SMEs?

Literature Review

The adoption of e-commerce in SMEs is a firm level of study. Various technological adoptions or acceptance models were introduced by multiple researchers and applied by them in different contexts for technology adoption studies ([Fonseka et al., 2020](#)).

The Technology-Organization-Environment (TOE) framework ([Tornatzky & Fleischer, 1990](#)) identified three parts of an organisational context that influence the adoption and implementation of technological innovation. The technological factor associates with both the internal and external technologies that are relevant to the firm, which includes inter-organisational current practices, equipment of the firm, and available technologies external to the firm. The organisational factor refers to the descriptive measures about the organisation and includes the scope, size, and management structure. The environmental factor refers to the area in which a firm conducts its business, which consists of its industry, competitors, and government involvement. The organisation-level theory of Diffusion of Innovations (DOI) ([Rogers, 1995](#)) explained that the innovativeness is related to three elements. The leader characteristics described the leaders' attitude towards innovative change. The internal characteristics of an organisational structure referred to the centralization of power and control, complexity of members, formalization, interconnectedness, and organisational slack. The external characteristics refer to system openness. Parasuraman ([2000](#)) introduced a Technology Readiness Index (TRI), to measure the beliefs and thoughts of using new technology in general. There are two different perceptions of the use of technology at the individual and firm levels. The positive view comprises optimism and innovativeness, and the negative view consists of discomfort and insecurity. In the recent past, Sanchez-Torres &

Juarez-Acosta ([2019](#)) introduced an Integrated Model for the Adoption of E-commerce among SMEs (IMAES) and the model integrated the theories of contingency, DOI, and the Technology Adoption Model (TAM).

Nevertheless, Sánchez-Torres, Rojas Berrío & Ortiz Rendón ([2021](#)) explained TOE theory commonly used by many researchers for e-commerce adoption studies in different contexts. Therefore, TOE and DOI theories were used as the foundation, since this is a firm-level of study. Perceived benefits represent the technological context, and competitive pressure represents the environmental context of the TOE theory. Similarly, transformational leadership relates to the leader characteristics of DOI theory. Moreover, Fonseka *et al.* ([2020](#)) explained that, during the last decade, the majority of researchers have used TOE and DOI theories for technology adoptions, especially in e-commerce technology adoption at the firm-level of studies in different contexts in the world.

E-commerce in developing countries

E-commerce has transformed businesses into an electronic era without limiting them to their geographical boundaries. Researchers pointed out that, due to many reasons, such as lack of basic infrastructure, inadequate socio-economic conditions, and national strategies imposed by the governments in developing countries, SMEs are delaying the adoption of e-commerce ([Wen & Guy, 2019](#)). E-commerce adoption is a process, which initially starts with simple technology-based activities and gradually changes to a more complex and integrated system ([Xuhua, Chosniel Elikem & Akaba, 2019](#)). Effective adoption and utilization of e-commerce contribute to tangible and intangible benefits with regards to the growth of SMEs in developing countries ([Ibrahim, Turyakira & Katumba, 2018](#)). The use of e-commerce affects gaining a competitive advantage in the global environment, and it allows SMEs to secure new market opportunities ([Xuhua, Chosniel Elikem & Akaba, 2019](#)). E-commerce adoption impacted marketing activities such as improved penetration internationally and the conduct of B2B or B2C transactions ([Lee, 2021](#)). Mahliza ([2019](#)) elaborates how the adoption of e-commerce affects an increase in profitability, growth in sales, and expansion of the market, which ultimately increases the business performance of SMEs. Nevertheless, SMEs in developing countries are still struggling to adopt e-commerce due to many reasons.

Technological context

The technological context refers to the internal and external technological infrastructure and its impact when adopting technological innovation or e-commerce in an organisation, and technological context has a positive influence on e-business adoption ([Sánchez-Torres, Rojas Berrío & Ortiz Rendón, 2021](#); [Hadi Putra & Santoso, 2020](#); [Kuruwitaarachchi et al., 2020](#);

[Dahbi & Benmoussa, 2019](#)). There are many factors under the technological context, such as relative advantage, perceived risk, compatibility, simplicity, observability, perceived usefulness, perceived facility, and security concerns ([Sánchez-Torres, Rojas Berrío & Ortiz Rendón, 2021](#); [Hadi Putra & Santoso, 2020](#); [Kuruwitaarachchi et al., 2020](#); [Abed, 2020](#)). Perceived benefits influence e-commerce adoption that refers to the degree of acceptance of the possible advantages that e-commerce technology can provide for the organisation ([Mahliza, 2019](#); [Govinnage & Sachitra, 2019](#); [Alnaser, Saeed & Alrawashedh, 2018](#)). Ezzaouia & Bulchand-Gidumal ([2020](#)) explained that perceived benefits significantly influenced IT adoption intention, which is associated with marketing benefits, management benefits, and competitive advantage. The characteristics of innovation are vital in the technological adoption environment including perceived relative advantage and its benefits ([Kuruwitaarachchi et al., 2020](#); [Hidayati, Permatasari & Fajry, 2019](#)). Govinnage & Sachitra ([2019](#)) explained that the perceived benefit refers to how the e-commerce adoption fits with the internal technical infrastructure. Mahliza ([2019](#)) pointed out that perceived benefit is the most influencing factor of e-commerce adoption. Hence, it is worth testing the impact of perceived benefits on the adoption of e-commerce among SMEs in Sri Lanka, since it has been validated in many different contexts ([Ezzaouia & Bulchand-Gidumal, 2020](#); [Hadi Putra & Santoso, 2020](#); [Kuruwitaarachchi et al., 2020](#); [Govinnage & Sachitra, 2019](#); [Dahbi & Benmoussa, 2019](#); [Mahliza, 2019](#)).

H1: Perceived benefits influence the adoption of E-commerce among SMEs in Sri Lanka.

Organisational context

The organisational context refers to the internal environment of an organisation that significantly influences the adoption of innovation ([Abed, 2020](#); [Hadi Putra & Santoso, 2020](#)). There are several factors categorized under the organisational context, such as top management support, firm size, organisational readiness, financial resources, capabilities of the internal staff, and knowledge of the senior managers ([Ezzaouia & Bulchand-Gidumal, 2020](#); [Abed, 2020](#); [Hadi Putra & Santoso, 2020](#); [Dahbi & Benmoussa, 2019](#)). Hidayati, Permatasari & Fajry ([2019](#)) explained the characteristics of decision-makers are vital in technological adoption that include the level of education of the decision-maker, the person's level of position in the firm, and the attitude of the person. The decision-maker's knowledge of technology and that person's leadership style is vital ([Okundaye, Fan & Dwyer, 2019](#)). The leadership style has been identified as an essential tool for an organisation to be successful, especially in the current business economy of organisations ([Hickman & Akdere, 2018](#)), which creates an innovative atmosphere within an organisation ([Xie et al., 2018](#)). Bass ([1985](#)) has explained two main leadership styles operating in a business environment: transformational

and transactional leadership styles. Further, the transactional leadership style facilitates a reward system for the employees to reach specific goals. In contrast, the transformational leadership style transforms employees to adopt innovative culture through aspirations, attitudes, morality, and values. Transformational leadership style builds trust between leaders and team members and creates an innovative atmosphere within the organisation to adopt innovative technologies, such as e-commerce ([Okundaye, Fan & Dwyer, 2019](#); [Xie et al., 2018](#)). The transformational leadership style is commonly used in many different contexts and is the most important style for leaders of SMEs ([Okundaye, Fan & Dwyer, 2019](#)). Hence, it is worth examining the impact of transformational leadership style on the adoption of e-commerce in SMEs in Sri Lanka.

H2: Transformational Leadership Style influencing the adoption of E-commerce among SMEs in Sri Lanka.

Environmental context

The environmental context refers to the external involvement or influence from outside parties, such as government support or involvement, competitors' pressure, suppliers' pressure, customers' pressure, and other related market forces, when adopting innovative technologies to the organisation ([Sánchez-Torres, Rojas Berrío & Ortiz Rendón, 2021](#); [Ezzaouia & Bulchand-Gidumal, 2020](#); [Abed, 2020](#); [Sanchez-Torres & Juarez-Acosta, 2019](#); [Govinnage & Sachitra, 2019](#)). On most occasions, the customers or suppliers can create pressure on the organisation to adopt innovative technology ([Ezzaouia & Bulchand-Gidumal, 2020](#); [Abed, 2020](#)). Many international companies frequently pushed their branches and suppliers to adopt e-commerce technology to enhance their global production network ([Ezzaouia & Bulchand-Gidumal, 2020](#); [Alnaser, Saeed & Alrawashedh, 2018](#)). When competitors start using e-commerce for their business, firms are forced to adopt e-commerce technology more widely to gain competitive advantages ([Dahbi & Benmoussa, 2019](#); [Govinnage & Sachitra, 2019](#); [Ezzaouia & Bulchand-Gidumal, 2020](#)). When there is a higher level of competition within the industry, an automatic pressure is generated on individual organisations to adopt e-commerce to survive in the competitive market ([Alnaser, Saeed & Alrawashedh, 2018](#)). Hence, it is vital to test the competitive pressure impacts on the adoption of e-commerce among SMEs in Sri Lanka, since it is validated by many scholars in different contexts ([Ezzaouia & Bulchand-Gidumal, 2020](#); [Sánchez-Torres, Rojas Berrío & Ortiz Rendón, 2021](#); [Abed, 2020](#); [Govinnage & Sachitra, 2019](#); [Hidayati, Permatasari & Fajry, 2019](#); [Dahbi & Benmoussa, 2019](#); [Alnaser, Saeed & Alrawashedh, 2018](#)).

H3: Competitive pressure influences the adoption of E-commerce among SMEs in Sri Lanka.

Adoption of e-commerce impact on organisational performance

E-commerce is an important tool in business practices in the current competitive environment, and it is significantly affecting the effectiveness and efficiency of trade ([Hidayati, Permatasari & Fajry, 2019](#)). Performance is the ultimate result of the effectiveness and efficiency of the organisational activities and innovativeness in developing new processes or a product by using the latest technology, which affects the enhancement of organisational performance ([Durst, Hinteregger & Zieba, 2019](#)). Hadi Putra & Santoso ([2020](#)) elaborated that performance can be measured in terms of financial and non-financial. Further, it can be measured in three ways: business performance, innovative performance, and operational performance ([Kuruwitaarachchi et al., 2020](#)). Technology adoption affects the overall performance of an organisation ([Ammirato et al., 2019](#)). Furthermore, with the rapid growth of technology-based innovative strategies in an organisational context, customer satisfaction on online transactions has become a challenging task of the e-commerce industry, which leads to the firm's performance ([Vakulenko et al., 2019](#)). Hence, it is essential to examine the adoption of e-commerce effects on SMEs' organisational performance in Sri Lanka.

H4: Adoption of e-commerce influencing the organisational performance of SMEs in Sri Lanka.

Methodology

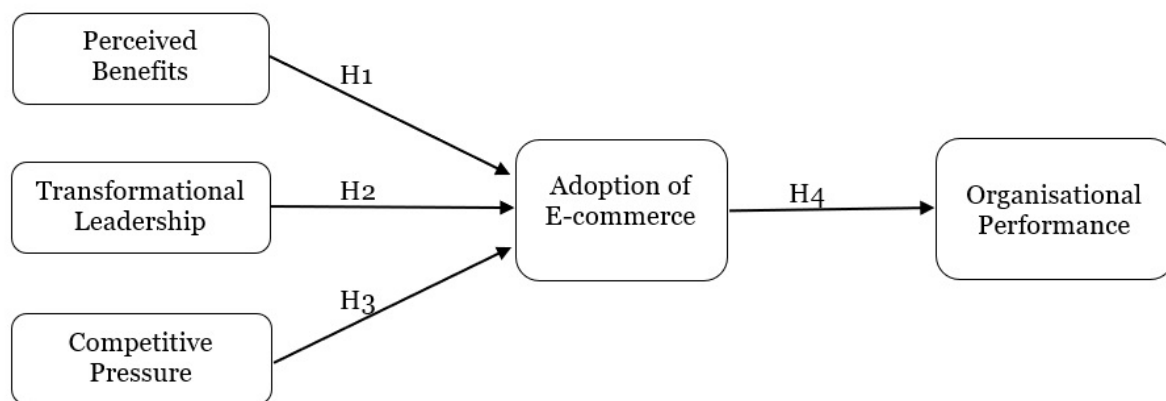


Figure 1. Conceptual Framework (Source: Author's elaboration)

TOE and DOI theories have been utilized as the foundation of the conceptual model of e-commerce adoption of SMEs. After a critical evaluation of the literature, the researcher identified perceived benefits, transformational leadership, and competitive pressure influencing the adoption of e-commerce among SMEs, and these factors represent the technological, organisational, and environmental contexts. Moreover, it was identified through empirical literature that e-commerce adoption impacts organisational performance.

Thus, the conceptual model shown in Figure 1 was developed to examine the perception of senior managers among SMEs in Sri Lanka.

Sampling and procedure

The samples were collected from the senior managers and owners of SMEs in Sri Lanka, since the unit of analysis is individual companies. The structured questionnaire was circulated among SMEs using electronic methods (e-mails and LinkedIn), and one response was collected from each company. A simple random sampling method was used to collect data: 575 questionnaires were circulated, and 350 samples were collected. SPSS was used to analyse the descriptive and inferential statistics, and AMOS ([Zainudin Awang, 2015](#)) was used to confirm the theory and test hypotheses.

Instrument development

The questionnaire consisted of two parts. Part “A” was related to the descriptive data, and part “B” represented the variables of the study. The instrument was developed by adapting items from previous similar studies ([Sanchez-Torres & Juarez-Acosta, 2019](#); [Mahliza, 2019](#); [Dahbi & Benmoussa, 2019](#); [Sattayaraksa & Boon-Itt, 2018](#); [Xuhua, Chosniel Elikem & Akaba, 2019](#); [Hidayati, Permatasari & Fajry, 2019](#)) to identify the perception of SMEs when adopting e-commerce. A five-point Likert scale was used to measure the questionnaire and was validated by two university academics and one industry expert.

Table 1 elaborates the variables, the instruments used to measure those variables, and the mean values of each item. Perceived benefits, transformational leadership, competitive pressure, and organisational performance were measured by using eight (8) instruments in each construct, and adoption of e-commerce was measured by using ten (10) instruments.

Table 1. Operationalisation

Factor	Instrument		Mean
Perceived Benefits (PB)	PBo1	The use of e-commerce simplifies work routine	4.22
	PBo2	Helps to increase the online traffic to the website	4.02
	PBo3	Improves the communication process	4.23
	PBo4	Compatible with our industrial practices	4.03
	PBo5	Helps to enhance staff satisfaction and ease of use	4.08
	PBo6	Accelerates the work process to complete faster	4.27
	PBo7	Enhances the staff work effectiveness	4.17
	PBo8	Flexible and easy to interact with global markets	4.36
Transformational Leadership (TR)	TL01	Demonstrates high standards of ethical and moral conduct	4.09
	TL02	Motivates the staff by communicating the vision to be achieved	4.20

Factor	Instrument		Mean
	TL03	Shows the intention towards adoption of e-commerce	4.11
	TL04	Creates the adoptive culture in an organisation towards e-commerce	4.07
	TL05	Employees are appreciated by the CEO for technological innovation	4.19
	TL06	Capable of guiding the staff and motivate them for innovative adaptation	4.11
	TL07	Emphasizes the need of technological innovation for the company growth	4.25
	TL08	The company strategy has a priority on various types of innovations set by the leader	4.13
Competitive Pressure (CP)	CP01	Business partners requested to adopt e-commerce	3.75
	CP02	The company experienced competitive pressure to adopt e-commerce	3.77
	CP03	The company has experienced of competitive disadvantage without adopting e-commerce	3.68
	CP04	The intensity of rivalry among competitors in the industry, push us to adopt e-commerce	3.79
	CP05	Easy for our customers to switch to another company for their easiness	3.65
	CP06	Competitors are doing business using e-commerce	3.82
	CP07	Industry is pressurizing us to adopt e-commerce	3.81
	CP08	Local authorities are pressurizing us to adopt e-commerce	3.65
Adoption of Ecommerce (AE)	AE01	Affecting to expand market share of the company	4.15
	AE02	Enhances the operational efficiency	4.23
	AE03	Helps to improve distribution channels	4.25
	AE04	Helps to create effective partnerships with business contacts	4.21
	AE05	Affecting to increase competitive advantages	4.25
	AE06	Provides new business opportunities	4.35
	AE07	Allows the accomplishment of specific online tasks more quickly	4.27
	AE08	Sellers and buyers have a positive attitude towards e-commerce	4.08
	AE09	Easy to touch, untapped markets by adopting of e-commerce	4.25
	AE10	Able to improve customer satisfaction	4.18
Organisational Performance (OP)	OP01	Enhance the global market reputation	4.33
	OP02	Expand the geographical reach	4.37
	OP03	Expand the trade	4.35
	OP04	Constantly grow the market	4.30
	OP05	Increase profitability of the company	4.20

Factor	Instrument		Mean
	OPo6	Increase the number of sales transactions	4.28
	OPo7	Increase the sales volume	4.26
	OPo8	Increase the return on sales	4.12

Source: Authors

Results and Discussion

Results

Table 2. Descriptive Statistics of the Respondents

Characteristic	Range	Respondents	%
Gender	Male	228	65.1%
	Female	122	34.9%
Age	20–30	23	6.6%
	31–40	139	39.7%
	41–50	159	45.4%
	51–60	29	8.3%
Education	Advanced Level	24	6.9%
	Diploma Level	22	6.3%
	Bachelor's Degree	144	41.1%
	Master's Degree	137	39.1%
	Doctoral Degree	8	2.3%
	Professional Qualification	15	4.3%
Length of Operation	< 5 Yrs	46	13.1%
	06–10 Yrs	69	19.7%
	11–15 Yrs	143	40.9%
	16–20 Yrs	59	16.9%
	> 20 Yrs	33	9.4%
No of Employees	11–25	174	49.7%
	26–50	73	20.9%
	51–100	63	18.0%
	101–200	40	11.4%
Position	Director/Owner	109	31.1%
	Senior Manager	156	44.6%
	Manager	74	21.1%
	Senior Officer/Executive	11	3.1%

Source: Authors

The responses were analysed according to demographic and company-wise information as shown in Table 2. Thus, 65.1% of respondents are males, and 34.9% are females. The

population's age group is between 20 to 60 years, and 85% represent the age between 31 and 50. More than 85% of them have bachelors degrees or higher qualifications. Furthermore, 44.6% of the respondents are Senior Managers, 31.1% are Directors/Owners, and 21.1% are Managers.

The majority of respondents are from the Western Province of Sri Lanka, which consists of three main districts. The responses were collected from more than 20 industries: 25.4% represent IT and related services; 10.9% were received from the consultancy and professional services; and 9.1% from the education and related services. Approximately 70% of companies have been in the business for more than 11 years. Only 13% have been in the business for less than five years.

Table 3. Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %
1	13.605	36.771	36.771	13.605	36.771	36.771	5.768	15.590	15.590
2	3.802	10.276	47.047	3.802	10.276	47.047	5.351	14.462	30.052
3	2.865	7.742	54.789	2.865	7.742	54.789	4.505	12.177	42.228
4	1.993	5.387	60.176	1.993	5.387	60.176	4.308	11.644	53.872
5	1.572	4.248	64.424	1.572	4.248	64.424	3.904	10.552	64.424

Source: Authors

Principal Component Analysis was used as the extraction method, since it is the most expedient way of extracting by using a total variance. Five components collectively explained the total cumulative variance of 64.424%, which was shown in Table 3. The Kaiser-Meyer-Olkin (KMO) value indicated the sampling adequacy: it was 0.931, which exceeded the threshold value of 0.6 (Howard, 2015).

Table 4. Rotated Component Matrix

Construct	Item	Component				
		1	2	3	4	5
Perceived Benefits	PB01	.624				
	PB03	.641				
	PB04	.627				
	PB05	.738				
	PB06	.759				
	PB07	.782				
	PB08	.569				

Construct	Item	Component				
		1	2	3	4	5
Transformational Leadership	TL01		.687			
	TL02		.786			
	TL03		.788			
	TL04		.809			
	TL05		.798			
	TL06		.801			
	TL07		.850			
	TL08		.799			
Competitive Pressure	CP01			.540		
	CP02			.729		
	CP03			.750		
	CP04			.762		
	CP05			.630		
	CP06			.717		
	CP07			.762		
	CP08			.644		
Adoption of E-commerce	AE01				.657	
	AE02				.706	
	AE03				.740	
	AE04				.690	
	AE05				.758	
	AE06				.755	
	AE07				.720	
	AE09				.571	
	AE10				.553	
Organisational Performance	OP04					.734
	OP05					.752
	OP06					.797
	OP07					.839
	OP08					.727
Cronbach's Alpha	-	0.876	0.942	0.877	0.924	0.901

Source: Authors

Table 4 shows the factor loading; items were loaded into five components after the loss of a few items due to cross-loading and unloading. The Cronbach's alpha value of each construct was above 0.7.

Table 5 describes the reliability and validity of the measurement models. Cronbach's alpha and composite reliability (CR) measure the internal consistency in scale data, which exceeded the threshold values of each construct ([Zainudin Awang, 2015](#)). Moreover, the average variance explained (AVE) measures the construct validity, which exceeded the threshold value of 0.5 ([Zainudin Awang, 2015](#)).

Table 5. Reliability of Measurement Model

Construct	Alpha	CR	AVE
Perceived Benefits	0.876	0.881	0.516
Transformational Leadership	0.942	0.939	0.660
Competitive Pressure	0.875	0.879	0.514
Adoption of E-commerce	0.924	0.922	0.569
Organisational Performance	0.901	0.895	0.634

Source: Authors

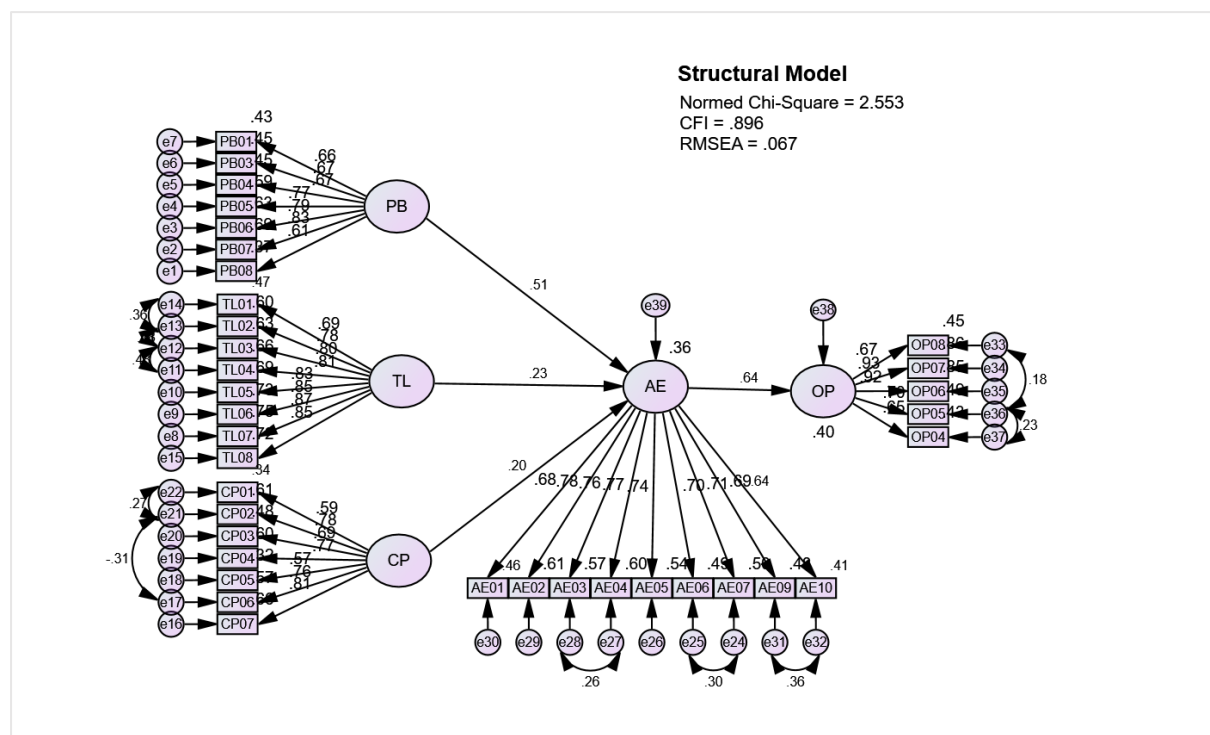


Figure 2. SEM Path Analysis (Source: Authors)

Figure 2 describes the structural model (Amos Diagram); all fitness categories of the model are in an acceptable range. Standardized beta values of perceived benefits (PB), transformational leadership (TL), and competitive pressure (CP) are 0.513 (actual beta: 0.632), 0.234 (actual beta: 0.163), and 0.196 (actual beta: 0.132), respectively. All predictor variables collectively explained 36% (R-squared) of the variance in the adoption of e-commerce (AE). Adoption of e-commerce (actual beta: 0.594) explained 40% (R-squared) of the variance of organisational performance (OP).

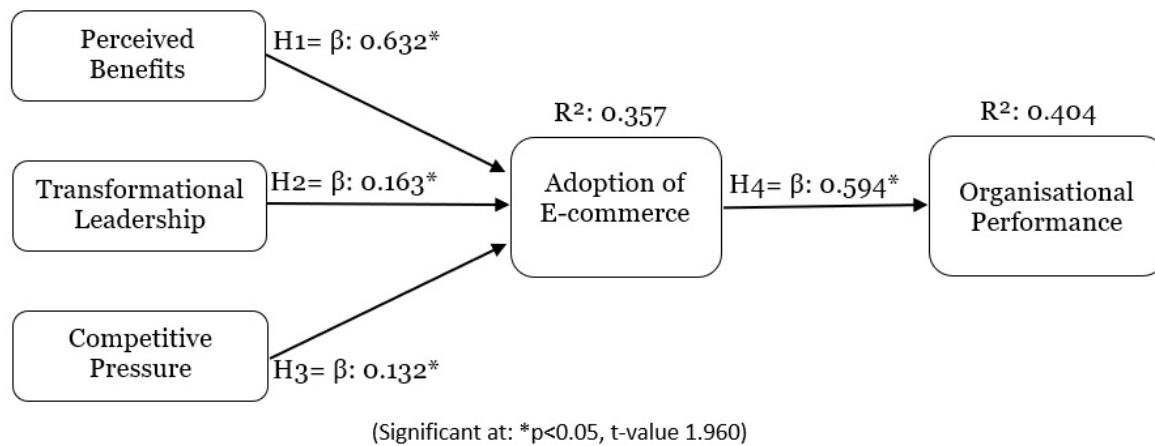


Figure 3. Adoption of E-commerce and its Impact on Organisational Performance of SMEs in Sri Lanka (Source: Authors)

Table 6. Regression Weights of the Structural Model

Hypothesis	Path	Actual Beta	SE	Critical Ratio	P-Value
H1	AE <--- PB	0.632*	0.084	7.501	0.000
H2	AE <--- TL	0.163*	0.036	4.579	0.000
H3	AE <--- CP	0.132*	0.035	3.798	0.000
H4	OP <--- AE	0.594*	0.066	8.962	0.000

Source: Authors (Significant at: $*p < 0.05$, t-value 1.960)

Figure 3 and Table 6 show the conceptualized model and regression weights of the structural model. All four hypotheses have achieved highly significant P-values (< 0.001) for all the relationships in the model. Perceived benefits, transformational leadership, and competitive pressure are the independent variables of the model. All these variables show a significant influence on the adoption of e-commerce. Furthermore, the adoption of e-commerce indicated a highly significant p-value (< 0.001) on organisational performance.

Discussion

The study aimed to identify the determinants affecting the adoption of e-commerce and its impact on the organisational performance of SMEs in Sri Lanka. Hence, the conceptualized model was developed using TOE and DOI theories to identify the level of influences between variables in the model. Four hypotheses were developed in total: three hypotheses were involved to measure the influence on e-commerce adoption, and one hypothesis has measured the influence of e-commerce adoption on the organisational performance of SMEs.

Table 7. Summary of Hypothesis Testing

Hypothesis	Statement	Actual Beta	P-Value	Results
H1	Perceived benefits influence the adoption of e-commerce among SMEs in Sri Lanka	0.632*	0.000	Supported
H2	Transformational Leadership Style influencing the adoption of e-commerce among SMEs in Sri Lanka	0.163*	0.000	Supported
H3	Competitive pressure influences the adoption of E-commerce among SMEs in Sri Lanka.	0.132*	0.000	Supported
H4	Adoption of e-commerce influencing the organisational performance of SMEs in Sri Lanka.	0.594*	0.000	Supported

Source: Authors (Significant at: * $p < 0.05$, t-value 1.960)

Table 7 shows the results of the hypothesis testing. Perceived benefit, transformational leadership, and competitive pressure were related to technological, organisational, and environmental contexts, respectively. As explained by Tornatzky & Fleischer (1990), TOE factors affect technological innovation in an organisation. Rogers (1995) explained how innovation characteristics and organisational characteristics influence technologically innovative adoption by an organisation. Thus, SEM path analysis (Figure 2) confirmed related theories. Nevertheless, Hypotheses 1, 2, and 3 tested the influence on e-commerce adoption, and p-values are highly significant ($p < 0.001$) on all paths. H4 tested the impact of the adoption of e-commerce on organisational performance and has shown a highly significant p-value ($p < 0.001$). Hence, all hypotheses are supported. Moreover, the study focused to find answers for two specific objectives.

Table 8. Objective Results

Objectives	Hypothesis	Summary	Results
a. To determine the most influencing factor which affects the adoption of e-commerce.	H1, H2, H3	- The p-values are highly significant of all paths. - Perceived benefits, transformational leadership, and competitive pressure collectively explained 36% (R-squared value) of the variance in the adoption of e-commerce. - The highest estimated value was indicated by perceived benefits, which is 0.632. - Hence, the perceived benefit was the most influencing factor.	Achieved

Objectives	Hypothesis	Summary	Results
b. To examine the adoption of e-commerce impact on organisational performance.	H4	- The p-value was highly significant. - The adoption of e-commerce explained 40% (R-squared value) of the variance in organisational performance. - The estimated value of 0.594 indicated between variables.	Achieved

Source: Authors

Most influencing factor affecting e-commerce adoption

Perceived Benefits, Transformational Leadership, and Competitive Pressure influence the adoption of e-commerce in the model. The beta-values (estimate) are 0.632, 0.163, and 0.132, respectively. All these factors show highly significant p-values (<0.001) in the regression weights. All predictor variables collectively explained 36% ($R^2: 0.357$) of its variance in the adoption of e-commerce. Nevertheless, Sánchez-Torres, Rojas Berrío & Ortiz Rendón (2021) examined many factors that affect the e-commerce adoption in Colombian SMEs and discovered managerial characteristics, observability, relative advantage, and customer pressure significantly influenced e-commerce adoption, and the R^2 value was shown as 0.318. However, the perceptions of Colombian SMEs and Sri Lankan SMEs are similar in the adoption of e-commerce. The perceived benefit indicated the highest beta-value of 0.632, which shows that, when one unit of the perceived benefit goes up, the adoption of e-commerce goes up by 0.632 units (Zainuddin, 2015). Therefore, the most influencing factor on the adoption of e-commerce of SMEs in Sri Lanka was the perceived benefits.

Impact of e-commerce adoption on organisational performance

A highly significant p-value was indicated in the path between the adoption of e-commerce and organisational performance. The beta-value of the path is 0.594, and adoption of e-commerce is explained as 40% ($R^2: 0.404$) of the variance of organisational performance. Hence, it is concluded that the adoption of e-commerce impacts SMEs' organisational performance in Sri Lanka.

Furthermore, as described previously, perceived benefits represent the technological context of the model, and it refers to the degree of acceptance of the possible advantages that e-commerce technology can provide for the organisation (Alnaser, Saeed & Alrawashedh, 2018). Thus, it is one of the important factors in the technological perspective, whether the buyers or customers will accept the e-commerce platform and how far it will support the audience. This situation is one of the critical factors to gain a competitive advantage over the competitors in the global market. The transformational leadership style represents the framework's organisational context, and this is the leaders' perception towards innovative adoption in an

organisation ([Xie et al., 2018](#)). Therefore, the leader creates the adoptive culture within the organisation which drives it forward. The competitive pressure represents the environmental context, which comes from the outside world, increasing the competitive power to compete in the market. The organisation's performance was measured in the study in terms of financial and non-financial performance. The results concluded that the adoption of e-commerce is able to increase constant market growth, the number of transactions, sales volume, and profitability of SMEs.

Implications and Conclusions

Implication for practice

The study facilitates to find out the management perception of e-commerce adoption to their businesses as a business strategy. The managers assumed that e-commerce technology provides some value additions to their organisations, especially when expanding the marketing strategies, which simplify the work routing, improve communication process, and are easy to interact with global markets. Furthermore, the leadership style of managers is playing a significant and critical role when adopting e-commerce technology in organisations. This creates an adoptive culture within the organisation by demonstrating a high level of ethical and moral conduct, communicating the vision to be achieved, and emphasizing the need for technological innovation for the company's growth. Likewise, the intensity of rivalry among competitors in the industry can impose the adoption of e-commerce to survive in the market and gain a competitive advantage over the competitor.

Nevertheless, many entrepreneurs have changed their mindsets to adapt e-commerce as a remedy to overcome this COVID-19 crisis. This study helps entrepreneurs to identify the important areas when adopting e-commerce: it was statistically proved that e-commerce has the power to enhance the organisational performance of SMEs in Sri Lanka, which ultimately impacts the gross domestic product (GDP) of the country. Therefore, government and policymakers in Sri Lanka must set their policies and regulatory structures to support and encourage SMEs to adopt this innovative business strategy. Further, regulators must consider the implementation of the data protection act, cyber-security controls, and funds transfer policies to facilitate SMEs to expand their market penetration.

Implication for research

As discussed above, many studies have related to e-commerce adoption in a different context and have found different types of factors that influenced the adoption of e-commerce ([Sánchez-Torres, Rojas Berrío & Ortiz Rendón, 2021](#); [Ezzaouia & Bulchand-Gidumal, 2020](#); [Dahbi & Benmoussa, 2019](#)). However, Ezzaouia & Bulchand-Gidumal ([2020](#)) identified the

perceived benefits, individual characteristics, and external factors that significantly influenced the adoption of technology in the hospitality sector in Morocco. Moreover, Sánchez-Torres, Rojas Berrío & Ortiz Rendón (2021) examined many factors and found out that managerial characteristics, observability, relative advantage, and customer pressure significantly influenced the adoption of e-commerce in Colombian SMEs. Further, trading partner pressure, perceived usefulness, and top management support significantly influenced the social commerce adoption in Saudi Arabian SMEs (Abed, 2020).

Similarly, there are a few studies in the Sri Lankan context. Govinnage & Sachitra (2019) tested the adoption of e-commerce related to the retail sector and examined perceived benefits, computer literacy, government support, and technological infrastructure as predictors in the study: perceived benefits were not supported for the adoption of e-commerce. Kuruwitaarachchi *et al.* (2020) proposed a framework that affects e-commerce adoption and suggested testing information technology perspective, technology know-how, and network security as predictors of the adoption. Gunawardana (2018) examined e-commerce in SMEs in Sri Lanka and identified very basic levels of Internet usage by SMEs to communicate with each other, such as customer service, e-marketing, supplier services, and e-payment.

However, this study examined three variables as predictors of e-commerce adoption in Sri Lanka. Transformational leadership is not widely studied in similar studies, especially in the Sri Lankan context, and observed the e-commerce adoption affecting the organisational performance of SMEs in Sri Lanka as a modern business strategy.

Conclusion

The study aimed to identify the determinants affecting the adoption of e-commerce and its impact on the organisational performance of SMEs in Sri Lanka. After a critical review of the literature, perceived benefit, transformational leadership, and competitive pressure were identified as factors that could influence e-commerce adoption. After analysing the data, it was recognized that the perceived benefit is the most influencing factor of the adoption, and the other two factors also significantly influenced the adoption. Moreover, the adoption of e-commerce affects the organisational performance of SMEs in Sri Lanka. As a contribution, the study investigated the perception of management about e-commerce adoption and its benefits, which are vital to improving the technological development of SMEs in Sri Lanka.

Limitations and future research directions

Concerning the limitations, the study mainly focused on the SME sector in Sri Lanka. It is possible to study for a particular province, district, and different sectors. Further, many other factors affect e-commerce adoption, such as cybersecurity, cultural changers, Internet facility,

and Internet speed. These affect e-commerce adoption in developing countries. Similarly, it is important to investigate the moderating factors that affect the organisational performance of SMEs and examine the post-e-commerce adoption. Hence, it is open for future researchers to investigate those areas.

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Factors Determining the Use and Acceptance of Mobile Banking in Colombia

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Abstract: The purpose of this paper is to identify the factors that influence the acceptance and use of mobile banking among users in Medellín (Colombia). The factors we propose are built upon on seven constructs (customer service and support, perceived attitude, perceived usefulness, ease of use, perceived trust, intention to use, and perceived security), which were developed based on the Technology Acceptance Model (TAM) and the literature. We collected the data from 220 questionnaires self-administered by mobile banking users in Medellín. Subsequently, we conducted a confirmatory factor analysis to determine the correlation between the set of observed variables and the constructs defined in the proposed acceptance model. We empirically conclude that the use of mobile banking among the population under study is mainly influenced by users' perceived usefulness, perceived trust, and ease of use. The results show a strong correlation between perceived trust and perceived security and between perceived usefulness and intention to use.

Keywords: Adoption model, Colombia, mobile banking, perceived ease of use, technology acceptance

Introduction

Companies strive to innovate their products and processes to organize themselves and interact with customers in new ways ([Herman, Sulhaini & Farida, 2020](#)). For instance, technological changes and the use of smartphones have transformed the way the banking sector delivers

financial products to users, moving from traditional to self-service channels that save time and trips to the branch ([Nichkasova & Shmarlouskaya, 2020](#)).

Despite the growing use of mobile devices, there is still a gap between mobile banking users in different countries ([Ortiz & Núñez, 2017](#)). In particular, Latin American users still have a hard time to access financial and banking services in spite of the considerable potential demand for such services ([Roa, 2013](#)). The use of mobile technologies becomes, thus, an opportunity to bring financial services closer to vulnerable population groups. In Colombia, according to the Private Council of Competitiveness ([2017](#)), online access to banking services (especially new e-payment schemes) should be promoted across the country as a relevant and necessary strategy to increase the use of Information and Communication Technologies (ICTs), favour financial inclusion in e-commerce and productive sector practices, and create access channels to reduce transaction costs for agents.

Online banking has emerged as an effective channel to enhance financial inclusion ([Avendaño, 2018](#)). In addition, mobile banking (m-banking) offers multiple services and creates new technology-based banking products ([Singh & Srivastava, 2020](#)). In the latter, customers interact with the bank via smartphones to transfer funds, check their balance or detailed account information, issue cheques, and pay bills, among other options ([Joy & James, 2018](#)). Therefore, this transactional channel makes it possible to overcome the space and time constraints of traditional banking activities conducted at bank branches and offices.

A vast number of studies have investigated the use and acceptance of mobile banking in countries such as Turkey, Iran, South Korea, Pakistan, India, Jordan, and China ([Glavee-Geo, Shaikh & Karjaluoto, 2017](#); [Lee & Son, 2017](#); [Altin, Kaya & Ozlu, 2018](#); [Hamidi & Safareyeh, 2018](#); [Singh & Srivastava, 2018](#); [Siadat, Najjar & Nezafati, 2019](#); [Choi et al., 2020](#); [Ibrahim, Khalil & Ahmed, 2020](#); [Kumar et al., 2020](#); [Al-Dmour et al., 2020](#); [Zhu et al., 2021](#)). However, there is no empirical model to understand the factors that influence such acceptance and use in Colombia ([Mejía & Quintero, 2017](#)) despite the great importance mobile technology has gained in this country. According to the Colombian Ministry of Information and Communication Technologies ([2020](#)), only 43.09% of the country's current demand for mobile Internet services has been met.

In Colombia, electronic transactions have become popular in recent years due to their low costs and multiple access possibilities. Transactions over different channels reflect the development of the national financial system. For instance, by the end of the first half of 2020, there had been 3,517 million electronic transactions for COP 2,351 billion ([Superintendencia Financiera de Colombia, 2020](#)). Furthermore, the total amount of transactions over the Internet reached COP 1,646 million, which represented the largest share (45.3%) over the total

number of electronic transactions; at ATMs, it was 637 million (17.5%); at branches, 82 million (27.6%); and via mobile phones, 2,469 million (9.6%) ([Superintendencia Financiera de Colombia, 2020](#)). These figures, however, reveal the low acceptance and use of mobile banking compared to other channels regardless of the high demand for mobile devices in the country.

According to previous studies, the success of new channels for delivering financial services and products (e.g., mobile banking) is due to their acceptance among customers ([Tan & Lau, 2016](#)), which depends on their different levels of understanding and skills to use them ([Alkhaldi, 2017](#)). Keisidou, Sarigiannidis & Maditinos (2011) claim that multiple factors influence users' acceptance and use of these channels, such as the type of product or service and its characteristics and individuals' perceptions of security, trust, ease of use, and usefulness.

The mandatory preventive social distancing measures imposed by the Colombian government due to the COVID-19 pandemic revealed shortcomings in the country's financial system, especially in terms of financial inclusion. These shortcomings have prompted the country to adopt digital channels as low-cost and simple tools to carry out transactions ([Formento, 2020](#)), making this topic increasingly interesting to scholars. Therefore, motivated by the fact that mobile banking and its low acceptance are difficult to understand, this study poses the following research question: What are the main factors that drive users in Medellín (Colombia) to accept and use mobile banking?

In view of the above, this research aims to identify the main factors that drive users in Medellín (Colombia) to accept and use mobile banking. For this purpose, we adapted the Technology Acceptance Model (TAM) and applied it to a questionnaire self-administered by 220 mobile banking users to determine the way specific factors (perceived attitude, customer service and support, perceived trust, ease of use, intention to use, perceived security, and perceived usefulness) influence the acceptance and use of said service.

Theoretical Background

Overview of Mobile Banking

The banking sector is one of the leading industries in the adoption of Internet and mobile technologies for consumer markets, and, nowadays, its actions must consider additional aspects, such as advanced technology, competitiveness, market uncertainty, and technological progress ([Souiden, Ladhari & Chaouali, 2020](#)). According to Hoehle, Scornavacca & Huff (2012), the banking industry has changed the way it provides services to its customers; even before the emergence of Internet banking, banks had invested heavily in information technologies and, as a result, their operations became electronic, using systems such as ATMs and online banking. The Internet has, thus, significantly influenced the expansion of electronic

banking, which is regarded as one of the most successful applications of business-to-consumer (B2C) relationships in e-commerce ([Joshi, 2013](#)).

However, despite the rapid increase in many commercial wireless services, the level of use of online banking is far lower than expected, which is why it is considered to be underutilized ([Muhammad, Chin-Hong & Arif, 2015](#)). The reason for this, according to Premalatha & Sundaram ([2014](#)), is that banking consumers are still reluctant to use the online services provided by banks, maybe, as mentioned by Mohammadi ([2015](#)), due to a lack of effective communication strategies to promote their use, rather than because these products or services should be changed.

Online banking and m-banking are considered part of electronic banking and represent competitive areas for banks to generate resources ([Kashmari, Nejad & Nayebyazdi, 2016](#)). Nonetheless, they are, in turn, two alternative channels for banks to provide their services and for customers to access them ([Kapinus & Skrygun, 2014](#)).

According to Han & Baek ([2004](#)), Security First Network Bank (SFNB) was a pioneer in Internet banking through its website. Thereafter, thousands of banks have adopted this delivery channel. As a result of globalization, the operating environment of the banking industry tends to be more dynamic. In this regard, Cheng, Gaur & Rahim ([2020](#)) point out that banks are increasingly focused on providing differentiated products by improving service quality through security, customer service, and trust, which becomes a competitive strategy that translates into higher revenues, percentage of sales, customer retention, and brand expansion.

Technological developments applied to mobile banking have also led to organizational changes: that is, creating products and services (in the financial sphere, in this case) has become a social innovation that also adopts inclusive business approaches ([Lashitew, Bals & van Tulder, 2018](#)). M-banking is characterized by providing banking services via applications designed for smartphones, regardless of users' location or bank opening hours ([Changchit, Lonkani & Sampet, 2017](#)). Using electronic banking services through effective applications and means of communication, such as mobile banking, can fundamentally change the way bank–customer relationships are built and maintained ([Muñoz-Leiva, Climent-Climent & Liébana-Cabanillas, 2017](#)).

Mobile banking in Colombia

The wide variety of studies into mobile banking acceptance reflects the significant interest of many researchers in understanding the way users decide, adopt, and form their perceptions,

attitudes, intentions, and behaviour towards the use of mobile banking ([Mehrad & Mohammadi, 2017](#); [Baabdullah et al., 2019](#); [Singh & Srivastava, 2020](#)).

Colombia has made efforts to increase the number of channels and encourage the development of products in the national banking system as part of an overall government policy on financial inclusion. In terms of creation of new channels, the geographical coverage of banking and mobile banking agents has been expanded. On the other hand, in terms of product development, the use of electronic deposits and savings accounts has been promoted ([Fernández de Lis et al., 2014](#)).

Thus, the country has made significant progress in financial inclusion in recent years. According to the latest report on financial inclusion published by the Banca de las Oportunidades ([2019](#)), “as of December 2019, 82.5% of the adult population had access to at least one financial product; that is, of the 35.6 million adults in Colombia, 29.4 million had a deposit or credit product” (p. 58). In addition, in the first nine months of 2020, 2.2 million adults were included in the financial system, doubling the number of people who were banked in the previous year.

Additionally, the COVID-19 pandemic has caused fear of contagion in physical branches, as well as the need to distribute government aid. These events have, in turn, accelerated the country’s transition to mobile banking, a process that had been underway for ten years and whose goals were met more than two years ahead of schedule ([Portafolio, 2021](#)). According to Forbes Advertorial ([2021](#)), banking digitalization in the countryside of Colombia has become an ally for micro and small businesses seeking financial inclusion precisely using digital solutions.

In Colombia, many people believe that mobile banking is only related to electronic transactions, which has generated resistance to innovation, mainly in rural communities ([van Klyton, Tavera-Mesías & Castaño-Muñoz, 2021](#)). Therefore, mobile money should be distinguished from mobile banking. Gichuki & Mulu-Mutuku ([2018](#)) classify mobile money technologies into four categories: (i) mobile money transfer; (ii) mobile banking services; (iii) mobile payments; and (iv) group transaction services.

Mobile money transfer refers to services that allow users to send or receive money via mobile phones. Mobile banking enables users to access banking services, such as payments, account balance inquiry, transfers, bill payments, and financial management ([Malaquias & Hwang, 2019](#)), via online banking channels and mobile phones. This has important implications for financial transactions. In turn, mobile payments are services that allow users to pay for goods and services without using cash ([de Luna et al., 2019](#)). Finally, group transaction services

enable members of banking groups to send savings and loan repayments to virtual group accounts ([Gichuki & Mulu-Mutuku, 2018](#)).

Proposed model and hypotheses

The original TAM — designed and published by Davis in 1989 — defines the factors that influence individuals' intention to use new technologies. According to Al-Gahtani & King ([1999](#)), the main purpose of this model is to provide a basis for measuring the impact of external factors on beliefs, attitudes, and intentions. Among multiple theoretical models, the TAM is one of the most widely employed to understand technology adoption and usage, particularly in the field of information systems ([Gangwar, Date & Ramaswamy, 2015](#)). Davis' model is considered one of the most reliable, cited ([Tamilmani, Rana & Dwivedi, 2020](#)), and widely used ([Loiacono, Watson & Goodhue, 2007](#)) native technology adoption theories, making it the ideal choice to predict the usage of information technologies such as mobile banking.

Recently, the adoption of mobile banking has attracted increasing interest because it provides significant information on consumer behaviour and marketing communication for bank marketing ([Glavee-Geo, Shaikh & Karjaluoto, 2017](#)). Since the TAM has been one of the most widely accepted and used models in information technology (IT), it is no surprise that it has been implemented in recent studies into the adoption of mobile banking services in several contexts ([Chawla & Joshi, 2019](#); [Siyal, Ding & Siyal, 2019](#)). Likewise, this study (on the key factors that affect the adoption of mobile banking by customers of financial institutions) employs the TAM because it is in line with its approach.

Since its inception, the TAM has been tested in multiple contexts. In particular, Malaquias & Hwang ([2019](#)) recently implemented it to compare the factors that determine the use of mobile banking in Brazil and the United States, thus contributing to the field of technology acceptance in developed and developing countries. This model has served to study the adoption and acceptance of m-banking by different types of users ([Alalwan, Dwivedi & Rana, 2017](#); [Lee & Son, 2017](#); [Altin, Kaya & Ozlu, 2018](#); [Hamidi & Safareyeh, 2018](#); [Singh & Srivastava, 2020](#); [Azhari & Usman, 2021](#)). Additionally, it is considered one of the most popular and recognized models in the literature, as evidenced by the fact that, by 2021, the international Google Scholar search engine had reported 56,925 citations of the original article by Davis.

Davis took into account fundamental, determining, and significant factors in the field of computers and their use. He drew upon previous studies and applied a psychological hypothesis; hence, the TAM is used to model hypotheses that correlate factors that are thought to be determining ([Davis, 1989](#)). Importantly, using mobile banking technologies does not necessarily imply that they have been accepted. Guner & Acarturk ([2020](#)) explain that, if

individuals consider that a technology or information system is useful and easy to use, they will be more likely to adopt it. Davis (1989) identified two constructs: (a) *perceived usefulness*, defined as the degree to which individuals believe that using a specific technology would improve their job performance; and (b) *perceived ease of use*, defined as the degree to which individuals consider that using a specific technology would be easy. The next subsections present the hypotheses proposed in this paper.

Users' perceived usefulness

Stewart & Jürjens (2018) summarize this main premise of the TAM as follows: the use of a specific technology is influenced by users' intention to use it, which, in turn, is determined by its perceived usefulness and ease of use. As reported by Baki, Birgoren & Aktepe (2018), perceived usefulness and perceived ease of use (and the relationship between them) are the most frequently accepted variables in the literature. According to this premise, we formulate the first hypothesis in this study:

H1. *Users' perceived usefulness of mobile banking significantly influences ease of use.*

Customers are more likely to use mobile banking when they perceive it is useful and improves their work efficiency; on the contrary, they are less likely to use it when they feel it is difficult to interact with it, even if it may turn out to be useful for their work (Davis, 1989). The more useful and simple mobile banking tools are, the more likely they will be employed (Yamakawa, Guerrero & Rees, 2013). Previous research has proven that user acceptance based on trust is the most significant factor for online transactions (Kim, Jin & Swinney, 2009). For this reason, within perceived usefulness, trust is influenced by the usability of mobile applications, as well as by users' beliefs and expectations regarding websites (Boon-Itt, 2019). Therefore, in order to build a relationship based on trust, banks must strive to foster a customer-focused culture that revolves around privacy, security, and ethics by instilling shared values and the concept of commitment in the two parties (Mukherjee & Nath, 2003; Wichittakul & Prasongsukarn, 2018). In light of the above, we develop the following hypothesis:

H2. *Users' perceived usefulness of mobile banking influences their perceived level of trust.*

Several studies have demonstrated the direct relationship between perceived usefulness and attitude towards adoption (Azad, 2016; Changchit, Lonkani & Sampet, 2017; Mehrad & Mohammadi, 2017; Muñoz-Leiva, Climent-Climent & Liébana-Cabanillas, 2017). According to Mehrad & Mohammadi (2017), users tend to have a more positive attitude towards the adoption and use of new technologies when they understand their many benefits. The literature on the adoption of online banking has shown that perceived usefulness has the closest relationship with attitude towards its adoption (Lévy Mangin et al., 2011). In other

words, perceived usefulness is a factor that determines mobile banking adoption. Considering this, we propose our third hypothesis:

H3. *Users' perceived usefulness of mobile banking directly influences their attitude towards its adoption.*

Users' intention to employ a technology has been reported to be affected by its perceived usefulness ([Amoako-Gyampah, 2007](#)). For instance, Glavee-Geo, Shaikh & Karjaluoto ([2017](#)) found a relationship between perceived usefulness and intention to use mobile banking, where the former influences the latter. This is supported by the findings of Oliveira *et al.* ([2014](#)), who argue that the behavioural intention to adopt and accept a new technology is determined by its usefulness. Some authors have even claimed that users' perceptions of the usefulness and relevance of a technology can contribute to its successful implementation, i.e., its effective usage ([Amoako-Gyampah, 2007](#)). In view of the above, we propose the following hypothesis:

H4. *Users' perceived usefulness of mobile banking influences their intention to use it.*

Customer service and support

Other studies have shown that customer service and technical support encourage users to adopt Internet banking ([Abd Ghani et al., 2017](#)). As stated by Alawan, Dwivedi & Rana ([2017](#)), mobile banking users feel more motivated to use this service when they receive customer service and support. Therefore, if a bank has a customer service team that provides quick and effective responses to user inquiries, users tend to trust that financial service provider ([Das & Ravi, 2021](#)). Thus, according to Chung & Kwon ([2009](#)), the mobile experience and technical support strengthen the relationship between technology features and users, which, in turn, enhances trust. According to this, we present the following hypothesis:

H5. *Customer service and support provided by bank staff to consumers influence their perception of trust in mobile banking.*

Users' perceived trust

The importance of trust has been investigated in order to better understand the determinants and key factors that influence the acceptance of mobile banking ([Ramos et al., 2018](#); [Shareef et al., 2018](#)). Regarding the latter, Tham *et al.* ([2017](#)) also consider trust to be the ideal situation, in which an individual voluntarily becomes susceptible and vulnerable to the actions of a bank, a mobile device, and a telecommunications service provider, considering, though, that this is a gradual process, similar to that of interpersonal relationships.

Furthermore, Oliveira *et al.* ([2014](#)) found that providing the necessary organizational and technical infrastructure to support the use of m-banking may decisively influence its adoption and acceptance. Countries like Japan have made efforts to improve security in mobile banking

because this has increased trust between banks and users of the service. In line with this approach, Muñoz-Leiva, Climent-Climent & Liébana-Cabanillas (2017) point out that trust effortlessly reduces users' need to understand, control, and monitor the situation, thus facilitating the use of this mobile banking tool. Based on the above, we establish the following hypothesis:

H6. *Users' perceived trust in mobile banking management influences its ease of use.*

Mobile devices increasingly expose individuals to mobile threats, such as identity theft and viruses that come from web browsers and spread via Bluetooth, Wi-Fi, SMS, and other methods (Cano & Domenech-Asensi, 2011). For this reason, financial institutions must protect customers against these threats by incorporating effective technological tools and send them messages that build trust and reflect their commitment to personal information security. In this regard, Changchit, Lonkani & Sampet (2017) state that security is influenced by how secure banks can make users feel about their financial data and risk avoidance. In turn, Vejačka & Štofa (2017) suggest that trust is associated with perceived security and grows stronger as the latter increases. In addition, Mohammed *et al.* (2016) indicate that perceived security and privacy have a significant relationship with perceived trust in Internet banking services. Thus, we hypothesize that:

H7. *Users' perceived trust when they interact with mobile banking significantly influences their perceived security.*

Stewart & Jürjens (2018) stress that m-banking's susceptibility to hacking, in addition to not having antivirus software installed on mobile phones, may lead to security breach problems; as a result, m-banking cannot be a completely reliable tool. Moreover, banks find it difficult to communicate risks to their customers, because this may affect their reputation. However, if they focused on finding ways to increase trust in their mobile banking service, the number of frauds, uncertainties, and potential risks would be minimized, thus facilitating mobile banking transactions (Hamidi & Safareyeh, 2018). For instance, according to Stewart & Jürjens (2018), banks should be transparent and inform users about how their data are safely used and stored. In this regard, Luo, Zhang & Shim (2010) consider initial trust to be the main factor influencing the acceptance of mobile banking, because incorporating this construct into the services provided via banking channels encourages individuals to trust not only in new technologies but also in new business partners and in the structural assurance offered by mobile banking companies. In other words, the more consumers trust a bank's services, the more likely they are to use them. Then, we put forward the following hypothesis:

H8. *Users' perceived trust in mobile banking influences their attitude towards its use.*

Users' perceived security

Security is paramount when doing business online because fear and anguish among consumers are highly likely, which might potentially prevent them from using mobile banking, as they may be required to provide personal information that they consider sensitive ([Haque et al., 2009](#)). Likewise, Haque et al. (2009) argue that most transactions (not all) are made through web browsers connected to commercial websites that carry out data encryption, protection, verification, and authentication processes, which build trust between users and m-banking.

In the context of banking services, mobile technologies offer alternative channels to deliver financial products, such as social media ([Kemal, 2018](#)). According to Molony (2006), mobile phones are perceived as a technology that facilitates the provision of services and can be used to build trust and security in business relationships. As a result, economic activities rely on social media to transform their processes and engagement with users. Furthermore, according to Wichittakul & Prasongsukarn (2018), security is the most critical factor influencing the use of mobile banking. In view of the above, we present the following hypothesis:

H9. *Users' perceived security in social media significantly influences the ease of using mobile banking.*

Privacy and security have been considered the main sources of dissatisfaction in the use of web services and systems, which has affected user experience with banking transactions ([Mohammed et al., 2016](#)). However, new applications, such as mobile banking, have turned their attention to aspects such as accessibility, comfort, design, and content to improve customer satisfaction. Additionally, speed, product characteristics, availability, and reasonable rates and charges have become fundamental factors for banks' success ([Moraga, Campos & Villalón, 2008](#)). Based on this, we propose the following hypothesis:

H10. *Users' perceived security in web tools influences their attitude towards the use of mobile banking.*

Ease of use

According to Muñoz-Leiva, Climent-Climent & Liébana-Cabanillas (2017), the TAM considers attitude towards the use of new technologies to be a factor that determines ease of use. Additionally, it has been demonstrated ([Lévy Mangin et al., 2011](#)) that ease of use positively influences customers' attitude towards the use of new banking technologies. Likewise, Changchit, Lonkani & Sampet (2017) suggest that users' perceived ease of use plays an important role (as a factor) in their attitude towards the use of mobile banking. As a result of this close relationship between these two constructs described in the literature ([Azad, 2016](#)), we posit that:

H11. *The ease of use of and access to a bank's websites influences users' attitude towards their use.*

According to Davis' premise ([Davis, 1989](#)), the less effort users expect to put into using mobile banking technologies, the greater their intention to use them. Thus, this effort expectation, defined as the degree of ease of use of this delivery channel, has a positive impact on the intention to accept said channel ([Azad, 2016](#)). This premise is supported by previous studies that demonstrate that ease of use significantly influences the intention to use mobile banking ([Luarn & Lin, 2005](#)). In light of the above, we establish the following hypothesis:

H12. *The ease of use of digital tools provided by banks significantly influences users' intention to use them.*

Users' attitude

Muñoz-Leiva, Climent-Climent & Liébana-Cabanillas ([2017](#)) demonstrated that attitude towards mobile banking is the main factor that determines the use of mobile applications, followed by other factors like usefulness and risk. In this study, users' intention to use m-banking services is considered a factor that depends on other constructs, such as attitude. The growing use of the Internet in the future is expected to enhance customers' expectations and perceptions of mobile banking and, thus, their intention to use it not only once but constantly ([Lee & Son, 2017](#)), which makes this an increasingly important topic to analyze. Considering the studies mentioned above, this paper presents the following hypothesis:

H13. *Users' attitude towards mobile banking significantly influences their intention to use it.*

Based on the classical TAM structure and the theoretical evidence we collected from the field of banking digitalization, we proposed the research hypotheses mentioned above. As a result, we obtained a behavioural model (Figure 1) that serves to identify the variables involved in the acceptance and use of mobile banking in Medellín.

Research Methodology

This study adopted a quantitative, nonexperimental, causal-correlational approach. The primary source of information to test the hypotheses was a set of 220 questionnaires answered, during 2020, by mobile banking users in Medellín (Colombia), selected by convenience sampling ([Otzen & Manterola, 2017](#)).

Considering the context of the study population, this instrument administered here was written in Spanish. It was validated by an expert in the field to ensure that the items were sufficiently clear and in line with the dimensions previously outlined. Given the COVID-19

situation, the questionnaire was distributed online to mobile banking users in Medellín during the second half of 2020. First, the instrument was applied as a pilot test with 10 students to make sure that the information it presented was clear and understandable.

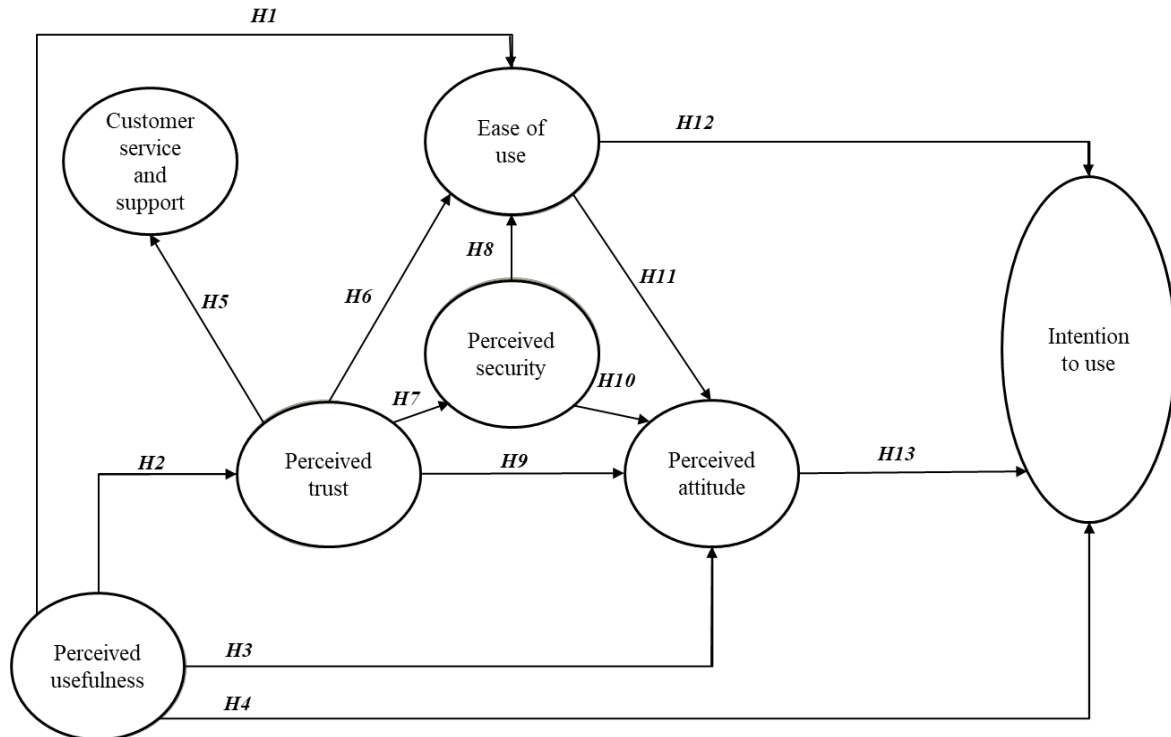


Figure 1. Adoption model proposed to analyse individuals' behaviour towards mobile banking

The questionnaire addressed seven constructs (customer service and support, perceived attitude, perceived usefulness, ease of use, perceived trust, intention to use, and perceived security), which were developed based on the TAM and the literature ([Muñoz-Leiva, Climent-Climent & Liébana-Cabanillas, 2017](#)). This instrument included 16 Likert scale questions and 5 closed-ended and multiple-choice questions with multiple answers. We collected the data using anonymous forms.

The results revealed that 61.63% of the respondents were female, with the majority of them (40.45%) being between the ages of 25 and 34. It should be noted that our findings (in terms of acceptance of mobile banking) cannot be generalized to all types of banking users in Medellín.

After data collection, we conducted a confirmatory factor analysis and processed and examined the data to ensure that the items in the questionnaire generated the expected number of factors and that each factor had an appropriate loading. In other words, we performed reliability and validity tests to verify the suitability of the constructs and the instrument. Furthermore, the Cronbach's alpha coefficients of the individual variables allowed us to assess the reliability of the instrument, as explained below.

Confirmatory factor analysis

Using factor reduction analysis, we empirically evaluated the model's suitability to measure the use of mobile banking *versus* face-to-face banking services. With this analysis, we can test the validity and reliability of each variable based on the understanding that an instrument can be reliable but not valid, but must necessarily be reliable if it is valid.

We may say that there are three types of validity. First, validity can be expressed in terms of content. *Content validity* provides evidence of the degree to which the items in an instrument are relevant to and represent the target construct for assessment purposes. For said assessment, a panel of experts evaluates the items in the instrument and classifies them according to their relevance and representativeness within the scope of the content ([Almanasreh, Moles & Chen, 2019](#)). Second, *criterion validity* is also used to examine the validity of an instrument. Its purpose is to measure the degree of correlation between an instrument and the external variables (criteria) to which it is hypothetically and somehow expected to be related. Finally, *construct validity* complements the assessment of an instrument by determining whether the relationships between the variables define a dimensional structure in the questionnaire that remains unchanged and could serve as the basis to interpret the results in different populations ([Lacave et al., 2016](#)).

Data processing and analysis

Although several statistical software packages can be used for data processing and analysis (e.g., Minitab, SAS, R-programming, STATA, SEM-AMOS, SEM-SmartPLS, and WarpPLS), we employed the Statistical Package for Social Sciences (SPSS) because it is one of the most widely implemented in social sciences, and it is easy to use for correlational comparison and correlation statistical tests in the context of univariate, bivariate, and multivariate analysis for parametric and nonparametric statistical techniques ([Ong & Puteh, 2017](#)). Thus, the data were processed and analyzed using SPSS software (version 22.0) for Windows.

All the variables were adjusted in terms of typology, nature of the data, dimensionality reduction, and categorical transformation. The Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy, which tests whether the partial correlations between the variables are sufficiently low, was used to evaluate the validity of the convergent construct. The KMO statistic takes values between 0 and 1. A value below 0.5 indicates that the correlation is not significant enough, and, hence, analyzing the relationships between the variables with the data sample being used would be pointless.

The previous result was then verified using Bartlett's test of sphericity, which tests the null hypothesis that the correlation matrix of the variables is an identity matrix, in which case said

variables would not be related. Therefore, if the significance level of the Bartlett's test is above 0.05, the null hypothesis cannot be rejected, and thus performing a dimensional structure analysis or factor analysis of the questionnaire would be meaningless ([Bartlett, 1950](#)).

Finally, we measured the internal consistency of the questionnaire using Cronbach's alpha and analyzed the items' discriminant power with Spearman's rank correlation coefficient. To assess the correlation strength between the variables, we employed Somers' D, interpreting values close to 0.30 as satisfactory; between 0.30 to 0.50 as of moderate magnitude; above 0.50 as of strong magnitude; and below 0.30 as of little value in practice even if statistically significant.

Interpretation and Analysis of Results

Construct validity

The proposed model demonstrated convergence between its variables (as shown in Table 1) because most of the standardized factor loadings were above 0.7, as recommended by Bagozzi & Yi ([1988](#)). In addition, the indicators' average factor loading was above 0.7 for each construct ([Hair et al., 1999](#)).

Table 1. Standardized factor loadings of the indicators

Construct	Item	Standardized factor loading	Average standardized factor loading
Perceived attitude	ATT1	0.757	0.703
	ATT2	0.552	
	ATT3	0.800	
Customer service and support	CS1	0.740	0.740
	CS2	0.740	
Perceived trust	TRU1	0.797	0.792
	TRU2	0.806	
	TRU3	0.772	
Ease of use	EU1	0.870	0.870
	EU2	0.870	
Intention to use	INT1	0.900	0.900
	INT2	0.900	
Perceived security	PS1	0.926	0.926
	PS2	0.926	
Perceived usefulness	PU1	0.886	0.886
	PU2	0.886	

After that first test, we conducted Bartlett's test of sphericity. Table 2 reveals that the coefficients calculated by the SPSS software for each construct meet the minimum criteria to perform a data reduction analysis.

Table 2. KMO measure and Bartlett's test of sphericity

Construct	KMO value	Bartlett's test value	Meets criteria
Perceived attitude (ATT)	0.561	0.000	Yes
Customer service and support (CS)	0.500	0.000	Yes
Perceived trust (TRU)	0.672	0.000	Yes
Ease of use (EU)	0.500	0.000	Yes
Intention to use (INT)	0.500	0.000	Yes
Perceived security (PS)	0.500	0.000	Yes
Perceived usefulness (PU)	0.500	0.000	Yes

Moreover, we tested the presence of common method bias using Harman's single factor test in SPSS. Since the total percentage of variance extracted by a single factor (extraction method: maximum likelihood) was below the generally established cut-off point (50%), we concluded that common method bias was not present in this study (as shown in Table 3).

Table 3. Harman's single factor test using SPSS

Item	Total variance explained					
	Initial eigenvalues			Sum of the squared saturations of the extraction		
	Total	% of variance	Accumulated %	Total	% of variance	Accumulated %
1	8.142	50.890	50.890	7.704	48.151	48.151
2	1.540	9.626	60.516			
3	1.032	6.448	66.964			
4	.889	5.559	72.523			
5	.654	4.089	76.612			
6	.542	3.387	79.999			
7	.498	3.116	83.114			
8	.477	2.979	86.093			
9	.431	2.694	88.787			
10	.354	2.214	91.002			
11	.325	2.033	93.035			
12	.274	1.714	94.748			
13	.250	1.566	96.314			
14	.225	1.409	97.723			
15	.190	1.186	98.909			
16	.174	1.091	100.000			

Also, we calculated and compared (Table 4) the standardized regression weights of the model with a Common Latent Factor (CLF) and without it in a confirmatory factor analysis conducted in AMOS. Since no difference (i.e., the difference between the standardized regression weights with and without CLF) was above 0.2, we concluded that none of the paths was affected by common method bias.

Table 4. Standardized regression weights and confirmatory factor analysis

Item	Standardized regression weights		
	With Common Latent Factor	Without Common Latent Factor	Difference
ACT1 <--- ATT	0.737	0.683	-0.054
ACT2 <--- ATT	0.029	0.036	0.007
ACT3 <--- ATT	0.558	0.578	0.02
CON1 <--- TRU	0.713	0.679	-0.034
CON2 <--- TRU	0.746	0.671	-0.075
CON3 <--- TRU	0.808	0.824	0.016
SP1 <--- PS	0.838	0.834	-0.004
SP2 <--- PS	0.888	0.896	0.008
UP1 <--- PU	0.788	0.783	-0.005
UP2 <--- PU	0.811	0.843	0.032
FU2 <--- EU	0.734	0.745	0.011
FU1 <--- EU	0.791	0.765	-0.026
INT2 <--- INT	0.77	0.809	0.039
INT1 <--- INT	0.749	0.786	0.037

Instrument reliability

We evaluated the reliability of the proposed measurement scales by calculating their Cronbach's alpha coefficients. As observed in Table 5, this coefficient takes values higher or close to the recommended minimum values (0.7 and 0.5, respectively) in all cases ([Hair et al., 1999](#)), which confirms the internal reliability of the proposed constructs.

Table 5. Reliability index

Factor	Cronbach's α coefficient
Perceived attitude (ATT)	0.730
Customer service and support (CS)	0.715
Perceived trust (TRU)	0.842
Ease of use (EU)	0.878
Intention to use (INT)	0.911
Perceived security (PS)	0.939
Perceived usefulness (PU)	0.895

Moreover, we measured the discriminant validity of such scales following the procedure described by Anderson, Gerbing & Hunter ([1987](#)), which calculates the confidence intervals of the correlation between the constructs and compares them with the unit. Table 6 shows that, in none of the cases, the proposed estimates of intervals presented as a cross-correlation matrix contain a value of 1, which demonstrates the discriminant validity of the proposed model.

Table 6. The discriminant validity of the proposed model

	Perceived attitude (ATT)	Customer service and support (CS)	Perceived trust (TRU)	Ease of use (EU)	Intention to use (INT)	Perceived security (PS)	Perceived usefulness (PU)
Perceived attitude (ATT)	1.000						
Customer service and support (CS)	0.043	1.000					
Perceived trust (TRU)	0.413	0.334	1.000				
Ease of use (EU)	0.408	0.188	0.608	1.000			
Intention to use (INT)	0.475	0.162	0.601	0.664	1.000		
Perceived security (PS)	0.459	0.267	0.737	0.593	0.607	1.000	
Perceived usefulness (PU)	0.442	0.149	0.554	0.699	0.688	0.540	1.000

Hypothesis testing

To continue the statistical analysis, we next evaluated the adapted structural model's suitability to measure the use and acceptance of mobile banking in Medellín. For this purpose, we listed the hypotheses proposed above and estimated the level of association between pairs of variables using Somers' D. According to Schreiber *et al.* (2006), this correlation coefficient takes values between -1 and 1; those close to 1, in absolute value, indicate a strong correlation between the variables; and those close to 0, a low or null correlation between them.

Table 7 presents the values obtained from the SPSS software, which reveal a significantly high level of association (all p-values < 0.001). One of the most significant and revealing correlations was found between perceived usefulness and intention to use (0.688), which means that users decide whether or not to use a service based on their expectations of what they will experience. Moreover, perceived trust is a fundamental aspect in users' perceived security (0.737) in mobile banking because it is key to explaining their behaviour towards banking access (Ramos *et al.*, 2018). Similarly, the positive effect of perceived trust on ease of use (0.608) and perceived attitude (0.413) proves that it is a multidimensional construct. Finally, the weakest correlation in this study was established between perceived trust and customer service and support (0.334).

Table 7. Hypothesis testing between pairs of variables

Hypothesis	Correlation between variables	Somers' D
H1	Perceived usefulness → Ease of use	0.699 ***
H2	Perceived usefulness → Perceived trust	0.554 ***
H3	Perceived usefulness → Perceived attitude	0.442 ***
H4	Perceived usefulness → Intention to use	0.688 ***
H5	Perceived trust → Customer service and support	0.334 ***
H6	Perceived trust → Ease of use	0.608 ***
H7	Perceived trust → Perceived security	0.737 ***
H8	Perceived trust → Perceived attitude	0.593 ***
H9	Perceived security → Ease of use	0.413 ***
H10	Perceived security → Perceived attitude	0.459 ***
H11	Ease of use → Perceived attitude	0.408 ***
H12	Ease of use → Intention to use	0.664 ***
H13	Perceived attitude → Intention to use	0.475 ***

Note: *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

Furthermore, we extracted the Somers' D coefficients and listed them in a table of crossed factors to show the level of association between the variables that were part of the hypotheses and those that were not. The purpose of this procedure was to corroborate that some constructs in the model had no established correlation. As observed in Table 8, none of the levels of association is high.

Table 8. Somers' D correlation statistic

	(ATT)	(CS)	(TRU)	(EU)	(INT)	(PS)	(PU)
(ATT)	1.000						
(CS)	0.043	1.000					
(TRU)	0.413 ***	0.334 ***	1.000				
(EU)	0.408 ***	0.188	0.608 ***	1.000			
(INT)	0.475 ***	0.162	0.601	0.664 ***	1.000		
(PS)	0.459 ***	0.267	0.737 ***	0.593 ***	0.607	1.000	
(PU)	0.442 ***	0.149	0.554 ***	0.699 ***	0.688 ***	0.540	1.000

Note: *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$

The results summarized in Figure 2 support the causal relationships proposed in the hypotheses for the sample of mobile banking users who participated in this study. Therefore, we can confirm the positive influence of users' perceived usefulness of mobile banking on their intention to use it and perceived ease of use. These results also reveal that perceived trust has a significant influence on the perceived usefulness and ease of use of mobile banking.

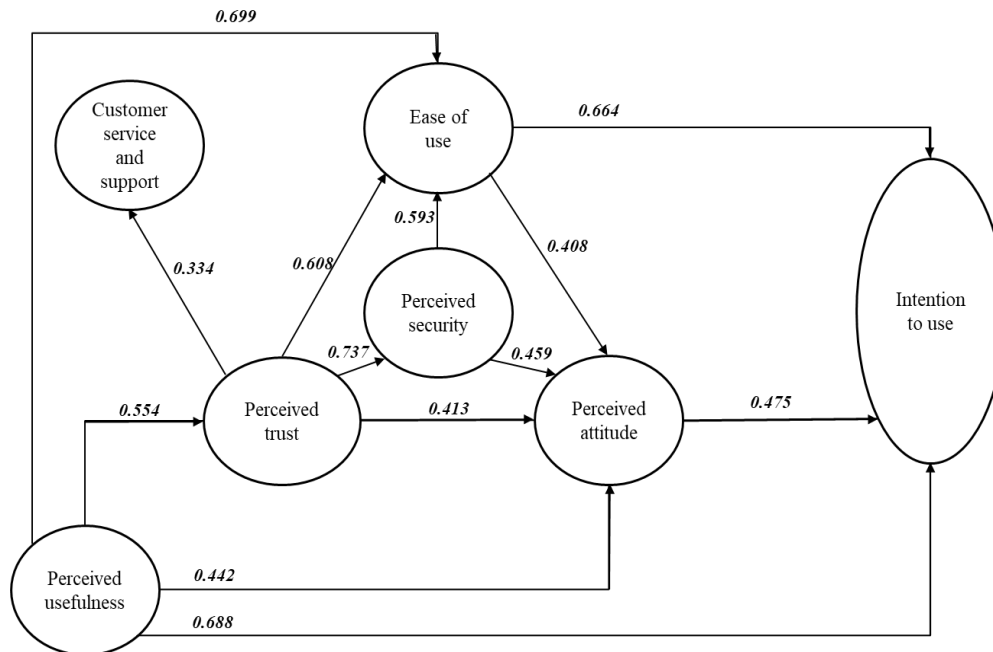


Figure 2. Variables in the proposed model and their correlations (Somers' D)

Discussion

Mobile banking services are well rated because they allow users to make transactions at any time and place, and their general characteristics reduce the effort necessary to use them (ease of use). According to Mallat, Rossi & Tuunainen (2004), security and comfort (perceived ease of use) are key to increasing mobile banking usage. In line with this, Muñoz-Leiva, Climent-Climent & Liébana-Cabanillas (2017) propose attitude, intention to use, perceived usefulness, perceived ease of use, and social image as constructs that determine the acceptance of mobile devices to access banking services. Additionally, trust, which has generally been most peoples' concern about adopting new technologies (Hanafizadeh *et al.*, 2014) can also provide several benefits to financial institutions and increase consumer satisfaction (Glavee-Geo, Shaikh & Karjaluoto, 2017).

In the Latin American context, a study conducted by the Deloitte Center for Financial Services (2012), which evaluated the potential of mobile banking in countries such as Argentina, Brazil, and Mexico, revealed that this type of banking will eventually be a need rather than a choice and may become an integral component of banks' commercial strategy. This will occur because users may be increasingly satisfied with the ease of access to financial services, low-cost investment, and inclusiveness that this delivery channel provides. For this reason and in accordance with the study by Hanafizadeh *et al.* (2014), in this paper, the factors that have the greatest influence on the adoption of mobile banking are mostly related to the infrastructure of banks. Hence, their research departments should pay more attention to said infrastructure.

When we compared our findings to those reported in other Latin American studies, we found that, in Peru, for instance, the factors that influence the intention to use this new technology are perceived ease of use and usefulness, according to Yamakawa, Guerrero & Rees (2013). These authors also propose lifestyle compatibility and personal innovativeness toward information technologies as additional factors that increase the intention to use these channels.

In the case of Colombia, Giraldo (2013) presents a theoretical model that studies the intention, adoption, and continuance scenarios of the use of mobile banking in this country. In each scenario, he highlights the factors that might be determining: attitude of use, perceived ease of use, perceived credibility, and perceived service quality (intention scenario); transaction costs, lack of information, perceived usefulness, and perceived effectiveness (adoption scenario); and intention of continued use (continuance scenario). In addition, this author proposes six risks: performance risk, security risk, privacy risk, convenience risk, financial risk, and social risk. Among the studies into the digital commercial channel of banks, we highlight the paper by Sánchez-Torres, Rojas Berrío & Ortiz Rendón (2021), where the most important adoption factors in Colombia were precisely those related to the technological infrastructure and those factors were found to assume a fundamental role.

In the business field, the rapid growth of smartphones and wireless and mobile service channels in the market is seen as a promising opportunity for companies to provide easy access and inclusion (Lashitew, Bals & van Tulder, 2018). Such growth has been driven by globalization and technological development, which have, in turn, reduced access barriers not only for competitors but especially for today's users, who wish to perform banking transactions while on the move, regardless of bank opening hours (Sepashvili, 2020).

Theoretical implications

This study built upon the two behavioural premises of the TAM (perceived usefulness and perceived ease of use) (Davis, 1989) and five other constructs commonly used in the literature on mobile banking acceptance (security; attitude; trust; customer service and support; and intention to use) (Chung & Kwon, 2009; Tan & Lau, 2016; Vejačka & Štofa, 2017).

Our findings reveal that perceived usefulness, trust, and ease of use are the most important factors to understand the use and acceptance of mobile banking, which is corroborated by Sampat (2016) and Tham *et al.* (2017). They, however, contradict the results reported by Joy & James (2018), who claim that trust in m-banking is the least significant variable when deciding whether or not to use it. Nevertheless, our findings do support the results obtained by Hanafizadeh *et al.* (2014), who explain that banks themselves should be more reliable than cell phone manufacturers and telecommunications operators for customers to trust them.

Figure 2 shows five strong associations between the variables analyzed in this study: (1) a significant correlation between perceived usefulness and ease of use, which confirms the results of the original study by Davis (1989); (2) an association between perceived usefulness and intention to use, which is in agreement with the findings of Teo *et al.* (2012) and refutes those of Muñoz-Leiva, Climent-Climent & Liébana-Cabanillas (2017), who did not find this factor to be significant; (3) a relationship between perceived trust and ease of use, which is consistent with the results of the study by Ifeonu & Ward (2015) and suggests the need to provide users with a user-friendly interface that enhances trust and makes it easier for them to use mobile banking services; (4) a relevant correlation between perceived trust and security, which corroborates the results obtained by Vejačka & Štofa (2017) because m-banking users consider that improving security and banking standards increases their trust in it; and (5) a correlation between ease of use and intention to use, which is in line with the findings by Singh & Srivastava (2020), who state that the perceived ease of use of mobile banking helps to significantly increase the intention to use this channel.

Practical implications and contributions

In practice, the results of this study have four implications. First, they contribute to the established theory in order to understand the financial practices of mobile banking users. Second, they shed some light on the factors or determinants that influence the acceptance of mobile banking and encourage the use of these tools in some developing countries, such as in the case examined here. Third, this study provides readers with an overview of the current mobile banking environment in Colombia. Fourth, these results may draw the attention of Colombian financial regulators to detect factors that could pose a threat to transactions, the stability of the financial system, and the country's financial inclusion efforts.

More studies are needed to analyze financial inclusion and the new normal because the current pandemic and crisis due to COVID-19 have forced a reduction in human interaction and an increase in the use of mobile technologies (Agarwal, Poddar & Karnavat, 2020). Some people even had to open a bank account for the first time on their mobile devices. Therefore, this study can help identify challenges in the use and acceptance of financial services and mobile devices. It can also prepare the financial industry for the post-COVID-19 period in order to accelerate the banking of several segments of the population, especially people who consider themselves digital natives.

Another significant contribution of this study is that it presents the characteristics of the expectations of mobile banking users and their knowledge about finance. Thus, financial service providers can learn more about the behaviour of their consumers from this paper and improve the services they offer: i.e., if banks and banking institutions want to establish strong

relationships with their users, they should provide services that minimize risks and improve the quality of mobile banking.

Conclusions and Future Research

Investigating the main factors that influence the acceptance and use of mobile banking is clearly important, as evidenced by the numerous studies on this subject. Few studies, however, have examined the acceptance and use of this service in Medellín (Colombia). This paper provides insights on people's intention to use mobile banking in said city, which will be useful for banks to promote their products and better understand people's behaviour towards new technologies and their characteristics, especially in a developing country. In addition, this study presents an overview of the current mobile banking environment in Colombia and shows that, since the COVID-19 crisis, financial inclusion has changed from being a future goal of the national government to a reality that has brought Colombians closer to mobile banking.

Thus, our findings contribute to a better understanding of the factors that influence the use and acceptance of mobile banking technologies in Medellín and provide local banks with a basis to implement strategies for bridging the financial inclusion gap that has been identified. Understanding these factors would represent an opportunity for the country's financial institutions to design and develop novel banking applications.

In this study, we stressed that perceived usefulness and trust and ease of use are the key factors that influence users' acceptance and use of mobile banking in Medellín. We developed 13 hypotheses to assess the relationships between the proposed constructs and empirically found strong correlations in 12 of them. According to our findings, ease of use, perceived trust and attitude, and intention to use are all directly influenced by perceived usefulness (H1, H2, H3, and H4, respectively), while ease of use, perceived security, and attitude towards the use of mobile banking are highly influenced by users' perceived trust towards such services (H6, H8, and H9).

Regarding perceived security, we may conclude that it has a medium level of association with ease of use and perceived attitude towards the use of mobile banking (H7 and H10). This is because, if users assume that mobile banking is risky, they will not choose mobile devices to access banking services, which may change their attitude towards its use. Moreover, ease of use also exhibited a medium to high level of correlation with perceived attitude and intention to use (H11 and H12). In this case, when users realize that learning how to use mobile banking is simple, their perceptions of and attitude towards its use improve. Finally, perceived attitude showed a medium level of association with intention to use, which suggests that a significantly positive attitude towards the acceptance of mobile banking influences users' intention to use this service.

This model designed to evaluate users' acceptance of mobile banking in Medellín also allowed us to identify relationships with a low level of correlation between the constructs. For instance, perceived trust presented a low level of association with customer service and support (H5), which indicates that this model empirically examined the influence of external variables on users' decisions to use mobile devices to access banking services. We can thus conclude that the delivery of financial products via information technologies and mobile devices is necessary not only because it is in line with banking modernization but also because the users of mobile banking and its related services perceive desirable characteristics in them, such as immediacy, ease of access, and virtuality.

In accordance with the main purpose of this study, we were able to identify the variables that influence the use and acceptance of mobile banking and presented, beyond the descriptive scope, an empirical analysis of the theoretical model we proposed. Our results show that the proposed model has a considerable explanatory power because it applies the theoretical constructs introduced in previous studies, which have already been empirically tested in other contexts and countries. Therefore, our model is empirically significant, since it explains the variation in users' intention to accept and use mobile banking in Medellín.

Future studies should collect data from a longitudinal perspective, that is, from various periods in order to understand how the influence of the factors under analysis evolves over time in the same population and compare their findings. It may also be relevant to conduct qualitative research to analyze the acceptance and use of mobile banking considering two dimensions: service effectiveness and user experience with this technology.

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Iterative Interference Cancellation for Multi-Carrier Modulation in MIMO-DWT Downlink Transmission

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Abstract: The Multiple-Input Multiple-Output Orthogonal Frequency Division Multiplexing (MIMO-OFDM) scheme represents the dominant radio interface for broadband multicarrier communication systems. However, with insufficient Cyclic Prefixes (CP), Inter-Symbol Interference (ISI) and Inter-Carrier Interference (ICI) occur due to the time-varying multipath channel. This means that the performance of the system will be degraded. In this paper, we investigate the interference problem for a MIMO Discrete Wavelet Transform (MIMO-DWT) system under the effect of the downlink LTE channel. A Low-Density Parity-Check (LDPC) decoder is used to estimate the decoded signal. The proposed iterative algorithm uses the estimated decoded signal to compute the components required for ICI/ISI interference reduction. In this paper, Iterative Interference Cancellation (IIC) is employed to mitigate the effects of interference that contaminates the received signal due to multiple antenna transmission and a multipath channel. An equalizer with minimum mean square error is considered. We compare the performance of our proposed algorithm with the traditional MIMO-OFDM scheme in terms of bit error probability under insufficient CP. Simulation results verify that significant improvements are achieved by using IIC and MIMO-IIC for both systems.

Keywords: MIMO-DWT, IIC, conventional OFDM, LDPC, iterative decoder

Introduction

Multiple-Input Multiple-Output Orthogonal Frequency Division Multiplexing (MIMO-OFDM) scheme is used to increase coupling capacity and spectrum efficiency in a radio multicarrier communication system. That is to say, it improves the overall system performance by providing huge throughput and coverage probability of all users simultaneously. However, to address the issue of block fading multipath channel under insufficient cyclic prefix (CP) and guard interval, effective receiver design is important.

To increase the spectral and power efficiency, the Discrete Wavelet Transform (DWT) with a Multi-Carrier Modulation scheme (MCM) has been designed and represented in different scenarios ([Zhang & Cheng, 2004](#); [Galli & Logvinov, 2008](#); [Harbi & Burr, 2014](#); [Chaffi, Harbi & Burr, 2016](#); [Chaffi et al., 2018](#)). In Chaffi, Harbi & Burr (2016), the effect of varying the number of selected levels of the decomposition and reconstruction algorithms has been introduced. The main advantages of DWT-MCM over OFDM is the best time-frequency localization of its waveforms due to the choice of the mother wavelet and scaling functions ([Oltean & Isar, 2009](#)).

DWT-MCM also proved to be more robust with respect to the temporal variation (or changeability) of the wireless channel ([Oltean, 2007](#)). Better use of the channel in various interference environments was gained by using modulation techniques based on multirate wavelets, due to their dimensionality in time and frequency ([Lindsey & Dill, 1995](#)). Multichannel filter banks and wavelet transforms in encryption and channel modulation have been investigated and studied using various schemes, such as CDMA signature spread, fractal modulation and superimposed multi-tone modulation ([Wornell, 1996](#)). The inherent versatility of wavelet transforms, with a number of interesting additional advantages, makes it a good candidate for multi-carrier schemes ([Jamin & Mähönen, 2005](#)). The method of wavelet packets has been widely adopted in mobile networks as a multi-carrier multiple access technique and in cognitive radio applications ([Mathew, Premkumar & Lau, 2010a](#)). The ingrained orthogonality of multi-wavelets made it suitable for the single and multi-carrier schemes and for reducing the Multiple Access Interference (MAI) in a multi-user CR network ([Mathew, Premkumar & Lau, 2010b](#)). Recently, an iterative algorithm for interference reduction is shown in different systems, such as SISI-FBMC, SISO-OFDM, and MIMO-OFDM transceivers under insufficient guard interval and different channel conditions ([Harbi & Burr, 2016a, 2016b, 2018](#); [Mahama et al., 2019a, 2019b, 2020](#); [Harbi, 2017](#)).

In this paper, we propose an iterative algorithm scheme which reduces the interference among users for MIMO-DWT/OFDM systems to eliminate ISI/ICI interference due to fast fading multipath channel. The desired components can be calculated from the estimated decoded

signals. At a given received antenna, the proposed scheme uses these components to decrease the ICI/ISI from multiple antenna transmission.

The remainder of this paper is organized as follows. In the next section, we describe the DWT-based MCM formulation and summarize the reconstruction and decomposition algorithms. Following that, we define the system model of the proposed algorithm for interference management, and introduce the main assumptions required for our analysis. Then, we discuss our simulation results. Finally, we summarize our contributions as a conclusion to the paper.

Discrete Wavelet Transform-Multi Carrier Modulation (DWT-MCM)

The Discrete Wavelet Transform

Before explaining the data decomposition and reconstruction process, it is essential to introduce a discrete wavelet. This is because discrete wavelets have a direct effect on the properties of the decomposition and reconstruction of the data. The DWT plays significant role in signal processing where the signal can be decomposed into sets of wavelets that are orthogonal to its translations under different scaling. In other words, any signal in time-domain can be transformed into another domain that contains both time and frequency, which precisely positions frequency structures over time to analyse different sized signal structures.

The wavelet transform decomposes signals over dilated and translated wavelets $\varphi(t)$. The regularity conditions imply that the basis function of the wavelet transform must possess temporal and spectral localization ([Mallat, 2008](#)). The reconstruction condition for regular $\varphi(t)$ is:

$$\int \varphi(t) dt = 0 \quad (1)$$

The system orthogonality depends strongly on the time position (k) and the scale index (j), which are derived from the scaling function $\vartheta(t)$ or the translation and the dilatation function $\varphi(t)$. According to (1), appropriately discretizing these parameters, the scaling parameters can be discretized in a logarithmic manner, whereas the Nyquist sampling rule can be used to discretize the time variable to obtain the two-dimensional parameterization of the wavelet function $\varphi_{j,k}(t)$ ([Mallat, 2008](#)).

$$\varphi_{j,k}(t) = 2^{-j/2} \varphi(2^{-j}t - k) \quad (2)$$

where the scaling index $j = 1, 2, \dots, J = \log_2(\text{total number of subcarriers})$. Best time resolution is achieved when $j=1$ at the expense of poor frequency localization; whereas, if $j=J$, best

achievable frequency localization is obtained at the price of poor time resolution ([Mallat, 2008](#)).

Similarly:

$$\mathcal{G}_{j,k}(t) = 2^{-j/2} \mathcal{G}(2^{-j}t - k) \quad (3)$$

By using (2), members of the orthogonal wavelet family are obtained as:

$$\langle \varphi_{j,k}(t), \varphi_{m,n}(t) \rangle = \begin{cases} 1 & , j = m \text{ \& } k = n \\ 0 & \text{otherwise} \end{cases} \quad (4)$$

The transmitted signal is then represented as:

$$x(t) = \sum_{j=J_1}^J \sum_{k=1}^{2^j} w_{j,k} \varphi_{j,k}(t) + \sum_{k=1}^{2^{J_1-1}} a_{J_1,k} \mathcal{G}_{J_1,k}(t) \quad (5)$$

where w and a represent the scaling and wavelet coefficients.

Let $h(k)$ denote the impulse response of the low pass filter (LPF) and $g(k)$ represent the discrete impulse response of the high pass filter (HPF). At scale factor j , w and a are evaluated and related to the next factor $j+1$ as follows:

$$a_j(m) = \sum_k h(k - 2m) a_{j+1}(k) \quad (6)$$

$$w_j(m) = \sum_k g(k - 2m) w_{j+1}(k) \quad (7)$$

Reconstruction and decomposition algorithms

Figures 1 and 2 illustrate the basic configurations for implementing the DWT-MCM reconstruction (IDWT) and decomposition (DWT) algorithms. According to the Mallat algorithm ([Mallat, 2008](#)), $L = 1, 2, \dots, J = \log_2$ (total number of subcarriers) represents the IDWT or DWT levels. In the synthesis phase, the scaling and wavelet factors in (6) and (7) are further sampled by doubling, then followed by filter banks. On the other hand, the analysis phase passes these coefficients to the LPF and the HPF, and subsequently resamples them by a factor of 2. In this study, the total number of sub-channels (N) is equals to 128. In addition, the expected number of iterations of the reconstruction and decomposition process would range from 1 to 7.

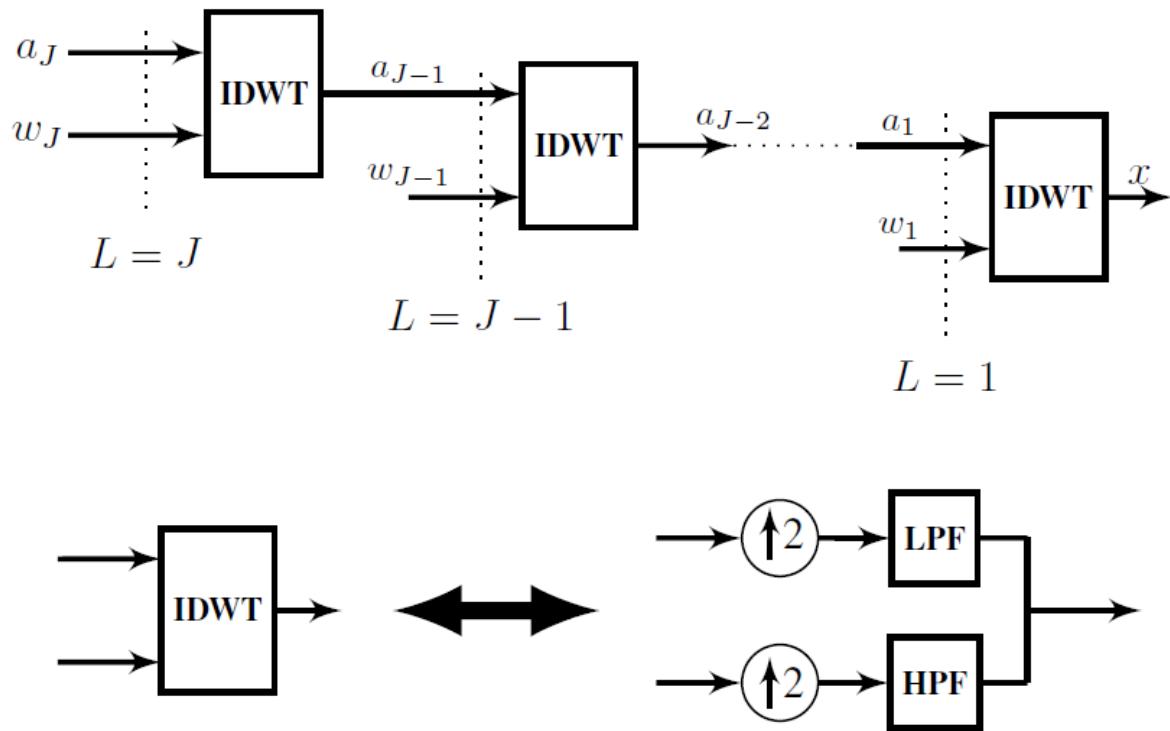


Figure 1. IDWT diagram using filter banks

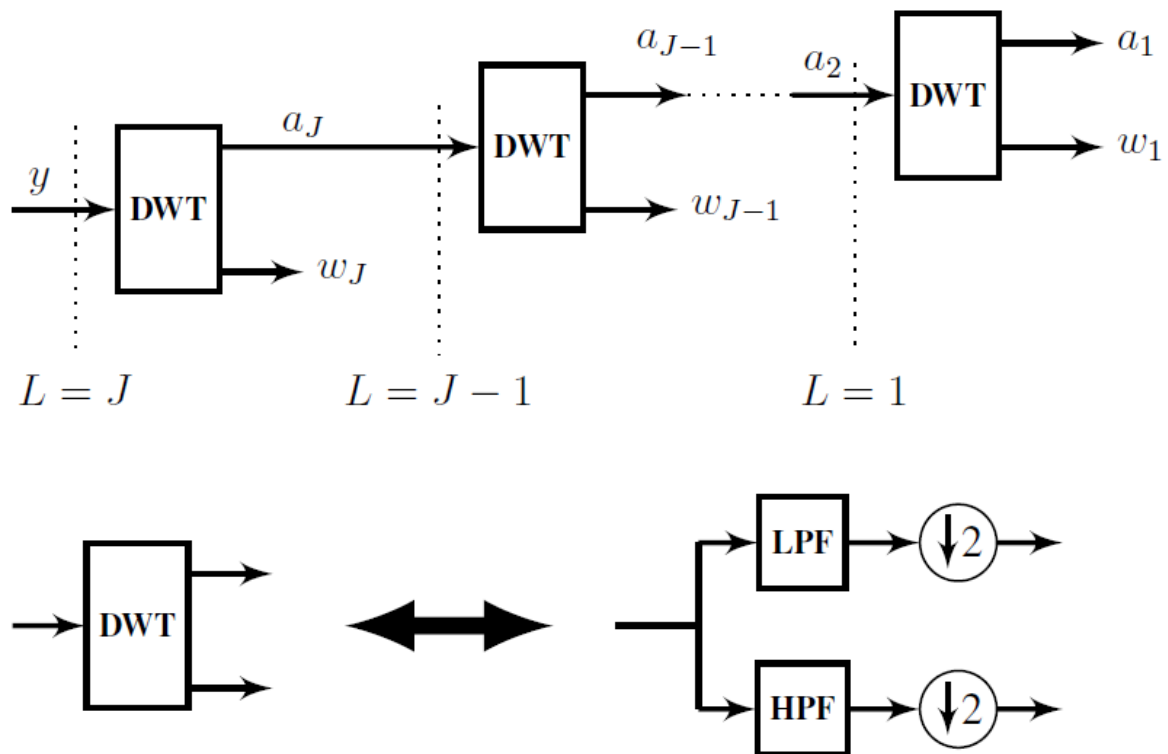


Figure 2. DWT implementation using filter banks

Proposed Model of IIC and MIMO-IIC

In a 2×2 MIMO scheme, the received signal at each receive antenna results from the combination of the transmitted signals from the transmitted antennas. At the first received antenna, the received signal contains four undesirable components — ICI components (H_{11}) and (H_{21}) and ISI components (H_{11}) and (H_{21}) — that result in interference issues. Those components occur due to the multipath fast-fading channel effect on the signal coming from both first and second antennas. At the second received antenna, the signal has four components — ICI components (H_{22}) and (H_{12}) and ISI components (H_{22}) and (H_{12}) — that result in interference issues, due to the multipath fast-fading channel effect on the signal coming from both first and second transmitting antennas, as depicted in Figure 3.

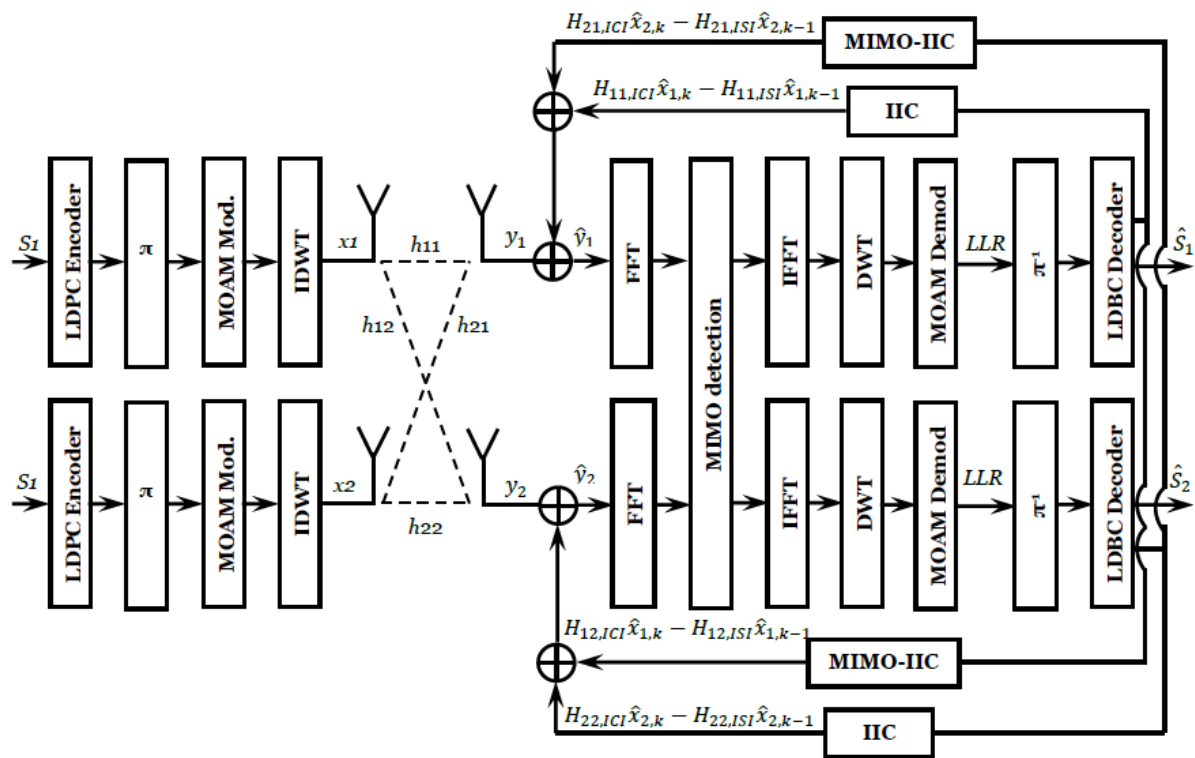


Figure 3. System architecture for our proposed algorithm for MIMO-DWT-MCM configuration

In general, with the index of the time instant k , the received data symbol $y_{1,k}$ received at the first antenna can be written as:

$$\begin{aligned}
 y_{1,k} &= x_{1,k} h_{11} + x_{2,k} h_{21} + n_k \\
 &= H_{11,CIRC} x_{1,k} + H_{21,CIRC} x_{2,k} - H_{11,ICI} x_{1,k} + H_{11,ISI} x_{1,k} - H_{21,ICI} x_{2,k} + H_{21,ISI} x_{2,k} + n_k
 \end{aligned} \quad (8)$$

where H_{11} and H_{21} are modelled as independent and identically distributed (*iid*) complex Gaussian variables with zero mean and unit variance. In addition, these matrices can be described as a circulant matrix, n_k is the additive white Gaussian noise (AWGN) at the k^{th} time instant, and the matrices $H_{CIRC}, H_{ICI}, H_{ISI} \in \mathbb{C}^{N \times N}$ (Harbi & Burr, 2016a, 2016b).

To remove the interference term from the signal received at the receiver, the undesirable components ICI and ISI must be decreased. The calculation of the channel matrices H_{ICI} and H_{ISI} requires knowledge of both the length of CP and the impulse response of the channel. During the IIC process, the estimated values of the transmitted signal coefficients $\hat{x}_{1,k}$ and $\hat{x}_{1,k-1}$ can be estimated from the first stream decoded signal (soft output of the upper LDPC decoder in Figure 3). Then, they are multiplied by the channel matrices to obtain $H_{11,ICI} \hat{x}_{1,k}$ and $H_{11,ISI} \hat{x}_{1,k-1}$. During the MIMO-IIC process, the estimated values of the transmitted signal coefficients $\hat{x}_{2,k}$ and $\hat{x}_{2,k-1}$ can be estimated from the second stream decoded signal (soft output of the lower LDPC decoder in Figure 3), multiplied by the channel matrices to get $H_{21,ICI} \hat{x}_{2,k}$ and $H_{21,ISI} \hat{x}_{2,k-1}$. Finally, after some iterations using all the obtained estimated components, the estimated received signal is given as:

$$\hat{y}_{1,k} = H_{11,CIRC} \hat{x}_{1,k} + H_{21,CIRC} \hat{x}_{2,k} + n_k \quad (9)$$

In the frequency domain, we can rewrite the signal received as:

$$\hat{Y}_{1,k} = FH_{11,CIRC} F^H \hat{X}_{1,k} + FH_{21,CIRC} F^H \hat{X}_{2,k} + Fn_k \quad (10)$$

The channel matrix can be rewritten as $H_{11,CIRC} = F^H H_{11} F$ (Sesia, Toufik & Baker, 2011) and the signal estimated at the receiver can be rewritten as:

$$\hat{Y}_{1,k} = H_{11} \hat{X}_{1,k} + H_{21} F^H \hat{X}_{2,k} + n_k \quad (11)$$

where $H_{11} \in \mathbb{C}^{N \times N}$ can be diagonalized using the discrete Fourier transform, with the diagonal elements representing the channel response in frequency domain. That means, instead of the wavelet domain, MIMO detection must be done in the frequency domain. To achieve that, prior to MIMO detection, the combined signal is converted to the frequency domain. After detection, the obtained signal is converted back to the time domain, as depicted in Figure 3.

Let N_{cp} , L_c , and T be the length of CP , the number of channel taps, and the coherence time of the downlink channel under the length of CP . Thus, $T = L_c - N_{cp} - 1$. Channel matrices $H_{11,ICI}$, $H_{11,ISI}$, $H_{21,ICI}$, and $H_{21,ISI}$ can be written as:

$$H_{11,ISI} = \begin{bmatrix} 0_{T \times (N-T)} & H_1 \\ 0_{(N-T) \times (N-T)} & 0_{(N-T) \times T} \end{bmatrix} \quad (12)$$

$$H_{11,ICI} = \begin{bmatrix} 0_{T \times (N-T-N_{cp})} & H_1 & 0_{T \times N_{cp}} \\ 0_{(N-T) \times (N-T-N_{cp})} & 0_{(N-T) \times T} & 0_{(N-T) \times N_{cp}} \end{bmatrix} \quad (13)$$

$$H_{21,ISI} = \begin{bmatrix} 0_{T \times (N-T)} & H_2 \\ 0_{(N-T) \times (N-T)} & 0_{(N-T) \times T} \end{bmatrix} \quad (14)$$

$$H_{21,ICI} = \begin{bmatrix} 0_{T \times (N-T-N_{CP})} & H_2 & 0_{T \times N_{CP}} \\ 0_{(N-T) \times (N-T-N_{CP})} & 0_{(N-T) \times T} & 0_{(N-T) \times N_{CP}} \end{bmatrix} \quad (15)$$

It is obvious that undesirable components embedded within the channel matrix $H_1, H_2 \in \mathbb{C}^{N \times N}$ depend on the actual value of the channel h_{11} and h_{21} , and can be expressed as:

$$H_1 = \begin{bmatrix} h_{11,L_C-1} & \cdots & \cdots & h_{11,N_{CP}-1} \\ 0 & \ddots & & \vdots \\ \vdots & \ddots & \ddots & \vdots \\ 0 & \cdots & 0 & h_{11,L_C-1} \end{bmatrix} \quad (16)$$

$$H_2 = \begin{bmatrix} h_{21,L_C-1} & \cdots & \cdots & h_{21,N_{CP}-1} \\ 0 & \ddots & & \vdots \\ \vdots & \ddots & \ddots & \vdots \\ 0 & \cdots & 0 & h_{21,L_C-1} \end{bmatrix} \quad (17)$$

for $N_{CP} = 0$, $H_{ICI} = H_{ISI}$.

Similarly, the ICI/ISI interference from the signal received at the second antenna can be decreased by using interference cancellation techniques. The received signal after some iterations can be rewritten as:

$$\hat{y}_{2,k} = H_{12,CIRC} \hat{x}_{1,k} + H_{22,CIRC} \hat{x}_{2,k} + n_k \quad (18)$$

In the frequency domain, we can rewrite the signal received as:

$$\hat{Y}_{2,k} = FH_{12,CIRC} F^H \hat{X}_{1,k} + FH_{22,CIRC} F^H \hat{X}_{2,k} + Fn_k \quad (19)$$

$$\hat{Y}_{1,k} = H_{11} \hat{X}_{1,k} + H_{21} F^H \hat{X}_{2,k} + n_k \quad (20)$$

Channel matrices $H_{22,ICI}$, $H_{22,ISI}$, $H_{12,ICI}$, and $H_{12,ISI}$ can be written as:

$$H_{22,ISI} = \begin{bmatrix} 0_{T \times (N-T)} & H_3 \\ 0_{(N-T) \times (N-T)} & 0_{(N-T) \times T} \end{bmatrix} \quad (21)$$

$$H_{22,ICI} = \begin{bmatrix} 0_{T \times (N-T-N_{CP})} & H_3 & 0_{T \times N_{CP}} \\ 0_{(N-T) \times (N-T-N_{CP})} & 0_{(N-T) \times T} & 0_{(N-T) \times N_{CP}} \end{bmatrix} \quad (22)$$

$$H_{12,ISI} = \begin{bmatrix} 0_{T \times (N-T)} & H_4 \\ 0_{(N-T) \times (N-T)} & 0_{(N-T) \times T} \end{bmatrix} \quad (23)$$

$$H_{12,ICI} = \begin{bmatrix} 0_{T \times (N-T-N_{CP})} & H_4 & 0_{T \times N_{CP}} \\ 0_{(N-T) \times (N-T-N_{CP})} & 0_{(N-T) \times T} & 0_{(N-T) \times N_{CP}} \end{bmatrix} \quad (24)$$

$$H_3 = \begin{bmatrix} h_{22,L_C-1} & \cdots & \cdots & h_{22,N_{CP}-1} \\ 0 & \ddots & & \vdots \\ \vdots & \ddots & \ddots & \vdots \\ 0 & \cdots & 0 & h_{22,L_C-1} \end{bmatrix} \quad (25)$$

$$H_4 = \begin{bmatrix} h_{12,L_C-1} & \cdots & \cdots & h_{12,N_{CP}-1} \\ 0 & \ddots & & \vdots \\ \vdots & \ddots & \ddots & \vdots \\ 0 & \cdots & 0 & h_{12,L_C-1} \end{bmatrix} \quad (26)$$

Simulation Results

The standard of the LTE downlink for 2×2 MIMO-OFDM is employed with insufficient CP. In addition, it is assumed that the channel (characteristic) is known at the receiver. The statistical model of the channel is defined by the Power Delay Profile (PDP) in accordance with the ones in (3GPP, 2014) and Jakes' model (Jakes, 1974). As a performance metric, we use Bit Error Rate (BER) to evaluate the performance of DWT-MCM with MIMO-OFDM systems. All deployments and channel model parameters are listed in Table 1.

The simulation results of BER versus the Signal-to-Noise Ratio (SNR) for the 2×2 MIMO-OFDM system are represented in Figure 4 for different cases of IIC and MIMO-IIC with 4-QAM modulation and the EVA-LTE time-variant multipath channel with 300 Hz Doppler frequency.

Table 1. Simulation Parameters Definition

Parameters and Definitions	Values
The total number of sub-channels (N)	128
Coherence intervals (N_{tau})	6
The number of sub-channels/coherence interval ($N_{\text{Sc_tau}}$)	12
The number of sub-channels occupied (N_{Sc})	72
The number of taps/coherence intervals (N_{slot})	2
The number of symbols/tap (N_{sym})	7
The total symbols/coherence intervals (N_s)	14
Modulation formats	4-QAM
Sub-channels spacing (KHz) (S_s)	15 KHz
Sample rate (F_s)	$S_s \times N$

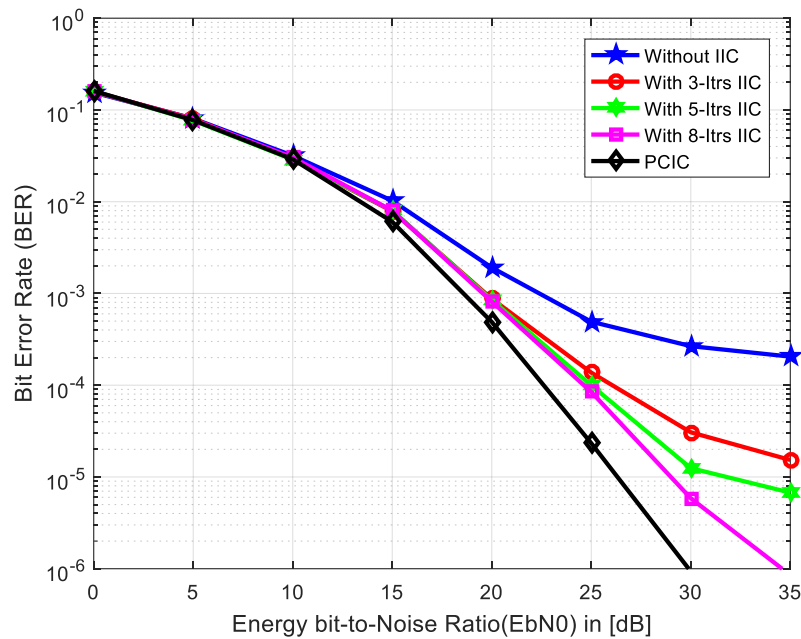


Figure 4. Bit error rate versus E_b/N_0 for MIMO-OFDM systems

The simulation results of BER versus SNR for the 2×2 MIMO-DWT system are represented in Figure 5 for different cases of IIC and MIMO-IIC with 4-QAM modulation and the EVA-LTE time-variant multipath channel with 300 Hz Doppler frequency. The Haar wavelet transform is employed with six levels of the decomposition and reconstruction process.

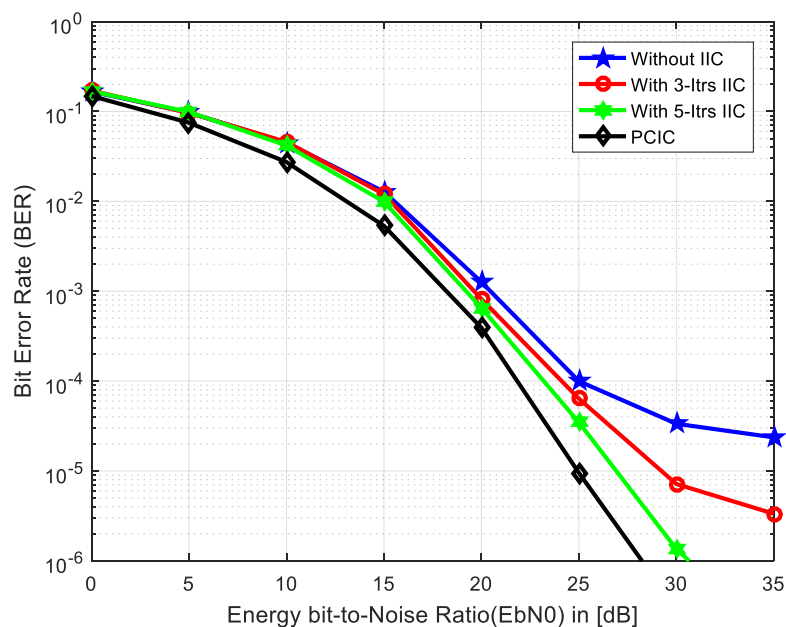


Figure 5. Bit error rate versus E_b/N_0 for MIMO-DWT systems

These figures demonstrate that the error rates are enhanced for MIMO-DWT systems compared with the traditional methods. For LDPC-MIMO-OFDM systems, the error rates are enhanced at the beginning of the process as depicted in these Figures. Later, after some iterations, the difference from perfect channel interference cancellation (PCIC) is about 2.7 dB

located at a bit error rate of 10^{-5} . Figure 5 depicts the bit error rate versus the E_b/N_0 for LDPC-MIMO-DWT systems. It indicates that error floors are improved after the first iteration. Last, after some iterations, the difference from PCIC is about 2.01 dB located at bit error rate of 10^{-5} .

Conclusions

We have studied the downlink transmission for the LTE channel to reduce the ICI/ISI interference using DWT and OFDM systems. In this paper, we proposed an iterative LDPC decoder algorithm to mitigate the interference issue for MIMO systems. Transmitted signals are affected by the time-variant multipath channel. The effective bandwidth will be reduced and a lack of orthogonality will occur. This will cause an error floor in the result of bit error probability and affect the quality of system performance. In the LDPC-MIMO-OFDM system, the difference in terms of E_b/N_0 from the perfect channel interference cancellation curve is about 2.71 dB located at bit error rate of 10^{-5} and without using CP. In LDPC-MIMO-DWT, beyond 5 steps, the difference in terms of E_b/N_0 from the PCIC curve is about 2.01 dB located at bit error rate of 10^{-5} under the LTE time-variant multipath channel with 300 Hz Doppler frequency and 4-QAM modulation. Hence, we conclude that our proposed iterative algorithm significantly improves the error floors.

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State Control by Stealth in the Big Data Era – From WeChat to the Social Credit System in China

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Abstract: This paper begins with a brief study on the development of the Chinese all-in-one app, WeChat, explaining how WeChat secured its popularity as the multi-functional ubiquitous mobile app in China. By using WeChat as an example, this paper further studies how the Social Credit System (SCS) in China was established out of collaboration between the Chinese government and eight entrusted private companies. This paper then analyses and evaluates the SCS from a socio-legal perspective, focusing on two key implications: the opaque algorithms and the potential abuse of power. The paper argues that the SCS needs to first gain trust from Chinese citizens. A starting point would be immediate action to standardise and reduce the opacity of the prototype. To enhance the longevity and effectiveness of the SCS, developing a legal framework to prohibit potential information misuse by the State and the entrusted companies is crucial: it needs to be put in place sooner rather than later. In constructing the much-needed legal framework, developing privacy laws is certainly a core step, but the framework needs more than just privacy laws. One crucial safeguard is the requirement for an independent tribunal or ombudsman to deal with credit-related complaints fairly and efficiently.

Keywords: cashless society, credit rating, mobile payment, Social Credit System, WeChat

Introduction

China has the largest number of mobile internet users, known as a mobile first country, the number of mobile internet users in China was reported to be 986 million in 2020 ([Huaxia, 2020](#)). With severe State censorship and the Great Firewall of China, worldwide social media platforms such as Facebook and Twitter are not accessible in China. This situation has created great opportunities for Chinese companies to generate China's own version of these social media platforms; WeChat, a mobile-based, all-purpose social media application has become one of the most promising answers.

Developed by Chinese multinational investment-holding conglomerate, Tencent, WeChat originally started in 2010 and quickly rose in popularity. The number of active users reached

one billion in March 2018, which means that almost every single smartphone user in China at the time would have had WeChat installed on their device ([Iqbal, 2021](#)).

Unlike its Western counterparts, Facebook Messenger and WhatsApp, WeChat's features were not only limited to internet messaging, voice and video calls. WeChat offered additional functions such as the ability to make payments using digital wallets, book doctor appointments, call taxis, pay electricity bills, view crowd density maps, read the news, play games, and much more ([Leung, 2015](#)). As a result of WeChat's development into China's all-in-one app, Chinese smartphone users are less likely to use any other apps and thus rely solely on WeChat for all of their needs. With the expansion of WeChat, opportunities emerged to shift some of the core governmental roles onto this platform, such as taxation and the citizen identification system. These functions provided wide access for WeChat to collect personal information on an unprecedented scale, WeChat's public image started to diminish as it became difficult to validate its independence as a private company ([Cook, 2019](#)).

The functionality of WeChat has further expanded with the introduction of WeChat Pay in 2014. At the time, there were a small number of platforms offering similar payment functions including the biggest platform, Alipay/Ant Finance. Benefiting from their large membership of subscribers, both WeChat Pay and Alipay were leading in third-party online payments and swiftly gained market popularity. Soon after, several other platforms launched similar functions by following this trend, for example, TikTok Pay and JD.com.

In retrospect, 2014–2019 was an important stage of third-party online payment development in China. This development served as an enabler and foundation for a cashless society, encouraging Chinese citizens to adapt to the new norm of cashless living. This cashless economy gave companies like WeChat large-scale access to consumer data.

The amount of consumer data collected by private companies quickly grew to an unprecedented level as a result of the fast growth of online payment platforms ([Yang et al., 2015](#)). The Chinese government embraced this opportunity and incorporated it into its grand plan for the national Social Credit System (SCS). In 2018, a close collaboration between the Government and eight key private companies, including WeChat and Ali, was established for the purpose of rolling out the SCS.

The SCS is regarded as an ambitious project which has received extensive media coverage worldwide. International narratives have often simplified this project as a centralised rating system that generates a social credit score to each citizen ([Carney, 2018](#)). Since its inception, the generalisation and moralisation of the SCS has captured the dominant discourse ([Shen, 2019](#)). However, the SCS as an ongoing project is much more complex – involving an

extremely diverse range of decentralized, experimental, and fragmented programs across social, economic, and legal fields ([C. Zhang, 2020](#)).

In this context, this paper starts with a brief explanation of the development of WeChat Pay. By using WeChat Pay as the example, this paper explains how the Chinese government mandates key online payment platforms to adapt into its central bank system and consequently, to participate in the SCS as exclusive credit collators. The aim of this research is to examine the SCS from a socio-legal perspective with a focus on the role of the participating private companies. In doing so, this paper articulates the key socio-legal implications of the SCS and highlights two imperative concerns of the current model: the opaqueness of the system, and the potential risk for abuse of power. In conclusion, this paper posits that the current SCS model lacks public confidence and trustworthiness. This paper suggests that, as a starting point, standardising the algorithm and making it publicly available will help the system gain some level of trust from citizens. Further long-term solutions include developing overarching legal frameworks – including core privacy laws, as well as supporting laws and regulations – to prohibit potential abuse of power by the State and the entrusted companies. These are critical steps to safeguard the purpose of the SCS and the society of China as a whole.

WeChat and WeChat Pay

As WeChat emerged as the ubiquitous element of China's social communications, and became stitched into the country's financial and social fabric, the company declared that WeChat alone had one billion active daily users in 2019 ([Cao et al., 2020](#)). While the company has been forced to comply with strict Chinese Communist Party information controls since its inception, the combination of growing government demands and WeChat's market saturation in China has increased the scope and impact of any functions that WeChat offers ([Harwit, 2016](#); [Jiang et al., 2021](#); [Tu, 2016](#)).

As the most important function of WeChat Finance, in 2014, WeChat Pay began to facilitate the in-app transfer of money both domestically and internationally between users. WeChat borrowed from the traditional Chinese concept of the 'red envelope' to enable this one-to-one payment method. As a marketing campaign, WeChat joined forces with the Chinese Central Television Network (CCTV) to promote its red envelope payment during the CCTV's Annual Gala Night on the 2014 Lunar New Year's Eve which resulted in a massive success for the company. The total number of red envelope transactions during the CCTV Gala Night recorded figures of 11 billion – the peak time was within two minutes after midnight on the Lunar New Year's Day in 2015 during which more than 500 million red envelope transactions were made in each single minute ([Ling, 2015](#)). Since then, WeChat Pay has gained substantially in popularity. To date, uses of WeChat Pay include retail purchases, e-commerce, in-app

purchases, and multiple services such as paying for taxis, making doctor appointments, paying bills, and even filing taxes.

The explosion of WeChat Pay in 2015 triggered a wild development of a cashless economy in China in the subsequent years. As a snapshot, in 2016, the volume of mobile payment transactions had increased at an annual rate of more than 100 per cent; the total transactions reached the value of US \$16.7 trillion in 2017, US \$44 trillion in 2019, and more than doubled to US \$97 trillion in 2020 ([Chan, 2015](#); [Tencent, 2017, 2019](#); [Tencent Credit, 2019](#)).

China is now the leading country in mobile payment both in transaction volumes and penetration rate ([Huang, 2020](#)). A large-scale cashless economy has emerged with mobile payment facilities not only available at almost all of the major shopping centres and public areas, such as train stations and airports, it is also widely available at small-scale street markets, corner stores, and even individual grocers who sell fresh vegetables on their tricycles.

However, this scale of operation and development introduced new issues. When WeChat Pay was introduced, payment via platforms like WeChat Pay did not provide the Chinese government with any transaction data. This was a common situation for all third-party payment platforms at the time. This meant that transactions via the third-party platforms bypassed China's central bank clearing system, and as such, details like the merchant name and location of transactions were not recorded. This situation quickly caught the attention of the Chinese government which was cautious of potential avenues for money laundering, illegal transactions, and theft ([Wildau, 2017](#)).

To address this concern, in August 2017, the Chinese central bank introduced a new policy regarding third-party processing platforms. It regulated that all transactions must go through a clearing system operated by the People's Bank of China (PBC) ([Yoo, 2017](#)). After the launch of the Online Settlement Platform for Non-Bank Payment Institutions, all of the country's payment companies were to work within a standard set of clearing protocols and rules, with the aim of tightening supervision of the country's fast-growing mobile online payment market ([People's Bank of China, 2017](#)). The centralised clearing house sets a more regulated financial environment that allows the PBC to track and monitor all capital flow via third-party payment providers in China. This also sets up a stable foundation for the joint data collection required by the SCS framework.

The Social Credit System (SCS) in China

In most countries, the existence of a credit system is not new or controversial. Past financial information is often used to predict whether individuals will pay their credit card bill in the future. However, China has taken this simple concept to a new level with the SCS.

On 14th June 2014, the State Council of China published a document titled ‘Planning Outline for the Construction of a Social Credit System’ (Planning Outline). The Planning Outline proposed a radical idea: to construct a national trust score system that rates individuals based on data collected from every component of their daily life. The plan specified that this credit system is to form an important mechanism of the socialist market economy and the social governance system. According to this plan, all Chinese citizens would be enrolled in a vast national database that compiles private and government information. The information would cover citizens’ individual activities, online behaviours, everyday purchases, traffic violations, and much more. All of this information would then be distilled into a single number rank for each citizen. The Planning Outline estimated six years to build this immense database, with a deadline outlined for 2020 ([The State Council, 2014a](#)). The Planning Outline also specified that building the SCS would be urgently needed to regulate ‘the market economic order, improve the trust environment of the market, lower transaction costs, prevent risks and reduce government intervention in the economy’ ([The State Council, 2014b](#)). Immediately after the release of the Planning Outline, a series of new public and private initiatives were implemented and State investment contributions to this project have been generous and continuous. As a snapshot, the Chinese government spent over CNY ¥1.5 billion on this project just between 2016–2017 ([Credit China, 2017](#)).

However, questions, concerns and controversies have simultaneously emerged with the development of this plan: whether the plan will remain true to its original design; the vast difficulties of setting up such a system on a national level; and the limits to what it will actually be able to deliver ([Ahmed, 2019](#)).

The Involvement of WeChat

Data collection is the key to the construction of the SCS. The Chinese government started a credit-sharing platform in 2015 which engaged with 38 key government service offices, including the Taxation Office, industry and business regulatory bureaus, and policy bureaus ([PRC National Development and Reform Commission, 2015](#)). The purpose of this platform is to collate and analyse citizens’ behaviour from the 38 government services offices. In the same year, the central bank, PBC, identified eight private companies and gave them a six-month period to prepare to become the first group of licensed credit collectors to gather information from its users (The State Council, 2015). Tencent, WeChat’s parent company, was one of these eight. All eight companies were expected to collect the data from their users, analyse this data, and develop their own red list and blacklist for their users ([People's Bank of China, 2016](#)). Tencent Credit was consequently established to fulfil this mission ([Tencent, 2015](#)).

As the all-in-one multi-purpose app, users of WeChat started to gain credit ratings in considerable ways by using their mobile phones. For example, people started to rate taxi services, banking services, online purchases, and relevant individuals within the app. At the same time, all personal data from individual WeChat users was recorded and analysed, and amalgamated into the credit rating algorithm despite no public disclosure of the algorithm and rating criteria.

This trial period started in January 2015 for a duration of six months ([The State Council, 2014a](#)). On 21 April 2017, at the International Conference on Personal Data Protection and Credit Collection Management, Mr Cun Wan, Director of Credit Collection Management in PBC, revealed that none of the eight entrusted companies had performed well enough to receive the anticipated credit licence ([Cun, 2017](#)).

In 2018, a compromise eventuated, two-and-a-half years after the announcement of the original plan. On 4 January 2018, PBC granted its first private credit collection licence to the newly formed company, Baihang Credit Collection. Baihang registered as a private limited company with headquarters in Beijing and registered capital of CNY ¥1 billion. Baihang has nine shareholders including all of the eight private companies that participated in the PBC 2015 trial and the National Internet Finance Association of China (NIFA). As the major shareholder, NIFA holds 36 per cent of Baihang and all of the other eight companies hold 8 per cent each, accounting for a total of 64 per cent of Baihang ([People's Bank of China, 2018](#)). At the time, NIFA was a new government agency jointly established in March 2016 by ten Chinese government departments and bureaus, industry regulators, and policy makers ([Baihang, 2018](#)). The grant of this licence to Baihang thus signalled the formal introduction of the system for financial credit collection in China, with close collaboration between the State and the eight key entrusted companies.

The Implications

There is a growing number of people across the world who are willing to trade in their privacy for convenience to use services and apps. A common example is Facebook. Despite the frequent backlash for privacy and data breaches, the number of Facebook users has not been heavily impacted ([ABC News, 2018b](#)). People in China are not very different in this regard. Although Chinese people seemed to be even more willing to trade in their personal information to gain the convenience of using WeChat services ([Chen & Cheung, 2018](#); [Kostka & Antoine, 2019](#)).

Living in a highly populated society without any credit system for decades, Chinese people largely welcomed a credit system where people can obtain more information on the goods and services that they engage with, whether it be a taxi service or an online shop. Trustworthiness

has not been highly honoured in Chinese society in the past two decades, with economic development as the key goal of the country, creating a multitude of social issues including corruption, expired vaccines, toxic milk products, corporate fraud, tax evasion, and academic misconduct. For instance, *pengci* (碰瓷) is a well known misbehaviour in China in the past few years. *Pengci* literally means 'break porcelain' and its origin is traced back to merchants who displayed porcelain antiques for sale on the street and in areas of high foot traffic to encourage the likelihood of pedestrians in damaging the goods. The merchant would then demand a large sum of financial compensation for the damage. The practice of *pengci* was witnessed more and more often, including circumstances where people deliberately fall near motor vehicles and allege negligence against the driver, demanding financial compensation on the spot. Mr Wanxiang Sun, a 66-year-old man, was sentenced to seven years' imprisonment after being found to have committed 156 counts of *pengci* in the span of nine years ([Beijing Daily, 2020](#)). As a further example, in a case involving arson in Hangzhou in 2017, a nanny started a fire that killed a mother and three children in an attempt to elicit more money from the wealthy employer to pay off her large debts ([Jia, 2021](#)). In the context of this society, it is unsurprising for many to desire a credit system that might be able to help them avoid situations like these ([Jun, 2018](#)).

Against this backdrop, the move to a social credit system can help to determine trustworthiness through people's daily interests and activities, and represents a clear response to many Chinese social crises. Reward and punishment are directly linked to trustworthiness. For example, in Shanghai, a housing project offered one year of rent-free accommodation to a trustworthy young person with impressive records in volunteering. In contrast, a man in Nanjing who defaulted on his debts was banned from overseas travel for failing to comply with a court judgment. Two construction companies in Sichuan province were placed on a blacklist for failing to pay back wages to its migrant workers. These examples were among a nationwide 'Top 10 Model Cases of Joint Rewards and Sanctions' selected by the National Development and Reform Commission (NDRC) as part of China's emerging SCS ([Wang & Liu, 2018](#)).

The rapid development of internet technologies has provided the nation with technical support and opportunities to realise the SCS ([C. Zhang, 2020](#)). Admittedly, some social problems have been quickly resolved after the introduction of the SCS. The timely punitive measures have involved public shaming and bans on purchasing airline tickets and booking luxury hotels, and are enforced on low credit score holders who have been deemed untrustworthy ([Xu & Xiao, 2018](#)). Some of these punitive measures can even be extended to family members, such as not allowing a child or children of an offender to attend a good school ([Zeng, 2018](#)).

Nonetheless, building a monitoring system on such a large scale invokes huge social, economic and legal concerns. As Robin Li, the chief executive of Baidu (China's version of Google) stated openly, 'it doesn't matter if user is willing, it matters that people don't have the right to defend themselves in this social environment' ([ABC News, 2018a](#)). This statement triggered enormous backlash from Chinese netizens, revealing the far-reaching and pervasive implications of a social setup where every part of people's lives is monitored and studied by multiple government agencies and private firms, especially when this regime is carried out by multiple platforms with different, but all opaque, algorithms and criteria. The following section of this paper analyses this situation in detail, focusing on two specific implications from a socio-legal perspective.

The opacity of the prototype

The development of digital technology has enabled new ways to collect, handle, and process large samples of qualitative data, reinforcing the number's epistemological claim to truth and perpetuating an ideology of dataism – the widespread conviction that data is truthful, objective, and neutral ([Dijck, 2014](#)). However, extensive studies have shown that predictive algorithms naturalize and reproduce social inequity ([Eubanks, 2018](#)). Thus, algorithms are crucial when analysing, especially rating, human behaviours based on data collected from every aspect of a person's life.

At its current stage, the SCS should be understood *not* as a single rating system that provides a single score for Chinese citizens, *but* as a system comprised of a number of rating systems that can provide scores based on its own scoring algorithms. These rating systems include government key function bodies, different levels of administrations, and private companies. The landscape is complex due to the number of rating agencies in operation, lack of information disclosure, different scoring systems and final scores, as well as the intricate interplay between all these agencies.

Government rating agencies

As the national system is still being fully realised, dozens of pilot social credit systems have already been tested by local governments at provincial and city levels. Further, there are multiple online platforms hosted by different rating agencies which people can voluntarily sign up for. Algorithms amongst different platforms run by different levels of governments are different, and thus the individual scores are recorded with different standards as well. For example, rating systems run by local council in some cities rate people based on 100 points to start, but online rating platforms normally rate people with 350 points to start.

Not only are the scoring systems different, the consequence of being a low score holder is different too. In Shenzhen, a city in the south of China, authorities launched the use of facial recognition and online shaming to crack down on small crimes such as jaywalking ([Xu & Xiao, 2018](#)). In Xiamen, another city in the south, public security authorities were reported to have automatically attached messages to the mobile phone lines of blacklisted citizens – a message of ‘the person you're calling is dishonest’ is played before any call is connected to a low-rated person ([Xie & Liu, 2018](#)).

This situation is confusing and potentially misleading ([WeChat Pay, 2020](#)). Hu Naihong, a finance professor at Shanghai University of Finance and Economics, who participated in the SCS infrastructure build, commented that ‘[t]he top-level design, the institutional framework, and the key documents are all in place, but there are still many problems to be solved. The most serious problem is that all kinds of platforms are rigorously collecting [data], while having vague legal and conceptual basis and boundaries’ ([Hu, 2017](#)).

Payment platforms

Online payment rating agents are doing things differently in this regard. For example, WeChat Pay started offering WeChat Pay Score (WPS) on 3rd June 2020. The design of the score allows individual WeChat Pay users to rate transactions and check their scores at any given time within the app. The product release page on WeChat’s website is concise, containing information regarding what WPS is, how to use it, the benefits of gaining high WPS scores, and how to realise these benefits (the lures). Information on the actual construction of the algorithm –how the WPS is calculated, or what criteria are used to differentiate high-score behaviours from low-score behaviours – is merely one sentence: ‘WPSs are a comprehensive calculation of personal identity characteristics, payment behaviours, usage history, etc., aiming to provide users with a simpler and more convenient lifestyle’. In contrast, the lures are explained in much more detail, such as the ability to borrow power banks and umbrellas without needing to leave a bond, and to book a hotel room without a deposit and in-advance room charge payment ([WeChat Pay, 2020](#)).

Other similar rating agents have been following suit. According to Sesame Credit, an affiliate of the Alibaba Group which owns the largest online payment platform Alipay, ‘a complex algorithm’ is being used to measure individuals by a score between 350 and 950 points. The company published five factors that it uses to rate their users, including credit history, a user's ability to fulfil their contract obligations, personal characteristics (such as their phone number and address, behaviours and preferences), and lastly, interpersonal relationships ([Sesame Credit, 2017](#)). Under this system, ‘someone who plays video games for ten hours a day, for example, would be considered a lazy person’, said Li Yingyun, Sesame Credit's Technology Director. ‘Someone who frequently buys diapers would be considered as probably a parent,

who on balance is more likely to have a sense of responsibility'. Also under this system, interpersonal relationships are important which means that people are required to be conscientious of who they are friends with, and the public activities of their friends, both in real life and online ([Liang et al., 2018](#)).

These insights can, of course, only provide a limited understanding of how the scores are calculated by different rating agents. Alipay and WeChat Pay have long enjoyed their duopoly status in China's online payments ([Kapronasia, 2020](#)). Together, they hold 90–95 per cent of the online payment market, which is equivalent to USD \$97 trillion in transaction value, and more than 2.4 billion active users on a yearly basis ([Chen & Cheung, 2018](#); [Wang Yi Tech News, 2021](#)). This disproportionate level of transparency on scoring calculation and algorithm simply does not justify the massive user base.

Baihang

As the only licensed credit collector, Baihang emerged with market advantages. As explained previously, Baihang has nine shareholders: the NIFA (the major shareholder) and the eight private firms.

Baihang is certainly an important component to the construction of the SCS. How it handles the collaboration with powerful companies such as WeChat and Tencent, how it deals with the relationship with other government bodies, and how it works with the central bank are all challenging tasks. Unlike its shareholder companies which have vast user bases, Baihang does not have any existing data sources. Aside from strong government support, gaining trust from Chinese citizens to encourage them to sign up to its platform is still crucial to Baihang's establishment. Unfortunately for Baihang, the company has not dealt effectively with these challenges. To date, about three years after its inception, Baihang's coverage of users is still patchy in comparison to its own shareholders. Currently, most of Baihang's users are small financial institutions and companies with the majority of them being online microlenders. The fact that these companies are connected to Baihang's credit database means that they can trade their credit transaction data for fuller credit histories on users ([Zhao, 2019](#)).

In addition, dealing with its own shareholders has appeared to be a difficult task for Baihang as well. Reportedly, Baihang struggles to find the right balance working together with some of its shareholders including WeChat and Ali over the control of user data. Baihang's shareholding scheme has done little to smooth the pathway to data sharing. The reason behind this is not difficult to understand since WeChat Pay/Tencent Credit and Sesame Credit/Alibaba dominate and hold the most customer data – they have the least to gain from pooling their credit data with Baihang. In fact, only three of the eight shareholding companies have agreed to feed their data into Baihang's system, neither Tencent Credit nor Sesame Credit

were willing to share their data ([Yang & Liu, 2019](#)). Many questions arise: are Baihang's shareholders obliged to feed their data to Baihang? Can they even do so without the consent of their users? How much information do they need to share with Baihang even with the government's explicit intention of Baihang's role as the main credit collector? Is the government in any position to mandate who owns the data? Baihang, same as all of the eight shareholders, is a private company so why should one private company be given priority over other private companies? What authority does the central bank have to decide such a setup? Considering that credit collection as a business activity, Baihang is in direct competition with its shareholders, why should Baihang's competitors share key business information with Baihang? What is in it for them? Questions like these can go a long way in trying times, unfortunately the battle is likely still being waged between Baihang and its eight shareholders, however no answers to these questions have been offered, or at the very least, been openly discussed.

Potential conflict of interest and abuses of power

Digital technology developments have enabled new ways of data-driven governance and have perpetuated the conviction that data sharing and management are the keys to solving many problems. In this sense, the SCS is considered constitutive of an emerging 'operating system for global normative orders' ([Backer, 2018](#)). As stated, the SCS aims 'to forge a public opinion environment where keeping trust is glorious... [to] strengthen sincerity in government affairs, commercial sincerity, social sincerity and the construction of judicial credibility' ([PRC State Administration of Taxation, 2018](#)). But can these goals be achieved in the current model?

We are already living in a world where our daily activities are under constant monitoring and evaluation. Activities such as where we are at any given time; what we buy at the shops and online; who we are friends with and how we interact; what our daily routine looks like; how many hours we spend online either watching videos or playing games; and whether we pay bills and taxes. Many of these activities are already being tracked by companies like Google, Facebook and Instagram. Even health tracking apps such as Fitbit and Apple Watch are collecting information such as users' heart rates and step counts. In other words, many people are already well-adapted in this digital world through consenting to give up some of their private information. However, situations can become more alarming where there is a system that categorises all of these behaviours as either positive or negative, and distils this into a single score – a score that would tell the rest of the world how trustworthy the score holder is. It may become more alarming when the score is publicly ranked against that of the entire population of the country and used to determine any individual's eligibility for important

things, such as job seeking, travelling, their children's schooling, or even the chances of getting a date ([Botsman, 2018](#)).

This forms an obvious imbalance of power between the citizens who are being rated, and the agents that have the power to determine the score calculation, the rating algorithm as well as the ramifications for low scores. Whether this imbalanced power play can encourage 'a public opinion environment where keeping trust is glorious' may work to a certain extent, however it is certainly lacking in persistence for the group that has the power to set the rules of the game.

The State

Personal data in the SCS prototype is a wide category of information comprising public, financial, market, and personal credit. All personal credit is collected simultaneously through the use of legal, administrative, and technical means ([C. Zhang, 2020](#)). This is a brand-new model that has never been ventured into anywhere in the world and has been met with fierce international criticism since the State released the SCS Planning Outline in 2014. 'It is very ambitious in both depth and scope, including scrutinising individual behaviour and what books people are reading. It's Amazon's consumer tracking with an Orwellian political twist', described Johan Lagerkvist, a Chinese internet specialist ([Lagerkvist, 2015](#); [Netkin, 2018](#)). Rogier Creemers, a scholar specialising in Chinese law and governance at the Van Vollenhoven Institute at Leiden University, published a comprehensive translation of the plan and compared it to 'Yelp reviews with the nanny state watching over your shoulder' ([Creemers, 2017](#)).

The epistemological foundation of the SCS lies in a conviction that data and quantified indicators are truthful reflections of social reality and their scientific deployment provides a technological fix to socio-economic problems, improves administrative efficiency and transparency, and maximizes the entrepreneurial potential of society. This technological fix entails data sharing among different regulatory authorities, reputation mechanisms aimed at effective enforcement of laws and regulations, and the diffused application of financial technologies to evaluate the performance of enterprises, individuals, and governments. It shifts attention from the field of the political, which concerns contests and empowerment, to that of governance which focuses on finding 'innovative and effective ways of steering and organizing society' ([Lievens, 2015](#)).

In collaborating with the State in the government prototype, the eight private companies are playing an important role, whether willingly or unwillingly. The fact that all eight companies are shareholders of Baihang, and that Baihang is entrusted to run the credit system for the State, indicates that all eight companies will ultimately be responsible for running the government's own system. It is difficult to claim that the government will not want to extract

the maximum amount of data from it. If this happens, and continues as the new normal, it will form a legitimate perception that private platforms are essentially acting as spy agencies for the government. When that time arrives, the companies may not have a choice to say no, or would the companies be willing to say no to the government?

This lack of public information has created a perfect storm for doubts and controversies: are these companies being paid for sharing the information? What is the benefit to these private firms in Baihang's setup? Do they have the choice not to collaborate with the government? Are they participating for commercial benefits? Or under the political pressure? ([Lee, 2019](#); [Li, 2019](#)). All of these questions remain unanswered.

Comparing the SCS to data-driven analytics in private risk and compliance systems, Larry Backer has argued that these systems 're-center the object of obligation of responsibility from the law's command and obey structure' to 'one grounded in the centrality of accountability and assessment – to oneself and to others' ([Backer, 2018](#)). Beyond legal orders, the system also exemplifies a more general ethos of data-driven governance that 'the ontological unit of analysis is the discrete data point' isolated from constitutive social relations and power structures ([Lake, 2017](#)).

Individual credit scores are currently being used in China on a mass scale, even by the country's judicial system, where a blacklist of people deemed untrustworthy is published by the courts ([PRC Legal Enforcement, 2013](#)). Low scores may lead to many undesirable consequences, including court-issued bans from travelling by plane or train ([Chen & Cheung, 2018](#)); reducing Internet speeds ([Mistereanu, 2018](#)); bans from attending good schools ([Ni, 2018](#)); bans from staying in good hotels ([Hatton, 2015](#)); and public shaming and branding as 'bad citizens' ([The State Council, 2019](#)).

Liu Hu, a vocal journalist who has criticised government officials on social media, was accused of spreading rumours and defamation. While seeking legal redress in early 2017, Mr Liu realised that he was blacklisted as 'untrustworthy' and was subsequently prohibited from purchasing airline tickets ([Tracy, 2018](#)). A similar case occurred to Xiaolin Li, a lawyer who was placed on the blacklist in 2015, who found himself unable to purchase a plane ticket home during a work trip and was barred from applying for credit cards ([Wang, 2017](#)). In 2015, Zhong Pei, who was a 16-year-old student living in Jiangsu at the time, was blacklisted for being 'dishonest' after her father killed two people and died in a car accident. It took Mrs Zhong four months to dispute the court's decision and to strike her name off the list in 2017 to be able to board a train and enrol in university ([Kania, 2018](#)).

While these situations may be isolated incidents, on the whole, this system demonstrates the clear potential to be used to push the government's agenda and crackdown on dissent ([Zeng,](#)

[2018](#)). It is important for a country to be able to enforce court orders, but when the judicial and legislative systems malfunction, it raises questions about whether the ability to expose and punish without due process can lead to concealed abuses of power.

The companies

Good social scores bring convenience and benefit to people's daily lives and as such high scores are becoming more and more desirable. Not surprisingly, ways to improve social scores are now an attractive service to the public. Score advisers, who can share tips on how to gain points, or credit consultants who offer expert advice on how to strategically improve a ranking or be removed from the blacklist, are amongst a list of newly emerged services. As an example, some of the tips offered by these service platforms include warnings on the negative consequences of being friends with someone with a low score ([Tian, 2016](#)).

Arguably, this might not be a huge concern if the rating agencies are not offering services like this, as only the agencies know the detailed algorithm and score calculation, however there has been no public policy to prohibit this potential conflict of interest. Considering the algorithm not part of public knowledge and is solely owned by the rating agencies (or perhaps jointly with the government), one would naturally believe that the help from the rating agencies to improve the score would be the most effective way for the user while also creating an immense business opportunity for those entrusted companies. At the current time, there is no prohibition to stop these companies offering services of this nature. This situation calls for a timely policy response especially since conflicts of interest might have already occurred widely and is only likely to increase.

Another potential conflict of interest rests within the complex competitive relationship between the entrusted companies and Baihang. As all eight private companies are running their own commercial credit collection services, they are competitors with Baihang. At the same time, these companies are also shareholders of Baihang. This relationship requires more consideration. Simply forcing together companies who undertake credit collections may potentially enlarge the pool of information, but this can only be achieved when all pre-requisites are met. For example, pooling information together requires all participating companies to share a common goal. Since these companies are separate commercial companies and some of them are in direct competition, it is difficult to identify the common goal. While government direction may work as a top-down measure, the effectiveness of this measure is questionable. Moreover, proficient information sharing requires all participants to be at similar level in terms of information capacity. This is certainly not the case in the Baihang setup. WeChat/Tencent Finance (WeChat Pay) and Ant Finance (Alipay) are by far the largest platforms in terms of users as well as information reserves. The quantity of information that these two companies are required to transfer to Baihang remains a question. Baihang's

establishment has not done away with competition. In fact, the relationships between all of these competitors have become more complex. This complex landscape offers more potential for conflicts of interest that might benefit either Baihang, or its individual shareholders, and the benefit is certainly gained with the cost of the public giving up their personal information.

Conclusion and Suggestions

The SCS poses significant challenges to researchers not only because it is an ongoing endeavour, but also due to the heterogeneous and experimental nature of the vastly different initiatives operating in both public and private sectors that loosely fall under its purview. As a result, much of the emerging literature on the subject remains largely descriptive, which is nonetheless of crucial importance given the prevalence of mischaracterisations ([T. Zhang, 2020](#)).

The SCS is swiftly expanding in China with solid support from the Chinese government. The current system is effective in luring people in with treats for good behaviour despite the fact that the system is designed so that ‘untrustworthy people can't rent a car, can't borrow money or even can't find a job’ ([Tencent Credit, 2019](#)). At the same time, fragmentary government rating systems in cities, agencies, courts and even schools are also being used to discipline and punish undesirable behaviours. The consequences of a low score rating is far-reaching. The overriding principle, as noted in the State Council General Office policy entitled ‘Warning and Punishment Mechanisms for Persons Subject to Enforcement for Trust-Breaking’ is: ‘If trust is broken in one place, restrictions are imposed everywhere’ ([The State Council, 2019](#)).

Currently, across 26 cities, the government is trialling to have WeChat replace traditional state-issued social security cards with digital versions connected to users’ accounts ([Chen, 2018](#)). The likelihood of WeChat being used as the official Chinese virtual identification card is reasonably high once this wider scale trial completes. If this happens, WeChat/Tencent, as a private company, would hold all personal information of citizens, including social security number, date of birth, medical history, daily activities, friends, hobbies, expenses, and much more. When all of these government functions are transferred onto a private platform, laws and regulations that ensure entrusted company/ies will not breach the privacy of citizens and will not abuse this information should be well thought-out before the roll-out. Regrettably, this safeguarding process is yet to come at this stage.

There has been no public information regarding why the State has chosen these SCS participating companies, or any relevant public consultation nor criteria for decisions. One can only assume that the State would have chosen the companies that obtained certain level of trust or the trust between the State and the SCS-participating companies may have long been established. Unfortunately, trust has not been established between the SCS and

individual citizens. Without this trust, the SCS may not have the longevity that it aims to achieve. As a starting point, reducing the unknowns is important. This involves taking steps to reduce the opacity of the algorithms and to standardise various score systems. This will require a disclosure of mandatory information on the rating systems, in particular the scoring criteria. The argument against mandatory disclosure always involves the scenario whereby if people know what happens on the backend, the system can be rigged or hacked. However, if humans are being reduced to a score that could significantly impact their lives, there must be transparency in how this scoring system works.

To enhance the longevity and effectiveness of the SCS in the longer term, effective measures to prohibit potential conflicts of interest and abuses of power are crucial. To achieve this, specific laws and regulations regarding data collection and processing need to be developed in a timely manner in order to prohibit potential information misuse from the State and the entrusted companies. Once the scope of data collection and processing is established by laws, there will be a need for an independent tribunal or ombudsman to deal with credit related complaints efficiently and fairly. This independent agency would be best established to assist individual citizens with low or no cost to request rating agencies to correct their errors. It is also important to ensure that this independent agent is able to have access to the various platforms, as well as government bodies, to carry out their complaint investigation.

It is pleasing to see the first guideline for improvement to the SCS published in December 2020. This document signifies the awareness of the government on various issues of the current SCS model. The guideline highlights the importance of central legislation and lays the ground for future national law on the SCS. The government also highlighted that some local authorities misconstrued the definition of 'bad behaviour', for instance, spitting in public and fare-dodging should not be part of the credit score ([The State Council, 2020](#)).

The determination to pass relevant laws that will bring much-needed clarity to social credit systems seems strong but the timing is uncertain. The only unknown is time. Until then, the motley collection of credit scores, ranging from city-level schemes to commercial credit scores and national blacklists, will continue to confuse Chinese citizens ([Sun, 2021](#)). Just as Botsman has said, 'if we are not vigilant, distributed trust could become networked shame. Life will become an endless popularity contest, with us all vying for the highest rating that only a few can attain' ([Botsman, 2018](#)).

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A Predictive Algorithm for Handover Decisions between LTE and LTE-A Networks

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Abstract: A heterogeneous wireless network needs to maintain seamless mobility and service continuity; for this reason, we have proposed an approach based on the combination of particle swarm optimization (PSO) and an adaptive neuro-fuzzy inference system (ANFIS) to forecast a handover during a movement of a mobile terminal from a serving base station to target base station. Additionally, the handover decision is made by considering several parameters, such as peak data rate, latency, packet loss, and power consumption, to select the best network for handover from an LTE to an LTE-A network. The performance efficiency of the new hybrid approach is determined by computing different statistical parameters, such as root mean square error (RMSE), coefficient of determination (R^2), mean square error (MSE), and error standard deviation (StD). The execution of the proposed approach has been performed using MATLAB software. The simulation results show that the hybrid PSO-ANFIS model has better performance than other approaches in terms of prediction accuracy and reduction of handover latency and the power consumption in the network.

Keywords: Handover Decision, PSO, ANFIS, Heterogeneous network, Neural networks

Introduction

One of the most challenging issues in the future of heterogeneous wireless networks is to maintain the quality of service (QoS) during a vertical handover ([Kassar, Kervella & Pujolle, 2008](#)). In this paper, vertical handover is done between two heterogeneous networks that are LTE and LTE-A. From the existing work, we can conclude that the most important issue is to ensure the Quality of Service (QoS) when the mobile station moves away from one base station towards another ([Miyim, Ismail & Nordin, 2014](#); [Aboelezz, Nafea & Zaki, 2020](#)). Thus, the major problems are a large number of handovers, delay in a correct handover decision,

deficiency of maintaining a seamless connectivity and service continuity, and high energy consumption in the network. For this reason, a hybrid computing-technique-based handover decision system design is applied to make more intelligent, comprehensive and quick decisions to select the optimal network between LTE and LTE-A ([Hashim & Abido, 2019](#)). Therefore, the primary focus was to improve the QoS while the mobile terminal moves across the heterogeneous wireless networks, to reduce the number of handovers and the energy consumption in the network, and to maintain the required connectivity ([Davaasambu, 2018](#); [Chinnappan & Balasubramanian, 2016](#)).

An adaptive neuro-fuzzy inference-system-based handover decision system design is used to make more intelligent, comprehensive, and quick decisions to select the best network ([Bin, Xiaofeng & Zianzhong, 2013](#)). Indeed, the primary focus was to improve the quality of service (QoS) while the mobile terminal moves across the heterogeneous wireless networks. Then, we have proposed an approach based on the combination of adaptive neuro-fuzzy inference system (ANFIS) and particle swarm optimization (PSO) with four different parameters (peak data rate, latency, packet loss, and power consumption) to enhance the accuracy of our handover decision algorithm ([Benaatou, Latif & Pla, 2017](#)).

The main contribution of this study is to propose a new hybrid approach combining a particle swarm optimization algorithm and an adaptive network-based fuzzy inference system for decision making of handover in wireless networks by using the statistical parameters ([Benaatou, Latif & Pla, 2019](#)) the coefficient of determination (R^2), the root mean square error (RMSE), the mean square error (MSE), and error standard deviation (StD) to make a comparison between the real and predicted values for the ANFIS and PSO-ANFIS models ([Jang, 1993](#)).

The rest of this paper is structured as follows. In the next section, we describe the proposed approach and the structure of the ANFIS model that corresponds to it. Following that, we present the analytical results, the data evaluation for ANFIS-PSO modelling, and the implementation of the PSO-ANFIS algorithm. Next, we carry out a comparison between vertical handover algorithms. Finally, we present the conclusions.

Proposed Approach

In our proposed system, we have designed a simulation scenario where the mobile terminal (MT) moves away from the eNB of LTE towards the eNB of LTE-A network, as shown in Figure 1 ([Devi et al., 2017](#)).

In our system, we have used the architecture of the adaptive network to develop the ANFIS model (Calhan & Ceken, 2010; 2012). This structure is composed of five layers, four inputs, and three rules, as shown in Figure 2.

To predict a handover from LTE to LTE-A network, we have used a hybrid approach PSO-ANFIS and the reason to use PSO algorithm is to improve the ANFIS performance (Israt, Chakma & Hashem, 2009). This approach is made by taking into account several parameters, such as peak data rate, latency, packet loss, and power consumption (Goudarzi *et al.*, 2017). Additionally, we have considered four parameters to achieve a good handover decision calculated for choosing the best target cell using the ranges of the inputs that are defined based on the standard parameters of LTE Advanced networks (Patil & Patil, 2021). The values for each parameter are shown in Table 1 (Sharma, 2012).

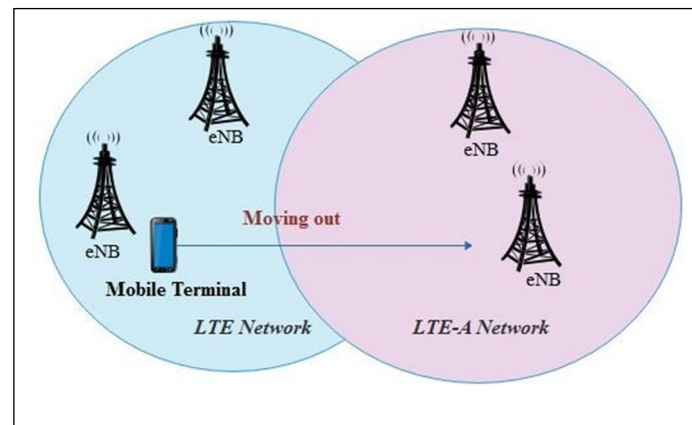


Figure 1. Network simulation model

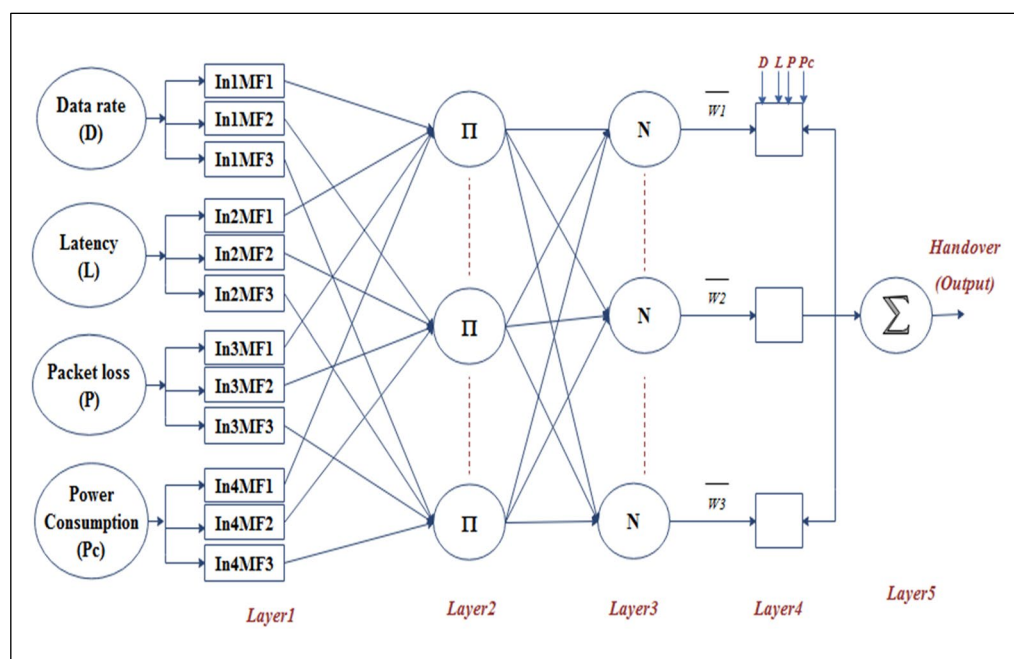


Figure 2. Structure of ANFIS model

Table 1: Ranges of inputs

Metrics	Low	High	Unit
Peak data rate	0	500	Mbps
Latency	0	50	msec
Packet loss	0	24	Packet/s
Power consumption	0	22	Watt

After calculating the output that is the handover factor according to layer 5 (see Figure 2), we have laid this rule: if the handover factor is larger than 0.7, the decision of handover should be executed to the target cell; and when the handover factor is smaller than 0.7, the decision should be not executed ([Thumthawatworn, Tillapart & Santiprabhob, 2017](#)).

Results and Discussion

Hybrid approach PSO-ANFIS

In this approach, we have used PSO to enhance the accuracy of the ANFIS model ([Suleymani & Bemani, 2018](#)). The steps and data evaluation for ANFIS-PSO modelling and the process of how PSO and ANFIS work together for a handover decision and how the input parameters are collected are explained as follows and depicted in Figure 3 ([Wang et al., 2011](#)).

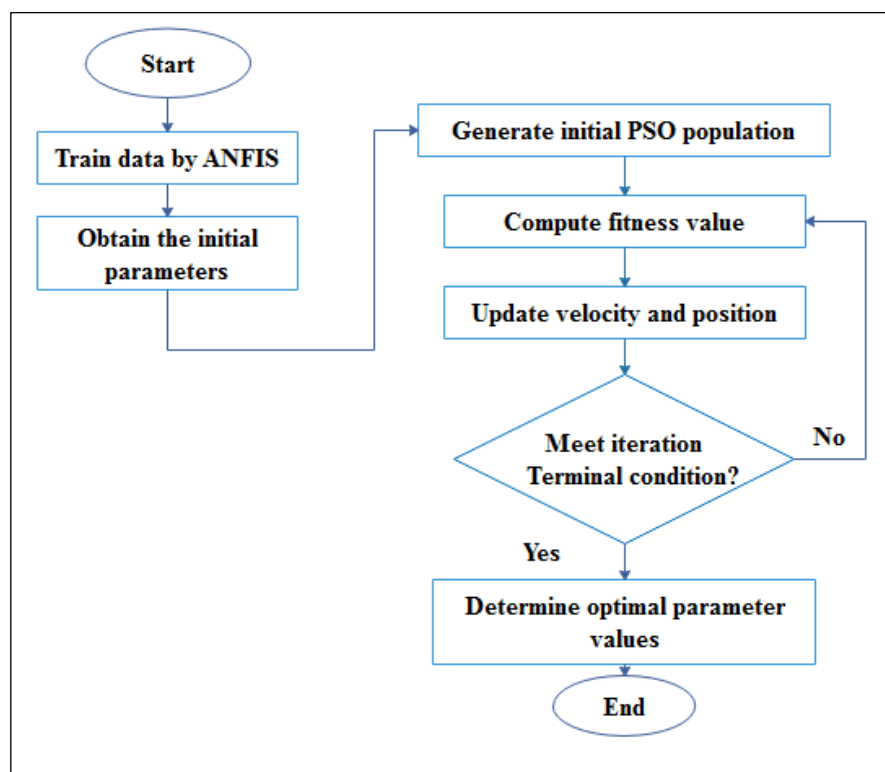


Figure 3. Scheme of the PSO-ANFIS algorithm

The detailed parameters for training PSO-ANFIS are presented in Table 2.

Implementation of PSO-ANFIS algorithm

In this section, we have applied the PSO-ANFIS algorithm in decision-making for vertical handover between LTE and LTE-A integrated networks.

In the first part, ANFIS and PSO-ANFIS models are implemented and developed in MATLAB. The ANFIS structure, including grid partitioning, sub-clustering, and fuzzy c means clustering (FCM), and the performance of the proposed hybrid PSO-ANFIS models is determined by computing different statistical parameters, such as root mean square error (RMSE), coefficient of determination (R²), mean square error (MSE) and error standard deviation (Std) in each of the grid partitioning, sub-clustering, and FCM ANFIS structures.

Table 2. Detailed parameters for training PSO-ANFIS

Parameter	Value
No. of inputs	4
No. of outputs	1
No. of Data items for training	25
No. of Data items for testing	25
No. of Membership Functions (MFs) for each input	3
No. of particles for each population	25
Epoch for each population	100
Inertia Weight W ₁	1
Inertia Weight Damping Ratio W ₂	0.99
Personal learning Coefficient C ₁	1
Personal learning Coefficient C ₂	2

The statistical results of the developed ANFIS and PSO-ANFIS models for training and testing stages are presented in Tables 3, 4, and 5.

Table 3. Statistical criteria for the ANFIS and PSO-ANFIS models in the case of Grid partitioning

Grid Partitioning					
Model	Analysis	RMSE	R ²	MSE	Std
ANFIS	Training	0.00039	0.046	1.478e-07	0.0040
	Testing	1.48	-0.51	2.217	1.48
	All	0.788	0.26	0.628	0.787
PSO-ANFIS	Training	0.00127	-0.032	1.6219e-06	0.00131
	Testing	0.0356	0.53	0.00127	0.0255
	All	0.0189	0.99	90.00036	0.0177

Table 4. Statistical criteria for the ANFIS and PSO-ANFIS models in the case of Sub clustering

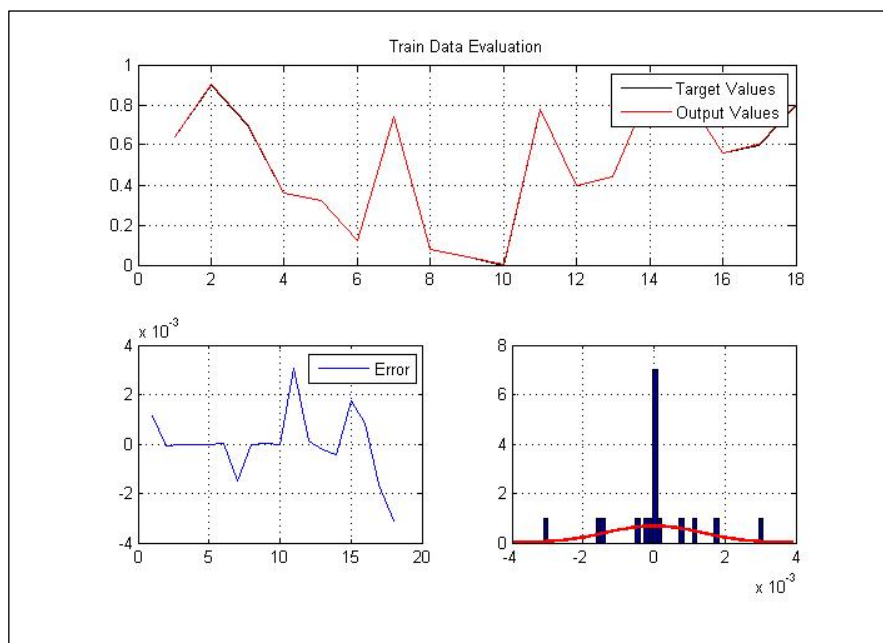
Sub clustering					
Model	Analysis	RMSE	R ²	MSE	Std
ANFIS	Training	0.00194	0.11	3.7424e-06	0.00199
	Testing	0.00537	0.57	2.6386e-05	0.00517

Sub clustering					
Model	Analysis	RMSE	R2	MSE	StD
PSO-ANFIS	All	0.00318	0.99	1.0083e-05	0.00319
	Training	0.00222	-0.087	4.9276e-06	0.00229
	Testing	0.00469	-0.125	2.2017e-05	0.00507
	All	0.00317	0.9999	1.0012e-05	0.00323

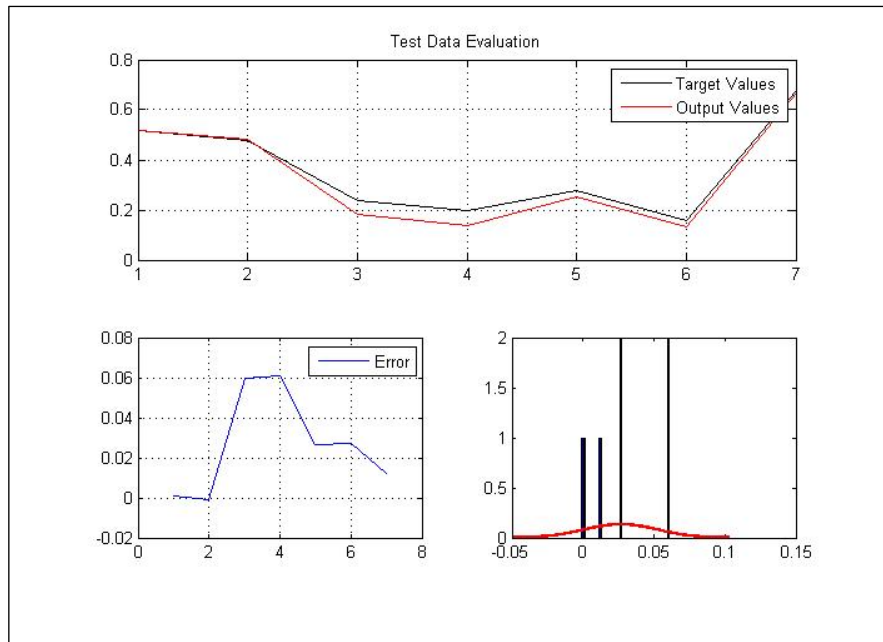
Table 5. Statistical criteria for the ANFIS and PSO–ANFIS models in the case FCM

Case FCM					
Model	Analysis	RMSE	R2	MSE	StD
ANFIS	Training	0.0264	0.298	6.695e-05	0.00272
	Testing	0.0204	0.0067	0.00041	0.0183
	All	0.011032	0.999	0.00012	0.0107
PSO-ANFIS	Training	0.0028	0.25	7.8878e-06	0.00289
	Testing	0.00362	-0.038203	1.3124e-05	0.00357
	All	0.00303	0.9999	9.1952e-06	0.00308

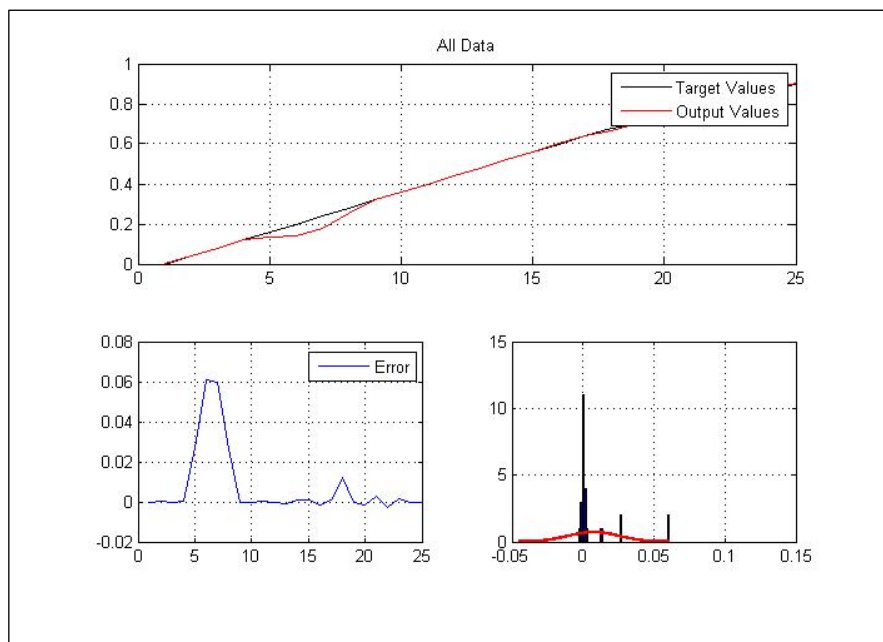
The comparison of the predictive models showed that the PSO-ANFIS model with RMSE of 0.018 and R2 of 0.96 performed better than the ANFIS with RMSE of 0.78 and R2 of 0.26.



(a) Training data set



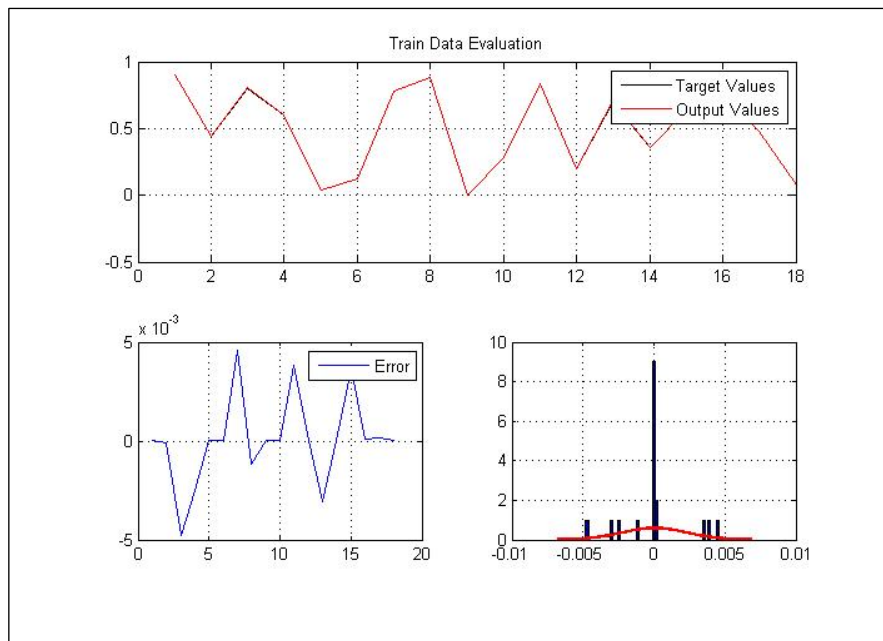
(b) Test data set



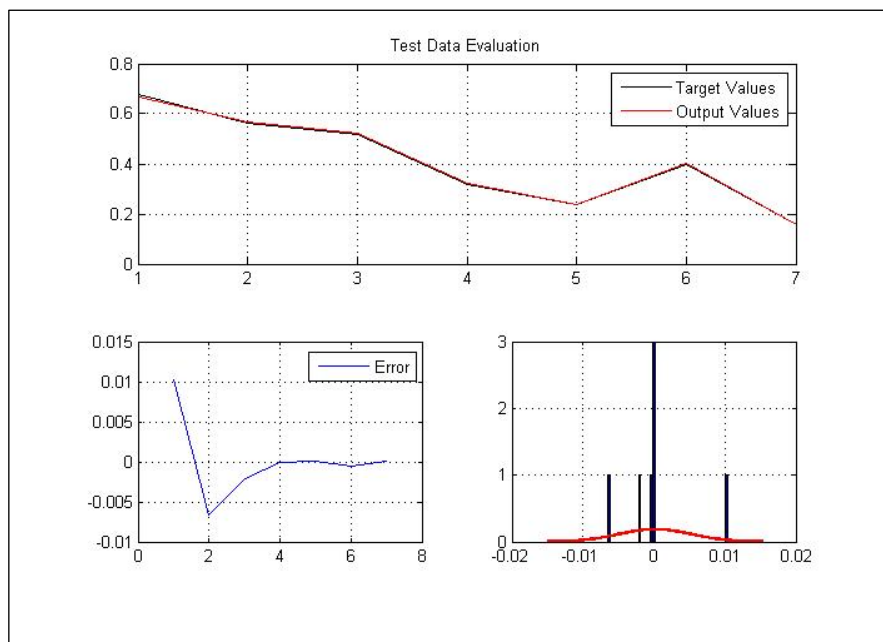
(c) All data sets

Figure 4. PSO-ANFIS model, Grid Partitioning type of ANFIS: (a) Training data set (b) Testing data set (c) All data sets

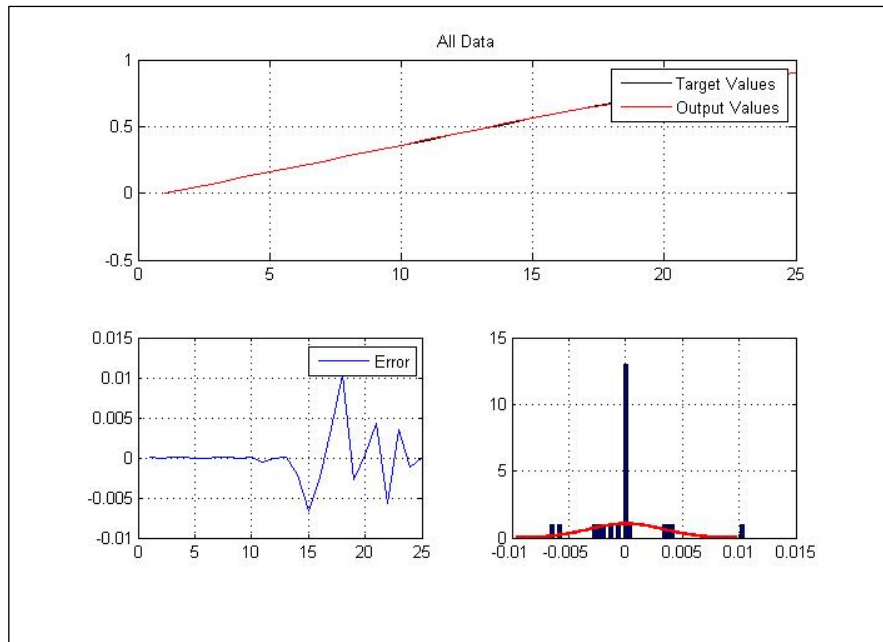
From Table 3, grid partitioning ANFIS structure testing and training errors in the PSO-ANFIS model are closer to zero than in the ANFIS model, as shown in Figure 4.



(a) Training data set



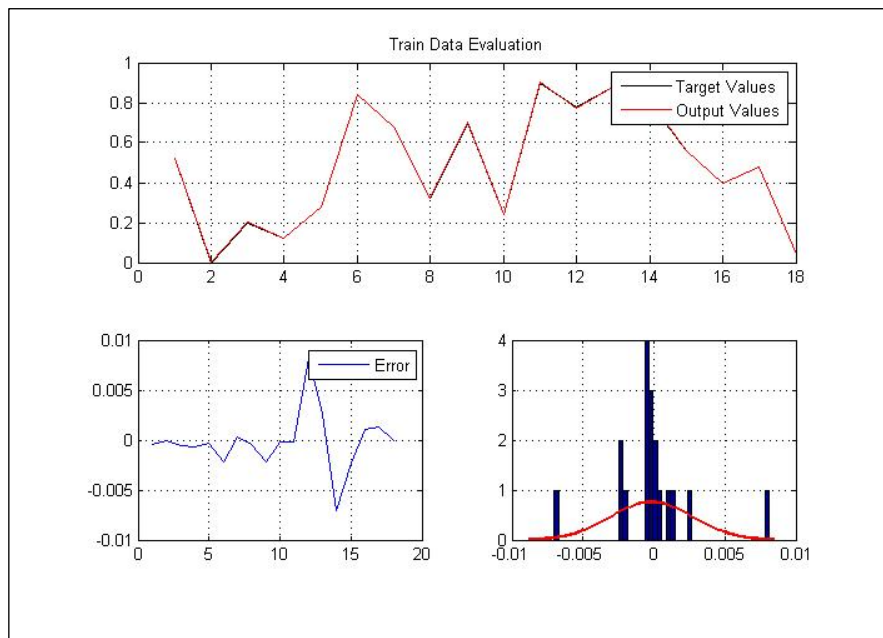
(b) Test data set



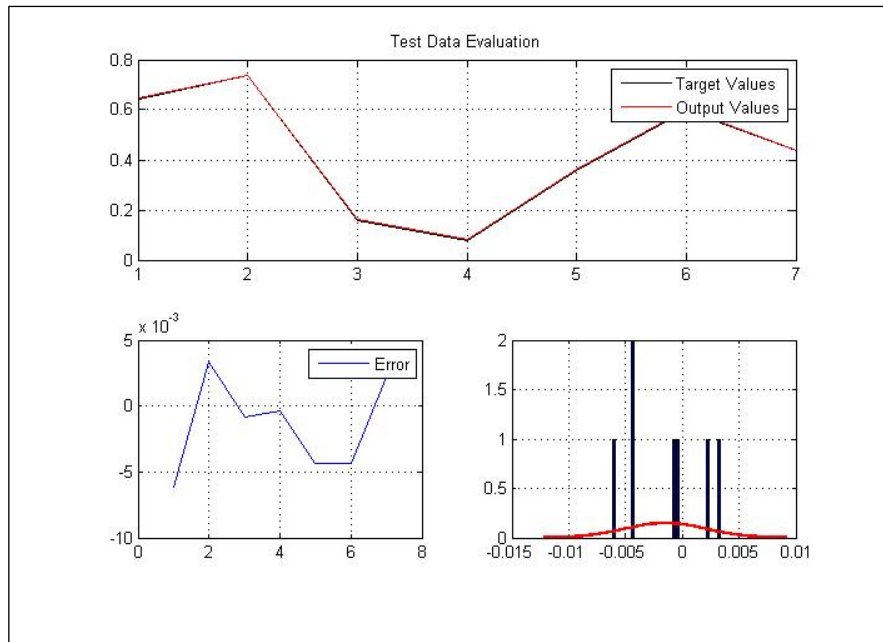
(c) All data sets

Figure 5. PSO-ANFIS model, Sub clustering type of ANFIS: (a) Training data set (b) Testing data set (c) All data sets

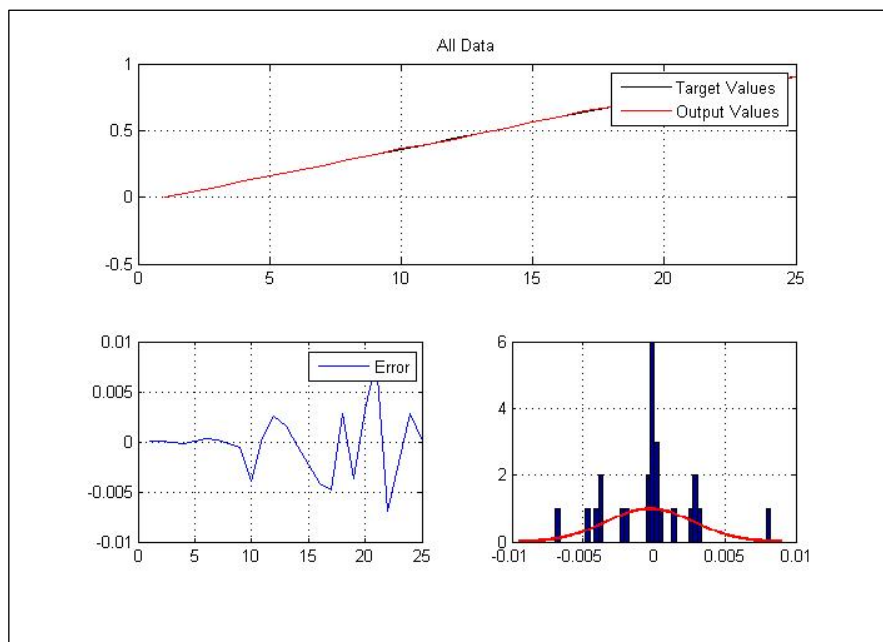
It is clear from Table 4 that the sub-clustering ANFIS structure with hybrid PSO optimization method has the least test error. Training and test results are shown in Figure 7. As can be seen from Figure 5, learning errors are concurrent around zero. Testing errors are also close to zero.



(a) Training data set



(b) Test data set



(c) All data sets

Figure 6. PSO-ANFIS model, FCM type of ANFIS: (a) Training data set (b) Testing data set (c) All data sets

Based on Table 5, FCM of ANFIS structure with PSO training algorithm has the least test error. As shown in Figure 6, the FCM type of ANFIS has training errors around zero. Testing errors are also close to zero. That is another reason for efficiency of the model in predicting the best network and decision-making of handover.

Using this last FCM type of ANFIS structure, we have demonstrated the PSO-ANFIS model for handover prediction through graphical representation, as shown in the Figures 7–12.

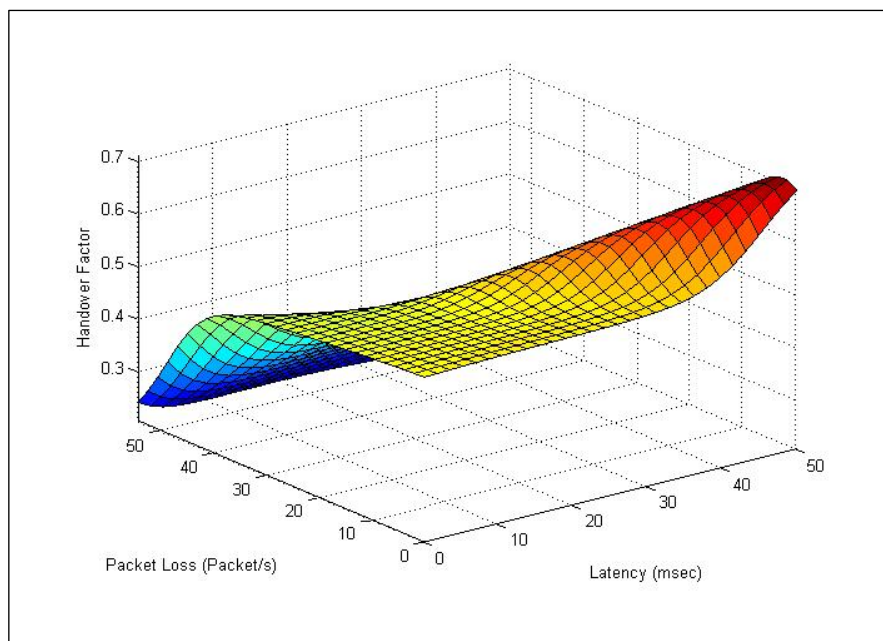


Figure 7. Handover factor versus latency and packet loss

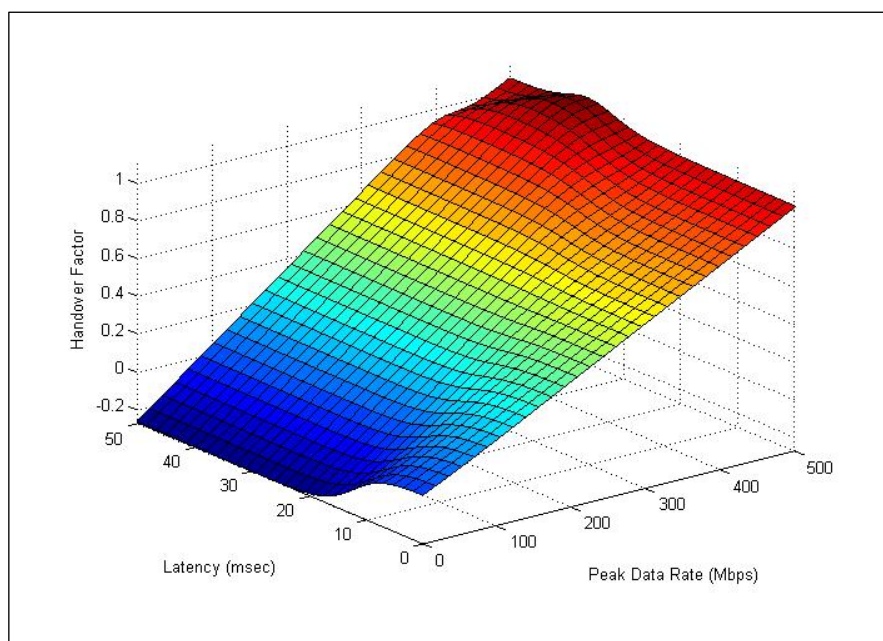


Figure 8. Handover factor versus latency and peak data rate

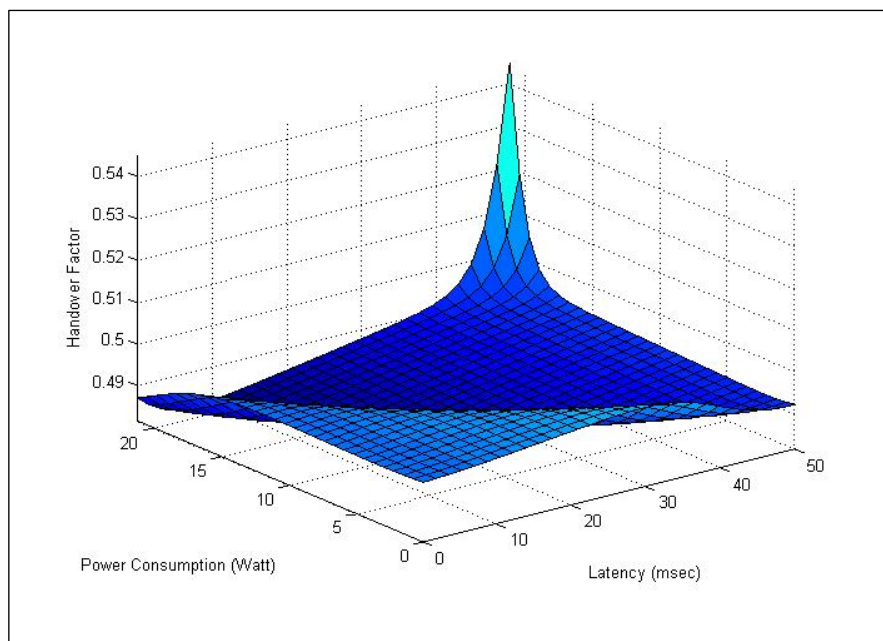


Figure 9. Handover factor versus latency and power consumption

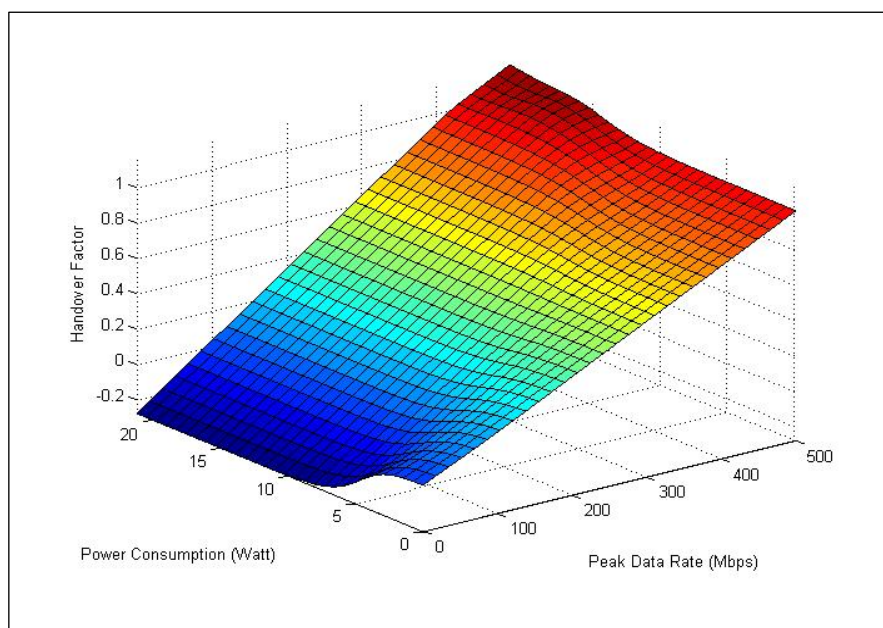


Figure 10. Handover factor versus peak data rate and power consumption

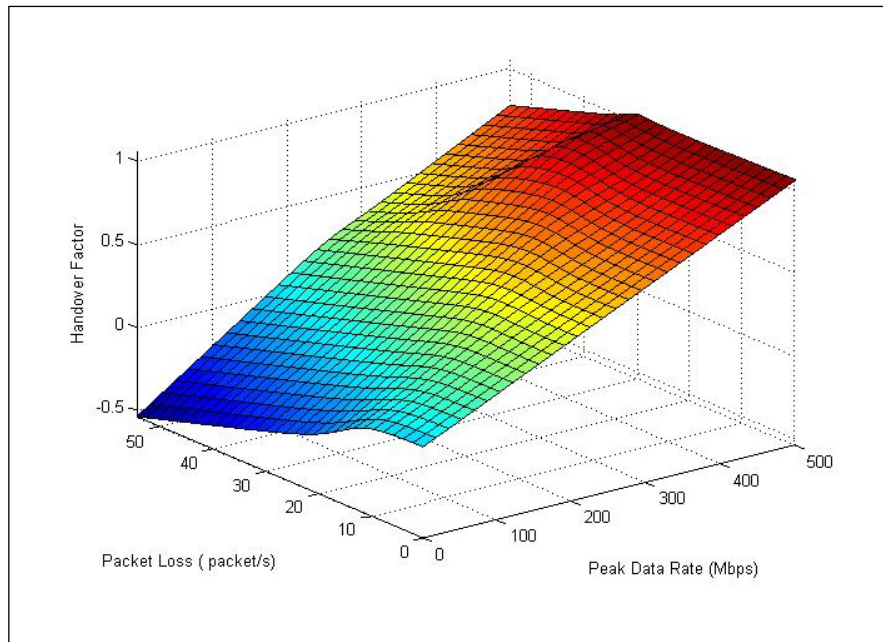


Figure 11. Handover factor versus peak data rate and packet loss

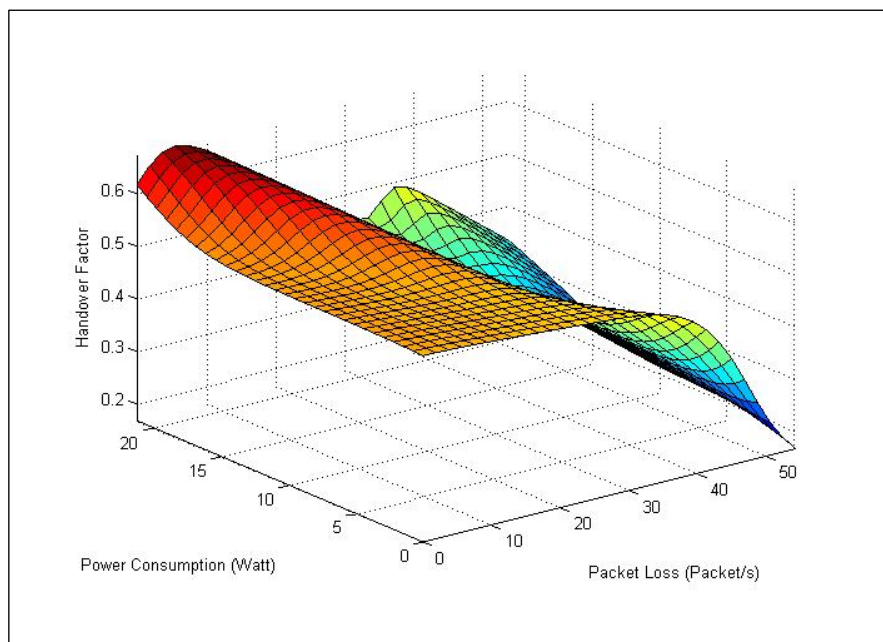


Figure 12. Handover factor versus packet loss and power consumption

The ANFIS-PSO surface for handover decision is shown in Figures 6, 7, 9, 10, 11 and 12 for the four parameters: peak data rate; latency; packet loss; and power consumption. If the handover factor is larger than 0.7, the decision should be executed and the mobile station initiates handover to chosen LTE-A; and when the handover factor is smaller than 0.7, the decision should not be executed and the mobile station stays in the current access network (LTE).

It can be seen from Figures 7, 9 and 12 that, when the latency, packet loss, and power consumption are high, the system chooses to not perform a handover. Otherwise, when the peak data rate is high and the latency or power consumption is weak, the

system chooses to perform a handover from LTE to LTE-A network, as shown in Figures 6, 10, and 11.

According to these figures, the proposed PSO–ANFIS model can provide higher performance in estimating handover compared to the ANFIS model.

Comparison between vertical handover algorithms

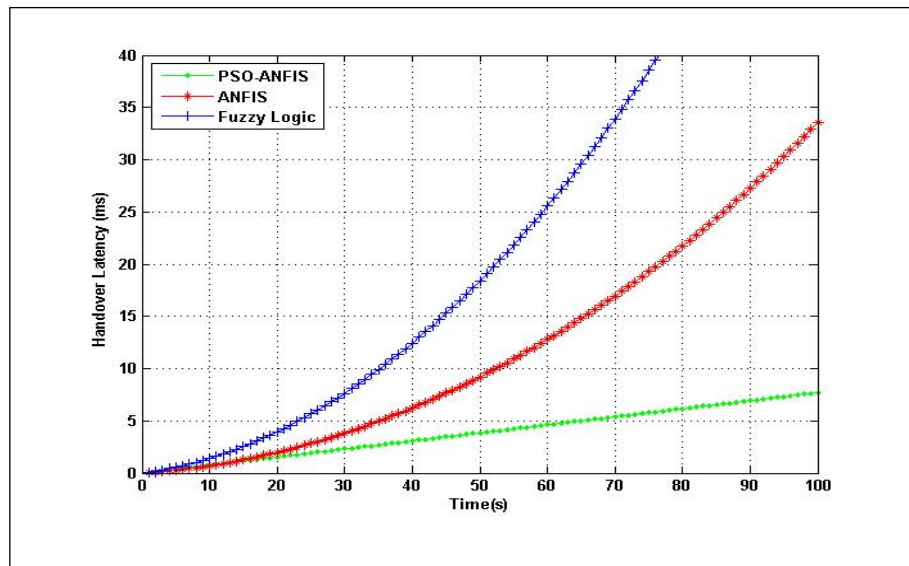


Figure 13. Handover latency comparison between the fuzzy logic, ANFIS and PSO-ANFIS approaches

Figure 13 illustrates the handover latency for the VHD approach based on fuzzy logic, ANFIS, and PSO-ANFIS hybrid. It can be seen that our approach based on PSO-ANFIS reduced the handover latency.

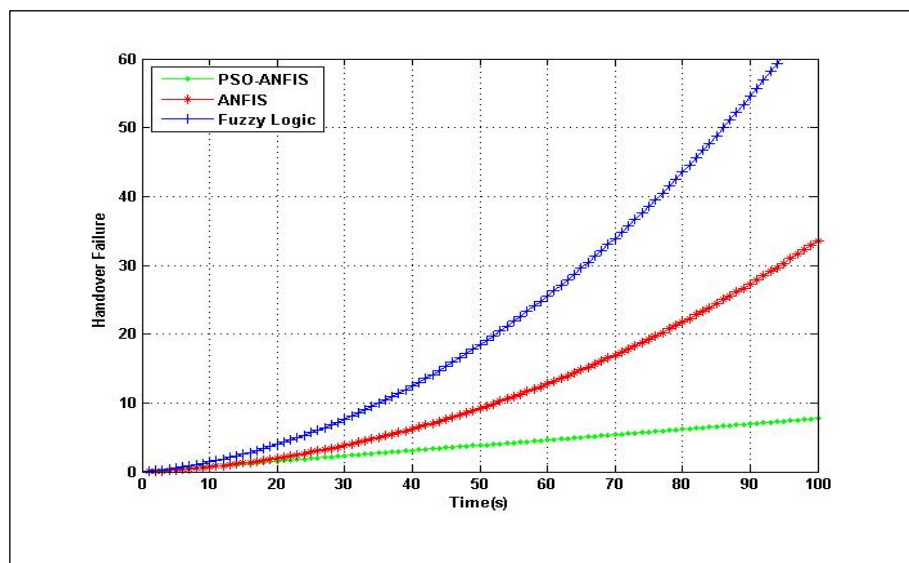


Figure 14. Handover failure comparison between the fuzzy logic, ANFIS and PSO-ANFIS approaches

Figure 14 illustrates the handover failure for the vertical handover decision (VHD) based on the fuzzy logic, ANFIS, and PSO-ANFIS hybrid approaches. It can be seen

that the VHD-based PSO-ANFIS approach results in a substantial reduction in comparison to the other approaches.

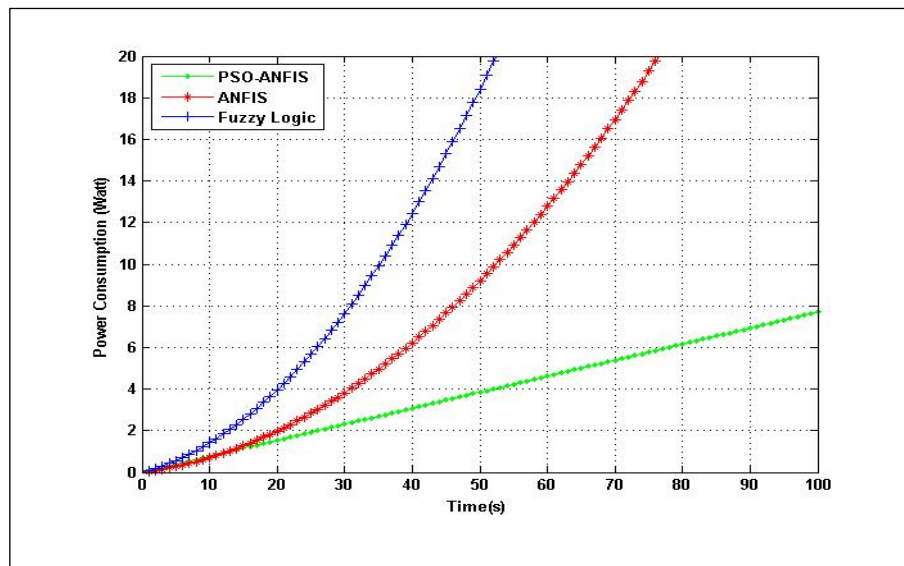


Figure 15. Power consumption comparison between the fuzzy logic, ANFIS and PSO-ANFIS approaches

In different networks, the energy consumption of the terminal devices differs. The users generally choose the network with lower energy consumption. The simulation results in Figure 15 show that the VHD-based PSO-ANFIS leads to lower energy consumption compared to fuzzy logic and ANFIS.

Therefore, it can be concluded that the VHD based on hybrid and soft computing techniques provides an overall better performance than other vertical handover algorithms.

Conclusion

This research has proposed a hybrid approach based on an adaptive neuro-fuzzy inference system (ANFIS) to enhance the accuracy of the handover decision algorithm between LTE and LTE-A networks, as well particle swarm optimization (PSO) to improve the ANFIS performance and to achieve a good forecasting accuracy of the target network during a movement of a mobile terminal from a serving base station to a target base station. Performance evaluation results show that the proposed approach based on PSO-ANFIS reduces and minimizes the effect of handover latency and the power consumption in the network by calculating the statistical parameters R2, RMSE, MSE, and StD. The comparison and simulation results show that the hybrid PSO-ANFIS model has better performance than other approaches in terms of prediction accuracy, reduction of handover latency, and power consumption in the network. Future work will focus on the implementation of an optimal prediction method for the handover decision-making process based on deep learning.

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The Broadband Futures Forum

Affordability of Broadband Services

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Adjunct Professor, RMIT University

Johanna Mithen

Social Inclusion Project Manager, North East Healthy Communities

Abstract: On 25 August 2021, TelSoc hosted the ninth Broadband Futures Forum, held online, to discuss the affordability of broadband services in Australia. A panel of four speakers, drawn from broadband providers and social policy advocates, outlined their experiences with affordability and digital inclusion. Discussion following the speeches ranged over the topics of a broad social policy response, the definition of affordability in relation to financial hardship, the provision of public Wi-Fi, and the availability of suitable devices.

Keywords: Broadband, affordability, social policy

Introduction

The Broadband (formerly NBN) Futures Project ([Holmes & Campbell, 2019](#)) has been organizing a series of public forums under the title Broadband Futures to encourage debate, and potentially to build consensus, about the future of Australia's National Broadband Network (NBN) and a National Broadband Strategy for Australia ([Holmes et al., 2020](#)). The forums are hosted by TelSoc (the Telecommunications Association Inc, publisher of this *Journal*) and have been held regularly since July 2019.ⁱ The ninth in the series, held on 25 August 2021, was entitled "Affordability of Broadband Services" and provided some insight into how affordable fixed and mobile broadband services are for low-income households in Australia and what solutions there might be for improving digital inclusion. Specifically, the forum was designed to address three critical questions:

- How can the objective of affordable broadband services for all Australian residents, especially low-income households, be realised in the emerging markets of fixed and mobile broadband?
- What solutions may be available from retail markets or from regulation?

- Is this a matter for social policy solutions by the Government?

The remainder of this paper summarizes the content of the Forum.

The NBN Futures Forum

The Forum was conducted online via Zoom, with at least 83 participants online.

Introduction

Mr John Burke, convenor of the Broadband Futures Group, introduced the topic and the panellists. He outlined the work of the Group over the past 2½ years, emphasising, in particular, the focus on inclusion in the digital economy and society. He noted that in the recent Digital Economy Strategy ([Australian Government, 2021](#)) there was an absence of consideration of broad issues of inclusion as underpinning the future digital society. Through this consideration, TelSoc had proposed to the Minister of Communications a review of inclusion and affordability for broadband services ([Herring, 2021](#)).

John Burke suggested that the understanding of affordability is often different between policy perspectives, commercial and business perspectives (to deliver broadband services economically), and user perspectives. Discussion, as in the present forum, is needed to identify common ground.

Teresa Corbin, Australian Communications Consumer Action Network (ACCAN)

Ms Teresa Corbin, the CEO of ACCAN, began her remarks by noting that ACCAN has championed broadband affordability for the past decade. Evidence has been built up by ACCAN and others, including the Australian Digital Inclusion Index ([Wilson, Thomas & Barraket, 2019](#)), that there is an issue with affordability of broadband services. ACCAN's latest proposal, "No Australian Left Offline" ([ACCAN, 2019](#)), is that Australia's National Broadband Network (NBN) should offer a 50 Mbps unlimited broadband access at a wholesale rate of \$20 per month (about \$30 per month retail price) to households receiving government financial support. She indicated that this proposal had garnered widespread support from potential users and other social organizations.

Teresa Corbin outlined how the COVID crisis had increased the perception of the importance of broadband affordability. Overall, people had spent many more hours online and those with the necessary skills had taken up videoconferencing, remote learning and telehealth. For unconnected communities, however, the lack of connectivity has proved to be a great disadvantage. The lack of affordable broadband has meant that school pupils are unable to keep up with schoolwork and interact socially, while young people in transition to work have

been unable to access training and skills development. For those on low incomes, it has hampered the search for better-paid employment. For the elderly or those with limited mobility, social interaction has been reduced. ACCAN has collected many stories of families, unable to afford a fixed broadband connection, struggling with a single mobile hotspot from a parent's phone to stay connected to school or work, a near impossibility in many cases.

Teresa Corbin believed that an effective response cannot be left to the market alone. She acknowledged that there were initiatives from NBN Co, retail service providers and mobile service providers early in the COVID pandemic, but the response has not been sustained at the same level in later lockdowns.

To gain an understanding of what assistance is available for low-income households, ACCAN commissioned a study in early 2021. From 217 providers, 16 relevant programs were identified: 11 from Telstra, 1 from Optus, and the others from smaller retailers, including Start Broadband. It was found that these programs are not always easy to access, nor were the eligibility criteria clear in many cases. They were not necessarily well advertised. ACCAN compiled the list of offers and displayed them on its website.

In conclusion, Teresa Corbin reiterated the importance of no Australian resident being left offline. She believed that the ACCAN proposal of an NBN broadband service for low-income households was the best way to achieve this result.

Ken Walliss, NBN Co

Mr Ken Walliss is Executive General Manager, Commercial, at NBN Co and has been leading recent NBN Co consultations on low-income offers and digital inclusion.

He began by noting that NBN's stated purpose now includes lifting the digital capability of Australia. This is seen as a key enabler of social and economic value, as well as supporting productivity in the economy. He outlined NBN Co's observation that the perceived value of broadband had increased during the COVID responses, with remote learning being a key driver of increased use of the Internet.

He indicated that NBN Co had spent considerable effort in engaging with consumer and industry groups to understand the issues around digital inclusion. He suggested that there was no single solution for improving digital inclusion; rather, multiple initiatives would be needed, such as NBN Co's education package, which waived access fees to assist service providers in connecting low-income households with home-schooling needs.

One challenge, he noted, was affordability, but accessibility and digital competence are also significant. On affordability, he referred to a report from Accenture ([Accenture, 2021](#)) commissioned by NBN Co, which was published about one month after the Forum. He

indicated that the report would show favourable price comparisons with other OECD countries and would calculate that, on average, broadband costs are about 1.1% of weekly household income, less than the average cost of electricity. He emphasised that NBN prices had to be set to provide financial sustainability for NBN Co in the longer term.

He outlined other NBN Co initiatives: a reduction in price for the entry-level service; a COVID-19 relief package; and targeted support for Retail Service Providers (RSPs) to connect unconnected customers. The entry-level wholesale price is now \$22.50 per month. The COVID-19 relief package had included distance learning, support for emergency services, and support for RSPs to keep customers in financial difficulty connected. He foreshadowed that from 1 September 2021 there would be a rebate available to RSPs to help them connect unconnected premises.

He noted that the Australian Competition and Consumer Commission (ACCC) is considering NBN Co's Special Access Undertaking (SAU), including pricing issues. NBN Co has proposed a targeted low-income offer in consultations with the ACCC and the industry. The feedback has been that there is a preference for broader targeting and even lower prices. The financial implications of lower prices are being actively considered in discussions with the ACCC on the SAU. The entry-level price will also be a consideration for the SAU.

In summarizing, Ken Walliss reiterated that NBN Co continues to work on affordability – and also accessibility and digital literacy – both for the SAU and in discussions with the wider industry, while keeping in mind the need for ongoing support for broadband in Australia.

Johanna Mithen, North East Healthy Communities

Ms Johanna Mithen is the Social Inclusion Project Manager for North East Healthy Communities, a primary care partnership in north-east Melbourne that works to support partner organisations including community health organisations and local government.

Digital inclusion became an especially important issue for local communities in 2020, when COVID-related lockdowns started to happen. Johanna Mithen pointed out that community health organisations often work with highly disadvantaged local communities. It became difficult for staff to maintain contact with community members, because the community members were often running out of prepaid data allowance on their mobile services. There were also reports of cancelled telehealth appointments because of insufficient mobile data allowance. In addition, access to free Wi-Fi at centres and libraries decreased due to COVID restrictions.

Johanna Mithen emphasised that digital inclusion is an increasingly important aspect of social inclusion. One often cannot easily access government services or search for accommodation

or work except online. Those who experience digital exclusion are likely to suffer a greater degree of social exclusion in the future as more services move onto the Internet.

She questioned why some people were running out of prepaid mobile data allowance. Anecdotal evidence suggests that some people are unaware of how much data they have, and how much data is needed for specific tasks. For others, it is because they are only able to afford prepaid data at low price points. A market scan in August 2020 showed that the unit price for 1 GB of data allowance was very high at low price points (e.g., \$10) and with a very short expiration period (e.g., less than one week). The offers can also be complex, with “roll-overs” and “bonuses”, making it difficult for customers to compare which options offer the best value.

She emphasised that, moving forward, we need data that gives us a nuanced understanding of digital exclusion. She suggested that it was important not to think of those facing affordability issues as a homogenous group. There may, for example, be large families of 5 or more Internet users; or old people living alone with a low but stable income; or young people whose housing and income are unstable. There may also be other barriers to Internet use, such as a lack of skills, old or difficult-to-use devices, or difficulties in navigating the consumer market. She emphasised that listening to community voices is essential in finding solutions to digital exclusion. She suggested we keep in mind the relationship between Internet affordability and poverty in general, and posed the question: “What does Internet affordability mean for people experiencing affordability issues relating to housing, food and utilities?”

Given this environment, a “one size fits all” solution is unlikely, and a variety of solutions may be needed. She considered that a low-cost home broadband service, as advocated by ACCAN, would work well for some. A fair and reasonable mobile prepaid data plan at a low price point would also be necessary. In addition, free access to Wi-Fi is available at some centres and public spaces and could be extended to social housing. She noted, however, that local efforts to extend free Wi-Fi to a nearby social housing estate had suffered various challenges due to the layout and age of buildings.

In the broader picture, Johanna Mithen noted that increased investment in public and social housing presents an opportunity to plan and implement digital inclusion solutions for future residents.

Andrew Whelan, Start Broadband

Mr Andrew Whelan is the Managing Director of Start Broadband, a broadband retailer with an emphasis on getting people connected at home.

He started by noting how domestic service delivery has changed since the 1990s, with home-delivery takeaway ordering, banking and payments, and access to music and videos all

dependent on Internet access. That is, for many Australians – but not for all – engagement with the Internet has changed dramatically. For others, a lack of access has consequences.

Start Broadband believes that every family deserves access to a home Internet connection. Andrew Whelan indicated that about 2 million Australians are not online and 40% of the lowest income families are without a home Internet connection. He suggested that these families will remain at financial and social disadvantage. Start Broadband donates 50% of company profits towards providing a home Internet connection for low-income families, thereby opening up new opportunities and helping to break the poverty cycle.

He proposed that consumers had a role to play, along with the government, NBN Co, retail service providers and other stakeholders, in redirecting some of the money they pay for home Internet services to support getting the unconnected online. He cited examples from other industries of consumers choosing a product that “makes a difference” to alleviate poverty or social disadvantage.

He described what he believed a successful low-income Internet access product should contain. It should have adequate data and speed inclusions to meet education and work requirements; it should stand as an affordable product in its own right, without price rebates or time-limited price discounts; it should enable a provider to qualify customers at the point of sale, without manual intervention; it should permit remote support for modems to maintain quality of service; and it should be supported by appropriate systems and processes. On the latter point, he noted that bad debts need to be managed fairly, to ensure that they did not build up.

As a conclusion, Andrew Whelan recounted the story of an immigrant family living in poverty for which a home Internet service had assisted with access to education and work qualifications, laying the foundations for improved social circumstances.

Questions and Discussion

John Burke first invited the panellists to ask questions of each other or provide further comment.

Teresa Corbin noted the earlier emphasis on prepaid mobile services and asked if fixed broadband could also be prepaid. Ken Walliss suggested that NBN pricing was such that an RSP could offer a prepaid service. Johanna Mithen pointed out that prepaid is also a method for managing debt and the risk of falling into debt. Andrew Whelan, while believing that a prepaid broadband service would be suitable for some customers, noted that prepaid also implied that a service could run out and this would need to be managed. Teresa Corbin reported that ACCAN had had feedback from some groups, including Indigenous

communities, that prepaid is a common method for households to manage their finances and would be a preferred option. She noted that a prepaid option should be offered at a price that did not include a “poverty premium”. Johanna Mithen supported the need to listen to community responses and suggested that a range of offers, include prepaid services and home Internet access, would be required to respond to community needs.

Ken Walliss responded to a comment from a participant (in the “chat” window of the Zoom session) on possible retail offerings that NBN Co cannot be a retail provider under its current legislation. If it were to become a “retail provider of last resort”, for example, it would require legislative change.

Andrew Whelan noted that Start Broadband works with some customers for whom *any* broadband solution is unaffordable. He asked if there were any solutions for these customers. Teresa Corbin indicated that ACCAN had received feedback that its proposed subsidised fixed broadband service would still be unaffordable for some households. Prepaid mobile offers would still be needed. She observed that free public Wi-Fi services had security and privacy issues. Responding to the full complexity of affordability issues is important.

Ken Walliss suggested that one complexity is that households may be in need only temporarily. He noted that NBN Co’s COVID relief package had included provisions to support retailers in managing customers who may need credit relief in the short term.

John Burke then guided the discussion through the issues that had been raised by participants while the panellists were speaking.

At the broad social policy level, it was suggested that, rather than provide subsidies for fixed broadband, it may be preferable just to raise the level of income support. Teresa Corbin outlined the earlier problems with eligibility for telephone concessions and the discussions ACCAN had held with various stakeholder groups. She suggested that the approach via subsidised access had the benefit that it directly provided for getting more people online. A member of the audience observed that it may still be preferable to raise the level of income support and let families choose how they spend that money. Ken Walliss suggested that a greater understanding of the reasons for unaffordability was needed before appropriate policy could be developed. Johanna Mithen remarked that pragmatic approaches are needed to make a difference to digital and social inclusion. Andrew Whelan noted that a concession has the direct effect of making an essential product more affordable.

There had been some comments on how “affordability” should be defined in designing responses. Is it about averages or the lowest percentiles of income? Should it be understood in terms of affordability of specific offerings for particular social groups?

Ken Walliss noted that his earlier remarks were largely based on averages – average prices and average incomes. He recognized, however, that affordability can depend on individual circumstances and priorities, as well as transitory issues such as a period of unemployment. Teresa Corbin noted that the issue was related to management of financial hardship. She reported that the ACMA has recently released some data on responses to financial hardship and is looking to overseas experience. She suggested that options for payment plans or temporary waivers of charges should be highly visible to customers and be easily available for valued customers. Andrew Whelan reiterated that an agreed definition of affordability would be required if service providers are to be able easily to identify customers eligible for relief.

Regarding free public Wi-Fi, Andrew Whelan suggested that, while the Wi-Fi service is valuable, it is not a substitute for a fixed broadband connection into the home to support, say, education of children. Johanna Mithen noted that some people are currently dependent on public Wi-Fi to reduce their mobile charges and to stay connected. For large families, a home Internet connection would be beneficial. Again, multiple solutions for different circumstances are required. Teresa Corbin suggested that COVID-related lockdowns had changed both the ability to access free Wi-Fi and the use to which broadband is being put. For example, some people are using public Wi-Fi for video conferencing, but it is not common or ideal. In addition, technical support through public libraries or community centres has not been accessible. She suggested that, in any case, all payphones should be equipped with open-access Wi-Fi, as happens in some Indigenous communities and in some other countries.

On the question of affordable devices, Teresa Corbin reported that there are cheaper devices available but they are not well publicised; customers are often directed instead to the most expensive options. She emphasised again that there would be some customers for whom any available device would be too expensive. Johanna Mithen noted that suitable devices are one of the many barriers to good online access. She has seen cases where devices being used for access were difficult to use and not really fit for purpose. This is part of the more general issue of digital literacy and confidence. Having one-on-one technical support in local libraries has been found to be advantageous.

In closing the discussion segment, John Burke thanked the audience for the wide-ranging discussion and invited further contact with the Broadband Futures Group. He especially thanked the panellists for their contributions.

Jim Holmes: Closing Remarks

Jim Holmes, President of TelSoc, also thanked the audience for their participation, which had enriched the understanding of the issues related to affordability of broadband. He suggested

that improving digital inclusion is important for achieving the desired social and economic benefits from broadband.

He noted that much work had been done by a wide range of groups but it was somewhat uncoordinated. He indicated that the Broadband Futures Group also looked to greater involvement by the government. To that end, TelSoc had recently proposed to the Minister of Communications that there should be a review of digital inclusion and affordability of broadband services ([Herring, 2021](#)). The proposed review should focus on three main issues: the current status of affordability and digital inclusion in Australia; the factors contributing to improvements in affordability and digital inclusion; and approaches to be taken for improvements over the next five years. Jim Holmes indicated that TelSoc would welcome comments on this proposal.

Conclusion

This was the ninth of a planned series of forums related to the future of the NBN and a broadband strategy for Australia. It was the first to be devoted to affordability of broadband services as a specific aspect of digital inclusion. There was general agreement that the desired social and economic benefits of broadband could not be fully achieved if there was significant digital exclusion, which will increasingly lead to social exclusion.

All speakers agreed that the issues of affordability and social exclusion were complex and multi-faceted, leading to a multiplicity of responses. There could be no “one size fits all” solution. ACCAN had been advocating for a subsidised entry-level home broadband service for those households receiving income support. It was agreed that this proposal would be helpful in some cases, especially for large households struggling with access to remote learning and job seeking. However, even a \$30 per month Internet access would be unaffordable for some households.

Mobile broadband will therefore provide a significant portion of the solution. Prepaid plans are particularly important, because prepaid better matches the budget management of those on low or irregular incomes: they can purchase small quantities of access at low cost. At present, however, these prepaid plans come with a “poverty premium”: that is, the unit cost of a GB of data is much higher than on more expensive plans and the expiration periods may be quite short. Without further refinement, then, these plans provide for only intermittent access for those suffering financial hardship.

No cost (to the end user) solutions will also play a part. Various free public Wi-Fi initiatives were mentioned by the panellists, together with advocacy for extensions of these programs to public and social housing. Fee-free solutions, especially Wi-Fi, will be part of the mix, but the

issues of security and privacy will need to be addressed. Free technical support, to get users connected and confident, will also be required, as now provided by some public libraries and community centres.

The broadband providers noted the need for long-term financial viability of any solutions, including the ability to invest in improved services and technologies. At best, solutions for affordability issues should be stand-alone products in their own right and be straightforward for providers to implement. As Start Broadband has shown, there can also be a social responsibility dimension to broadband provision: some part of the profits can be ploughed back into supporting customers who would otherwise be disconnected.

While there was a strong emphasis on the capacity of industry to provide products that improve the affordability of services, there was also clear recognition, particularly within the comments by participants, of the limits on some people to pay for essential services — particularly remote Indigenous Australians and people living in poverty. The effectiveness of provider offerings and support, such as the Centrelink Telephone Allowance, needs further consideration, as does the broader question of the adequacy of income support to ensure access to essential services.

The issues of affordability and digital inclusion are part of the wider arena of public policy. In Australia, the government has underwritten, through NBN Co, the provision of fixed broadband access potentially to all premises. This has been a major undertaking but barriers to take-up remain, of which affordability and digital awareness are significant components. There is a greater role for government in support of digital inclusion. In this regard, TelSoc has proposed a government review of digital inclusion and affordability, as a first step in designing future government programs and making measurable progress over the next five years.

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Endnote

ⁱ The first forum was held in July 2019 ([Campbell & Milner, 2019](#)), the second in October 2019 ([Campbell, 2019](#)), the third in February 2020 ([Campbell, 2020a](#)), the fourth in August 2020 ([Campbell, Smith & Brooks, 2020](#)), the fifth in November 2020 ([Campbell, 2020b](#)), the sixth in March 2021 ([Campbell, 2021a](#)), the seventh in May 2021 ([Campbell, 2021b](#)), and the eighth (on LEOs for broadband) in August 2021.

Revisiting the Power Co-ordination Challenges of the Original Snowy Mountains Scheme

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Abstract: The Snowy Mountains Scheme (1949–1972) was an Australian hydro-electricity generation triumph. However, the power co-ordination challenges were significant before the invention of fibre optic cable, as this historic paper from June 1964 attests.

Keywords: history, telecommunications, Snowy Mountains scheme, power co-ordination.

Introduction

Power distribution and telecommunications are strange bedfellows but their marriage was essential to the success of the Snowy Mountains Scheme. Traditionally, power co-ordination is concerned with minimising low frequency electromagnetic interference in communications cabling due to the proximity of high voltage power conductors, and avoiding dangerous earth potential rises due to electromagnetic coupling from faults and imbalances in the power infrastructure. The historic paper ([Muir & Lochhead, 1964](#)), which follows, details the magnitude of the challenges, given the huge generation capacity being provided in the Snowy scheme and its relative inaccessibility, forcing telecommunications and power infrastructure to share the same easements for maintenance reasons. All this occurred well before fibre optic cable became generally available to the telecommunications designer.

To make matters worse, the high soil resistivity in this rugged mountain terrain aggravated the coupling between telecommunications routes and adjacent high voltage power infrastructure. Several examples are given where the earth potential rise under fault conditions at the Jindabyne Zone Sub-station and Upper Tumut Switching Station could reach 4,000 and 8,000 volts, respectively. Special care is required when the earth potential rise exceeds around 1,000 volts, as the use of gas arrestors is no longer satisfactory.

The historic paper discusses a number of telecommunications mitigation techniques, including installing cabling well clear of power station earth mats, prudent selection of cabling

in respect of type of insulation and breakdown voltages, floating earths, installation of fuses, as well as isolation or neutralising transformers. The maintenance of these transformers needed to be carried out by personnel trained in high voltage techniques because dangerous voltages could appear on either type of transformer during a fault situation.

The paper also provides an example of a significant interference problem on the trunk route between Kiandra and Cabramurra, where several mitigation actions were undertaken but were only partially successful. It illustrates the complexity of power co-ordination situations, where conductive and inductive effects invariably exist together. It also emphasises that the most important potential difference between line wires and local earth can occur at any point, depending upon the location of the power fault. This fact is particularly important in designing protection, so that arrestors are deployed along the route to reduce the possibility of big differences in potential between lines of differing lengths along the same route.

The Snowy Mountains scheme was continuing to evolve in 1964 when this historic paper was written. The power co-ordination requirements needed to be continually reviewed as more generation capacity came on line and the potential for fault situations increased. This requirement was eased in the longer term with the availability of fibre optic cable, which is largely immune to electromagnetic interference.

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The Historic Paper

June, 1964

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POWER CO-ORDINATION IN THE SNOWY MOUNTAINS AREA

R. J. MUIR, B.E.(Hons.)* and R. A. LOCHHEAD, Dip.E.E., A.M.I.E.E., A.M.I.E.Aust.**

INTRODUCTION

The Snowy Mountains Scheme is the largest engineering works ever attempted in Australia and is one of the largest in the world. It involves the construction of seven major dams, 11 power stations, over 80 miles of large diameter tunnels, miles of aqueducts, shafts ranging up to 1,100 ft. deep and hundreds of miles of mountain roads in rugged alpine country. Its purpose is power generation and diversion of waters inland to provide irrigation. By 1970 it is anticipated that 2,555 megawatts of power will be available from the area. Fig. 1 shows the general layout of the scheme including the disposition and capacity of the generating stations. Table 1 lists for comparison some data about power generating capacity in Australia.

Because of the remoteness and poor accessibility of the working sites, good communications have been essential to the Scheme since its inception. Reliability of service is paramount and is complicated by the rugged terrain and the extremely severe climatic conditions. Within the Snowy Mountains Hydro-Electric Authority's (S.M.A.) own organisation, radio circuits are used to maintain contact throughout the area to construction sites and to vehicles; radio provides a high degree of flexibility enabling equipment to be recovered and reinstalled at new sites as required, and avoids the need for special land lines designed to withstand the severe winter condition at high altitudes. Public telephone service in the area is the responsibility of the Postmaster-General's Department. This is provided by aerial wires or cable in most cases, both for economic reasons and because radio would not cater fully for local reticulation to subscribers in exchange areas which are sometimes only separated by radial distances of up to 10 miles. Radio is used, however, for communication between some of the major exchanges in the area.

The choice of location of telephone circuits has proved difficult, especially in the mountainous regions, because of the need for adequate separation from power lines and H.V. switching stations to avoid power interference and because of the need for a route which is relatively accessible for maintenance purposes. The position is worsened by the high soil resistivity of the region which aggravates the coupling between telephone routes and adjacent power plant. Even with wide separation of telephone and power plant the induced voltages can be high as a result of the high earth resistivity when combined

with the high fault current levels which exist on most of the power lines. Apart from the obstacles imposed by the geography of a mountainous area, the combined growth of telephone and power lines has increased the difficulty of keeping these lines mutually separated. At the present time the total length of power transmission lines in the Snowy is 290 miles, including 40 miles of 330 KV steel tower routes while main telephone trunk routes extend for a distance of 215 miles. This distance does not include subscribers' lines.

The technical difficulties which have to be overcome in developing a telephone network for the Snowy Mountains area and to ensure that telephone plant is properly safeguarded from power interference have necessitated a high degree of co-ordination and special consideration in the design of all telephone plant. The standards adopted are those laid down in the Directives of the International Telephone and Telegraph Consultative Committee (C.C.I.T.T.) for the protection of telecommunication lines against the effects of longitudinal voltages caused by nearby power lines. These Directives recommend that the longitudinal voltage should not exceed 430 V R.M.S. or, in the case of high security power lines, 650 V R.M.S. if hazard to personnel or undue stress on equipment is to be avoided.

Most HV power lines in Australia operating at 66 KV or higher fall in the category of high security by virtue of their high standard of electrical and mechanical construction. Further safeguards are provided by the preventive maintenance techniques adopted by most power authorities and the high speed fault clearance equipment fitted to their main transmission lines. On power lines operating below 66 KV the average

fault clearance time may vary between $\frac{1}{2}$ sec. to 2 sec. and lines so protected are not considered to come within the high security category.

GENERAL CO-ORDINATION ASPECTS

Co-ordination of power and telecommunication construction is required to avoid noise in telephone circuits, and to prevent creation of potentials on telephone lines which may endanger telephone plant, telephone users, or workmen in contact with telephone lines or equipment.

The noise is usually associated with the normal operation of the power lines and results from the presence of unbalances and harmonics in the power system, concurrent with the presence of unbalances in the telephone system. As power lines in the Snowy Region carry well balanced currents, and have a low harmonic content, little noise interference is experienced. On the other hand, dangerous voltages on telephone lines result from fault conditions on the power system, and are a function of the capacity of the power source and the mutual impedance between the power and telephone circuits. The mutual impedance is primarily dependent on the separation between the two circuits and on the resistivity of the earth. The value of the mutual impedance increases with increasing soil resistivity. These problems have been discussed in detail by various authors (1), (2), (3), (4), (5).

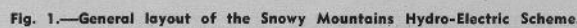
In the Snowy Mountains area most difficult conditions for power co-ordination exist because, firstly, large amounts of power are being generated at the hydro-electric power stations and distributed at extra high voltages; secondly the rugged terrain restricts

TABLE 1.—PUBLIC POWER GENERATING CAPACITY AND MAIN POWER STATIONS IN AUSTRALIA AT 30/6/62

Location of Station	Capacity of Main Stations	Total Capacity
New South Wales		2,989 megawatts
Snowy Mountains	660 megawatts	
Bunnerong	375 "	
Other Stations in Sydney	479 "	
Wangi	330 "	
Tallawanna	320 "	
Victoria		1,676 "
Yallourn	621 "	
Stations in Melbourne	408 "	
Queensland		767 "
Stations in Brisbane	518 "	
South Australia		559 "
Port Augusta	270 "	
Western Australia		331 "
Tasmania		594 "
Commonwealth Territories		43 "
Total for Commonwealth		6,959 "
Major Stations under Construction		
Vales Point (N.S.W.)	875 megawatts	
Munmorah (N.S.W.)	1,000 "	
Hazelwood (Vic.)	1,200 "	
Ipswich (Q'ld.)	360 "	
Snowy Mountains	1,900 "	

* Mr. Muir is Engineer Class 3, Transmission Planning, N.S.W. See page 334.

** Mr. Lochhead is Engineer Class 2, Transmission Planning, N.S.W. See Vol. 12, No. 4, page 298.



A potential gradient will also exist round the electrode while current is passing through it which extends over a definite area around the electrode.

The formula accepted for use in determining the extent of the gradient area is:

$$V = \frac{I\rho}{2a}$$

Where V volts is potential of the earth at a distance 'a' metres from the earth electrode in soil of resistivity ρ metre ohms when a current of I ampere is flowing to earth via the electrode. This formula gives a voltage for small values of 'a' in excess of the maximum earth mat potential rise, which equals IR_0 where R_0 = resistance of the earth mat to earth, for the normal installations where R_0 = 0.5 ohms. The formula therefore provides a margin of safety for distortion of the gradient due to geological irregularities, buried conductors such as water pipes, etc. For accurate application of the formula it is necessary to determine the earth resistivity at the depth of the actual main current path, whereas normal measurements, using an earth megger, give

values for nearer the soil surface. An alternative approximation is that the potential drops to one half at a distance from the earth mat perimeter equal to half the diagonal. The extent of the potential gradient increases with increased soil resistivity.

Wherever possible, actual measurements of gradient distribution are made by passing a known current to earth through the station mat and measuring the potential rise of earth stakes with respect to remote earths.

Effect of Ground Potential on Communication Circuits

When a fault current flows to the neutral ground at a power station the potential of the station ground rises relative to remote earth. As far as the power system is concerned there is no particular harm in this unless the potential gradient within or near the station becomes so great as to constitute a danger to the personnel by way of potential differences in the station area.

For telephone plant in the vicinity, however, the rise in ground potentials can create hazards, which must be considered under separate categories as follows:—

- Cables passing through the gradient area.
- Aerial routes passing through the gradient area.
- Telecommunication earths, located within the gradient area, and used for protection of circuits through arrestors.
- Lead-ins to services within the power installation area.

A typical case illustrating most of the principles involved is that of the Khancoban area where an existing telephone aerial route will be inundated by waters of the proposed Khancoban Pondage, and must be replaced. The most suitable route for construction and maintenance for the replacement plant is along the proposed new road, but this will run, in part, along the boundary fence of the Murray Switching Station, for which the ultimate maximum fault current is calculated to be 25,000 amps, and the earth resistance of the station earthing system, 0.5 ohms. This could result in a potential rise of 12,500 volts at the switching station, with a widespread gradient such that, at a distance of 2,000 feet, the earth would be 900 volts above true earth potential.

If metal sheathed cable were laid through this gradient area, the sheath would assume the potential of the earth through which it passed, whilst the conductors remained at approximately true earth potential due to connection to earth at the Khancoban Telephone Exchange. When the earth potential rise exceeded the breakdown voltage of the cable, i.e., 2 KV, failure would occur. Alternatively a plastic cable, with plastic of sufficient thickness to withstand the potential rise, could be used. In any case, however, a jointer working on the cable in the gradient area, unless adequately insulated from earth, would experience the full potential rise if a power fault occurred while he was touching a conductor. Adequate insulation of the man from earth would be extremely difficult to achieve in practice. If the dangerous potentials were not as widespread as in this case, joints in the gradient area could be avoided in the initial construction, but the possibility cannot be overlooked of a fault requiring subsequent attention and installation of joints in the gradient area. Considering all possibilities, the only completely safe solution is to avoid underground construction in such areas.

Similarly, if aerial construction is used, a wet pole or wet ladder will provide a conducting path to earth, and the same hazards exist, particularly when running new wire. If lightning arrestors are fitted to lines, and connected to earth within the gradient area of the switching station, a rise in earth potential above the striking voltage of the arrestor due to a power fault will connect the high potential to the line, creating a hazard throughout its length.

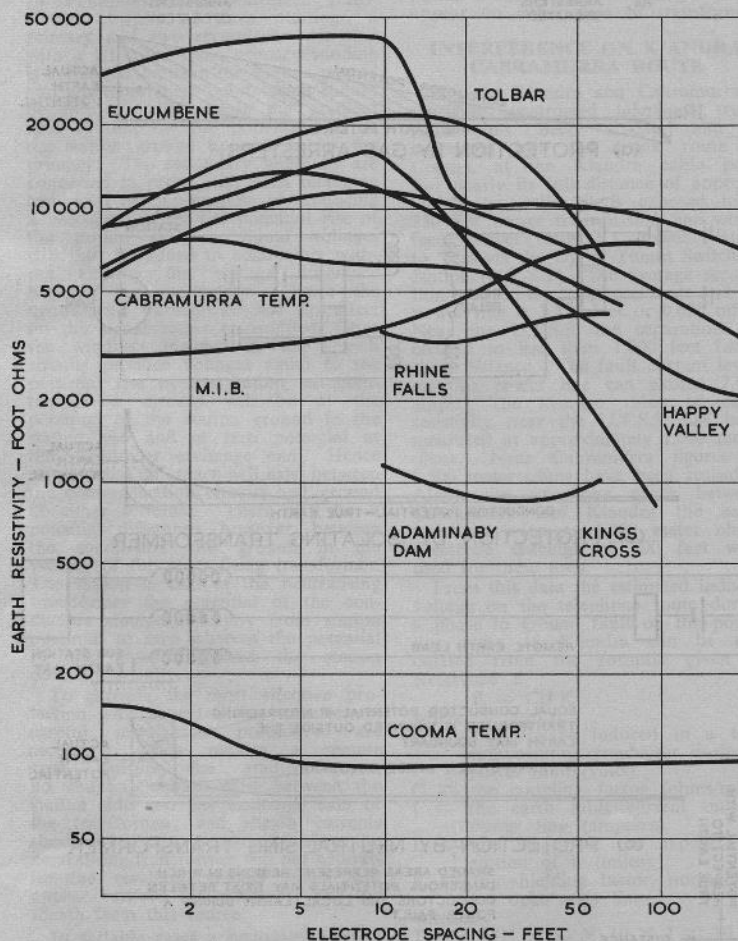


Fig. 2.—Earth resistivity figures measured at a number of localities in the Snowy Mountains.

It is obvious, then, that telephone routes should be selected to avoid, by the greatest distances possible, any power installations capable of passing heavy fault currents to ground, particularly in high earth resistivity areas. In the case of Khancoban, these considerations have dictated selection of a route remote from the road, and, therefore, more difficult to maintain.

PROTECTION OF TELEPHONE CIRCUITS ENTERING POWER INSTALLATIONS

General

Where telephone lines are required within the power installation area, construction must be provided in the potential gradient area, and special precautions taken. Underground cable is generally chosen for the lead in, although aerial construction would have some advantage in reducing potential stress between conductors and sheath under earth potential rise conditions. Underground construction provides some degree of shielding against electrostatic and electromagnetic induction from high tension lines and permits greater flexibility in power route layout. Irrespective of the protection method adopted, a dangerous potential can exist between conductors and earth at some locations along the route as Fig. 3 illustrates and, because of this, it is necessary to use plastic insulated cable which has substantially greater dielectric strength than paper insulated cable.

The alternative conditions applying for lines into power installations are:—

- For normal telephone services, the cable conductors and telephone equipment have no local connection to earth, and so tend to remain at remote earth potential. When a power fault occurs, the whole environment is raised to a high potential, creating a hazard to the telephone user and equipment.
- For lines connected to local earth at the power installation, such as where local earthed battery supply is provided, the full potential rise is transferred through the line to its termination at an exchange or external extension location.

Use of Gas Arrestors

Protection for condition (a) can be provided by ensuring that the telephone equipment is only accessible in a situation well insulated from local earth potentials, or by equalising the potentials between line and local earth. The latter can be most simply done by fitting gas arrestors between each wire and the earth mat (Fig. 3a). These will fire at approximately 250 V and short circuit the line to earth for the duration of the potential rise. This converts the situation to that of condition (b), where in the potential rise is transmitted along the line. Provided that gas arrestors are fitted at a remote point, and connected to a low resistance earth, the potential at the remote end will be held within safe limits—being the voltage drop across the resistance of the earth electrode only. The potential on

the cable pair will, of course, increase towards the power installation, and may endanger jointers or cable insulation. For this reason the gas arrestor method of protection is used only where the potential rise is comparatively small (to about 1200 V). It should be noted that, with arrestors operated, the full potential would never be found between the conductors and earth, at any particular point, because the earth itself has risen in potential.

In conjunction with arrestors, fuses are fitted at the power installation to disconnect the line if excess current flows. The subscriber must, therefore, agree that interruption to the service under these circumstances is tolerable. Dummy fuses must be fitted at the re-

mote end (exchange, etc.) as fuse operation there would disconnect the arrestors, leaving the full earth mat potential rise on the line.

Alternative Protection

Where this simple protection is not applicable, two other remedial measures are possible:

- Complete isolation from earth using isolating transformers.
- Injection of an equalising potential using a neutralising transformer.

The cost of a neutralising transformer is £580 for a typical installation handling 25 pairs. In cases where D.C. signalling is not imperative the use of an isolating transformer may be practicable and its use does away with the necessity for a remote earth point.

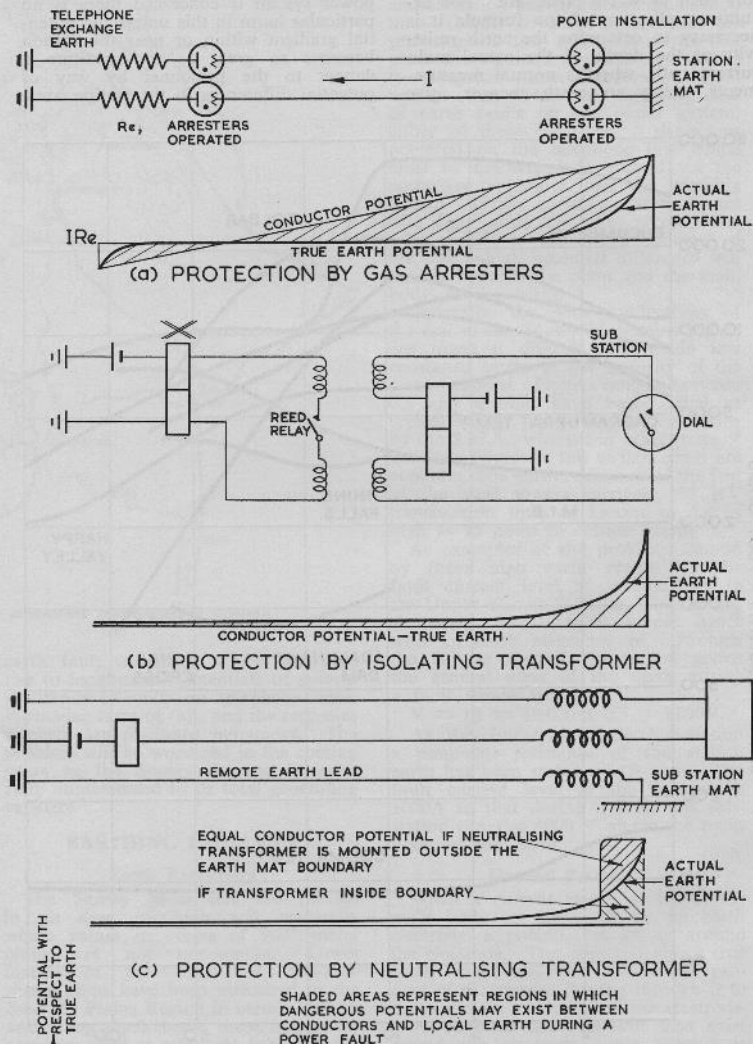


Fig. 3.—Protection methods for Telephone Circuits entering Power Installation.

Isolating Transformers. (Fig 3b): A 2-winding 1:1 ratio transformer, in conjunction with a suitably insulated cable sheath, enables the telephone pairs to be completely isolated from the station ground and the effects of the potential gradient existing in the vicinity during a fault. The transformer can be suitably designed to pass magneto ring current but elaborate and expensive provision is required for D.C. Loop Signalling which will be usual in the Snowy Mountains area.

A typical isolating transformer for one line costs approximately £12 for installation but the provision of VF signalling equipment adds a further £370 per channel to the over-all cost. An alternative method for loop signalling is by the use of bridging relays which repeat the telephone dialling impulses around the transformer. No costs are available for installations of this type; they are used extensively in Europe, but are not yet available in Australia.

Neutralising Transformers. (Fig. 3c): In its simplest form a neutralising transformer consists of three windings, a primary and two secondaries designed with a 1:1 ratio. The primary winding is connected between the station ground and a remote earth point which should be located well outside the gradient area so that the full potential rise of the station ground appears across the primary. The secondary windings are connected in series with each incoming conductor for the purpose of producing a voltage equal to the potential rise of the station ground. Equal voltages will thus be added to conductors without altering the voltage difference between the conductors. Hence the neutralising transformer has no effect on the signal to be transmitted. Since the windings inserted in the speech circuits produce voltages equal to the potential rise of the station, all communication circuits will be at the potential of the station ground at the station end and at zero potential at the remote or exchange end. Hence no potential difference will exist between the communication circuits and ground at either terminal. There will be a potential difference, however, between the conductors and ground in the vicinity of the neutralising transformer. The reason is that at the neutralising transformer the potential of the conductors changes abruptly from station potential to zero whereas the potential of the ground around the station decays gradually.

To provide the most effective protection with a neutralising transformer, careful installation procedures are necessary. They require a remote earth outside the gradient area; no coupling should exist between the station side and the exchange side of the transformer; and sheath currents should be kept to a minimum since the neutralising transformer will not neutralise the resultant voltage which will appear between the conductor and the sheath from this source.

In suitable cases a neutralising effect might be achieved by enclosing the

cable in a highly conductive iron pipe over sufficient length to extend outside the gradient area. This method is to be tried during some proposed field tests to determine the actual degree of coupling and the effect of saturation of the magnetic material.

Safety Aspects: Comparing neutralising and isolating transformers from the safety aspect, a hazard will exist with a neutralising transformer only if its windings or the remote earth connection becomes open circuit or otherwise faulty. The maintenance of the remote earth connection is vital in this regard since this constitutes portion of the primary winding across which the station earth potential is developed. With isolating transformers there is no significant risk so long as the cable remains insulated from the station ground potential.

Maintenance on either isolating or neutralising transformers installed at power station premises should only be carried out by personnel trained in high voltage techniques, since, during a power fault, dangerous voltages could appear on either type of transformer.

INTERFERENCE ON KIANDRA CABRAMURRA ROUTE

Between Kiandra and Cabramurra a specially constructed telephone trunk route has been erected and is connected into the trunk route to Cooma, at the Kiandra cable pole. For nearly its full distance of approximately ten miles it is exposed to a 330 KV power transmission line which feeds power from T.1 Power Station to Yass via the Upper Tumut Switching Station (U.T.S.S.). The average separation between the telephone route and the power line is 3,350 feet or 0.625 miles. Near the U.T.S.S. the separation decreased to less than 1,000 feet for a short distance. The fault current levels on this power line can exceed 7,950 amps. The average value of earth resistivity near the U.T.S.S. has been measured at approximately 1,000 meter ohms. Near Cabramurra figures of 1,500 meter ohms have been recorded. Along the telephone route between Cabramurra and Kiandra the earth resistivity averages 1,000 meter ohms. Electrode spacings of 100 feet were used for these tests.

From this data the estimated induced voltage on the telephone route during a phase to ground fault on the power line close to Kiandra can be calculated from the formula given in Reference 6.

$$E = CILK$$

where

E = the voltage induced in a telecommunication conductor during a power fault (volts).

C = the coupling factor (ohms/mile).

I = the earth fault current on the power line (amperes).

L = the length of the exposure or section of it (miles).

K = the shielding factor, normally 1 for open wire lines.

whence

$$E = 0.13 \times 7,950 \times 10 \times 1 = 10,300 \text{ volts.}$$

The surest way to reduce this induction to a safe figure would be to arrange for greater separation between the power lines and the telephone route. But in this area, due to high soil resistivity and great concentration of fault current, an average separation of greater than three miles would be required for this particular exposure to limit the induced voltage to 650 volts. The rugged nature of the terrain and the need for feeding a common location made it impracticable to arrange for such a separation and both the power and telephone routes are confined to relatively close paths.

A normal method of protection against voltages liable to be induced in these circumstances is to fit gas arrestors or arrestor relays between each line wire and earth at such intervals that, when the arrestors operated, the line voltage is reduced to within the limit of 650 volts to earth (for high security power lines). This, however, necessitates that the earth connection for the arrestors should be of low resistance so that the voltage drop does not exceed 650 volts when current passed to earth. Soil resistivity in the area is, however, so high that the required earth resistances could not be obtained. Special methods were, therefore, required to protect the telephone plant from the excessively high induced voltages which could occur.

The methods devised were:—

- To reduce the induced voltage in the telephone line by decreasing the area enclosed by the line wires and the earth return path, a copper earth wire was ploughed into the ground under the route.
- To provide a barrier to prevent the transfer of induced voltages into the trunk system beyond Kiandra, the point where the exposure ceases, by fitting drainage coils capable of carrying 200 amps for two seconds between the line wires and earth at the Kiandra cable pole.
- To sectionalise the route by means of series condensers and drainage coils, effectively shunting the lines to earth at 50 cycles per second. This increased the transmission loss at voice frequency and prevented its use for physical circuits but the attenuation at carrier frequencies remained suitable for the use of 1 + 4 and 12 channel systems.

When the telephone route was equipped, field tests were carried out to test the efficiency of the arrangement. A simulated fault current of approximately 140 amps was fed over the power line into the ground at the U.T.S.S. from the 330 KV sub-station at Yass to provide a disturbing electromagnetic field over about three-quarters of the length of exposure.

The telephone line was grounded at Kiandra and voltage-to-earth measurements were carried out at the end of each isolating section. As induced voltage is directly proportional to disturbing current, these figures, divided by the current, gave the effective mutual impedance in volts per ampere which was then projected for the ultimate

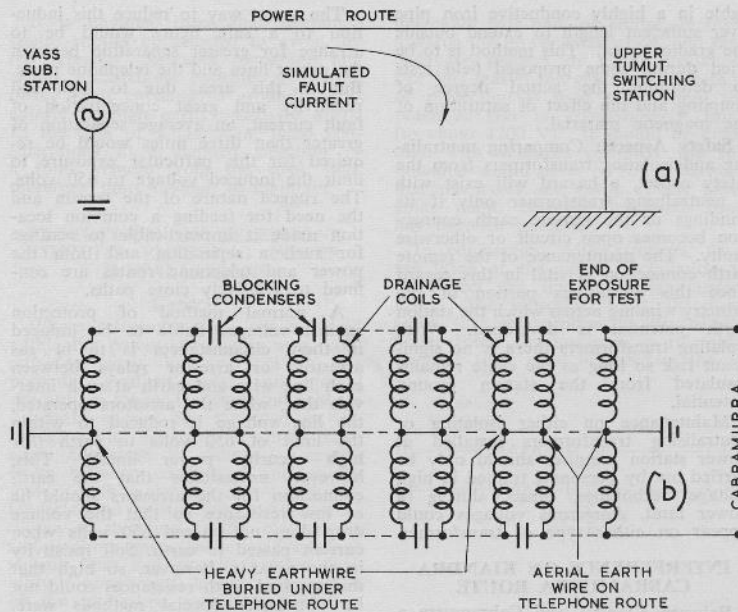


Fig. 4.—Kiandra—Cabramurra Low Frequency Induction Test.

fault current levels. These figures showed that:

- The voltage induced for an 8,000 amp fault near Kiandra would be approximately 1,100 volts between the telephone wires and ground.
- At Cabramurra, which is outside the exposure, a voltage rise of the order of 3,000 volts could be expected.

These facts emerged:

- While the induced voltage on the telephone line had been substantially reduced by isolation and drainage, the difficulty of obtaining sufficient good earths along the route meant that the danger had not been completely removed.
- At Cabramurra, which is 1½ miles past the end of the exposure, the voltage reading was considerably higher than at the end of the exposure, which is inconsistent with the fact that no additional voltage could have been induced into the line.

Complete explanation of the highly complex factors influencing the potential distribution is not possible without further extensive tests but a possible theory, illustrating some of the complexity of power co-ordination problems in general, is given below. In simple form, neglecting the variations in separation between power and telephone routes, the circuit conditions during the tests were as shown in Fig. 4. Voltage measurements using high impedance meters were made between telephone line wire and earth at Cabramurra and at each section end. The component and resultant voltages in the ground, and on the telephone earth and line wires are shown in Fig. 5, and an ex-

planation for the higher measured voltage at Cabramurra follows:—

The factors influencing the voltages measured are:—

- The voltage induced into the line wire.
- The voltage induced into the earth wire, which would be essentially equal to (a).
- The earth potential rise due to the passage of fault current through the switching station earth mat. This is important because the test point at the end of the exposure was close to the switching station. Voltages (a) and (b) would be approximately 90° out of phase with (c). Because of the high resistivity, the earth wire was at appreciably different poten-

tial from that of the earth adjacent even in the buried section. Its actual potential with respect to remote earth is the resultant of its induced voltage (curve A of Fig. 5), the earth potential rise (curve D) and the voltage drop across its earth leakage. The resultant is shown as curve E, which changes slope where the aerial earth wire joins the underground section, due to differing earth leakage.

The graph of induced line voltage, curve A, is shown as a straight line to the end of the exposure, with slope equal to a mutual impedance which assumes uniform separation between the two routes and uniform earth resistivity along the route. The effect of the drainage coils is also neglected. Curve C shows the resultant line potential after allowing for the shielding effect of the earth wire. Outside the exposure the graph is horizontal, as no further induction takes place. This means that the line potential, with respect to remote earth, remains constant. The measured potential, however, was 60 volts at Cabramurra and only 2 volts at the end of the exposure with a fault current level of 140A on the power line because:—

- Near the switching station the earth was raised in potential by the passage of fault current. The earth point to which the measurement was made was closer to the earth point of the earth wire on the telephone route so that the voltage induced in the earth wire was further superimposed leaving only a small difference in potential between local earth and the line wire.
- The earth at Cabramurra being 1½ miles out on the gradient, was closer to true earth potential.

This explanation is intended mainly to illustrate the complexity of power co-ordination situations, where conductive and inductive effects invariably exist together, and to emphasise the fact that the most important potential difference between line wires and local earth can occur outside the exposure, or in fact,

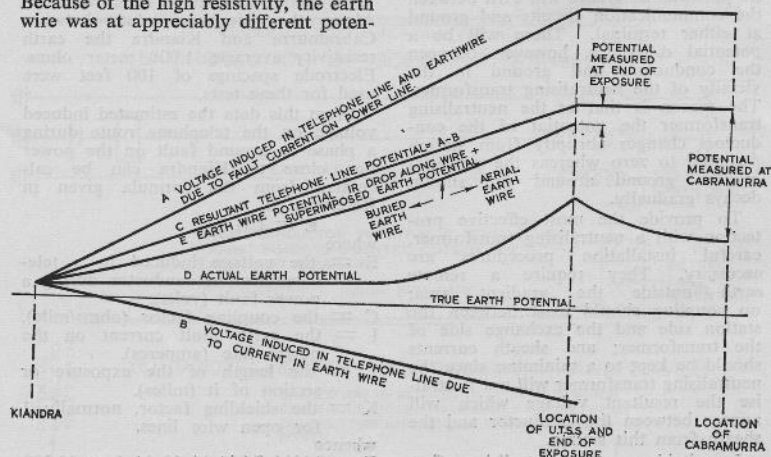


Fig. 5.—Kiandra—Cabramurra Induction Tests. Component Potentials.

at any point within the exposure, depending upon the location of the power fault. This point is of particular importance in designing protection, so that arrestors are so located as to obviate the possibility of big differences in potential between lines of differing lengths along the same pole route.

The validity of the theory outlined above still remains to be confirmed by further field tests as the case has been oversimplified by neglecting the varying separation, varying earth resistivity, the drainage effect of the shunt coils, and, in addition, the actual phase relationships between the voltage components on both line and earth wires.

Pending further tests the line will be split into completely isolated sections by isolating transformers. Thus the line will "float" with respect to earth and no potential difference can exist.

EXPOSURE TO PROPOSED 66 KV POWER LINE—SNOWY ADIT TO JINDABYNE

For a distance of 5.3 miles and proceeding in a northerly direction from Jindabyne, the Island Bend-Jindabyne trunk route is exposed to a newly constructed 66 KV power line connected between the Snowy Adit and Jindabyne. Over this portion of the route it is estimated that a voltage of 1,650 volts to ground will appear on the telephone plant should a phase to ground fault occur on the power line at Jindabyne.

Assuming gas arrestors were fitted on each end of each wire and connected to earths of 5 ohms each, the magnitude of the current circulating in the telephone lines during a fault after operation of the arrestors is given by—

$$I_{ab} = \frac{E_{ab}}{Z_{ab} + R_{ea} + R_{eb}} \text{ amps}$$

where E_{ab} = the induced longitudinal voltage between points A and B.

Z_{ab} = the parallel impedance of all telephone conductors in the exposed portion

$= \sqrt{R^2 + (WL)^2}$
 WL = Inductive reactance of conductors

R = resistance of all wires in parallel.

R_{ea} = the electrode resistance at point A

R_{eb} = the electrode resistance at point B

The equivalent circuit is shown in Fig. 6.

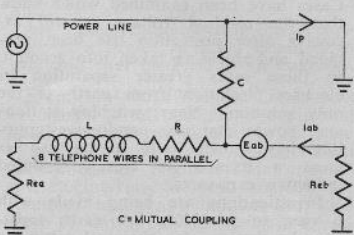


Fig. 6.—Jindabyne-Snowy Adit Exposure. Equivalent Circuit.

For more than four conductors on a route it is a sufficient approximation to take account of the inductive reactance as being 1 ohm/mile. In this particular case eight 237 lb. cadmium copper wires are involved with a resistance of 4.5 ohms/mile each.

$$Z_{ab} = 5.3 \sqrt{1^2 + \left(\frac{4.5}{8}\right)^2} = 6.07 \text{ ohms}$$

$$R_{ea} = 5 \text{ ohms}$$

$$R_{eb} = 5 \text{ ohms}$$

then, from the formula above:

$$I_{ab} = \frac{1650}{6.07 + 10} \text{ amps} = \frac{1650}{16.07} = 103 \text{ amps}$$

This current will divide between the eight wires on the exposed section of the route so that the current per wire will be 13 amps, this current value determining the type of arrestor required.

The residual voltage at A after the protection has operated is given by—

$$E_a = I_{ab} \times R_{ea}$$

$$= 103 \times 5$$

$$= 515 \text{ volts}$$

Similarly for point B residual voltage will be 515 volts. Both voltages are in excess of the allowable limit of 430 volts.

With this method of protection, using gas arrestors, three alternatives remain to reduce the residual voltage:—

- (i) Improvement to the earth connections so that their voltage drops are reduced.
- (ii) Fitting of additional protectors at intermediate points along the route.
- (iii) Provision of shielding by a parallel earth wire in addition to the arrestors.

Neither of the first two courses offer a straightforward solution for a short exposure to high fault current, as in this case.

The first because the combined impedance of the lines (6 ohms) is comparable with the resistance of the earth connection (assumed 5 ohms) a decrease in earth resistance to say 4 ohms at each end results in an increase in circulating current from 103 to 117 amps. Across the 4 ohms earth resistance this gives a line potential of 468 volts. The cost of improvement below 4 ohms would be prohibitive, so the desired reduction in induced potential cannot be achieved by this means.

It might be thought that fitting an additional set of gas arrestors at the mid-point of the route, by halving the exposure length, would halve the residual voltage on the lines. This, however is not the case. In fact, if the separation is uniform and the earth resistivity constant throughout the exposure (as is approximately the situation on this route) an arrestor at the mid-point would contribute nothing whatsoever to the protection when the power fault is beyond the exposure.

Fig. 7 shows the induced potential, the voltage drop along the lines and the resultant potential on the lines after the operation of the arrestors at each end for such a uniform exposure. It

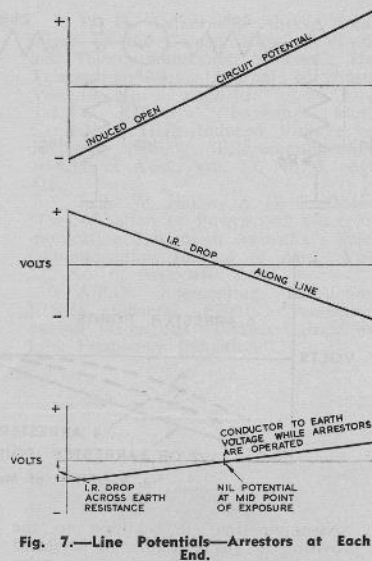


Fig. 7.—Line Potentials—Arrestors at Each End.

will be seen that at the mid-point, the resultant potential after the operation of the arrestors is nil, therefore, an arrestor at this point will not operate, and even if it could be made to operate no current would flow to earth.

If arrestors are fitted at the one third points or 1/6th points along the route, the situation will be approximately as shown in Fig. 8. The potentials induced into the three sections of the line will be equal ($E_{ab} = E_{bc} = E_{cd}$) and the line impedances will be equal ($Z_{ab} = Z_{bc} = Z_{cd}$).

The current I_a through the earth connection R_a from E_a will be opposed by I_b , reducing the drainage effect of this connection. By solving simultaneously the Ohms Law equations for the three sections—

$$E_{ab} = I_{ab} (R_a + R_b + Z_{ab}) - I_{bc} R_b$$

$$E_{bc} = I_{bc} (R_b + R_c + Z_{bc}) - I_{ab} R_b$$

$$- I_{cd} R_c$$

$$E_{cd} = I_{cd} (R_c + R_d + Z_{cd}) - I_{bc} R_c$$

it will be found that the current at the two ends is reduced by only about 3½% and the residual voltage by the same amount, leaving it still about 497 volts.

Use of Insulated Aerial Earth Wire on Telephone Routes

If a heavy copper conductor is erected close to the telephone wires and permanently connected to ground at each end, it will carry a substantial current when power induction occurs. This current will create its own electromagnetic field, and induce a voltage in the line wires, in opposition to the direct induction from the power fault. The wire must be insulated throughout its length as there may be appreciable differences in potential between it and the line wires (for example, the potential drop across the gas arrestors in the line wires, differing voltage drops across their respective earth connections, etc.).

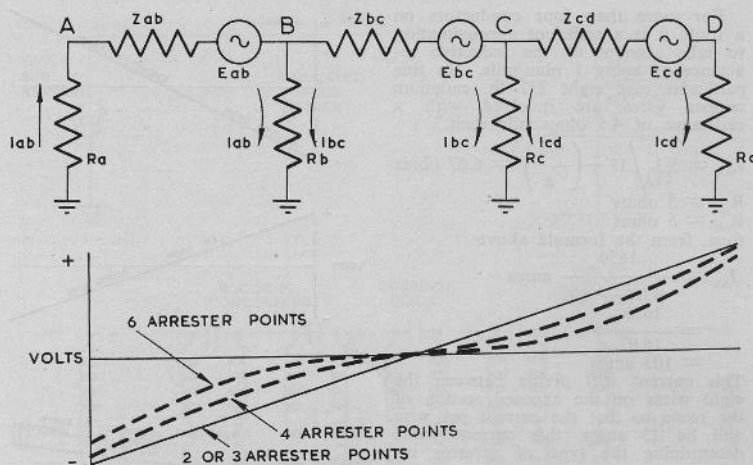


Fig. 8.—Effect of Multiple Arrestor Points.

Assuming that in addition to the provision of gas arrestors an insulated copper wire was run on the same poles but $2\frac{1}{2}$ feet mean distance from the line wires and connected to separate 5 ohms earths at each end, the resultant potentials are calculated below:—

$$\begin{aligned} \text{Resistance of earth wire } R_{ew} &= 4.4 \text{ ohms/mile} \\ &= 23.3 \text{ ohms for 5.3 miles.} \\ \therefore \text{Loop resistance} &= R_{ew} + \text{Rearths} \\ &= 23.3 + 2 \times 5 = 33.3 \text{ ohms} \\ E &= 1,650 \text{ volts} \\ \therefore I &= \frac{1650}{33.3} = 50 \text{ amps} \end{aligned}$$

Coupling factor between earth wire and line wires at 2.5 feet spacing $C = 0.85$
 $\therefore$ Opposing voltage induced in the line wires $= C I L K = 0.85 \times 50 \times 5.3 \times 1 = 226 \text{ volts}$
 $\therefore$ The resultant open circuit voltage on a line wire, before operation of the arrestors, will be $1650 - 226 \text{ volts} = 1424 \text{ volts}$. This means that the aerial earth wire has achieved shielding to the extent of 13.7%.

This same percentage reduction will apply to the circulating current and the residual voltage after protector operation, which will now be 87 amps and 444 volts respectively.

As 444 volts is still above the limit it would be necessary to reduce the resistance of the earth wire by the use of 300 lb./mile wire. The earth wire must, of course, be connected to earths at each end which are separate from the gas arrestor earths, otherwise the earth wire current would add to the IR drop across the earth connection increasing the potential of the line wire.

It should be noted that this overhead earth wire may only be applied in particular circumstances due to the following factors:—

- (a) An earth wire on a pole route will vary the line characteristics with respect to earth, and may produce

third circuit effects for carrier working.

- (b) If the protection earth system is within the potential gradient area of the power earth system, part of the power fault current will flow through the telephone earth wire and line wires, increasing the IR drop across the earth connection at the far end thus increasing the line potential.

These two factors must be studied in each case and if their consequence is serious the only remaining solution is to isolate the line using two winding transformers designed to withstand the expected potentials. Since such transformers would interrupt the D.C. loop, V.F. signalling or bridging relays with remote batteries must be fitted as required.

Some shielding can be achieved by the provision of earth wires on the power routes. Earth wires are fairly common on E.H.T. lines for lightning protection, but they are usually of steel for mechanical strength. Their impedance is therefore too high to provide worthwhile shielding.

For aerial earth wires of low impedance, copper or aluminium conductors of greater cross sectional would be required. The increased sag liability under ice loading would require greater tower height and/or shorter spans, adding greatly to the cost of power routes. The shielding effect of such earth wires is also limited by the minimum spacing from the phase wires that can be provided.

ACTUAL PROTECTION ON JINDABYNE-ISLAND BEND TRUNK ROUTE

From the foregoing it will be seen that complete protection of this and other routes exposed to high power fault currents can be complicated and expensive. In this particular case the route will be inundated by flooding of the Jindabyne Dam, and must therefore be removed. For this reason no action other than fitting of gas arrestors at

the two ends will be taken pending removal. The new construction would normally have been provided along the proposed road deviation, but this is even closer to the power route and adequate protection against induced voltages would be impossible.

It is, therefore, proposed to use underground cable laid across country with the greatest possible separation. Armoured cable will be used to take advantage of its additional shielding effect, but gas arrestors between each wire and earth at each end will still be necessary to achieve a satisfactory reduction in induced voltage.

TYPES OF ARRESTORS

Ericsson Gas Arrestors, Type NGC 3133, are normally used for protection against induced voltages. These arrestors can carry a current of up to 18 amps for periods up to one minute. Where the circulating current per line is likely to exceed 18 amps, arrestor relays are fitted in the earth lead. The relay contacts shunt the gas arrestors during passage of current.

INCIDENCE AND DURATION OF POWER FAULTS

Most power faults capable of producing heavy earth currents are due to line breakage, pole breakage by collision, etc., and flashover across insulators, particularly from lightning strikes. In the Snowy area an additional hazard is climatic severity and a number of faults has been due to excessive sag of line and earth wires, coupled, in some cases, with snow build-up on the ground.

Protective equipment on the E.H.T. lines is designed to disconnect a faulted phase wire within six cycles (about $\frac{1}{4}$ second), testing again for six cycles after $\frac{1}{2}$ second delay before finally disconnecting all three phases.

The statistical probability of any person being in a dangerous situation on a telephone line when the hazardous voltage occurs is therefore low, but nevertheless cannot be overlooked and adequate protection is essential to safeguard both staff and telephone equipment.

CONCLUSION

The necessity of good protective earths in the Snowy region is vital to safeguard telephone plant and staff. The difficulty in obtaining earths of low resistance makes special protective devices necessary in this region. The high earth resistance also reduces the shielding effect of cable sheaths, in certain areas to an insignificant level. Cases have been examined which show that the residual voltage is still excessive after protection has been provided and shielding taken into account. In these cases greater separation or electrical isolation from earth is the only solution. Near switching stations and power stations, conductive coupling has shown itself to be just as great a hazard as closely coupled inductive exposures.

Investigations are being made with a view to providing low earth resistance by the use of a chemical substance known as Sanick-Gel. This is claimed to effectively increase the diameter of

an electrode in contact with the soil and thereby lower its resistance. Unlike the soluble salts which have been used for this purpose Sanick-Gel forms a jelly-like substance in the ground. Where soluble salts would leach out, the jelly is reputed to remain indefinitely. Results of these tests are not yet available but if successful this would greatly simplify the protection against power induction in high resistivity areas.

The likelihood of a maximum fault to ground must be considered in the light of the fact that power line construction is mainly of high security design. Furthermore most contacts will occur through some finite earth resistance which will restrict the flow of current through the circuit and reduce the

severity of induction on telephone plant. To date the protection provided for telephone lines in this area has proved adequate but consideration must be given to the future when the Snowy Scheme is operating at its full capacity so that each new aerial or cable installation must be carefully investigated against all aspects of power interference.

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Assessing Australia's Progress Towards a National Broadband Strategy at December 2021

TelSoc Broadband Futures Group

Abstract: This paper is based on a report by the TelSoc Broadband Futures Group in which Australia's progress during 2021 towards a National Broadband Strategy is assessed against the criteria set out in *Towards a National Broadband Strategy for Australia: 2020-2030*, a report prepared by TelSoc in November 2020. The *Journal* publishes this assessment of progress as a Special Interest Paper. The Assessment shows that there has been some, albeit limited, progress towards a National Broadband Strategy, including in various Australian Government statements about the development of the digital economy and its expectations of NBN Co in the provision of fixed broadband access services nationally.

Keywords: broadband, strategy, TelSoc, digital economy, online society

Introduction and Background

TelSoc

The Telecommunications Association (TelSoc) is a not-for-profit society registered as an incorporated association. TelSoc's purpose is to support the development of the telecommunications and related sectors and harness the potential of the sector for Australia's economic and social development. TelSoc does this by promoting public discourse and assessment of the key telecommunications and digital economy issues of the day through public forums, member newsletters and publication of the *Journal of Telecommunications and the Digital Economy*.

TelSoc Broadband Futures Group

In February 2019, the TelSoc Broadband Futures Group (TelSoc BFG) was established by interested TelSoc members to examine in greater detail issues associated with the rollout of the National Broadband Network (NBN) and a range of related issues such as public policy settings in Australia for broadband, harnessing the potential to transform Australia to a digital economy and an online society, and equitable and fair access to broadband services.

In November 2020, the TelSoc BFG completed and launched its report, *Towards a National Broadband Strategy for Australia, 2020-2030* (TelSoc NBS Report) ([Holmes et al., 2020](#)). The themes and proposals in this report are discussed in more detail [below](#).

The purpose of this report is to provide an assessment of how Australia has progressed towards a National Broadband Strategy during 2021, using the themes and proposals in the TelSoc NBS Report as a framework.

TelSoc recognises a certain presumption in this assessment, and taking the framework of our NBS proposal as a basis for it. Broader examination of this proposed framework as the reference, and other contributions to the assessment, would be welcome. More particularly welcome would be the establishment of a National Broadband Strategy with a generally agreed framework and set of objectives and stages that could be assessed in a broad public policy context.

Executive Summary

A year has passed since the TelSoc NBS Report was published. That is sufficient time to make an assessment of the progress that has been made towards a National Broadband Strategy since then.

However, a number of initiatives, reviews and programs are continuing as at December 2021. Where these may have relevance as progress towards a National Broadband Strategy, they are mentioned, but full assessment will need to await further development of each initiative.

Overall, although some progress has been made towards a National Broadband Strategy, it has been implicit rather than explicit, fragmentary and limited, and significant gaps remain, as set out in detail in our summary of key gaps [below](#).

On the positive side of the ledger, the Government, in May 2021, published the **Digital Economy Strategy**, which seeks to set out a 10-year strategy for the development of an effective digital economy in Australia.

But this is not the strategy that TelSoc is proposing. It is concerned with capabilities in economic sectors and not in society or the economy at large. It has been based on consultation, but there is no evidence of the level of bipartisan support that will ensure its future impact and effectiveness across multiple electoral cycles. Lastly, it adopts broad terms for expressing a vision and objectives, but lacks the detail to ensure achievement of concrete targets for those objectives over the next decade and the clear accountabilities that are needed.

Nevertheless, the Digital Economy Strategy could provide the basis for a National Broadband Strategy, and become an important building block to support the expansion of scope and

strengthening of detail that is required. Clear strategic intent is required, and leadership from the Federal Government.

Another promising development, with strategic potential, is the **Statement of Expectations of NBN Co (SOE)**, which the Ministers for Finance and Communications published on 26 August 2021. The SOE is necessarily confined to the fixed broadband operations of NBN Co, and consequently does not reflect a broader vision covering mobile and other platforms that are part of Australia's broadband infrastructure. While a range of objectives for NBN Co, and by extension for the broadband system generally, can be extracted, the SOE is short on critical detail that would enable targets to be understood and their implementation better monitored. It is disappointing that an opportunity has been missed to set out a larger series of objectives, express stronger strategic intent, and then better contextualise the expectations of NBN Co within that broader canvas. This would have enabled NBN Co's role in contributing to critical social outcomes, such as broadband service availability to low income and remote Indigenous communities, to be more clearly defined and any limitations to be better understood.

Substantial gaps remain in terms of research, monitoring and assessing broadband usage and needs. Programs to address service shortfalls, whether in geographically or socially-defined categories, are typically sub-scale, disconnected and uncoordinated. Policy reviews are piecemeal and do not provide for the cohesive and continuous support that is needed to establish and to manage a longer-term, comprehensive National Broadband Strategy.

Towards a National Broadband Strategy for Australia: 2020–2030 (TelSoc NBS Report)

The TelSoc NBS Report provides a framework for an assessment of the progress made in 2021.

The TelSoc NBS Report was launched in November 2020. It argued for adopting a clear vision and objectives for broadband access and usage in Australia and for a long-term, coordinated, bipartisan national strategy to achieve the best social and economic outcomes as Australia further transforms to a digital economy within an online society. The TelSoc NBS Report recognised that the NBN would be a central part of such a strategy, especially in the earlier years, but that a comprehensive policy framework needed to recognise the contribution of mobile and other access technologies.

Recognising the initial central role of the NBN, the Report was also concerned to ensure that NBN Co was not privatised either in the shorter term (next five years) or without substantial consideration of all of the issues that need resolution beforehand. In the event, TelSoc members working on these issues have come to understand that none of the major political

parties has any interest in pursuing short-term sale of NBN Co and, consequently, the matter has not been part of our priority agenda for 2021.

Developing a bipartisan National Broadband Strategy

To be robust and meaningful, a long-term national broadband strategy will extend beyond the term of many Parliaments and other political cycles and needs genuine bi-partisan support. The NBN and the policies associated with provision of broadband services more generally are about investing in and maintaining fundamental infrastructure. Like other programs of that kind, broadband strategy needs to have the broadest base of support in the community for social and economic benefit to be maximised.

Vision and objectives

The TelSoc NBS Report recognised that it is crucial for there to be a clear understanding and general agreement on the vision and objectives for the digital society and economy. It noted that statements of vision and objectives are the key plank in the policy framework. These statements ensure there can be meaningful discussion, engagement and evaluation of the means employed to deliver broadband infrastructure and services efficiently, creatively and equitably.

The TelSoc NBS Report included a working characterisation of such a vision statement, as follows, but recognised that widespread adoption of a statement is necessary for a national strategy:

“... ubiquitous, high-quality, high-speed broadband that is affordable to all in Australia and which will provide an essential service needed for Australia to develop and remain an inclusive online society and a competitive online economy into the future” ([Holmes et al., 2020](#), p. 214).

The TelSoc NBS Report noted that the value and benefits of investment in the NBN, and in broadband generally, needs to be assessed in the broadest terms, but particularly taking account of social and economic objectives, which need to be clearly identified. These objectives need to be the basis of agreed means of assessing digital equality and inclusion, of ensuring that, regardless of economic or social status, all Australians have the opportunity to effectively participate in the online digital economy. A means of determining related goals in terms of digital capabilities across industry and society, affordability and availability of basic and standard services is required.

Social and economic benefits

In recognising an increasing emphasis being given to realising the social and economic benefits of broadband services, particularly from the experiences during the COVID pandemic, the TelSoc NBS Report observed a number of requirements to ensure these benefits be achieved. including: a continuing “demand side” policy focus; a broad consideration of benefits across a range of applications, supported by underpinning inclusion; the generation of continuing research and discourse; and taking a long-term, effectively scaled, approach.

Technology and technical pathways

The TelSoc NBS Report recognised that the multi-technology mix was a reality that provided different technical and quality-of-service outcomes for customers being served in different areas. The Report concluded that pathways were necessary towards improved service characteristics over time, and that NBN fixed-line services should be upgraded to at least 100/50 Mbps service capability as soon as possible in the first five years of the initial National Broadband Strategy and to 1000/500 Mbps service capability everywhere by the end of the 10-year period, prioritised as appropriate in terms of commercial benefit.

The Report also noted that broadband users being served by fixed wireless and satellite technologies need to have defined pathways to these improved service characteristics.

Finance, regulation and ownership

The TelSoc NBS Report made various recommendations in relation to financing, regulation and ownership of NBN Co, the most important relating to keeping the company in public ownership for at least the next five years, and not considering sale of the enterprise after that until a comprehensive regulatory framework was developed. Telsoc’s aim was to ensure that the problems of other privatisation exercises, and particularly sacrificing longer-term community benefits for improved sale price, were not repeated.

It became apparent in the early part of 2021 that sale of NBN Co was not being considered by any of the major political parties and that this was likely to be the position for the medium term or longer. For that reason, issues associated with ownership of NBN Co have not been further considered in this report.

Progress Towards a National Broadband Strategy During 2021

The programs, activities and initiatives set out below are by others, particularly NBN Co and the Federal Government, and have been included in this report because they represent progress, to some extent, to the development of a more comprehensive, longer term, strategic

approach to broadband issues and to broadband service delivery of the kind contemplated in the TelSoc NBS Report.

In this section the programs, activities and initiatives are described, together with an assessment of the contribution of each towards achieving the proposals in the TelSoc NBS Report.

NBN rollout

The Minister formally declared the completion of the initial NBN build and that it be treated as being fully operational in December 2020 ([Fletcher, 2020](#)).

In 2020, NBN Co announced a number of initiatives for:

- Providing wholesale broadband access within nominated industrial zones, particularly in regional areas, in partnership with state and local government. Implementation of this program continued throughout 2021; and
- Installing fibre deeper in access networks (closer to subscriber premises), providing up to 1 Gbps download speeds, in response to a willingness of subscribers to commit to a high-speed plan. Implementation of this \$4.5B program extended into 2021 and beyond ([NBN Co, 2021a](#)).¹

During 2021, NBN Co reported:

- 75% of households and businesses were connected on plans for 50 Mbps download speeds or higher ([NBN Co, 2021a](#), p. 39);
- the creation of a \$300 million regional co-investment fund;
- 8.2 million premises were connected to the NBN, an increase of 0.9 million over the previous 12 months;
- 12 million premises were ready to connect, an increase of 0.2 million over the previous 12 months; and
- Upgrades of speed across the NBN fixed-line network ([NBN Co, 2021b](#), p. 15).

Assessment

NBN Co continued in 2021 with network operations, including enhancements and extensions, as envisaged following the completion of the initial build in 2020. However, it has not addressed via public plans and strategies, yet, many of the fundamental problems experienced by customers in areas served by fixed wireless and satellite systems.

In some areas there have been initiatives to extend fibre systems into locations currently served by fixed wireless, but this will typically require commitment and financial contribution

by leading users. NBN Co has not yet made public any plans for implementation across the board to improve the performance of fixed wireless broadband delivery.

Some customers have reported on improvements provided by the NBN Co's upgraded satellite service, Sky Muster Plus. However, the latency issues associated with voice service via Sky Muster remain, because it is based on a geostationary satellite configuration.² There is no indication from NBN Co of any plans or intentions to examine other satellite technologies, and, in particular, low earth orbit (LEO) satellite services.

Statement of Expectations of NBN Co

The Ministers for Finance and Communications issued a revised statement of expectations of NBN Co on 26 August 2021, replacing the earlier statement from 2016, and recognising the formal determination of the completion of the initial build in December 2020.

In summary, the 2021 Statement of Expectations:

- Sets out objectives for the NBN and NBN Co and, in particular, for maximising the economic and social benefits of the NBN and operating NBN Co as a sustainable, commercial business, with Australia to be a leading digital economy and society by 2030;
- Sets out service expectations, including that NBN Co will upgrade technologies to expand access to peak download speeds of up to 1 Gigabit per second;
- Sets out an expectation that NBN Co will improve its wholesale services and assist in addressing access challenges in regional and remote areas, and that, where it cannot generate a commercial return in these areas, it will cross-subsidise from returns earned elsewhere in the business and contributions from the Regional Broadband Scheme;
- Seeks improved consumer experience;
- Seeks delivery of a reliable, resilient and secure network;
- Expects NBN Co to support initiatives to increase digital capability and inclusion;
- Requires NBN Co to facilitate regulatory certainty, by updating its Special Access Undertaking to incorporate all Multi-Technology Mix networks and by “working constructively with the ACCC”; and
- Expects NBN Co to utilise emerging and future technologies as appropriate to improve service.

Assessment

It is certainly timely for the 2016 Statement of Expectations to be updated. The 2021 Statement ticks many appropriate boxes.

In particular, the 2021 Statement does reaffirm the overall goal for Australia to be a leading digital economy and society by 2030 as an important policy setting. How progress towards and achievement of this goal might be measured is not addressed explicitly, although many of the specific expectations might provide a basis for assessment.

However, the 2021 Statement suffers from the same vagueness that affected its predecessor. There are no hard targets on which NBN Co might be held accountable or on which the Government itself might be held accountable. The life of the Statement is indeterminate, so there is no timescale for any of the expectations to be realised. This leads to the conclusions that the expectations will be met at any stage if NBN Co can show some progress towards achievement of the desired outcomes. In practice, this might be a low bar.

Other Infrastructure Developments

5G Rollout

The market-driven rollout of 5G has continued with market leader Telstra now having coverage of 75% of the population at the end of June 2021, with over two million 5G devices on its network. Telstra projects approximately 95% population coverage by 2025. In remote areas this will be low-band 5G; most regional areas will have two bands, low- and mid-band; and suburban and urban environments will have three bands — low, mid and mmWave ([Telstra, 2021](#)).

According to WhistleOut, 5G speeds between 100 Mbps and 1 Gbps can be expected, with testing around Sydney providing average speeds of 500 Mbps on Telstra and Optus, and 250 Mbps on Vodafone ([Choros, 2021](#)).

LEO (Low Earth Orbit) Satellites

As noted above, there is no indication of any plans by NBN Co to examine the possible deployment of LEO satellite services in its network. However, a number of LEO network operators are planning to extend services to cover Australia in 2022 and 2023.

Assessment

A comprehensive strategy is needed that will include all technologies and platforms for the provision of broadband services.

Digital Economy Strategy

The Digital Economy Strategy (DES) was developed by the Digital Technology Taskforce, within the Department of Prime Minister and Cabinet (PM&C) and launched in May 2021 in association with the Federal Budget ([Australian Government, 2021c](#)).

The DES is heavily focussed on economic issues, the digital transformation of Australian industries and Government, and the skills acquisition to enable improved functioning in the workplace. This focus is reinforced by the three pillars on which the DES is built ([Australian Government, 2021c](#), p. 3):

1. Building the foundations to grow the digital economy;
2. Building capacity in emerging technologies; and
3. Setting digital growth priorities “to lift our ambition”.

The DES contains immediate actions and allocations associated with the 2021-22 Federal Budget but also sets out some of the characteristics of the digital economy it is seeking by 2030, including:³

- All businesses will be digital businesses, using e-commerce tools and new technologies to improve productivity;
- All transactions will be electronic;
- Australians will have the capabilities to confidently use⁴ and create digital technology, and all will have learning opportunities to gain key digital skills;
- Government services will be easily accessible online;
- Smart regulation, including the most cyber secure environment.

The DES is explicitly linked with other Government initiatives, including NBN Co’s \$4.5 billion infrastructure expansion, regional co-investment plans and 240 business fibre zones, and the Australian Broadband Advisory Council (ABAC) key sector focus on maximising the benefits of high-speed networks ([Australian Government, 2021c](#), p. 26).

The DES acknowledges the importance of skills and inclusion generally, but examines these issues in detail only in the context of building digital capabilities for the current and future workforce ([Australian Government, 2021c](#), p. 32).

Assessment

TelSoc included an assessment in its submission to the Digital Technology Task Force to extend and deepen the DES ([TelSoc, 2021](#)).

TelSoc considers the DES to be an important statement by the Government because it attempts to be strategic and to take a longer-term view (albeit for 10 years) of issues and programs to address them. However, it is not comprehensive enough to be a National Strategy of the kind envisaged in TelSoc’s NBS Report.⁵

While a vision “[f]or Australia to be a leading digital economy and society by 2030” suggests a broad intent, the DES as it stands is essentially directed to economic aspects. TelSoc considers

a broader strategy is needed to cover the desirable outcomes for the Digital Society which support, and to some extent overlap, economic benefits. A broader strategy would include:

- applications development: scaling up the utilisation of services and technologies in various areas of social and economic activity, and actively encouraging and developing new applications; and
- ensuring all citizens are included in the Digital Society, through having the necessary core capabilities and being able to upgrade these capabilities over time, and having access to affordable, quality services.

These additions would be quite consistent with the fundamental approach of the DES.

In the area of applications development, the DES particularly identifies export-oriented sectors and government services. Other sectors also need attention, including the need for further work in areas highlighted by COVID-19 experiences, such as online learning, working at home, and social communication and connectedness.

The DES concentrates on digital skills and capabilities being developed for the workplace. There is undoubtedly a significant cross-over in digital skills for work and more generally. However, the strategy needs to be broadened to explicitly address digital skills and digital inclusion in social contexts. In addition, the DES needs to include an analysis of:

- measures to determine the meeting of digital inclusion and digital capabilities objectives;
- the extent to which these objectives are currently met, and therefore the gaps to be addressed; and
- the strategic approach to be adopted in addressing the gaps and the challenges.

The other core component of the DES objective is that by 2030 “all Australians have access to high-speed internet services and the ability to use it [sic] effectively” ([Australian Government, 2021c](#), p. 19). This requires ubiquitous, reliable and affordable high-speed broadband infrastructure.

It is timely, now that the rollout of the NBN is essentially complete and the presence of high-speed mobile services is expanding, to provide a strategic view of how the range of services can develop to provide an understood 2030 goal, covering:

- The roles of fixed, mobile and satellite services in providing ubiquitous coverage;
- Performance levels required for anticipated high-volume data applications and also to ensure at least international parity – including at least speeds of 100/50 Mbps in the near term and 1000/500 Mbps within the next 5-10 years, along with other clear

specifications of Quality of Service requirements. The intention of the Vision to be “world leading” would imply higher targets on these dimensions; and

- Programs to support identified targets and compliance conformance.

This strategic component would be an extension of the Digital Infrastructure section of the DES as it stands, which shows an underlying, though not fully articulated, strategic perspective.

As already noted, the DES links with other Commonwealth initiatives and programs, and recognises the need for a whole-of-government approach at the Commonwealth level. A National Strategy requires an explicit recognition of the need for greater collaboration at all levels of government, recognising in particular the many initiatives being taken at State level, and with industry and community stakeholders.

The DES needs to be extended to ensure that there is capacity and commitment to maintaining the continuity of the strategy, including its review and revision in response to changes in the economic and social environment. The organisational arrangements for ensuring continuity need to be made more explicit. Whether the Digital Technology Task Force approach is appropriate and robust for the future needs to be addressed in this context.

Australian Broadband Advisory Council (ABAC)

ABAC was established in 2020 and adopted a sectoral approach to examining how broadband services and related programs might transform particular industries and improve productivity and employment, both in the shorter term, as the economy emerges from lockdown and other pandemic-induced constraints, and in the longer term.

The emphasis on transforming particular industries has resulted in ABAC progressing its work through the creation of expert advisory groups. At least two expert advisory groups have made substantial progress during 2021, working on agricultural technology and health. Reports from both groups have been delayed during 2021, but the report of the AgriTech Expert Working Group was eventually published on 10 September 2021 ([Australian Government, 2021a](#)).

It is understood that further reports on the health, construction and creative industry sectors are in the pipeline.

The only report available for discussion therefore is from the AgriTech Expert Working Group (AEWG). It is not a typical report or one that will go through the green paper/white paper processes typical of government. Instead, the report draws on case studies in diverse areas of agriculture, as well as themes associated with connectivity challenges. The studies tend to

show substantial individual and community initiative at a local level in developing solutions, extending services and highlighting opportunities for further development.

Out of the various case studies, it is clear that there is no single overarching solution to the challenges the agriculturists involved need to address. As a result, the recommendations are framed in broad terms. They are ([Australian Government, 2021a](#), pp. 8, 71–76):

1. NBN Co should prioritise moving people from satellite on the ‘outskirts’ of its fixed wireless network by exploring technical ways and connection policies to ‘soften’ the 14 km boundary for the fixed wireless coverage.
2. Continue to provide and expand services such as the Regional Tech Hub, to enable farmers to better understand the full range of connectivity options they already have, including new RSPs.
3. Develop spectrum policy that promotes opportunities for innovative wireless solutions in rural and regional areas.
4. Promote the availability of fibre backhaul to support alternative providers in rural areas – the combination of fibre and class licensed spectrum provides a very cost-effective solution to provide broadband in sparsely populated areas.
5. NBN Co, and carriers generally, should be encouraged to explore technical solutions which allow interworking with lower cost, third-party providers to extend the reach of the carrier networks.
6. Enable local communities to realise their own connectivity infrastructure by removing regulatory barriers and promoting locally driven connectivity initiatives.
7. Invest in ensuring that the ‘stack’ of knowledge and skills required to ‘power’ connectivity and digital agriculture is in place.
8. Shift the weight towards involving local communities in regional specific assessment and planning processes to help ensure that local farming and community organisations are aware of funding from states, territories, and the Australian Government is coordinated and effective in improving telecommunications infrastructure in rural areas.
9. Stronger coordination between Federal, State/Territory and Local governments to ensure investments in communications infrastructure are more aligned with the priorities in each regional and rural area, and possibly in co-funding the key infrastructure projects.

Assessment

Many of the recommendations are well aligned with the recommendations in the TelSoc NBS Report.

The recommendations are at a broad level, perhaps necessarily so given the range of challenges and range of possible solutions that might be adopted. It is not at all clear where responsibility lies to take these recommendations further and to turn them into actionable programs that can be specifically funded and/or managed. The members of the AEWG are not going to perform that role. They will likely return to their “day jobs”, as one stated at the TelSoc forum on the report.

ABAC and the AEWG have indicated that the purpose of the report was to start a conversation which would lead, hopefully, to more concrete action plans in many areas. But this approach runs substantial risks of fading away without result, potential losing the advantage of substantial work and valuable insights in the report.

NBN pricing and Special Access Undertaking (SAU)

NBN Co published a discussion paper in February 2021 inviting all interested stakeholders to comment on various constructs for wholesale broadband pricing, which might be included in a variation to the SAU. NBN Co based its constructs on options that enabled recovery of its costs incurred to date and in the future, as well as various permutations of access circumstances, usage levels and data rates.

The existing SAU was entered into between NBN Co and the ACCC in 2013, and has proved to be largely ineffective in providing overall price and revenue constraint, keeping wholesale (and, consequently, retail) broadband service prices down, and generating price packages aimed at affordability, particularly amongst lower income users.⁶

It was expected, in 2013, that accumulated losses, would be recovered by or within a few years of the completion of the network build. Generally, this was expected to occur within 10 years – by 2023. This has clearly not occurred and the size of the loss is now \$32 billion (according to NBN Co). The result is that the overall revenue cap, an important regulatory constraint in the 2013 framework, cannot be applied while recovery of accumulated losses is required.

The SAU and variations to the SAU are voluntary. In order for the system to work, the undertaking must be made by NBN Co and agreed by the ACCC. Either party can refuse to agree, leaving outdated arrangements to remain in place. Variations to the SAU have been proposed in the past 5 years, but have failed for want of agreement.

In the meantime, NBN Co has developed and expanded a range of discounts and extensions (capacity increases) that have had the effect of passing reduced wholesale prices to the industry.

A specific component of the discussion paper was consideration of options for a low-income product offering.

Assessment

NBN Co has attempted industry and ACCC dialogue to explore the possibility of a broad industry consensus. Agreement appears to be remote, and the ACCC's own review of NBN Co regulation (see below) has complicated the matter. It is not yet possible to undertake an assessment, given the state of discussions at this time.

ACCC review of NBN pricing and regulation

In June 2021, the ACCC published a discussion paper seeking industry and other stakeholder comments on principles that should govern its approach to the regulation of pricing and other terms and conditions for wholesale access services provided by NBN Co, including the possibility of a low-income product. The ACCC has subsequently conducted a roundtable on 18 June 2021 and set up working groups of invited select industry participants to progress the issues. This is an initiative that is intended to have long-term consequences for how NBN Co prices its wholesale broadband services and the opportunities that it will have to recover its accumulated losses and capital investments over the longer term.

Assessment

The working groups established by the ACCC are continuing their work and this is expected to continue at least to the end of 2021. Assessment is therefore not yet possible.

Regional Telecommunications Review

A Regional Telecommunications Independent Review Committee is established every three years under Part 9B of the *Telecommunications (Consumer Protection and Service Standards) Act 1999* to conduct a review into telecommunications services in regional, rural and remote parts of Australia. The Minister, Paul Fletcher, appointed the Committee for the 2021 review in June 2021. The Committee has held various hearings, and submissions on its terms of reference were sought by a deadline of 30 September 2021. The Committee has been charged with completing its review on or before the end of December 2021.

The terms of reference of the review include specific regional issues such as addressing mobile service back spots, but are broad enough to cover a much larger range of policy issues.

Assessment

The initiative is required by legislation, and does not necessarily reflect any current enthusiasm by Government for addressing regional telecommunications issues or general issues that have a regional aspect.

The report from the review is expected to be completed and submitted to the Minister by the end of 2021 but when it is tabled in the Parliament or made public are matters that rest with

the Minister. Assessment will not be possible about the quality of the report and its recommendations until then.

TelSoc and others have proposed that each three-yearly Regional Telecommunications Review should not be a standalone activity. Rather, they should be linked with strong reference to recommendations of previous Reviews and summaries of outcomes. Further, they could be conducted within the framework of a National Broadband Strategy.

Joint Standing Committee on NBN

The Joint Standing Committee (JSC) has continued its work during 2021 and earlier in the year conducted hearings online to enable those who have made submissions to present and to engage with the JSC. The JSC published a 2-page progress report on 31 March 2021 and was due to report by 30 June 2021, but this date has been extended.

Assessment

Based on the specific issues that have been raised in various submissions, and upon the interests and focus of the JSC when TelSoc attended and gave evidence, it seems unlikely that the JSC, in its fuller⁷ report, will be a major agent for progressing longer term issues and bipartisan approaches to national broadband strategy of the kind contemplated in the TelSoc NBS Report. However, assessment of that cannot be undertaken until the JSC's fuller report is published.

Inclusion and affordability

Various studies or assessments of inclusion and affordability of telecommunications services generally, or of broadband services (and Internet access), have been published during 2021. TelSoc has examined some of these including:⁸

- Australian Communications Consumer Action Network (ACCAN): *Addressing Telecommunications Affordability: Evaluating Support for Low Income Consumers* (September 2021) ([ACCAN, 2021](https://www.accan.org.au/publications/Addressing-Telecommunications-Affordability-Evaluating-Support-for-Low-Income-Consumers)). Examines the experience of low-income consumers, and organisations assisting them, with a particular focus on financial supports provided by industry and other organisations, concluding that:
 - Affordability of phone and Internet is a key issue faced by all low-income households;
 - The financial programs examined can help to make life easier or more convenient, but they are not well known;

- Building awareness of the offers, proactively approaching consumers about deals, and providing simple to understand promotional material will help consumers.
- Australian Communications and Media Authority (ACMA): *Communications and media in Australia: How we use the internet* (May 2021) ([ACMA, 2021](#)). This annual survey is now presented in online interactive form, providing a range of information on the practices of users of the Internet, including channels and devices used and activities conducted.
 - An important primary conclusion is that 98.83% of the adult Australian population (18 and over) used the Internet in the last 6 months (anywhere); i.e., only 1.17% did not use the Internet, as compared to 9.61% in May 2019.
- ARC Centre of Excellence for Automated Decision-Making & Society at RMIT, the Centre for Social Impact at Swinburne University of Technology, and Telstra: *Australian Digital Inclusion Index (ADII)* (October 2021) ([Australian Digital Inclusion Index, 2021](#)). The Index has been significantly re-developed in a number of important features, including:
 - A revised survey, developed by the research team and conducted by the Social Research Centre;
 - Propositions of ranges of index values that constitute highly excluded, excluded, included and highly included – with a score of 61 said to indicate inclusion and 28% of the adult population said to be “excluded” (11% “highly excluded” with a score of 45 or less);
 - Online display of key data, with Excel access to databases;
 - A measure of affordability based on definition of desirable Internet bundles and proportion of household income required to meet these, resulting in the conclusion that 14% of all Australians would need to pay more than 10% of their household income to gain quality, reliable connectivity;
 - A new set of attributes to assess digital ability.
- NBN commissioned research, conducted by Accenture: *Consumer affordability of nbn™ services* (September 2021) ([Accenture, 2021](#)), which concludes:
 - NBN retail plan costs represent a small percentage of average household income and compare favourably to other household essentials;
 - The majority of Australians are not concerned about the relative affordability of their NBN service;
 - Australia has the 6th most affordable broadband across 13 OECD countries.

- The Good Things Foundation: *Digital Nation Australia 2021* ([Good Things Foundation Australia, 2021](#)) brings together a range of research sources to highlight aspects of the digital divide, including groups most affected, and to argue for the need for national digital inclusion strategies.

Assessment

Each of these organisations has undertaken important primary research or secondary research into inclusion and affordability. However, questions arise about the common understanding of these phenomena, including:

- The extent to which digital exclusion and problems of affordability are significant issues: the conclusions of the Accenture research for NBN and the significant reduction in ACMA's figure for non-use of the Internet contrast strongly with the grounded research of ACCAN and the conclusions of the ADII 2021.
- The establishment of potential national benchmarks through the ADII's determination of inclusion being assessed by a score of 61 on the index and ideal Internet bundles being used in the assessment of affordability.

No mechanism, government or otherwise, appears to exist to interrogate matters such as these and arrive at some generally accepted standards of definition and measurement that can be maintained over time.

Further, there is no evidence of the issues of inclusion and affordability being addressed or progressed by the Government in any direct way during 2021. The Ministers for Finance and Communication have indicated that they see a role for NBN Co to address inclusion and affordability in some sense in the Statement of Expectations referred to earlier. This direction does not address more fundamental issues of definition and measurement or the adequacy and effectiveness of current or future programs.

On 12 August 2021 TelSoc sent a proposal ([Herring, 2021](#)) for a serious review of inclusion and affordability issues and solutions to Minister Fletcher. The proposal set out the key issues and also the case for a review. In part, the proposal stated:

“... at the most basic level for formation of public policy there is no apparent clear understanding of what constitutes inclusion and affordability and the magnitude of the problem. A commonly used measure for inclusion is that of use of the Internet in a recent period of time – a frequently quoted figure is the ABS 2016-17 statistic that 13.8%, or 2.58 million, adult Australians did not access the Internet in the last three months; a dramatically contrasting figure arises, however, from the recently-reported ACMA study of June 2020 which concludes that 1.17%, which translates to approximately 0.23 million, adult Australians were not accessing the Internet in the last six months. Questions about appropriate definitions, timeliness, and measurement methods clearly arise.”

A reply has been received by email from the Minister's office, utilising the high-level Accenture conclusions about affordability as presented in the NBN Corporate Plan, that suggests that the Government considers that sufficient has been done over the past two decades. The reply invites further discussion with the Minister's advisers, but the specific issues raised by TelSoc are not canvassed in the reply.

Assessment of Progress in Terms of TelSoc NBS Report Proposals

Summary

There have been indications over the past two years of an implicit National Broadband Strategy, or at least components thereof. These indications lack cohesion and do not yet have clear bipartisan support. A comprehensive approach to a strategic framework still needs to encompass the provision of both fixed and mobile broadband services.

While elements of the kind of strategy envisaged by TelSoc are in place or emerging, there is not yet a thoroughgoing strategy based on broad consultation – such as the Green Paper-White Paper process TelSoc has proposed.

This section sets out an assessment of progress in 2021 towards a National Broadband Strategy in terms of the dimensions identified in the TelSoc NBS Report. There may be repetition of some points made in the previous section.

Bipartisan agreement on developing a National Broadband Strategy

While there has not been explicit commitment to an overarching strategy, there are strong indications of an implicit strategy by the Government through the development of the Digital Economy Strategy, the Statement of Expectations for NBN Co, the formation and work to date of the Australian Broadband Advisory Council (ABAC), and other developments that are expected to emerge from initiatives such as the Regional Telecommunications Review at the end of the year.

A question is the extent to which the Digital Economy Strategy fulfils this purpose. In a submission to the Digital Technology Taskforce, TelSoc has welcomed this strategy, with its 10-year focus, but indicated areas of desirable further development. These include a broader approach to digital inclusion and affordability; expansion of the foundation aspect of national broadband infrastructure; addressing the need for cohesion across government, industry and community; and ensuring continuity through emphases on development, monitoring and review.

In meetings with the Minister for the Digital Economy, Jane Hume, Shadow Minister Michelle Rowland, Joint Standing Committee members, Dr Katie Allen and independent Dr Helen Haines, and Minister Paul Fletcher's adviser, Grant Walsh, there has been no rejection of the idea of such a strategy.

Vision and objectives

Elements of Vision and Objectives have been stated or re-stated during 2021.

Vision

The Vision in the Digital Economy Statement is: "For Australia to be a leading digital economy and society by 2030".

While an initial statement of Vision is welcomed, this does not provide the sense of national intent around which efforts on a broad front can cohere. In contrast, TelSoc's suggestion was: "Ubiquitous, high-quality, high-speed broadband that is affordable to all in Australia and which will provide an essential service needed for Australia to develop and remain an inclusive online society and a competitive online economy into the future".

Objectives

NBN Co's Statement of Expectations includes the following:

"The Government's objective is to maximise the economic and social benefits of the NBN and for NBN Co to operate as a sustainable, commercial business. Within legal and policy parameters, NBN Co should generate sufficient revenue to support appropriate levels of investment in the network to meet the current and future needs of Australians, wherever they live. NBN Co will reliably and affordably meet the current and future broadband needs of households and businesses, including in regional and remote Australia, foster productivity and innovation, and support our goal for Australia to be a leading digital economy and society by 2030 ... The Company is expected to support initiatives to increase digital capability and inclusion."

The Statement of Expectations contains a number of constructs which will need clarification to be realistic components of objectives for NBN that can be monitored through appropriate measures and standards. These include clarification of the terms and phrases:

- *maximise the economic and social benefits of the NBN*
- *current and future needs of Australians, wherever they live*
- *reliably*
- *affordably*
- *digital capability*
- *inclusion.*

Objectives such as these should apply to the broadband system as a whole, including mobile service provision, with NBN's role delineated within that.

Determining appropriate measures and standards and then establishing an associated comprehensive national database and analytical framework is key to supporting policy and decision making for optimising infrastructure and achieving investment objectives.

Further statements of objectives are contained in the Digital Economy Statement, including that by 2030:

“All Australians have access to high-speed internet services and the ability to use it effectively ... All Australians have access to digital skills ... 90% of Australians are confident using digital technology, protecting their privacy and assessing whether information is credible”

Common objectives can clearly be developed from these points, with the challenge being to make them measurable and monitorable.

Extending Social and Economic Benefits

Overall, there has been substantially greater emphasis on extending the social and economic benefits of the broadband system, and accepting the importance of this approach, now that the initial build of the NBN has been completed. The circumstances resulting from responses to the COVID-19 pandemic may well have contributed to this greater emphasis. However, some of the initiatives are fragmented and lack scale and cohesion at this stage.

The Digital Economy Strategy has a major emphasis on economic benefits, as does the work of the ABAC. The social benefits have a less obvious specific focus.

Continuing demand-side policy focus

There is an emerging demand-side policy focus, though not yet comprehensive. The Bureau of Communications Arts and Regional Research (BCARR) has provided one example of a case study approach in its study of affordability issues for low-income people using prepaid mobile, and is open to a broader consideration of relevant groups in future. Academic and community groups have provided relevant research on the experiences of specific groups, but there is no thoroughgoing framework for ensuring a user focus to strategy and policy development.

Broad consideration of social and economic benefits

The November 2020 TelSoc report identified a number of dimensions of considering the extension of social and economic benefits:

(a) Assessment of macro-economic benefits

There are a number of studies (AlphaBeta Advisors for NBN Co, BCARR on AgTech, and others) purporting to show quantifiable economic benefits for broadband services either for the whole society or sectors of activity – though with no apparent commonality of methodology or expert critical analysis.

(b) Expansion of Internet use in a broad range of information, communication, transaction and entertainment applications

This embraces market-led applications, underpinned by the broad concepts of digital inclusion and digital capability/literacy. There is not yet a comprehensive program in existence or clearly in the making – although there have been specific relevant initiatives such as the Regional Tech Hub, established in December 2020, and the Be Connected program evaluation (though subject to critical appraisal).

In the absence of a coordinated approach, TelSoc has made a proposal for a Review of Inclusion and Affordability of Broadband Services to the Minister for Communications.

(c) Specific socially valued application areas, such as government services, education, health, banking

ABAC has adopted a selected sectoral focus with initial emphasis on those with greater economic benefit, though also addressing health and, later, education.

(d) Specific economic development areas, such as business (corporate and SMEs), agriculture, tourism

The Digital Economy Strategy has a strong focus on supporting applications development in business and other specific areas. ABAC's first report has been on AgriTech.

(e) Broader social impacts, such as decentralisation

The NBN Co Statement of Expectations recognises the importance of meeting service expectations in regional and rural areas, particularly because of the COVID pandemic.

(f) Possible benefits of future application areas, such as Internet of Things and augmented reality

The Digital Economy Statement pays some attention to emerging technologies and their applications, particularly noting Artificial Intelligence, Internet of Things, Data Analytics, Blockchain and Quantum Computing, and proposes to address these areas largely through existing initiatives and plans.

Generating discourse — transparency/consultation

The Digital Economy Strategy was developed with an advisory panel and a consultation phase, although this may not have been broadly known. ABAC's work has been done with expert groups which have consulted with identified groups. ABAC has shown a willingness for discussion post completion of the AgriTech report, in the first instance.

There has been a shift in the level of discourse being generated. It has been focussed on specific issues and on immediate problems and issues. It is therefore an open question about how strategic it has been, and it lacks any sense or driver of continuity.

Recognising scale requirements

There are questions with all recent initiatives about the recognition of necessary scale, particularly in the digital inclusion/capability area where current programs seem limited compared to likely actual need, and where likely actual need has not been fully analysed.

Future concept of “universal service”

The Universal Service Guarantee implemented from 2020 is the most recent initiative relevant to universal service. It embraces the loss-making aspects of NBN Co's rural and remote service provision under its existing Statement of Expectations. The Regional Connectivity Initiative is also part of a broader regional and rural broadband initiative. Attention has yet to be given to a construct of universal service based on an integrated technologies system, including fixed and mobile services delivered by fixed, mobile, wireless and satellite systems.

Long-term coordinated activity — with ongoing drivers such as a Broadband Institute

The TelSoc NBS report raised the possibility of a purpose-built organisation to drive the understanding and development of social and economic benefits of broadband networks, and provide ongoing policy and project support and research. This concept of a body collaborating between governments, industry, academic and community organisations was outlined in the form of a Broadband Institute in an early Discussion Paper ([NBN Futures Group, 2020](#)). The advent of the Digital Technology Task Force and ABAC reduced emphasis on such a body, pending information on how these bodies might serve such a purpose.

The Digital Technology Taskforce remains in existence to see the Digital Economy Strategy implemented, though with what resources and remit is unclear. ABAC is responsible for a set of task-oriented activities for a finite period; it remains to be seen what recommendations they may make for ongoing activity, underpinned by appropriate research facilities.

There is no clear evidence in 2021 that the notion of a Broadband Institute or similar agency to undertake longer-term comprehensive research and overall coordination has gained any

traction at all. In fact, in the discussions with politicians that TelSoc representatives have had during the year, there appears to be little appetite to create new bodies of this kind. From these conversations the view emerged that there were sufficient public and private agencies in the field, albeit uncoordinated. Despite this, the need for such a body is becoming more apparent to TelSoc.

Technology Pathways

Establishment of future targets for moving to data speeds of 100/50 and 1000/500

Longer term targets of this order seem to be accepted by NBN Co and the Minister, and are further reinforced by the capabilities of 5G. NBN Co's stated intention is that up to 75 per cent of households and businesses served by its fixed network will have available download speeds of up to 1 Gbps by 2023. This indicates NBN Co's acceptance of this as a desirable and achievable target. This apparent acceptance, and its ubiquitous nature in the longer term, needs to be made explicit in the context of a coordinated strategy.

The continuing development of 5G services brings into play standards that might apply to both fixed and mobile broadband services.

Establishment of pathways towards targets

(a) Specific focus on rural, regional and remote users

Explicit pathways towards longer term targets have not been set out by NBN Co or the Government. There has been no reported consideration of the use of emerging technologies, such as Low Earth Orbit (LEO) satellites, to meet targets.

(b) Consideration of options for NBN and 5G

There does not appear to be a cohesive examination of the relationship between NBN and 5G. So far, NBN Co has not been able to acquire 5G spectrum.

Financial considerations

Clarify cost of alternative technology pathways

Pathways have not been clearly defined with associated costs. This is especially important for fixed wireless and satellite service provision.

Determine if debt financing with long-term debt facilities is adequate for 5-year and 10-year periods

NBN Co has shown an ability to raise debt, and recently has been rated by Fitch for a Bond raising, described as "USD 50 billion medium-term note (MTN) programme" ([FitchRatings, 2021](#)).

Importantly, NBN Co has been able to establish suitable private debt facilities and is planning more private borrowings.⁹

Establish what other Commonwealth, State and Local funding, as well as private sector co-funding, might be available, and for what specific purposes

NBN Co has established co-funding arrangements of this kind over the past year, but further detail on how they are working needs to be reported on, over time.

TelSoc notes that State Government initiatives have been announced in this field as well – such as a \$400 million program by the NSW Government. How State, Federal and private initiatives are being coordinated, especially in the absence of a clear and agreed national strategy, is a matter to be pursued.

NBN Co Ownership Considerations

Clarify Government current thinking on ownership changes and timing

In discussion with TelSoc, Government politicians have suggested that the sale of NBN is not on the immediate horizon, as has Minister Fletcher in public statements.

Government MPs contacted by TelSoc are aligned in saying that sale of NBN Co is not on the current issues slate. For that reason, TelSoc has not raised the issue afresh, and does not intend to.

Specify changed policy and regulatory settings needed for (a) continued public ownership; and (b) changes in ownership whether to partial or wholly private ownership

There is no apparent public work on this issue.

Clarify Government approach to restructuring NBN Co, including changes to charter, that might be associated with ownership considerations

There is no apparent public work on this issue. As noted above, privatisation seems to be off the agenda for the medium term at least, and therefore changes that might be proposed to NBN Co's charter will arise from other considerations. TelSoc has sought to raise 5G and backhaul transmission opportunities for NBN Co where appropriate.

Key Gaps in Progress Towards an NBS

Based on the assessments of progress towards a National Broadband Strategy on the various dimensions in the previous section, the table below summarises the key gaps, as TelSoc sees them, and provides indications of what needs to be done in 2022 and beyond to address those gaps.

Table 1. Assessment of Key Gaps and Proposed Actions

Strategic Component	Key Gaps	Proposed Action
Bipartisan agreement on developing a National Broadband Strategy	Elements of a national strategy can be observed, but there is no explicit strategy or bipartisan support for one. No apparent continuity/cohesion of policy development, implementation, monitoring and review.	Ultimately the leadership in developing a National Broadband Strategy and achieving bipartisan agreement must come from the Federal Government. The task it includes the important role of coordinating the various activities and initiatives of State, territory and local governments. The Federal Government should establish the coordinated institutional structure, with clear accountabilities, to ensure continuity and cohesion of policy development, research, monitoring and review.
Vision and Objectives		
<i>Vision</i>	Statement proposed, but lacks a sense of national intent.	Further work should be undertaken by the Federal Government to expand and strengthen existing statements of vision in the proposed National Broadband Strategy.

Strategic Component	Key Gaps	Proposed Action
<i>Objectives</i>	Statement of Expectations for the NBN contain key constructs which need clarification for monitoring through appropriate measures and standards, including: • <i>maximise the economic and social benefits of the NBN</i> • <i>current and future needs of Australians, wherever they live</i> • <i>reliability</i> • <i>affordability</i> • <i>digital capability</i> • <i>inclusion.</i> These and objectives such as in Digital Economy Strategy need application to the broadband system as a whole, including mobile service provision, with NBN's role delineated within that. Establish accurate, regularly updated national databases of broadband availability, usage and affordability Establish regularly updated 'gap analysis' of activities and timing required to advance current status of Australian broadband to the level of its aspirations.	These key constructs need to be given meaningful targets and measures, to be effective and to define accountabilities. Note however that it cannot be a matter only for NBN Co to achieve, since they are operating at the wholesale level in the broadband market. Achieving these objectives will involve the whole system of industry, Federal Government and other policy-making bodies at State level. The Federal Government should establish institutional arrangements to ensure that research, monitoring and data collection are implemented in a coordinated and comprehensive manner, together with regular assessments.
Extending Social and Economic Benefits		
<i>Demand-side policy focus</i>	User-centred approaches need to be built into policy and research (use construct of "effective use" as core).	Methods for ensuring user-centred approaches need to be established.
<i>Broad consideration of social and economic benefits</i>	Strong focus on digital inclusion and affordability . Comprehensive approach to applications deployment, development and support	Review of Inclusion and Affordability of Broadband Services should be conducted by the Federal Government.
<i>Long-term coordinated activity</i>	Ensure long-term research and policy development	Devise and establish a Broadband Institute or similar agency. This links with the institutional focus referred to above.

Strategic Component	Key Gaps	Proposed Action
Technology Pathways		
<i>Establishment of future targets for moving to data speeds of 100/50 and 1000/500</i>	Apparent acceptance, but ubiquitous nature in the longer-term needs to be made explicit target .	These targets, together with clearer descriptions of the service characteristics that need to be better and more comprehensively specified, need to be built into the National Broadband Strategy.
<i>Establishment of pathways towards targets</i>	Technology pathways to long-term objectives for a fixed-mobile-wireless-satellite system	

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End Notes

¹ NBN Co Annual Report 2021 (NBN Co, 2021a), p. 8. The program aims at enhancing fixed network NBN services to provide capacity for 75% of households to be at the highest download speeds by 2023.

² AgriTech Expert Working Group Report, ABAC (Australian Government, 2021a) (June 2021, p 18). Also various of the 650 or so submissions to the Rural Telecommunications Independent Review, 2021 (Australian Government, 2021b).

³ Australian Government ([2021c](#)), p. 11. The measures of success are in some cases presented in more detail at p. 83: for example, that digitally-intensive industries are by 2030 employing more than 10% of the Australian workforce, and that 95% of SMEs are by then using e-commerce tools.

⁴ Australian Government ([2021c](#)), p. 19 – target set at 90%.

⁵ The DES does however seek to deal with new technologies affecting digital economy futures, such as artificial intelligence. The assessment relates only to its coverage of longer term social and economic dimensions of broadband.

⁶ NBN Co has used a series of discounts and service extensions, outside the SAU, to deliver improved price and service terms to retail service providers. The problem with these, unlike an accepted SAU, is that they are discretionary and capable of being withdrawn by NBN Co at short notice.

⁷ Because the Committee is a standing committee, it is not appropriate to refer to a final report. However, the publication of progress reports suggests that something more complete will be published in future.

⁸ Various other sectoral and cohort studies (such as older aged Australians) have been undertaken and published during the year. Resource constraints have prevented TelSoc from examining all work, and the result has been to focus on those considered to be more important or influential.

⁹ NBN Corporate Plan 2022 notes: “In order to finance the repayment of the Commonwealth loan by 30 June 2024 and to execute the investments outlined in this Corporate Plan, NBN Co is planning to raise a total of approximately \$27.5 billion of external debt by June 2024 plus additional working capital facilities. ... To date, the Company has raised in excess of \$14.5 billion in bank and capital markets debt” ([NBN Co, 2021b](#), p. 37).

Predictions from an Empirical Study in the Turkish Mobile Telecommunications Market on the Determinants of Mobile Customer Churn

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Abstract: Acquiring new customers compared to holding the existing ones is costlier and more troublesome for businesses, so customer retention is of great importance in today's intensely competitive environment. It is crucial in customer relations management to identify and analyse customers whose loyalty decreases and who tend to leave, and prevent churn through various methods under resource constraints. This issue is especially prominent in the mobile communication market. This paper uses a binomial logit model based on a survey with 637 mobile users in Turkey to determine the factors affecting customer churn and how they find their effect. Results indicate that, among various factors, network quality, billing, tariff level, tariff plan, and education level are the determinants affecting customer churn and associated with the intention to switch. Our findings demonstrate implications for both managers and rule-makers in the mobile telecommunications sector.

Keywords: Churn, Subscriber loss, Churn prediction, Switching, Customer retention.

Introduction

Recently, many previously monopolized network services have been liberalized and deregulated at the retail and wholesale levels. One of the main areas affected by this approach is the mobile telecommunication market. It is expected that globally 5.7 billion people or 70% of the population will use mobile phones by 2025. In 2020, mobile technology and services created \$4.4 trillion in economic value. As countries reap the benefits of a more widespread mobile service adoption resulting in increased productivity and efficiency, this number will rise to about \$5 trillion by 2025 (GSMA, 2020a). The majority of the rising number of mobile

Internet users are mobile-only users who do not have access to a computer. This exponential increase implies a massive expansion of the application and digital content business into markets ([GSMA, 2020b](#)).

Nowadays, customer churn management is a considerable worry for telecommunications service providers, and it is becoming more of a problem as the competition intensifies. With the help of supportive regulations in the mobile telecommunications market, the focus of mobile carriers has switched from attracting new subscribers to maintaining existing ones and drawing users away from competitors. In this new context, consumers' willingness and ability to compare market offers and switch to better services drive the suppliers' motivations to compete for existing users ([Lejeune, 2001](#)).

It is necessary to understand the elements that drive consumer decisions, how they differ among customers and the elements' roles, such as service satisfaction levels, consumer attributes, services plan and previous mobile switching experience, on mobile churn decisions to create advanced marketing strategies in a tough market like mobile telecommunications ([Kim & Yoon, 2004](#); [Ahn, Han & Lee, 2006](#); [Garcia-Marinoso & Suarez, 2019](#); [Jain, Khunteta & Srivastava, 2020](#)).

This paper explores a literature review of mobile churn, an overview of the Turkish mobile market, and presents the theoretical framework. The paper's main contribution is to add to the growing body of empirical research on the switching factors by using data based on a survey of 637 mobile users, containing a collection of individual and service variables unique to the mobile telecoms industry. In the following, the research method, sample and findings are expressed with the discussion and conclusions.

Literature Review

A high amount of customer turnover may be a desirable aspect of a well-functioning market, since it indicates both consumers' ability to make choices and to exercise those choices. On the other hand, customer churn is a severe concern that can cut into a company's revenues and profitability ([Keaveney, 1995](#)). Therefore, research into switching service providers continues unabated ([Ascarza, Netzer & Hardie, 2018](#); [Gerpott & Ahmadi, 2015](#); [Glady, Baesens & Croux, 2009](#); [Keramati & Ardabili, 2011](#)).

The ratio of customers departing divided by the total number of customers (churn/total customers) in a given period is defined as customer churn rate ([Mozer et al., 2000](#)). Businesses track consumers who switch their service providers regularly ([Sharma & Panigrahi, 2011](#)). Telecommunication markets are complex ([Garcia-Marinoso & Suarez, 2019](#)), and customers are prompted to switch their service providers for a variety of reasons ([Ahmed & Linen, 2017](#)),

including more than just unhappiness with the services ([Óskarsdóttir et al., 2016](#)). Preventing loyal customers from switching operators and ensuring that newly acquired customers form long-term connections with the operator will have a favourable impact on the operator's revenues and profitability ([Huang, Kechadi & Buckley, 2012](#); [Burez & Van den Poel, 2007](#); [Keaveney, 1995](#); [Ferreira, Telang & De Matos, 2019](#)).

Lambrecht & Skiera ([2006](#)) showed that customers with flat tariffs are less likely to churn than prepaid service plans, which has similar results to the study by Karacuka, Haucap & Heimeshoff ([2011](#)) on prepaid and post-paid customers price elasticity. Another research with Zambian mobile users revealed that poor customer services, network quality, tariff plans and billing are the main factors affecting customer churn ([Banda & Tembo, 2017](#)).

Some researchers suggest that the main factors influencing churn are service quality and pricing ([Kim, 2005](#); [Kim & Yoon, 2004](#); [Calvo-Porrall, Faíña-Medín & Nieto-Mengotti, 2017](#)), while others revealed that brand image, service plan types (prepaid & post-paid), data usage, customer services, value-added services, promotions, customer satisfaction levels and previous churn experience are also affecting customer decisions to leave their service provider ([Mahajan, Misra & Mahajan, 2017](#); [Shujaat, Ahmed & Syed, 2015](#); [Garcia-Marinoso & Suarez, 2019](#)).

Karacuka, Catik & Haucap ([2013](#)) analysed the data of 2,105 individuals from a survey conducted by Telecommunications Authority of Turkey and found that, in addition to the country-level network size, network characteristics and consumer preferences with respect to quality, coverage, tariffs, customer services and firm image also affect the choice of mobile network.

The present research contributes to the existing literature with a survey of 637 Turkish mobile operator users, including demographic, customer satisfaction level, past churn experience, service plan and user-specific data. It also aims to explore determinants of mobile churn in the Turkish mobile telecom sector to give clear insights for both managers and policymakers into churn management.

A Brief Overview of Turkish Mobile Market

Mobile telecommunication services in Turkey were launched in 1994 with two operators, Turkcell and Telsim. These two operators largely dominated the market until 2000, and the mobile subscriber base has reached over 16 million under this duopoly structure. By 2000, Aria and Aycell launched mobile services to create an oligopoly market. However, they could not generate an efficient subscriber base and merged into the new brand Avea by 2004. Currently, there are three leading mobile telecommunications service providers in Turkey with

the purchase of Telsim by Vodafone in 2005. As shown in Table 1, by the end of 2020, Turkcell has 40.3%, Vodafone has 31.6%, and Avea has a 28.1% market share in the Turkish mobile market ([Kar, 2018](#); [BTK, 2021](#)).

Table 1. Market shares of Turkish key mobile operators in terms of subscriber numbers

	1994	2002	2008	2010	2013	2019	2020
Turkcell	78.1%	67.3%	56.2%	54.2%	50.5%	40.5%	40.3%
Telsim ^a	21.9%	25.4%	25.2%	27.0%	28.6%	31.1%	31.6%
Avea	-	-	18.5%	18.8%	20.9%	28.4%	28.1%
Aria ^b	-	5.1%	-	-	-	-	-
Aycell ^b	-	2.1%	-	-	-	-	-

^a Vodafone acquired Telsim at the end of 2005.

^b Aria and Aycell merged into Avea in 2004.

In 2020, mobile operators generated some \$5.3 billion of revenues and invested \$1.32 billion in infrastructure. By the first quarter of 2021, there are 83 million mobile subscribers in Turkey with a penetration rate of 99.9%, lower than countries such as Finland, Portugal, Denmark, Austria, Sweden and Germany (average 149.2%). Post-paid users form 66.3% of the mobile market and have more than two times ARPU (Average Revenue Per User) than prepaid consumers ([BTK, 2021](#)).

Mobile number portability in Turkey was announced at the end of 2008; since then, regulators are pursuing policies to facilitate switching service providers with shorter porting periods (6 days) and fair fees. It has been agreed between the operators that separate 15-minute periods are required for the deactivation of the number to be transported at the donor operator and for the activation at the receiving operator. In this case, the communication interruption of the subscriber will be an average of 15 minutes. The time zone of the day for this interruption will be determined by the operators, considering the preference of the subscriber. The ported number will have the same functionality after the activation of the ported carrier. One of the issues that will come to the agenda with the number portability regulation is that a subscriber who initiates a call to a ported number will not know which operator the number is at. In order to prevent possible tariff and billing problems, operators that initiate calls are obliged to issue a distinctive warning tone for the calling subscriber which lasts 1.6 seconds ([NTS, 2021](#)).

Approximately 13 million numbers were ported in 2020 and, within the first quarter of 2021, Vodafone successfully gained 63,000 subscribers from Avea and Turkcell. Switching mobile carriers while keeping the same mobile number provides many advantages for customers and increases competition; however, it poses a substantial risk for mobile operator revenues. Currently, operators in the Turkish mobile market force termination terms that generate a penalty for ceasing services. On the other hand, fierce competition in the market results in

some operators paying the cancellation charges on behalf of the customer. Table 2 shows mobile churn rates in Turkey in 2020 ([BTK, 2021](#)).

Table 2. Churn rates^c of mobile operators in 2020

	January	April	July	October	December
Turkcell	2.5%	2.3%	2.5%	2.2%	2.6%
Vodafone	2.2%	1.5%	1.9%	1.8%	5.4%
Avea	2.1%	1.5%	2.5%	2.2%	4.3%

^c number of switched customers / average total subscribers in the term

The Information and Communication Technologies Authority (BTK) in Turkey periodically reports customer satisfaction statistics received via an online complaint management system. According to BTK, network and service quality (30.3%) is the leading issue decreasing customer satisfaction, while subscription processes (30%), billing (23.2%), lock-in contracts/penalties (9.5%) and tariffs/promotions (7.0%) are the additional factors. BTK reports support that these factors are important determinants of customers' intention to switch operators in Turkey ([BTK, 2021](#)). Such factors remain as the main complaint areas that operators need to resolve to increase customer satisfaction ([Kim & Yoon, 2004](#); [Kim, 2005](#); [Lunn & Lyons, 2018](#); [Garcia-Marinoso & Suarez, 2019](#)).

Research Methodology

The mobile users' probability of switching current operator is modelled using a binomial logit model relating factors including mobile carrier service attributes, demographic variables and user-specific characteristics, such as past churn experience and service plans. The methodology of the model makes use of studies carried out by Kim and Yoon ([2004](#)), Garcia-Marinoso & Suarez ([2019](#)) and Uner, Guven & Cavusgil ([2020](#)). The required data for the econometric model is obtained from an online survey of 637 random participants conducted in 2021.

Respondents were asked to indicate their satisfaction levels regarding different factors using a Likert scale with the following categories: 1 very unsatisfied; 2 unsatisfied; 3 neither satisfied nor unsatisfied; 4 satisfied; and 5 very satisfied. In addition, the participants were asked for their tariff types (prepaid or post-paid), contract profiles, and whether or not they have changed operators in the last year. According to Uner, Guven & Cavusgil ([2020](#)), data usage has a substantial effect on churn and increased data usage lowers the probability to churn. Thus, we ask our participants how often they use social media applications. We take the dependent variable as the intention for churning in the next one year, with the value set to "1" for churn and "0" for no churn.

Table 3 illustrates the coding of the variables to measure the relationship between predictors and the probability of churn.

Table 3. Description of variables

Variable	Description
Customer Satisfaction (CS): Billing (CS1), Tariff level (CS2), Network/Call quality (CS3), Customer services (CS4), Promotions/Products (CS5)	1: very unsatisfied, 2: unsatisfied, 3: not satisfied nor unsatisfied, 4: satisfied, 5: very satisfied
Gender	1: male 2: female
Age	1:16-24, 2:25-34, 3:35-49, 4:50-64, 5: ≥65
Education level	1: secondary or below, 2: tertiary or above
Employment	1: full time, 2: part time, 3: retired, 4: unemployed
Current Operator	1: Operator 1, 2: Operator 2, 3: Operator 3
Tariff plan	1: post-paid, 2: prepaid
Termination clause	1: yes, 2: no
Social media usage on mobile phone (daily)	1: never, 2: rarely, 3: sometimes, 4: often, 5: always
Switching experience	1: subscriber with past switching experience 0: otherwise

Estimation Results and Discussion

Some selected empirical findings are represented in Table 4. Of the respondents, 82.9% use post-paid tariff plans, while 69% include a termination clause; 47.5% of the participants always use social media daily indicating extensive data usage for the operators. The question to measure the previous churn experience gets 18.9% positive answers.

Table 4. Descriptive statistics

		n	%
Tariff plan	Post-paid	527	82.9%
	Prepaid	109	17.1%
Termination clause	Yes	439	69.0%
	No	197	31.0%
Social media usage on mobile phone (daily)	Never	11	1.7%
	Rarely	25	3.9%
	Sometimes	126	19.8%
	Often	172	27.0%
	Always	302	47.5%
Switching experience	No	516	81.1%
	Yes	120	18.9%

The research yielded some intriguing findings on the factors that influence churn decisions of Turkish mobile subscribers. We used a binary logistic regression to predict the factors that

affect churn intention, and then ran various robustness tests to ensure that the model fit was good and the overall model is statistically significant. For the research's dependent variable (churn), Table 5 lists significant independent variables and their respective contributions to the model, together with insignificant ones. To interpret the results, odds ratios higher than one imply a positive relationship between independent and dependent variables.

Table 5. Estimation results: odds ratios (robust standard errors in parentheses)

Variables	Churn
CS1: Billing (ref: very satisfied) very unsatisfied unsatisfied not satisfied nor unsatisfied satisfied	7.035*** (.689) 5.889*** (.557) 3.694*** (.445) 2.384** (.425)
CS2: Tariff Level (ref: very satisfied) very unsatisfied unsatisfied not satisfied nor unsatisfied satisfied	4.577*** (.492) 1.641 (.459) 1.474 (.396) .846 (.412)
CS3: Network/Call Quality (ref: very satisfied) very unsatisfied unsatisfied not satisfied nor unsatisfied satisfied	7.695*** (.501) 2.615** (.475) 2.122* (.408) .763 (.397)
CS4: Customer Services (ref: very satisfied) very unsatisfied unsatisfied not satisfied nor unsatisfied satisfied	2.056 (.630) .899 (.579) 1.298 (.526) 1.393 (.497)
CS5: Promotions/Products (ref: very satisfied) very unsatisfied unsatisfied not satisfied nor unsatisfied satisfied	1.700 (.522) 1.385 (.489) 1.196 (.454) 1.155 (.436)
Gender (ref: male)	.721 (.240)
Age (ref: 16-24) 25-34 35-49 50-64 65 and above	1.668 (.349) 1.786 (.357) 1.353 (.502) 3.141 (.971)
Education Level (ref: Secondary or below)	1.753** (.273)
Employment (ref: full time) Part time Retired Unemployed	.777 (.426) 1.245 (.557) 1.470 (.325)
Operator (ref: Operator 1) Operator 2 Operator 3	.393*** (.308) .556** (.268)
Tariff Plan (ref: Prepaid)	.420** (.380)
Termination Clause (ref: yes)	1.559 (.279)

Variables	Churn
Social Media Usage (ref: never)	
Rarely	.979 (1.021)
Sometimes	1.268 (.850)
Often	1.116 (.845)
Always	1.931 (.832)
Switching Experience (ref: yes)	.720 (.278)
Observations	637
Nagelkerke R ²	.408
Log Likelihood	568.171

*Significant at 10%. ** Significant at 5%. *** Significant at 1%.

Estimation results show that the probability of a subscriber churning is dependent on the level of subscriber satisfaction with service attributes that include call quality, tariff level, and billing. The estimated odds ratios for satisfaction levels were greater than one and significant; this means that unsatisfied customers are more likely to switch their providers ([Uner, Guven & Cavusgil, 2020](#)). Relative to being very satisfied, being very unsatisfied with the previous mobile service in terms of network quality and billing increased the odds of switching providers more than sevenfold. Customers who are very unsatisfied with tariff levels are four times more likely to churn. As one might assume, the quality of the consumer experience influenced switching decisions, with the odds ratios for consumer satisfaction having the most significant impact.

As expected, post-paid tariff users are less likely to churn and prepaid customers are more likely to change their mobile carrier, considering the ease of ceasing the services.

Termination clause, daily social media usage and switching experience are not found to be significant variables affecting churn decisions. As anticipated, operators in Turkey are willing to bear the expenses of churn penalties while winning new subscribers.

Finally, variables related to socio-economic and socio-demographic information, such as age, gender and employment, are not good predictors of switching behaviour. However, in contrast to the findings of Garcia-Marinoso & Suarez ([2019](#)), higher education level has a positive effect on mobile churn.

Conclusion

Like many other services or goods, mobile consumers tend to stick with their current service provider unless they discover a severe problem or are dissatisfied with the services provided by that operator. When the customer churn rate is high or continues to climb over time, the company must take immediate action, since an unhappy customer can quickly become a lost one. Negative word of mouth and unfavourable reviews can ultimately affect total brand value, in addition to the financial impact of a consumer leaving the operator. For this reason alone,

it makes sense to reach out to customers who are on the verge of switching carriers and repair their connections. It is also worth noting that keeping a current client costs less and gives more value than getting a new one ([McIlroy & Barnett, 2000](#); [Lejeune, 2001](#); [Catalan-Matamoros, 2012](#); [Saleh, 2017](#); [Guven, 2018](#)).

Our study shows that mobile users' satisfaction level with the service provider is the most potent motivator of switching; dissatisfied customers are more likely to switch next year. Operators should provide excellent services, especially for call quality and billing, rather than applying alternative methods to boost retention rates like penalty clauses. Operators should focus on identifying dissatisfied customers with the highest likelihood of churning and enhance their products. Mobile carriers should step up their efforts to keep major consumers and introduce churn management programs to increase loyalty. The present paper corroborates that consumer satisfaction is the most significant factor for mobile churn decisions ([Kim & Yoon, 2004](#); [Calvo-Porrall, Faíña-Medín & Nieto-Mengotti, 2017](#); [Garcia-Marinoso & Suarez, 2019](#)).

The mobile industry has thrived in an unregulated environment. However, regulatory authorities in many countries are increasingly scrutinizing it as the mobile network becomes a vital part of the national telecommunications system. Our study shows that more regulatory scrutiny is required on the retail side of the mobile industry, mainly focusing on the factors affecting customer satisfaction. In this direction, regulatory bodies could regularly publish quality parameters of operators to improve mobile operator service levels, set challenging targets for mobile network quality, introduce supportive regulations for network investments, or make decisions to ensure network sharing among operators. Furthermore, regulatory bodies may enact legislation to protect mobile customers from bill shock, and construct a web page that lists all of the offers made available to users, making tariffs easier to grasp.

Given client sentiments regarding the telecom business, losing customers is likely to be costlier than in other industries. Companies must become more aware of this fact and interact with customers more regularly to better understand their behaviour.

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