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Adoption of 5G in developing economies: A supply side perspective from India

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ABSTRACT

The current 3G and 4G telecom technologies present challenges in the form of network congestion, low average revenue per user and limited applications across different industries. This is driving the need for faster adoption and implementation of 5G technologies. Researchers have largely focused on the technical aspects of 5G and its adoption on the demand side, while the focus on the supply side—business implications, enablers and barriers to adoption for the telecom service providers (TSPs)—is limited. A supply side perspective on 5G adoption in developing economies needs more attention as their ecosystem of technology deployment is different from that of developed economies. India being one of the prominent developing countries and the second largest telecom market in the world, with 5G adoption at a nascent stage, is an apt case for studying enablers and barriers. Thus, this exploratory study focuses on identifying the factors for adoption of 5G by TSPs. The study makes theoretical contributions to literature by identifying seven unique factors and eight unique subfactors and proposing a new 5G adoption model for TSPs. Recommendations are provided to aid policy and decision-makers in designing policy interventions and strategies for faster 5G adoption from the supply side of the diverse ecosystem.

1. Introduction

Mobile technology over time has transformed business and customer experience. While each generation of mobile technology was revolutionary in terms of a paradigm shift in features and services offered to the users, the transition to fifth generation (5G) is much more transformational as it provides a 20 times faster data rate, 10 times shorter latency time, 10 times more than the maximum number of connections, and 3 times better spectral efficiency (Erunkulu et al., 2021; Agiwal et al., 2021; Tahir et al., 2020; Gao, 2021). Globally, it is estimated that 5G could generate $12.3 trillion in sales activity across multiple industries such as military (Bastos et al., 2021), healthcare (Akpakwu et al., 2018; Shafique et al., 2020), traffic monitoring (Shafique et al., 2020), smart cities (Akpakwu et al., 2018; Shafique et al., 2020; Guevara and Auat Cheein, 2020), smart farming and agriculture (Tang et al., 2021), and smart transportation (Akpakwu et al., 2018; Shafique et al., 2020; Guevara and Auat Cheein, 2020). Connectivity, networking, end-to-end visibility, and transparency provided by 5G technology for enabling massive deployment of Internet of Things (IOT) has been recognised as the change driver for managing supply chain, logistics, and operations (Dolgui and Ivanov, 2022).

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However, even though the environment and value for 5G are positive, there is an anxiety about its successful adoption (Ericsson, 2019), especially in least developed countries (Afghanistan, Nepal, Bangladesh, Bhutan, Uganda, Somalia) (Rahman et al., 2021) and low and middle-income countries (Malawi, Uganda, Kenya, Senegal, Pakistan, Albania, Peru, Mexico, India) (Puri et al., 2018; Oughton et al., 2022). Moreover, in developing countries, telecommunication service providers (TSPs) have not yet started earning sufficient return on investment (ROI) on the 4G networks that have been implemented so far (Rahman et al., 2021). At the same time, contemporary research suggests that low and middle-income economies can use 5G as an opportunity to drive economic growth (Forge and Vu, 2020). To take advantage of this opportunity, developing economies need to take appropriate decisions on facilitating timely 5G rollout and ensure its successful adoption by firms and individual users.

Earlier generations of mobile technologies followed the generic model with similar set of specifications to develop equipment and devices or provide products and services (Lee et al., 2022). However, 5G with its capabilities will enable different scenarios and applications for different users (across industries), leading to different standards and models. However, experience suggests that the promise of new mobile technologies generally does not get fulfilled in practical deployment, mostly due to technical and regulatory paradoxes. A similar fate may befall 5G technology—especially due to the deployment of new bands of spectrum in the millimeter waves, in the range of 24–40 GHz, as well as new usage scenarios of low latency and high throughput—unless sufficient technical and regulatory foresight is established prior to 5G rollout. Thus, it is essential for policy makers to understand the enablers and barriers for embracing 5G technology as perceived by the telecom firms on the supply side. A deeper understanding of the interests and motivation of telecom firms (especially TSPs) is very much required by the policy makers as major investment decisions need to be made by TSPs, which will be based on their views of smooth and timely rollout and anticipated ROI. On the demand side too, policy makers need to understand the aspirations of the citizens so that focused attention is directed toward the development of a suitable ecosystem for the development of appropriate use cases of 5G, which in turn will boost revenue for the TSPs (Oughton et al., 2018). Synergy in research-based efforts between the demand and supply sides will facilitate better leveraging of 5G capabilities. Therefore, the objective of the study is to identify enablers and barriers for the adoption of 5G in developing economies.

The study has been based in India because the country presents a unique and interesting context to study 5G adoption. Firstly, efficient deployment of 5G in India will enable the TSPs to increase their average revenue per user (ARPU) and sustain their profitability, which has been significantly eroded in the recent times due to intense competition. Secondly, 5G in India presents an opportunity for developing a plethora of use cases with significant social and economic impact (TRAI, 2019). Thirdly, India being the second largest telecom market in the globe with 1145.45 million mobile subscribers (TRAI, 2022a) presents a huge potential for 5G and is in the process of enhancing its technological competitiveness by adopting emerging technologies (Mittal and Momaya 2009; Mittal et al., 2013). Preparations for rolling out 5G in India started in 2018 with the setting up of a high-level forum, mandated by the Department of Telecommunications (DoT), for recommending policy initiatives and action plans to realize the 5G vision (DoT, 2018). Recommendations of the forum culminated in the recent auction of the 5G spectrum in July 2022, thereby placing India on the cusp of a 5G rollout.

Given the value 5G can bring to the growth of industries and the economy, as well as the importance of sustaining the motivation of stakeholders on the supply side, the research questions that are addressed in the study are as follows:

1. What enabling factors can contribute to 5G adoption by TSPs in developing economies?
2. What inhibiting factors create challenges for 5G adoption among TSPs in developing economies?

Accordingly, the objective of the study is to identify enablers and barriers on the supply side (from TSP perspective) for the adoption of 5G technology in developing economies, with a focus on India. The study will be a source of valuable insights for ecosystem strategies (policy- level and operational-level interventions), which can be considered by other developing countries planning to deploy 5G technology for achieving national goals. On the theoretical front, the study will deepen the body of knowledge on technology adoption, especially from the supply side of technology in developing countries.

The rest of the paper is organized as follows: Section 2 presents a literature review of 5G studies worldwide and in India, along with adoption theories and frameworks. Section 3 presents the research methodology adopted in the study. Section 4 and 5 present the data analysis, findings, and discussions. Policy and managerial implications are highlighted in Section 6. Section 7 presents the conclusions, limitations, and future work directions.

2. Literature review

Technology is a strategic resource both at the micro and macro level, leading to economic transformation and reducing inequality (Schot and Steinmueller, 2016). While countries and firms are moving fast to acquire and adopt new technologies to remain competitive, there exists current technological differences in terms of how intensively new technologies are eventually used once they arrive in a country. The more capable and technologically sophisticated firms are also more resilient and able to survive and bounce back from economic shocks, as observed during the COVID-19 pandemic (Cirera et al., 2022). It has also been observed that the lag between low-income and high-income countries in the adoption of technology has narrowed, while the gap in the intensity of use of adopted technologies has increased (Comin and Mestieri, 2018). It is important to consider how to combine technology push and demand pull for designing policies in shaping and creating new markets. In a developing country context, technology upgrading might be more challenging than in developed economies as market failures and missing complementarities are likely to more acutely affect the returns to new technology (Cirera et al., 2022).

There have been many studies in recent years around 5G, covering its features, performance, and deployment. Researchers around the world have started conducting research on the factors affecting 5G adoption. To identify the enablers and barriers of 5G, it is imperative to understand and look in detail at the developments of 5G worldwide as well as in India, along with the adoption frameworks and models.

2.1. 5G development and deployment worldwide

The initial commercial launch of 5G took place in 2019 in urban parts of South Korea, which was followed by the USA, Germany, Switzerland, Italy, and Finland (Forge and Vu, 2020; GSA, 2022). The United States and Europe are at the forefront of 5G deployment, but investments in 5G have been made in almost every country in Asia (Forge and Blackman, 2017; Statista, 2022). However, rural area coverage is still a challenge (Massaro and Kim, 2022). 5G subscriptions are forecasted to increase worldwide from 216.8 million in 2020 to 4.39 billion by 2027, with Northeast Asia, Southeast Asia, India, Nepal, and Bhutan having the most subscriptions by region (Statista, 2023).

2.2. 5G development and deployment in India

India's first 2G service was launched in 1995, with the adoption of GSM (Global system for mobile communication) technology and CDMA (Code Division Multiple Access technology) in the year 2002–03 (Gupta and Jain, 2020). Later, 3G services were launched in the country in 2008 by several TSPs, including the state-owned firms BSNL and MTNL. Subsequently, huge capital investments were made for the deployment of 4G-Long term Evolution (LTE) by the new entrant, Reliance Jio Infocomm, in the year 2016–17. Since launch of 3G and 4G, India has witnessed an impressive rise in the demand for mobile broadband data, growing from just 0.31 MB/user/month (in year 2013) to 17.18 GB/user/month (in year 2022) (TRAI, 2022a). In 2018, the government announced the futuristic National Digital Communication Policy (NDCP) to strengthen India's long-term competitiveness by creating an ecosystem of 5G technology coupled with Internet of Things (IOT) with reduced latency, high security, and strong data encryption to all equitably and affordably (NDCP, 2018).

Preparations for timely launch of 5G technology were initiated in 2018, when the government constituted a high-level forum (HLF) to provide recommendations for deployment of 5G technology in India. Keeping in mind the recommendations of the HLF and the evolving global standards, 5G spectrum bands in India were identified to include 700 MHz, 800 MHz, 900 MHz, 1800 MHz, 2100 MHz, 2300 MHz, 2500 MHz, with new spectrum bands as 600 MHz, 3300–3670 MHz, and 24.25–28.5 GHz (TRAI, 2022b). Spectrum auctions were initiated in July 2022, in which Indian TSP, Reliance Jio, emerged as the top bidder followed by Bharti Airtel. The

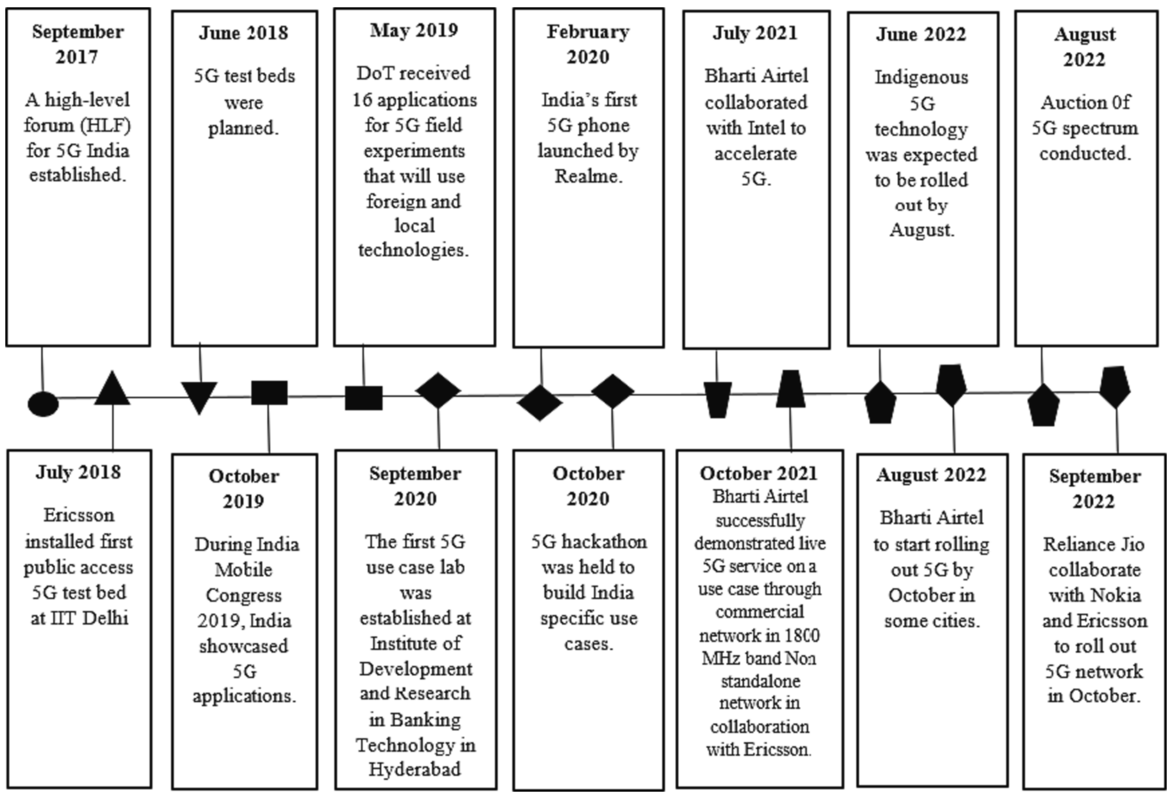

Fig. 1. Timeline of 5G initiation and deployment in India.

journey of 5G developments in India and policy interventions is presented in Fig. 1.

2.3. 5G technology adoption models and factors

Technological transitions and their adoption and diffusion have been one of the major concerns for the management of technology (Gupta and Jain, 2012, 2020; Sharma and Mishra, 2014). The decision to adopt a new technology by potential adopters (both by firms and individuals) calls for an assessment of the technology's capabilities and features as well as the adopter and firm's capabilities and challenges. Countries are pushing for research on 5G not only to understand and explore its technical aspects but also to unearth insights on its applications and adoption phenomenon. Technology adoption models and frameworks have been developed and applied across technological generations and sectors, both at the individual level as well as at the organizational level, including diffusion of innovation theory (DOI) (Rogers, 1962); theory of reasoned action (TRA) (Ajzen and Fishbein, 1977); theory of planned behavior (TBP) (Ajzen, 1991); technology acceptance model (TAM) (Davis, 1989); unified theory of acceptance and use of technology (UTAUT) (Venkatesh et al., 2003); value adaptation model (VAM) (Kim et al., 2007); TAM 3 (Venkatesh and Bala, 2008); and technology-organization and environment framework (TOE) (Tornatzky and Fleischer, 1990). A large body of research has focused on the TAM model and its derivatives to study telecom technology adoption at the individual level (2G- Lopez-Nicolas et al., 2008; Kim and Garrison, 2009; Gupta and Jain, 2014, 2016, 3G- Kuo and Yen, 2009; Pagani and Fine, 2008, 4G- Park and Kim, 2013; Kitchen et al., 2015). Maeng et al. (2020) used the logit model to study the consumer behavior associated with purchase delay of 5G services and found that the cost of 5G service and the lack of need were the main factors among Korean consumers. Recently, Shah et al. (2021), in their study of China extended the VAM and revealed that a user's attitude toward accepting 5G is greatly influenced by the user's environmental awareness and knowledge. In addition, privacy, speed, ubiquity, subjective norms, influence consumers' word of mouth and willingness to pay. Consumers with a prevention focus have high concerns about privacy risk, and this affects the attitude toward 5G negatively (Cheng et al., 2021).

At the organization level, the TOE framework and its integrated versions have been widely used (Gangwar et al., 2015; Chiu et al., 2017; Raut et al., 2018), with specific factors depending on the context. In addition, new technology adoption and implementation calls for changes in organizational capabilities. To adopt new technologies, firms need to have the required technological capabilities or the ability to reorganize their resource base. Firms with higher dynamic capabilities adapt themselves in rapidly changing markets (Teece, 2007). Technology opportunism, measured by technological sensing capability and technological responding capability, has been found to influence the technology adoption at a firm level (Srinivasan et al., 2002; Lopperi et al., 2006; Garrison, 2009; Vowles et al., 2011; Lucia-Palacios et al., 2014). Strong technologically opportunistic firms look at the potential to collaborate with other stakeholders such as suppliers, partners, competitors as well as customers to renew and reconfigure resources to the firm's advantage. However, the organization's size can be a barrier to an organization's response capability despite its increased capability to sense the technology earlier than smaller firms (Garrison, 2009). Recently, Graham and Moore (2021) developed a firm-level technology adoption framework, highlighting how dynamic capability constructs (absorptive capability and technology Opportunism) frame the firm's perceptions of a technological innovation and drive the adoption decision.

The 5G ecosystem has a large set of actors—end-users, industry verticals, government, content creators, application creators, device makers, technology integrators, TSPs, and infrastructure providers. Recently, Park et al. (2021) adapted the framework of Iansiti and Lakhani (2017), based on newness of application and complexity (involved in ecosystem coordination), to support managers' adoption decision of 5G-specific applications/use cases. Literature indicates that factors like incomplete ROI cycle for 4G, high pace of technology in terms of investment, and willingness of consumers and business to pay for 5G were found to be the barriers to 5G adoption in Europe (Forge and Blackman, 2017). Also, new market opportunities, security and privacy, the cost of deployment were found to be important factors for business and acceptance of 5G in the European market (Neokosmidis et al., 2017). The annual capital intensity of a TSP, the degree of infrastructure sharing in greenfield deployments, and the required end-user speed affected the pace of rollout of 5G in Britain and the Netherlands (Oughton and Frias, 2018; Oughton et al., 2019). While many studies report government policies to be an enabler of 5G technology, a study in China showed negative impact of government policies on telecom operators and revealed that 5G activities decrease firm value due to newness and unreliability of technology (Jeon et al., 2022). Puri et al. (2018), in India, identified 23 challenges, which they categorized into 4 broader groups—system level, network level, spectrum level, and performance based. Demands and needs of the end customers, cost reduction and additional revenue stream for mobile network operators, industry automation, and country competitive advantage were found as enablers of 5G deployment and adoption in Indonesia (Hutajulu et al., 2020). Praveen et al. (2020) conducted a study in North America, Europe, South America, Asia, Japan and Australia on the implementation challenges of 5G based on blockchain and found that multi-operator network slicing, fraud prevention, physical infrastructure sharing, and spectrum management were the major factors in 5G adoption. Kushwaha and Kushwaha (2019) very briefly mentioned that cost, uncertainties over coverage, overcrowded frequency range, need for skilled personnel, government policies, infrastructure development, research-based issue handling, security and privacy, spectrum, and switching costs from 4G to 5G can act as barriers for implementing 5G. It is understood that the adoption and implementation of 5G in developing countries like India will be greatly different from that in the developed ones (Forge and Vu, 2020).

After a careful study of scholarly literature, it is observed that research on 5G adoption is growing recently, especially in the context of developed countries. Although studies have been carried out on adoption of 5G technology (Hutajulu et al., 2020; Simon, 2020), they have mainly looked at factors of adoption from the perspective of individual users. Despite the obvious advantages of 5G technology in terms of wide-ranging new business cases, TSPs, in general, remain cautious in their deployment decisions. While TSPs are at the forefront of investing and rolling out the technology, very few studies have looked at 5G adoption from their viewpoint (Puri et al., 2018). 5G is a recent phenomenon and warrants further investigation especially in developing countries. Therefore, this study seeks to understand 5G adoption (key enablers and barriers) from a TSP perspective.

3. Research methodology

The key purpose of the research is to identify the enablers and barriers of 5G adoption among TSPs in India. The philosophical approach used in this study is constructivism as the study focuses on exploring and identifying the adoption factors of 5G. This involves interpreting the ideas of respondents and building constructs based on their explanation given by them. An exploratory qualitative approach has been followed with an attempt to generate in-depth and rich descriptions (Oettmeier and Hofmann, 2016). Open ended semi-structured interviews have been conducted, and the content analysis is based on the approach used by Miles and Huberman (Miles et al., 2014).

4. Data collection

Three criteria were applied to select TSPs appropriate for this study: (1) diversity of technology and services (successfully launched previous telecom technologies and its related services), (2) the spread/penetration within the country, and (3) initial investments in 5G. The authors have collected data through open-ended, semi-structured interviews with telecom experts. The questions were based on general information about 5G, benefits of 5G, and challenges in adopting and implementing 5G. Judgmental and snowball sampling was used to select the respondents. Responses from 11 experts from TSP firms with a minimum of 10 years of work experience (as shown in Table 1) were collected over telephone calls and video conferencing (due to COVID-19 pandemic restrictions), with an average interview time of 45–50 min.

The interviews were recorded with the permission of the participants and subsequently transcribed. A minimum of two interviews with senior personnel were targeted per TSP with the final number being determined by access to interviewees. Validity was ensured through search for multiple sources of evidence through triangulation (Patton, 1999). Also, to get multiple perspectives of the phenomenon under study, triangulation was attempted in two ways 1) within the interviews by asking questions in multiple ways (Bryman and Bell, 2015) and 2) by interviewing experts from telecom manufacturing firms and from a national-level telecommunication training institute. Nondirective and directive questions were asked for a deeper grounding of theoretical insights and to mitigate biases. Connecting with more experts and collecting data was halted at the point at which no new codes or concepts were getting revealed, indicating theoretical saturation (Bryman, 2013). In total 14 interviews were conducted (Table 1).

5. Analysis and findings

Each interview was transcribed immediately after the completion of the interview to avoid loss of meaning. Doing so allowed the authors to identify analytical structures and find similarities and differences between different interviewees' experiences. Data were analyzed using the three-step approach of content analysis (Miles et al., 2014). Content analysis is defined as a research technique for making replicable and valid conclusions from texts to the contexts of their use (Krippendorff, 1989). The analysis was conducted in two phases. The first phase of analysis was performed manually to ensure all meaningful qualitative data were seized (Weitzman, 2000). Coding started with the identification of concepts and constructs. The authors performed multiple versions of first-order coding constructs, staying close to the data. The commonalities were combined as one construct, and differences were retained as useful insights. For example, concepts extracted from the transcript data such as "time to market," "fast launch of new services," "less launch time," "high speed to develop services" were all combined under the first-order construct—"time to market." Attention was given to emerging and nascent concepts, especially in the context undertaken (Gioia et al., 2013). On similar lines, other first-order constructs were created; for example, open-source technology and platform, which highlighted the flexibility of telecom operators in 5G, was found to be an emerging concept and was labeled as "service providers' flexibility." In the second stage of coding, authors iterated the

Table 1
Profile of interviewees.

S.N.	Designation	Firm	Years of experience
1	Senior Manager	C1	12+
3	VP (Network Engineering & Delivery)	C1	15+
4	Head Customer Life Cycle Management	C1	15
5	VP (Network Engineering & Delivery)	C2	15+
6	Senior Manager	C2	15
7	Vice President, NOC & Operations	C3	25+
8	CTO broadband	C3	30+
9	Vice President- Regulatory affairs	C3	20+
10	Principal General Manager	C4	29+
11	Deputy General Manager	C4	10
12	Price Manager*	C6	10
13	Senior Project Manager*	C7	20+
14.	Chief of Public Policy & Regulatory*	C8	30+

Note: C1, C2, C3, C4 – presents TSP firms.
* indicates other telecom experts.

steps of creating and organizing second-order constructs among themselves, with the help of literature from technology adoption and technology management in general. For example, time to market, higher flexibility, and higher capacity were highlighted by respondents as advantages of 5G compared to previous generation technologies and hence were put under the second-order construct "relative advantage" (as defined in the technology adoption literature). However, service providers' flexibility was carried forward as a unique second-order construct. Creating categories (a group of content that shares a commonality and are mutually exclusive) is a core aspect of content analysis. Second-order constructs were carefully examined with the help of discussion, transcript data, and relevant literature for their exclusiveness and aggregation under one category. For example, the second-order constructs of relative advantage, service providers' flexibility, backward compatibility, data security and privacy, and availability of standards were categorized as technological factors as they represented the characteristics of technologies and platforms that impact firm-level decision-making towards its adoption. In the second phase of analysis, transcripts were revisited with the aim to identifying enablers and barriers towards 5G adoption for TSPs in India. To address the researcher's bias, a participant feedback mechanism was employed. A sample of the content analysis is shown in Fig. 2.

The analysis revealed 4 major categories: technological, socio-economic, organizational, and environmental. Nineteen (19) factors with seven (7) identified as new factors (second-order constructs) and twenty-two (22) subfactors (first-order constructs) with eight (8) new subfactors are categorized into four (4) categories as shown in Fig. 3.

The technological factors are related to the characteristics of technologies and platforms that impact firm-level decision-making towards its adoption. Environmental factors pertain to the factors that push or act as barriers, such as industry attributes, market competition, and regulations (Tripathy et al., 2022). Organizational factors are associated with the resources and capabilities of the firm, management structure and support, human resources, and linkages among employees (Tornatzky and Fleischer, 1990). Socio-economic factors are external to the firm and deal with the firm's potential 5G market and users. These factors indirectly affect the TSPs and other telecom firms' decision towards adoption, as their revenues are dependent upon the affordability of 5G services to the end-users. The definitions of the second-order constructs are presented in the Appendix. Further, the enablers and barriers identified from the second phase of analysis are summarized in Table 2.

6. Discussions

Content analysis of exploratory interviews with the respondents revealed several unique factors that may influence adoption of 5G technology by the TSPs in developing economies. While some countries do carry out stakeholder consultation before deciding on 5G rollout strategy, it is noticed that such consultations are often carried out just before the planned rollout, and they often focus more on the pricing of the spectrum. In the process, several important aspects that may have significant impact on the telecom firms' decisions to invest in 5G are overlooked, mainly in the clamor to start the auctions quickly. On the contrary, findings from this systematic research may be more valuable for the policy makers as they will enable them to plan suitable policy interventions for promoting the enablers and reducing barriers to adoption through appropriate changes to the relevant regulations, rules, and procedures. This study groups the factors influencing the decision of TSPs to adopt 5G technology under four categories: technological, organizational, socio-economic, and environmental.

6.1. Technological

The findings indicate that TSPs perceive following *relative benefits/advantages*— higher capacity, flexibility of using generic hardware instead of tied to the offerings of a specific vendor, and reduced time to market new services (especially for business users). The flexibility in 5G technology stems from the use of cloud infrastructure for providing the services, including the feature of "network function virtualization (NFV)" (Abdelwahab et al., 2016) that allows TSPs to choose the best cloud service provider at the lowest cost. However, TSPs need to also consider the potential challenges, such as multiple standards and vendor lock-in, and adopt a balanced approach in their NFV implementation. They may need further demonstration of reliability of the cloud infrastructure in real time. On the other hand, cloud service providers, too, may find that the commercial realities of cloud deployment for 5G are not as favorable as they may have anticipated.

Similarly, the feature of *backward compatibility* is an important enabler for the TSPs, as it is essential for reducing costs in the scenario of rapidly evolving mobile technologies. For example, implementing 5G through the non-standalone (NSA) mode has become popular among the TSPs in India, despite its limitation of not being optimized for new 5G use cases beyond mobile broadband (GSMA, 2019).

The *flexibility available to service providers* to choose open-source technology and platform is a critical enabler for TSPs because firms are under pressure to reduce their capital and operating expenses due to declining revenues (Chachondia and Momaya, 2014; Gupta and Jain, 2020; Gupta et al., 2021). Open radio access network (ORAN) architecture is an interesting example of how the TSPs in India have leveraged the flexibility to choose from radio network providers to reduce the cost of ownership.

The *availability of standards* has also emerged as an enabler for TSPs as it promotes innovation and investment in the 5G network. A specific case in point is the standard named 5Gi, which was proposed by the Telecommunications Standards Development Society India (TSDSI)—a standard development organization in 2016. It was developed for meeting the requirements of low mobility and large cell in rural area of India. After intense negotiations at 3GPP (3rd Generation Partnership Project), some features of 5Gi standard were formally merged with the 3GPP 5G standard and implemented into the 3GPP release-17 NR specifications in 2022 (TSDSI, 2022). This has ensured an alignment between India's local needs and global standards.

The 5G ecosystem, supporting millions of devices of IOT, is highly complex. It involves a large volume of data and multiple

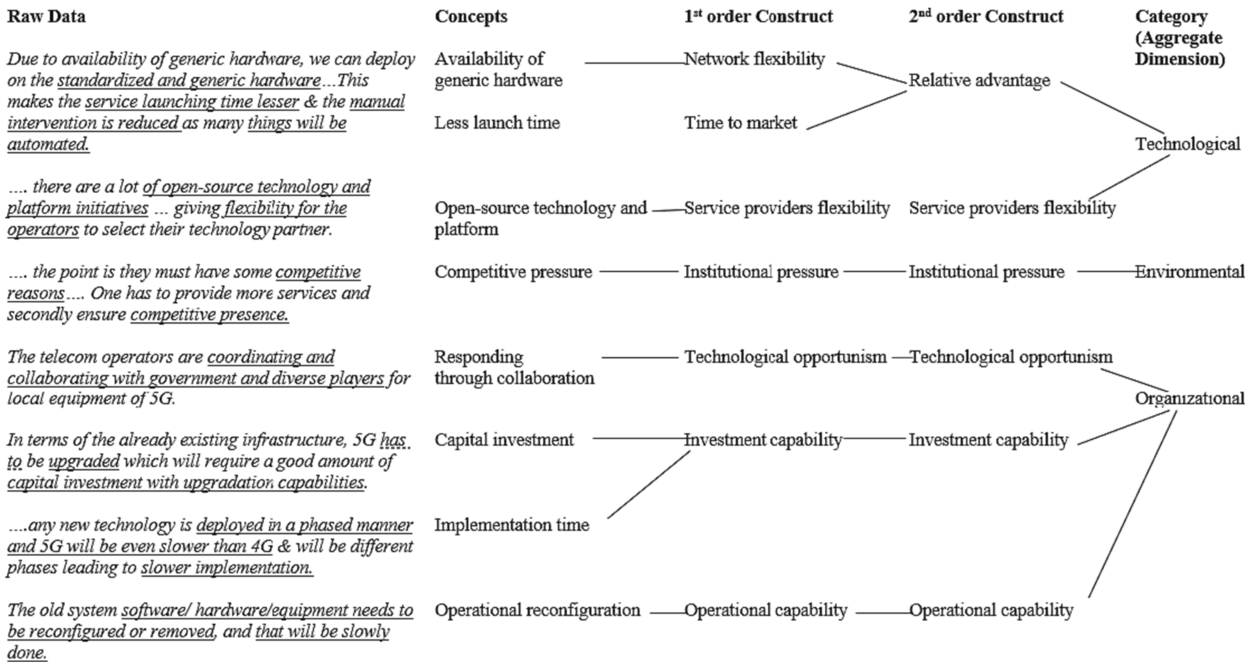

Fig. 2. Sample of content analysis-Coding process.

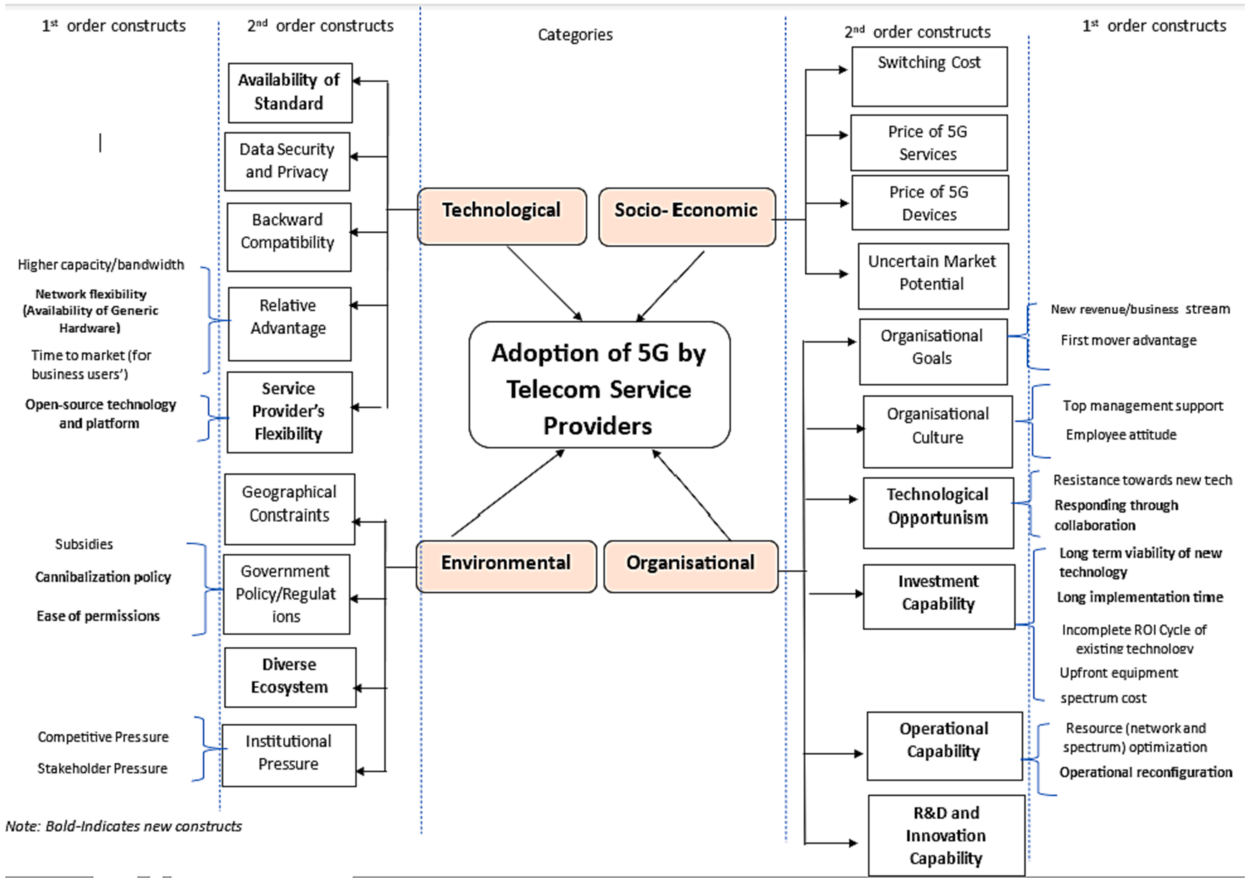

Fig. 3. Supply side 5G adoption model.

Table 2
Supply side 5G adoption enablers and barriers.

Categories	Enablers	Barriers
Technological	-Higher capacity/bandwidth, **Network flexibility (availability and use of generic hardware)**, Time to market; **- Open source technology and platform (service provider flexibility) -Availability of standards**	-Data security and privacy
Organizational	-New revenue stream, First mover advantage; -Top management support; **-Responding through collaboration**; -Resource optimization, **Resource reconfiguration**	-Employee attitude; -Resistance towards new technology; -**Long implementation time, Long term viability of new technology** Incomplete ROI cycle of existing technology, High upfront equipment cost, High spectrum cost
Socio-economic		-High switching cost, High price of 5G services, High price of 5G devices, Uncertain market potential/customer demand
Environmental	-Competitive pressure, Stakeholder pressure; -Subsidies, **Cannibalization policy**, **Ease of permissions**.	-Geographical constraints; **-Diverse ecosystem**

Note: **Bold** indicates unique enablers and barriers of adoption identified in the study. The enablers and barriers are identified at 1st order construct level (subfactor). In the case of absence of 1st order constructs, second order constructs (factor) are considered.

stakeholders and is prone to hacking and misuse, which makes *data security and privacy* one of the barriers. This is in line with Forge and Vu (2020).

6.2. Organizational

Early adoption of 5G technology not only provides firms with a competitive edge but also opens new businesses cutting across sectors, adding to revenue streams. As seen in the case of India, a leading TSP in India (Reliance Jio) publicly declared their intent to develop and deploy indigenous 5G technology[1] in the year 2021 itself. With this declaration, 5G adoption became the *organizational goal* of Reliance Jio, and the firm pooled resources for seizing the first-mover advantage and grabbing revenue share with faster 5G rollout from 2022 onwards. Such early adopters of new technology drive other competitors to follow suit, and other firms then attempt to imitate industry leaders' strategies and actions. This finding is in line with Saghafian et al. (2021).

It is observed that organization culture, specifically *top management support* and *employee attitude*, is critical to new technology adoption. The leadership within the leading TSPs publicly announced their intentions to cover all cities of India with 5G in a time-bound manner.[2]

Firms with high *technological opportunism* do not follow traditional paths, rather they analyze and build new environments through collaboration (Graham and Moore, 2021). For example, a leading IT firm in India (Tata Consultancy Services (TCS)), sensing the opportunity presented by 5G technology, decided to diversify into the telecom domain and collaborated with the Centre for Development of Telematics (CDOT) for developing a 5G core network[3] and with the firm Tejas Networks Limited for developing a 5G radio network. As a result, they have been successful in developing in-house 5G technology from scratch, which may open new business avenues for them.

Prior research reveals that the *investment capability* of the firm is positively correlated to the adoption of new technology (Gheitarani et al., 2022). In India, among the major TSPs, only two have announced aggressive plans to launch 5G services. This confirms our respondents' views that *high spectrum and equipment cost*, *long implementation period*, '*long term viability of 5G*, and *incomplete ROI cycle* from the existing technology act as barriers to the adoption of 5G technology by firms. *Lack of investment capability* implies that some TSPs are not adequately positioned to leverage the new technology.

Operational reconfiguration and *resource optimization* (both the network and spectrum) have been identified as enablers. Operational reconfiguration is demonstrated by the TSPs' ability to use the NSA mode for 5G rollout, which is less costly and can be rolled out quickly with slight reconfiguration of the existing 4G core network. These findings are in line with the literature highlighting the importance of recombinant and resource optimization capabilities especially in the case of 5G (Shao et al., 2017; Guo and Zheng, 2021). Further, *R&D and innovation capability* need to be enhanced through collaboration to seize innovation opportunities that would otherwise be difficult to realize individually. In India, CDOT, by their association with firms (like TCS and Tejas Networks Limited) for 4G technology development, has amply demonstrated that timely collaboration can lead to innovative technological solutions.

[1] https://telecom.economictimes.indiatimes.com/news/jio-made-in-india-5g-tech-globally-competitive-ready-to-quickly-upgrade-networks-to-5g-ambani/83806821.
[2] https://www.indiatoday.in/technology/features/story/5g-now-available-in-india-how-to-get-which-cities-covered-and-other-key-info-in-10-points-2007089–2022-10–01.
[3] https://www.financialexpress.com/industry/cdot-tcs-partnership-likely-to-launch-5g-core-solution-soon/2521217/.

6.3. Socio-economic

Switching cost refers to the one-time cost that is to be incurred by the users for moving to 5G technology. For example, many customers may have already invested in service packs of long duration (say, 6 months or 1 year), which may remain unutilized if they decide to move to 5G services. Apart from this, the cost of 5G handsets and the cost of 5G services will also have to be borne by the users, which may deter many of them from adopting 5G technology, confirming to the findings of Maeng et al. (2020).

While TSPs are making substantial investment in 5G, the market demand remains uncertain, not only because of the high cost of handsets and services but also due to an impending loss of revenue to private mobile captive networks[4], a service which is possible due to the feature of network slicing available in 5G technology. For example, in India, the Cellular Operators' Association of India (COAI), in June 2022,[5] opposed setting up of private 5G mobile captive networks, stating that such networks will eliminate the business case for the rollout of 5G networks. This confirms the finding from the study that uncertainties in market demand act as barriers to adoption of 5G by TSPs. This is in line with the findings of Forge and Vu (2020).

6.4. Environmental

In developing economies, the government is a major stakeholder impacting the environmental factors of 5G adoption. In India, the government is the custodian of the spectrum that is essential for the 5G network, and it regulates the extent of availability, frequency band, mode of allotment, pricing, conditions of license, rollout obligations, rules and regulations for providing services, and the extent of penalty to be levied on TSPs for any deviation from license conditions. *Ease of permissions* from the government departments positively influences the decision of TSPs to adopt 5G technology. For example, permission for providing right-of-way (RoW) is an important factor for 5G rollout as the number of towers and base stations required in 5G is much higher than that for earlier technologies. The Indian government has taken proactive steps in August 2022 for easing the bottleneck of RoW by amending rules, reducing the charges for RoW permissions, fixing a ceiling on charges for the installation of 5G small cells and optical fiber cable on street furniture, and setting up an online portal for RoW applications.[6] Further, *cannibalization policy* plays an important role with respect to diffusion of new technologies and its related services, especially in developing economies. To switch customers to a higher and new ARPU, cannibalization is desired. For example, in India, DOT is attempting to regulate and reduce the effects of cannibalization of TSP businesses due to over-the-top (OTT) applications being offered by OTT providers through the network of TSPs (TRAI, 2023). This finding is in line with Gupta et al. (2017).

Institutional pressure is the pressure on the TSPs from diverse stakeholders, such as handset manufacturers, network manufacturers, service providers, regulatory bodies, and customers to adopt 5G. All these stakeholders have a role in technology adoption and need to be managed properly by the TSPs. For example, some smartphones require a software upgrade to work with 5G technology, even though the hardware of the phone is 5G compatible. On the other hand, many smartphones may work with NSA 5G network but may require another software layer to work in standalone (SA) 5G network.[7] The TSPs have to deal with the smartphone device manufacturers to ensure that the network works seamlessly across a variety of devices. The firms also need to manage the competitive pressure from their rivals, which may be intense, given the significant investments made by them.

5G technology, by virtue of its open architecture, promotes diverse players in the technology ecosystem, collectively called *diverse ecosystem,* with the value chain comprising in-house R&D providers, 5G test beds, indigenous telecom manufacturers, innovative solution providers, software entrepreneurs, and system integrators, among others. Each element of the value chain presents their own set of challenges and implications for the adoption of 5G by the TSPs. The respondents pointed out that availability of trial spectrum and test beds at multiple locations was facilitated by the government and resulted in the faster rollout of 5G network in India.

Geographical constraint acts as a barrier to effective deployment of telecom infrastructure over a huge coverage area. For example, it may be easier for a TSP in a small country to commit to rollout obligations for 5G in time-bound manner, whereas in a vast country like India, which has a large rural area with less density of population and cities with high population density, a provider may hesitate to adopt 5G technology as it will involve much more time and resources. Moreover, in such diverse geographical conditions, it may be difficult for the TSPs to provide uninterrupted coverage, which again acts as a barrier to the adoption of 5G technology. In addition, recently in India, the TRAI has made recommendations for the use of street furniture to install small cell equipment for small cell coverage.

7. Policy and managerial implications

To speed up telecom investments in emerging 5G technology, the study presents policy and managerial implications. The countries that are heavily dependent on imports for telecom equipment need to cultivate the potential of 5G equipment manufacturing within and become self-sufficient in telecom equipment supplies. Collaboration with other value-chain partners could offer unique opportunities to leverage the advantages offered by 5G and its related services.

[4] https://economictimes.indiatimes.com/industry/telecom/telecom-news/telcos-say-private-networks-will-kill-5g-business-case/articleshow/90806358.cms?from=mdr.

[5] https://www.thehindubusinessline.com/info-tech/coai-writes-to-telecom-minister-to-address-privatecaptive-networks/article65509894.ece.

[6] https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1854472.

[7] https://epaper.hindustantimes.com/Home/ShareArticle?OrgId=1210588e8f9&imageview=0.

- On the technological dimension, government policies should ensure active participation in standard development process at the national and international level, promoting innovation capability of domestic R&D firms and increasing the competitiveness of domestic manufacturing firms. This will result in the availability of cost-effective indigenous technology to the TSPs.
- On the organizational dimension, the governments, especially in developing countries, should strive to look at the clearly established linkage between the spectrum band of operation and geographical coverage that can be provided in that frequency band, while deciding the frequency band for rollout of 5G technology. For example, 700 MHz band provides higher coverage than, say, 28 GHz band, which in turn reduces the capital cost, improves the ARPU for the TSPs, and results in affordable services for the users in the country, who have lower disposable incomes. At the same time, TSPs should promote a culture of innovation and resource optimization by rewarding employees with such initiatives.
- On the environmental front, government policies should focus on introducing easy processes for the allotting trial spectrum, facilitating RoW, developing 5G test beds, and promoting indigenous R&D. Further, to boost the adoption and diffusion of 5G, firms in the telecom value chain should contribute to the extensive development of open-source hardware and software. Policies to promote collaboration among TSPs and the local administration for developing innovative use cases that bring additional revenue to the TSPs should be devised. Further, transparent spectrum auctions at realistic prices after advance consultation with the stakeholders should be practiced.
- From a socio-economic perspective, awareness should be enhanced about the advantages of 5G over current mobile technology among both the business and end users, so that benefits are prominent vis-à-vis the price of the services and devices. TSPs should focus on promoting innovative 5G services, especially at the end-user level.

8. Conclusions and future directions

The novelty of this paper lies in the in-depth analysis of viewpoints shared by telecom experts on 5G adoption by TSPs. This study contributes to theory and practice as follows. First, the embryonic status of the 5G in industry in terms of adoption and implementation warrants a complex decision-making process, which has largely not been addressed in the available literature, especially from developing country perspective. Further, literature that offers a supply side perspective (i.e., TSP) on 5G adoption is limited. This paper contributes by exploring the factors that influence TSPs' decisions for 5G adoption. The contribution is valuable as early adoption of 5G can significantly impact the development and economic growth of developing countries.

Second, several studies have corroborated the necessity of all three facets of the TOE framework for facilitating the adoption and implementation of new technologies by an organization. This is also validated in our exploratory study. Third, this study significantly augments the growing body of literature on the TOE framework by incorporating the socio-economic dimension, which indirectly influences the revenues of the TSPs and their value-chain partners.

Fourth, the study identifies seven (7) unique factors and eight (8) unique subfactors influencing 5G adoption. The availability and use of generic hardware (network flexibility), open-source technology and platform (service provider flexibility), availability of standards, responding through collaboration, resource reconfiguration, cannibalization policy, and ease of permissions act as unique enablers in a developing country context for 5G adoption. However, long implementation time and a diverse ecosystem of multiple players are unique impediments to 5G adoption from a TSP perspective.

Although this research benefits from rich and focused data collection on 5G from the suppliers' side in India, it is limited only to TSPs. The research can be extended by considering players across the telecom value chain and integrating their perspectives on 5G although the findings are drawn from India, the current qualitative analysis provides a basis for testing the proposed model empirically across other developing economies and extending the model to look at deployment and operational challenges across different countries. 5G network infrastructure will require heavy investment in physical assets as well as in the development of higher applications and services for business activities. Globally, telecom companies are trying to analyze the present competitive landscape, given the technological changes occurring with the 5G system (Deloitte, 2020, Pedrosa et al., 2022). To date, a large chunk of the telecom demand is being fulfilled by importing telecom products based on foreign technology, which limits the bargaining power and technological competitiveness of TSPs (Mittal and Momaya, 2009). To enhance the technological competitiveness of the telecom sector, especially in developing countries, it is essential to build absorptive and upgradation capabilities through an efficient interplay of actors like the government, operating firms, local and foreign development firms, industry associations and research and academic institutions, especially in the case of 5G diverse ecosystem. Once TSPs start to adopt 5G, building technology absorption and upgradation capabilities becomes critical to move to the next generation technology, with less reliance on foreign counterparts. To some extent, the factors examined in this study—operational capability, R&D, innovation capability, and technological opportunism—highlight the importance of such elements in managing technology successfully. However, future research should focus on how the absorptive and upgradation capabilities of firms can be enhanced for next-generation telecom technologies. Further, the success of 5G adoption by TSPs, especially in developing countries, will depend on the adoption of highly desirable social-purpose-driven functionalities and related applications in healthcare (Siriwardhana et al., 2021), agriculture (Hilten and Wolfert, 2022) and education (Kizilkaya et al., 2021). Future researchers should focus on the adoption of specific use cases of such applications.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Appendix Definitions of second order constructs

Construct	Definition	Source (Adapted from)
Availability of standard	It refers to the availability of 5G standards at national level to meet the local needs and for the massive level deployment.	Authors
Data security and privacy	It refers to the confidentiality of personal data, trustworthiness of information flows, authentication when using 5G technology and its systems.	Neokosmidis et al., 2017
Relative advantage	It refers to the degree to which the TSP(s) recognize 5G as superior to the earlier technologies.	Rogers, 1962
Service providers flexibility	It is the flexibility available to TSP(s) through new technology to choose the open-source hardware and software, rather than being tied up with a specific vendor.	Authors
Backward compatibility	It refers to the ability of existing equipment of prevalent technology to be reused along with new technology, for taking full economic benefit of the investment made in prevalent technology.	Kholaif et al., 2007
Geographical constraints	It refers to the physical and logistical barriers for effective deployment of 5G infrastructure and services.	Authors
Government policy and regulations	It refers to an effective government policies and regulations facilitate the adoption of 5G telecom technology.	Authors
Diverse ecosystem	It refers to the diverse ecosystem and players of 5G telecom value chain	Authors
Institutional pressure	It is the pressure on the TSP(s) from diverse stakeholders such as handset manufacturers, network manufacturer, service provider, regulatory bodies, and customers to adopt 5G.	Oliveira et al., 2019
Switching cost	It refers to extra one time cost (financial, procedural and relational), apart from cost of handsets and cost of services, that are to be incurred by the users for moving to 5G technology	Basaure, et al., 2016
Price of 5G services	It refers to the possible expenses of using 5G telecom services.	Gupta and Jain, 2014
Price of 5G devices	It refers to the possible one-time expenses incurred in 5G mobile handset and devices used in the 5G system for business or end users	Gupta and Jain, 2014
Uncertain market potential	It refers to the uncertainty in future market demand related to 5G services	Authors
Organizational goal	It refers to objectives, purposes setting up the direction and focus of the organization	Saghafian et al., 2021
Organizational culture	It is defined as the way things are done in an organization to achieve its goals.	Sharma et al 2021
Technological opportunism	It is defined as an organizational capability to acquire knowledge and understand 5G technology developments and respond for competitive advantage.	Srinivasan et al., 2002
Investment capabilities	It relates to the skills and information needed to identify feasible investment projects, locate and purchase suitable technologies.	Gheitarani et al., 2022
Operational capability	It refers to optimum use of existing resources (both the network and spectrum) by the firm (resource optimization) and the extent of modification that the firm is able to carry out in its existing resources, so that they can be utilized in adoption of new technologies (operational reconfiguration).	Gheitarani et al., 2022
R&D and innovation capability	It is defined as the ability to continuously transform knowledge and ideas into new products, processes and systems for the benefit of the firm and its stakeholders.	Lawson and Samson, 2001

References

Abdelwahab, S., Hamdaoui, B., Guizani, M., Znati, T., 2016. Network function virtualization in 5G. IEEE Commun. Mag. 54 (4), 84–91. https://doi.org/10.1109/MCOM.2016.7452271.

Agiwal, M., Kwon, H., Park, S., Jin, H., 2021. A survey on 4G–5G dual connectivity: road to 5G implementation. IEEE Access 9, 16193–16210. https://doi.org/10.1109/ACCESS.2021.3052462.

Ajzen, I., 1991. The theory of planned behavior. Organizational behavior and human decision. Processes 50 (2), 179–211. https://doi.org/10.1016/0749-5978(91)90020-T.

Ajzen, I., Fishbein, M., 1977. Attitude-behavior relations theoretical analysis and review of empirical research. Psychol. Bull. 84 (5), 888–918. https://doi.org/10.1037/0033-2909.84.5.888.

Akpakwu, G.A., Silva, B.J., Hancke, G.P., Abu-Mahfouz, A.M., 2018. A survey on 5G networks for the internet of things: communication technologies and challenges. IEEE Access 6, 3619–3647. https://doi.org/10.1109/ACCESS.2017.2779844.

Basaure, A., Suomi, H., Hämmäinen, H., 2016. Transaction vs. switching costs—Comparison of three core mechanisms for mobile markets. Telecommun. Policy 40 (6), 545–566.

Bastos, L., Capela, G., Koprulu, A., Elzinga, G., 2021. Potential of 5G technologies for military application. International Conference on Military Communication and Information Systems (ICMCIS) 2021, 1–8. https://doi.org/10.1109/ICMCIS52405.2021.9486402.

Bryman, A., 2013. Social Research Methods. Oxford University Press, Oxford.

Bryman, A., Bell, E., 2015. Business Research Methods. 4th ed.

Chachondia, S., Momaya, K., 2014. Disaggregation of infrastructure and service: learning from Indian telecom sector. 2014 Proceedings of PICMET '14: Infrastructure and Service Integration. https://ieeexplore.ieee.org/document/6920988.

Cheng, L.-K., Huang, H.-L., Yang, S.-Y., 2021. Attitude toward 5G: the moderating effect of regulatory focus. Technol. Soc. 67, 101795.

Chiu, Yu, C., Shi, C., Chen, Liang, C., 2017. An integrated perspective of TOE framework and innovation diffusion in broadband mobile applications adoption by enterprises. International J. Manage., Econ. Soc. Sci., 6(1), 14-39. http://hdl.handle.net/10419/157921.

Cirera, X., Comin, D., Cruz, M., 2022. Bridging the technological divide: Technology adoption by firms in developing countries. The World Bank Productivity Project. http://hdl.handle.net/10986/37527.

Comin, D., Mestieri, M., 2018. If technology has arrived everywhere, why has income diverged?". Am. Econ. J. Macroecon. 10 (3), 137–178.

Davis, F.D., 1989. Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS Q. 13 (3), 319–339. https://doi.org/10.2307/249008.

Deloitte, 2020. Technology industry outlook. Accessed 9 June 2023.

Dolgui, A., Ivanov, D., 2022. 5G in digital supply chain and operations management: fostering flexibility, end-to-end connectivity and real-time visibility through internet-of-everything. Int. J. Prod. Res. 60 (2), 442–451. https://doi.org/10.1080/00207543.2021.2002969.

DoT, 2018. Making India 5G ready. Accessed 13 August 2022.

Ericsson, 2019. Ericsson Mobility report June 2019. Accessed 29 August 2022.

Erunkulu, O.O., Zungeru, A.M., Lebekwe, C.K., Mosalaosi, M., Chuma, J.M., 2021. 5G mobile communication applications: A survey and comparison of use cases. IEEE Access 9, 97251–97295. https://doi.org/10.1109/ACCESS.2021.3093213.

Forge, S., Blackman, C., 2017. Europe's 5G field of dreams: If we build it, will they come? Digital Policy, Regul. Govern. 19 (5), 337–352. https://doi.org/10.1108/DPRG-06-2017-0030.

Forge, S., Vu, K., 2020. Forming a 5G strategy for developing countries: a note for policy makers. Telecommun. Policy 44 (7), 101975. https://doi.org/10.1016/j.telpol.2020.101975.

Gangwar, H., Date, H., Ramaswamy, R., 2015. Understanding determinants of cloud computing adoption using an integrated TAM-TOE model. J. Enterp. Inf. Manag. 28 (1), 107–130. https://doi.org/10.1108/JEIM-08-2013-0065.

Gao, H., 2021. Big data development of tourism resources based on 5G network and internet of things system. Microprocess. Microsyst. 80, 103567 https://doi.org/10.1016/j.micpro.2020.103567.

Garrison, G., 2009. An assessment of organizational size and sense and response capability on the early adoption of disruptive technology. Comput. Hum. Behav. 25 (2), 444–449. https://doi.org/10.1016/j.chb.2008.10.007.

Gheitarani, F., Guevara, R., Nawaser, K., Jahanshahi, A.A., 2022. Identifying dimensions of dynamic technological capability: a systematic review of the last two decades of research. Int. J. Innov. Technol. Manag. 19 (4) https://doi.org/10.1142/S0219877022300026.

Gioia, D., Corley, K.G., Hamilton, A.L., 2013. Seeking qualitative rigor in inductive research: notes on the Gioia methodology. Organ. Res. Methods 16 (1), 15–31. https://doi.org/10.1177/1094428112452151.

Graham, K., Moore, R., 2021. The Role of dynamic capabilities in firm-level technology adoption processes: a qualitative investigation. J. Innov. Manag. 9 (1), 25–50. https://doi.org/10.24840/2183-0606_009.001_0004.

GSA, 2022. Global mobile suppliers association-5G Market Snapshot June 2022. Accessed 29 August 2022.

GSMA, 2019. Future Networks. https://www.gsma.com/futurenetworks/wiki/5g-implementation-guidelines/.

Guevara, L., Auat Cheein, F., 2020. The role of 5G technologies: challenges in smart cities and intelligent transportation systems. Sustainability 12 (16), 6469. https://doi.org/10.3390/su12166469.

Guo, Y., Zheng, G., 2021. Recombinant capabilities, R&D collaboration, and innovation performance of emerging market firms in high-technology industry. IEEE Trans. Eng. Manag. 1–16 https://doi.org/10.1109/TEM.2021.3095551.

Gupta, D., Gupta, R., Jain, K., Momaya, K.S., 2017. Innovations in mobile value-added services: Findings from cases in India. Int. J. Innov. Technol. Manage. 14 (6), 1–27. https://doi.org/10.1142/S0219877017500377.

Gupta, R., Jain, K., 2012. Diffusion of mobile telephony in India: An empirical study. Technol. Forecast. Soc. Change 79 (4), 709–715. https://doi.org/10.1016/j.techfore.2011.08.003.

Gupta, R., Jain, K., 2014. Adoption of mobile telephony in rural India: an empirical study. Decis. Sci. 45 (2), 281–307. https://doi.org/10.1111/deci.12068.

Gupta, R., Jain, K., 2016. Competition effect of a new mobile technology on an incumbent technology: an Indian case study. Telecommun. Policy 40 (4), 332–342. https://doi.org/10.1016/j.telpol.2016.01.001.

Gupta, R., Jain, K., 2020. What drives Indian mobile service market: policies or users? Telematics Inform. 50, 101383 https://doi.org/10.1016/j.tele.2020.101383.

Gupta, R., Gupta, D., Jain, K., Momaya, K., 2021. User Involvement in technology-based service innovations in telecom: cases from India. IEEE Trans. Eng. Manag. https://doi.org/10.1109/TEM.2021.3103667.

Hilten, M.V., Wolfert, S., 2022. 5G in agri-food - A review on status, opportunities, and challenges. Comput. Electron. Agric. 201, 107291 https://doi.org/10.1016/j.compag.2022.107291.

Hutajulu, S., Dhewanto, W., Prasetio, E.A., 2020. Two scenarios for 5G deployment in Indonesia. Technol. Forecast. Soc. Chang. 160, 120221 https://doi.org/10.1016/j.techfore.2020.120221.

Iansiti, M., Lakhani, K.R., 2017. Managing our hub economy. Harv. Bus. Rev.

Jeon, C., Han, S.H., Kim, H.J., Kim, S., 2022. The effect of government 5G policies on telecommunication operators' firm value: Evidence from China. Telecommun. Policy 46 (2), 102040. https://doi.org/10.1016/j.telpol.2020.102040.

Kholaif, A.M., Fayek, M.B., Eissa, H.S., Baraka, H.A., 2006. DRKH: A power efficient encryption protocol for wireless devices. Int. J. Pervas. Comput. Commun., 2(4). https://doi.org/10.1108/17427370780000162.

Kim, H.W., Chan, H.C., Gupta, S., 2007. Value-based adoption of mobile internet: an empirical investigation. Decis. Support Syst. 43 (1), 111–126. https://doi.org/10.1016/j.dss.2005.05.009.

Kim, S., Garrison, G., 2009. Investigating mobile wireless technology adoption: an extension of the technology acceptance model. Inf. Syst. Front. 11 (3), 323–333. https://doi.org/10.1007/s10796-008-9073-8.

Kitchen, P.J., Martin, R., Che-Ha, N., 2015. Long term evolution mobile services and intention to adopt: a Malaysian perspective. J. Strateg. Mark. 23 (7), 643–654. https://doi.org/10.1080/0965254X.2014.1001869.

Kizilkaya, B., Zhao, G., Sambo, Y.A., Li, L., Imran, M.A., 2021. 5G-enabled education 4.0: enabling technologies, challenges, and solutions. IEEE Access 9, 166962–166969.

Krippendorff, K., 1989. Content Analysis. In E. Barnouw, G. Gerbner, W. Schramm, T.L. Worth, L. Gross (Eds.), International encyclopedia of communication, 1, 403-407.

Kuo, Y.F., Yen, S.N., 2009. Towards an understanding of the behavioral intention to use 3G mobile value-added services. Comput. Hum. Behav. 25 (1), 103–110. https://doi.org/10.1016/j.chb.2008.07.007.

Kushwaha, P., Kushwaha, D.K., 2019. Impact of migrating from 4G technologies to 5G technologies in India. Inst. Manage. Educ. J. 13 (1), 45–51.

Lawson, B., Samson, D., 2001. Developing innovation capability in organisations: a dynamic capabilities approach. Int. J. Innov. Manag. 5 (3), 377–400. https://doi.org/10.1142/S1363919601000427.

Lee, C.K., Yu, L., L.,, 2022. A multi-level perspective on 5G transitions: the China case. Technol. Forecast. Soc. Change 182, 121812. https://doi.org/10.1016/j.techfore.2022.121812.

Lopez-Nicolas, C., Molina-Castillo, F.J., Bouwman, H., 2008. An assessment of advanced mobile services acceptance: Contributions from TAM and diffusion theory models. Inf. Manag. 45 (6), 359–364. https://doi.org/10.1016/j.im.2008.05.001.

Lopperi, K., Puumalainen, K., Kappi, J., 2006. Technological opportunism and wireless e-business adoption: a case of Finland. Int. J. Technol. Mark. 1 (3), 321. https://doi.org/10.1504/IJTMKT.2006.009944.

Lucia-Palacios, L., Bordonaba-Juste, V., Polo-Redondo, Y., Grünhagen, M., 2014. Technological opportunism effects on IT adoption, intra-firm diffusion and performance: evidence from the U.S. and Spain. J. Bus. Res. 67 (6), 1178–1188. https://doi.org/10.1016/j.jbusres.2013.05.004.

Maeng, K., Kim, J., Shin, J., 2020. Demand forecasting for the 5G service market considering consumer preference and purchase delay behavior. Telematics Inform. 47, 101327 https://doi.org/10.1016/j.tele.2019.101327.

Massaro, M., Kim, S., 2022. Why is South Korea at the forefront of 5G? Insights from technology systems theory. Telecommun. Policy 46 (5), 102290. https://doi.org/10.1016/j.telpol.2021.102290.

Miles, M.B., Huberman, A.M., Saldana, J., 2014. Qualitative Data Analysis: A Methods Sourcebook. Sage, London.

Mittal, S.K., Momaya, K., 2009. Technological competitiveness of telecommunication industry in India: glimpse of reality, opportunities, and challenges. Global J. Bus. Excellence 2 (1), 22–33.

Mittal, S., Momaya, K., Spurti., S.,, 2013. Longitudinal and comparative perspectives on the competitiveness of countries: Learning from technology and the telecom sector. J. Centrum Cathedra (JCC) 6 (2), 235–256. https://doi.org/10.7835/jcc-berj-2013-0090.

National Digital Communication Policy (NDCP), 2018. The National Digital Communications Policy, 2018 https://dot.gov.in/sites/default/files/Final%20NDCP-2018_0.pdf, Accessed 12 January 2023.
Neokosmidis, I., Rokkas, T., Parker, M.C., Koczian, G., Walker, S.D., Siddiqui, M.S., Escalona, E., 2017. Assessment of socio-techno-economic factors affecting the market adoption and evolution of 5G networks: evidence from the 5G-PPP CHARISMA project. Telematics Inform. 34 (5), 572–589. https://doi.org/10.1016/j.tele.2016.11.007.
Oettmeier, K., Hofmann, E., 2016. Impact of additive manufacturing technology adoption on supply chain management processes and components. J. Manuf. Technol. Manag. 27 (7), 944–968. https://doi.org/10.1108/JMTM-12-2015-0113.
Oliveira, T., Martins, R., Sarker, S., Thomas, M., Popovic, A., 2019. Understanding SaaS adoption: the moderating impact of the environment context. Int. J. Inf. Manag. 49, 1–12. https://doi.org/10.1016/j.ijinfomgt.2019.02.009.
Oughton, E.J., Comini, N., Foster, V., Hall, J.W., 2022. Policy choices can help keep 4G and 5G universal broadband affordable'. Technol. Forecast. Social Change 176, 121409. https://doi.org/10.1016/j.techfore.2021.121409.
Oughton, E., Frias, Z., 2018. The cost, coverage and rollout implications of 5G infrastructure in Britain. Telecommun. Policy 42 (8), 636–652. https://doi.org/10.1016/j.telpol.2017.07.009.
Oughton, E., Frias, Z., Russell, T., Sicker, D., Cleevely, D.D., 2018. Towards 5G: Scenario-based assessment of the future supply and demand for mobile telecommunications infrastructure. Technol. Forecast. Social Change 133, 141–155. https://doi.org/10.1016/j.techfore.2018.03.016.
Oughton, E.J., Frias, Z., Van der Gaast, S., van der Berg, R., 2019. Assessing the capacity, coverage and cost of 5G infrastructure strategies: Analysis of the Netherlands. Telematics Inform. 37, 50–69. https://doi.org/10.1016/j.tele.2019.01.003.
Pagani, M., Fine, C.H., 2008. Value network dynamics in 3G–4G wireless communications: A systems thinking approach to strategic value assessment. J. Bus. Res. 61 (11), 1102–1112. https://doi.org/10.1016/j.jbusres.2007.11.004.
Park, A., Jabagi, N., Kietzmann, J., 2021. The truth about 5G: It's not (only) about downloading movies faster! Bus. Horiz. 64 (1), 19–28. https://doi.org/10.1016/j.bushor.2020.09.009.
Park, E., Kim, J.K., 2013. User acceptance of long-term evolution (LTE) services: An application of extended technology acceptance model. Program 47 (2), 188–205. https://doi.org/10.1108/00330331311313762.
Patton, M.Q., 1999. Enhancing the quality and credibility of qualitative analysis. Health Serv. Res. 34.
Pedrosa, N., Montoni, L., Martens, C.D.P., Silva, L.F.D., Cunha, J.C.D., 2022. Absorptive capacity in information technology projects: A multiple case study in the telecommunication industry. Int. J. Project Organisation Manage. 14 (1), 36–64.
Praveen, G., Chamola, V., Hassija, V., Kumar, N., 2020. Blockchain for 5G: A prelude to future telecommunication. IEEE Netw. 34 (6), 106–113. https://doi.org/10.1109/MNET.001.2000005.
Puri, S., Rai, R. S., Saxena, K. 2018. Barricades in network transformation from 4G to 5G in India. 2018, 7th International Conference on Reliability, Infocom Technologies and Optimization (Trends and Future Directions) (ICRITO), 695–702. https://doi.org/10.1109/ICRITO.2018.8748303.
Rahman, A., Arabi, S., Rab, R., 2021. Feasibility and challenges of 5G network deployment in Least Developed Countries (LDC). Wirel. Sens. Netw. 13 (01), 1–16. https://doi.org/10.4236/wsn.2021.131001.
Raut, R., Priyadarshinee, P., Jha, M., 2018. Understanding the mediation effect of cloud computing adoption in Indian organization: Integrating TAM-TOE- risk model. Int. J. Serv. Sci., Manage., Eng. Technol. 8 (3) https://doi.org/10.4018/IJSSMET.2017070103.
Rogers, E.M., 1962. Diffusion of Innovations. The Free Press, New York, NY.
Saghafian, M., Laumann, K., Skogstad, M.R., 2021. Stagewise overview of issues influencing organizational technology adoption and use. Front. Psychol. 12, 654. https://doi.org/10.3389/fpsyg.2021.630145.
Schot, J., Steinmueller, W.E., 2016. Framing Innovation Policy for Transformative Change: Innovation Policy 3.0. Science Policy Research Unit (SPRU), University of Sussex.
Shafique, K., Khawaja, B.A., Sabir, F., Qazi, S., Mustaqim, M., 2020. Internet of Things (IoT) for next-generation smart systems: A review of current challenges, future trends and prospects for emerging 5G-IoT scenarios. IEEE Access 8, 23022–23040. https://doi.org/10.1109/ACCESS.2020.2970118.
Shah, S.K., Zhongjun, T., Sattar, A., XinHao, Z., 2021. Consumer's intention to purchase 5G: Do environmental awareness, environmental knowledge and health consciousness attitude matter? Technol. Soc. 65, 101563 https://doi.org/10.1016/j.techsoc.2021.101563.
Shao, B.B.M., Lin, W.T., Tsai, J.Y., 2017. An empirical study of the telecommunications service industries using productivity decomposition. IEEE Trans. Eng. Manag. 64 (4), 437–449. https://doi.org/10.1109/TEM.2017.2713771.
Sharma, R., Mishra, R., 2014. A review of evolution of theories and models of technology adoption. Indore Manage. J. 6 (2), 17–29.
Sharma, R., Mishra, R., Mishra, A., 2021. Determinants of satisfaction among social entrepreneurs in e-Government services. Int. J. Inf. Manag. 60, 102386 https://doi.org/10.1016/j.ijinfomgt.2021.102386.
Simon, J.P., 2020. The global internet market(s): a reconstruction of the views of the industry. Digital Policy, Regul. Govern. 22 (2), 109–133. https://doi.org/10.1108/DPRG-10-2019-0092.
Siriwardhana, Y., Gür, G., Ylianttila, M., Liyanage, M., 2021. The role of 5G for digital healthcare against COVID-19 pandemic: opportunities and challenges. ICT Express 7 (2), 244–252. https://doi.org/10.1016/j.icte.2020.10.002.
Srinivasan, R., Lilien, G.L., Rangaswamy, A., 2002. Technological opportunism and radical technology adoption: an application to e-business. J. Mark. 66 (3), 47–60. https://doi.org/10.1509/jmkg.66.3.47.18508.
Statista, 2022. Where 5G technology has been deployed. Accessed 13 August 2022. Accessed 23 August 2022.
Statista, 2023. Global 5G subscriptions 2019-2027. https://www.statista.com/statistics/1199693/north-america-5g-subscriptions/#:~:text=As%20of%202021%2C%20there%20were,4.39%20billion%20active%205G%20subscriptions. Accessed 23 August 2022.
Tahir, M., Habaebi, M.H., Dabbagh, M., Mughees, A., Ahad, A., Ahmed, K.I., 2020. A review on application of blockchain in 5G and beyond networks: Taxonomy, field-trials, challenges and opportunities. IEEE Access 8, 115876–115904. https://doi.org/10.1109/ACCESS.2020.3003020.
Tang, Y., Dananjayan, S., Hou, C., Guo, Q., Luo, S., He, Y., 2021. A survey on the 5G network and its impact on agriculture: Challenges and opportunities. Comput. Electron. Agric. 180, 105895 https://doi.org/10.1016/j.compag.2020.105895.
Teece, D.J., 2007. Explicating dynamic capabilities: The nature and microfoundations of (sustainable) enterprise performance. Strateg. Manag. J. 28 (13), 1319–1350. https://doi.org/10.1002/smj.640.
Tornatzky, L.G., Fleischer, M., 1990. The Processes of Technological Innovation. Lexington Books, Lexington, MA.
TRAI, 2019. Telecom regulatory authority of India-A White Paper on Enabling 5G in India 22 February 2019. Accessed 23 September 2022.
TRAI, 2022a. Telecom regulatory authority of India -The Indian Telecom Services Performance Indicators. Accessed 23 September 2022.
TRAI, 2022b. Telecom regulatory authority of India-Recommendations on 'Auction of spectrum in frequency bands identified for IMT/5G'. Press Release No. 21/2022. Accessed 28 September 2022.
TRAI, 2023. Telecom Regulatory Authority of India consultation paper on regulating converged digital technologies and services – enabling convergence of carriage of broadcasting and telecommunication services, Consultation Paper No.3/2023. Accessed 28 September 2022.
Tripathy, A., Bhuyan, A., Padhy, R., Corazza, L., 2022. Technological, organizational, and environmental factors affecting the adoption of electric vehicle battery recycling. IEEE Trans. Eng. Manag. https://doi.org/10.1109/TEM.2022.3164288.
TSDSI, 2022. Telecommunications standard development society, India, https://tsdsi.in/tsdsi-5gi-standard-merged-with-3gpp-5gnew/. Accessed 23 February 2023.
Venkatesh, V., Bala, H., 2008. Technology acceptance model 3 and a research agenda on interventions. Decis. Sci. 39 (2), 273–315. https://doi.org/10.17762/itii.v9i1.126.

Venkatesh, V., Morris, M.G., Davis, G.B., Davis, F.D., 2003. User acceptance of information technology: toward a unified view. MIS Q. 27 (3), 425–478. https://doi.org/10.2307/30036540.
Vowles, N., Thirkell, P., Sinha, A., 2011. Different determinants at different times: B2B adoption of a radical innovation. J. Bus. Res. 64 (11), 1162–1168. https://doi.org/10.1016/j.jbusres.2011.06.016.
Weitzman, E.A., 2000. Handbook of qualitative research. Softw. Qualit. Res. 2, 803–820.