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Exploring the influence of information and communication technology (ICT) on construction supply chain management: Empirical evidence from a construction project's perspective

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C H R O N I C L E

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A B S T R A C T

The purpose of this paper is to explore the influence of ICT on construction supply chain management (CSCM). Furthermore, this research proposes a model for ICT that can be used to test and improve CSCM within the Nigerian construction industry. The relationship between ICT and CSCM was highlighted in an integrated model. Structural equation modelling (SEM) was used to validate the hypothesised relationship by evaluating the responses of practitioners working in construction project management related firms using a sample of 214 respondents. The findings of this study show a link between ICT and CSCM on five (5) of the constructs on targeted construction firms engaged in supply chain (SC)-related construction activities in Port-Harcourt, Rivers State, Nigeria. This research is supported by the Technology Organisation and Environment (TOE) Model as a key theory of technology adoption. With an average R2 value, the SEM model is 76%, which is commendable (high). The current study offers an empirical and theoretical explanation of various aspects of ICT and CSCM, particularly in the Nigerian construction industry. As a result, this study adds to the body of knowledge by providing crucial insight into the influence of ICT on CSCM throughout the entire construction supply chain. The knowledge gained will aid industry stakeholders and the government in developing policies that will increase ICT adoption in current practice.

1. Introduction

The internet's introduction in the 1990s ushered in a new era centred on the deployment of ICT infrastructure in virtually all human endeavours. Most organisations around the world have incorporated ICT capabilities into their operations to a greater extent, preserving pre-existing inter-and intra-firm relationships (Adzroe and Awuzie, 2018; Tserng *et al.,* 2005), while others have gained economic benefits and extended supply chains with attendant impacts on the environment and society (Adzroe & Awuzie, 2018; Tserng *et al.,* 2005; Yao, Peng, Kurnia and Rahim, 2022). The fact that the entire project development process typically consists of several phases that require a variety of specialised services, and the involvement of numerous practitioners adds to the complexity of the construction industry (Amade, Ononuju, Adu, & Ogbu, 2019; Wang *et al.,* 2007). The tendency for effective control and coordination of construction project activities to become extremely difficult because of the involvement of numerous participants with diverse backgrounds becomes eminent. It's important for the construction industry to be able to share and manage information, according to Rivard (2000). ICT can help the

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construction industry achieve its goals through information processing and the development of new paradigms for construction project management, and it can also improve the efficiency of building design and construction activities (Mandicák, Mésáro, Kanáliková & Pak, 2021; Sarosa & Zowghi, 2003).

The use of ICT in construction is expected to increase as businesses recognise the value and role of ICT in achieving and maintaining a competitive edge in the industry (Gaith *et al.,* 2012; Wikforss and Löfgren, 2007). The use of ICT is critical in the support of project operations, while the organisational ICT infrastructure facilitates its implementation from the project level to the organisational level (Eliwa, Jelodar and Poshdar, 2022). There has been a rise in globalisation in the past, according to Xue *et al.* (2007). As a result, businesses have been able to focus on their areas of expertise, which has led to more supply chain coordination through Supply Chain Management (SCM).

SCM refers to a set of activities carried out within a company to achieve and improve efficiency through the management of finished goods, commodities, and knowledge from the point of production to the point of use by a network-connected organization (El-Garaihy, Badawi, Seddik & Torky, 2022). On the other hand, Ribeiro and Lopes (2001) defined SC as a collection of discrete activities or processes that result in the transformation of raw materials into finished products that can be purchased by a client. Additionally, they (Ribeiro and Lopes, 2001) stated that a SC in the context of construction can be defined as a process/series of activities that transform raw materials into finished deliverables such as roads or buildings, as well as services for use by a client. Similarly, Akintoye et al. (2000) defined SCM as the process of strategically managing the flow and storage of materials, components, and finished inventories from suppliers through the firm to final users. The plethora of definitions proposed by various scholars, as opined by Akintoye et al. (2000), demonstrates that SCM virtually defines the state of an organisational restructuring process that extends to the establishment of a company-wide collaborative culture.

Tserng e*t al.* (2005) state that professionals managing construction projects on the majority of sites require access to the sites in order to manage the activities occurring there. Due to the fact that the majority of construction projects are located in remote areas of the construction sites, the use of desktop computers or even notebook computers may be impractical, owing to the inconveniences associated with handling. On-site practitioners frequently deal with a variety of digitally-related documents, including reports, drawings, checklists, and specifications. Sheets of paper and/or field notes become the standard. As a result, a time and space disparity exists between the site and the head office, often resulting in low productivity, delays, and other issues that can affect the entire project. The use of ICTs has spread rapidly in other developed countries (Achimugu *et al.,* 2009; Elrefaey, Ahmed, Ahmad & El-Sayegh, 2022), but has been generally too slow in developing countries, resulting in a widening of the gap between the two divides in terms of ICT adoption (digital divide) (Studer and De Brito Mello, 2021). Construction is distinguished by a high degree of fragmentation, cost and schedule overruns, disputes and conflicts, and a low level of efficiency in comparison to other industries (Amade *et al.,* 2019; Xue *et al.,* 2007). Additionally, Xue *et al.* (2007) stated that these are the main characteristics and causes of the construction industry's performance-related problems. Contractors often communicate with manufacturers, subcontractors, and designers via telephone or fax. Typically, these transactions are lost or confused between sites and departments, as well as between all members, when these facilities are malfunctioning or do not exist at all. This sometimes results in ineffectiveness and inconvenient performance of their job functions (Wang *et al.,* 2007). As a result, the study's objectives are to explore the influence of ICT on CSCM from a construction project's perspective in Nigeria.

The advantages of incorporating ICT into CSCM have been well documented (Amade *et al.,* 2019; Eliwa *et al.,* 2022; Kazmi and Sodangi 2022; Mandicák *et al.,* 2021; Rivard, 2000; Rivard *et al.,* 2004; Yu, Yazan, Junjan & Iacob, 2022). The incorporation of ICT and its technologies in managing the supply chains of construction projects, however, has not been captured as it relates to emerging technologies in a developing clime like Nigeria. This is the gap this study aims to fill. Given the numerous advantages of incorporating ICT into the management of CSCs, it is reasonable to conclude that the effective use of ICT can have a significant influence on the transformation of CSC into a sophisticated and technology-driven business venture. As a result, the factors influencing ICT implementation on CSCs should be thoroughly investigated. It should be noted that without a thorough understanding of these constructs, the effective use of ICT to boost construction organization's supply chains will be severely limited. Hence, it is vital to investigate these constructs with a view to deciding the extent of their influence on CSCM.

2. Literature Review

2.1 ICT in construction

ICT has a lot of potential for managing a product efficiently throughout its life cycle in a collaborative and transparent way based on digitised data, which makes them valuable to the objective of a construction project (Yu *et al.,* 2022). In a nutshell, it has aided in the transformation of the activities of both individuals and organisations (Onyegiri *et al.,* 2011). Usman and Said (2012) state that construction firms use technological devices to solve problems and improve their construction activities. Additionally, Usman and Said (2012) stated that ICT capabilities contribute to improved communication among construction team members. These are, to a greater extent, some of the benefits and values associated with the use of technology and ICT facilities in mitigating risk and wasting valuable time in pursuit of specific goals.

According to Olalusi and Jesuloluwa (2013), the construction industry is increasingly reliant on the use of massive amounts of data throughout the construction and lifecycle of a project. In this case, it becomes necessary to make information readily available to construction sites in order to enable data integration, task control, and proper coordination of communication between various SC entities such as the company and its suppliers, as well as the entire materials and resources. As Olalusi and Jesuloluwa (2013) state, this type of information assists project participants in completing the construction phase of the project within acceptable cost and schedule constraints. Technology plays a significant role in SCM's development (El-Garaihy *et al.,* 2022). Without internet apps, organisations had problems accessing information, making it impossible to collect or relay information, alerts, replies, or other relevant data on a timely basis. Because of advancements in information technology, organisations will interact with one another on a regular basis within the SC. The logistics and supply chain activities of SC members are coordinated as part of the SCM architecture. This type of engagement with ICT is particularly feasible because these innovations go beyond the traditional boundaries of SC organisations. According to Kazmi and Sodangi (2022), ICT constitutes one of the leading drivers and enablers that primarily promote efficient SCM. Supply chains can better manage the threats and weaknesses of the business with the help of ICT.

2.2 SCM and the construction industry

With the accompanying increase in competition and technology-enabled activities, most businesses are beginning to recognise the importance of integrating SCM into their strategic competence, which is believed to result in achieving a competitive advantage (Amade *et al.,* 2019; Othman & Rahman, 2010). According to Amade (2017a), SCM is a mechanism that strategically manages the transportation and storage of products, components, and finished inventories from manufacturers to the firm and to the final consumers. According to Hai *et al.* (2012), the primary objective of SCM is to foster collaboration among SC members with the goal of maximising competitive advantage and achieving a more profitable outcome for the entire SC entity. Vrijhoef and Koskela (2000) reaffirmed that SCM originated and flourished in the manufacturing industry, citing as an example the just-in-time (JIT) delivery system, a subset of the Toyota Production System. According to Voordijk and Vrijhoef (2003), SCM has been identified as a developing field of study and a potential source of improving the construction industry's performance. Given the unique characteristics of construction SCs and their industrial and economic contexts, it is necessary to consider the temporal and fragmented nature of project-based multi-organizational construction SCs in comparison to permanent production-based organisations such as those found in manufacturing (Voordijk & Vrijhoef, 2003).

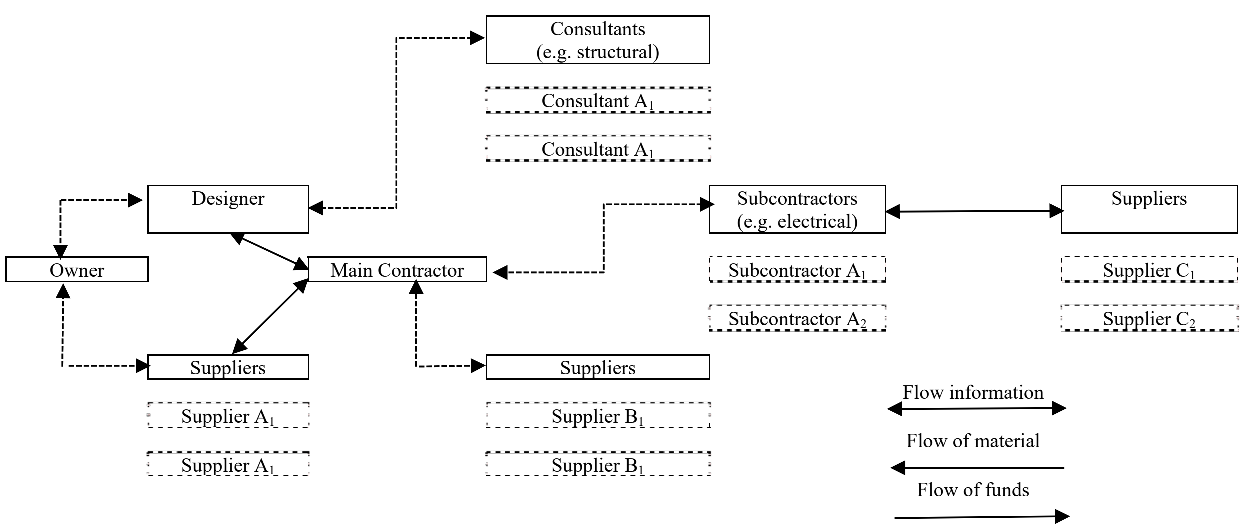


Fig. 1. A typical construction supply chain (Studer & De Brito Mello, 2021)

The deployment of SCM in the construction industry is a relatively recent development that presents significant challenges, owing to the nature of the industry and its hectic nature in terms of work package specialisation and process fragmentation among SC partners (Othman & Rahman, 2010). When compared to other industries such as manufacturing, the construction industry, according to Othman and Rahman (2010), entails a variety of component parts, each with its own unique site or project requirements. The manufacturing industry embraced (Nanayakkara, Perera, Senaratne, Weerasuriya & Bandara's, 2021) the concept of SCM, and incorporate the latest ICTs, including cloud technology, Internet of Things (IoT), big data, artificial intelligence, machine learning, multichannel communication, and social media. With this development, it is rare to presume that a single entity has the power or authority to coordinate the entire SC on its own, but each SC member has the power to influence and be impacted by the entire SC (Othman and Rahman, 2010). The goal of SCM, according to Robert *et al.* (1999), is to improve service cost-effectiveness, efficiency, and quality, as well as communication among SC components and improve flexibility through enhanced delivery and response time. They also stated that SCM is essential and critical in the construction industry in order to reduce inefficiency, avoid glitches, and address poor communication in the construction process. Kazmi and Sodangi (2022) believe that new supply chain operations are remoulded with the help of these technologies (ICT) through improved data gathering and the sharing of analysed information among key supply chain partners. They also help to make more information available, which leads to more trust between suppliers. At temporary sites and temporary organisational configurations, construction supply chains involve a diverse range of stakeholders (Studer and De Brito Mello, 2021). A typical CSC is a long and complex network of numerous organisations (e.g., clients/owners, designers, general contractors, subcontractors, and suppliers) and relationships, linked by information, materials, services, and product flows, and financial flows (see Fig. 1).

2.3 Theoretical underpinning

The Technology, Organization, and Environment (TOE) Theory served as the foundation for this study. In the 1990s, Tornatzky and Fleischer pioneered TOE as a technological innovation process (Amade, 2017b; Taherdoost, 2022). The TOE Model was created to drive the three major factors that influence technological adoption: technology, organisation, and environment (Angeles, 2014). According to Ramdani, Chevers and Williams (2013), this model is an integrative framework that provides a holistic and guiding theoretical basis for the adoption of ICT in evaluating the TOE entities in terms of assisting or inhibiting ICT adoption, as well as its impact on a firm in terms of innovation, implementation, and acceptance (Taherdoost, 2022). According to Cherian and Arun (2021), the construction industry's adoption of e-business technology has supported the TOE theory, whereas IoT adoption is based on the UTAUT theory (Unified Theory of Acceptance and Use of Technology). As a result, previous research has demonstrated that Tornatzky and Fleischer's TOE concept can be applied to technology adoption and technological innovation processes (Taherdoost, 2022). This theory describes the external and internal technologies that are relevant to an organisation in the achievement of a sustainable initiative from a technological standpoint. In this part, we talk about what it takes to make a system work well. We look at things like conflict/bargaining, systems life cycles, the socio-technical systems approach, and the socio-technical systems approach.

The organisational point of view examines the metrics for describing the organization's scope, size, and management structure. A variety of organisational factors have been suggested to have influenced innovation and technology adoption, according to Patterson, Grimm, and Corsi (2003). Larger organisations have proven, beyond a reasonable doubt, that they have the financial and technological resources to invest in cutting-edge technology and reap the benefits of economies of scale, as opposed to their smaller sister companies, which are more likely to be innovative due to the flexibility afforded by their size and the resulting low level of bureaucracy.

The TOE Model's environmental component is concerned with how the firm conducts its business and interacts with its competitors, industry, and government. According to Angeles (2013), a firm's desire for innovation can be influenced by a variety of factors such as competitors, suppliers, customers, and the government. Stakeholders have a strong preference for supporting or opposing technological innovation. According to Dong, Xu, and Zhu (2009), the use of information technology (IT) in the supply chain environment has gotten a lot of attention because it allows for the smooth and precise movement of materials, information, and funds in a network of consumers, suppliers, manufacturers, and distributors. According to Viswanadham and Kumar (2006), most construction firms are interested in capturing expenditure at every stage of their project by integrating construction design software with material, equipment, capital, and human resources. For the majority of their project visibility, cost, and scheduling modules, most firms in the industry use and apply productivity and cost-effective software applications like Primavera, CAD design tools, and enterprise information portals. As a result, this paper uses the TOE theory to determine the factors that influence ICT adoption in CSCM.

2.4 Conceptual model

2.4.1 Web-based and other software applications and portals- (WBSP)

ICT has significantly altered the way information is processed and moved from one location to another, and the construction industry is no exception (Viswanadham and Kumar, 2006). Additionally, they (Amade, 2017a; Viswanadham and Kumar, 2006) stated that the use of information technology in construction is restricted to accounting, project management, drafting, and wireless communications. Wal-Mart, Dell Computers, and others are examples of firms that have leveraged ICT capital to achieve transformational growth. According to Tarantilis *et al.* (2008) and Rivard (2000), web-based technologies are cost effective, reliable, and have been the focus of the majority of development efforts in recent years. Recent advancements in telecommunications and network technology have enabled web access by enabling the development of virtual private

network (VPN) systems that link various enterprise spatial entities with remote access to software packages and other resources (Elrefaey *et al.,* 2022). Computer-aided design (CAD) has consistently aided in reducing cycle time, increasing efficiency, and improving accuracy whenever a change in design is required in the construction sector. While other construction firms depend on software applications such as Primavera, CAD design tools, corporate knowledge portals for multi-project visibility, and other costing and scheduling modules to increase efficiency and reduce costs (Amade, 2017a). E-commerce is another method that is increasingly establishing itself as the primary mode of commerce in the European construction industry (Ribeiro and Lopes, 2009). According to Ribeiro and Lopes (2009), this is evidenced by the proliferation of portals in the market, such as e-commerce and e-business websites.
Accordingly, the hypothesis below is proposed:

H$_1$: *Web based and other software applications and portals have significant influence on CSCM.*

2.4.2 Internet applications and other technologies- (IAOT)

The importance of ICT in SCM cannot be overstated, as information has always been critical to efficient logistics management and the integration of business processes across functional units (AbTalib and Hamid, 2014; Amade, 2017a; Yu, 2015). With the advent of personal computers, fibre optic networks, the internet explosion, and the world wide web (WWW), access to information resources has become more affordable and accessible, resulting in faster connections that eliminate information-related schedule delays within any SC (Handfield and Bechtel, 2002). According to Handfield and Bechtel (2002), and Tserng *et al.* (2005), these innovations are SC enablers, which means they can be used to reduce paper work, boost connectivity, and shorten SC cycle times. On the other hand, Ribeiro and Lopes (2009) asserted that internet applications and web-based technologies have emerged as the most effective means of integrating SC into construction projects. According to Xue *et al.* (2007), the construction industry is classified as an information-dependent industry due to the variety of data-generating procedures associated with detailed drawings and photos, cost analysis sheets, budget reports, risk analysis, charts, contract documents, and planning schedules. On the other hand, the internet is critical in promoting the integration of construction business processes around the construction SC by facilitating the requisite information flows for organising construction activities. According to De Oliveira et al. (2011), the introduction of ICT had a substantial impact on supplier and customer-oriented processes. They asserted that consistent use of the internet and ICT applications resulted in an increase in information visibility among SC partners, resulting in an increase in SC performance. Additionally, critical benefits include the ability to break down organisational barriers by disseminating critical information and interacting in near real-time on-line across SCs, as well as the ability to monitor processes in order to shorten decision cycle times, allowing upstream suppliers and customers to respond more quickly and consistently. As a result, the following theory is advanced:

H$_2$: *Internet applications and other technologies have significant influence on CSCM.*

2.4.3 Mobile devices, and personal digital assistants- (MDPA).

ICT is critical for successfully controlling and managing construction projects, particularly for improving communication and coordination among SC partners (Tserng *et al.,* 2005). According to Usman and Said (2012), mobile technology refers to a situation in which a technology can travel with the user but is not always online in real time; for example, users can download apps, submit e-mail messages, and access web pages on their personal digital assistants (PDAs), laptops, or other mobile devices. Tserng *et al.* (2005) emphasised the importance of maintaining active contact and collaboration in order to facilitate the efficient sharing of resources and competencies within a construction SC network. Thus, incorporating promising ICT capabilities such as bar code scanners, personal digital assistants, and data entry mechanisms can be critical to increasing the efficacy and convenience of information dissemination in construction SC systems. As Ward *et al.* (2004) note, standardised packages are available for use by mobile site workforces that are often assigned pre-defined inspection and reporting tasks. In comparison to the manufacturing sector, the construction site is a more reactive area, with sudden changes to work occurring on a regular basis.

Accordingly, the hypothesis below is proposed:

H$_3$: *Mobile devices and personal digital assistants has significant influence on CSCM.*

2.4.4 Radio frequency and identification (RFID) technology- (RFID)

RFID is a self-contained device that is used to identify and capture data. It consists of three components: a tag attached to a chip via an antenna; a reader that transmits radio signals and receives responses from tags; and a middleware that links RFID hardware and business applications (Sarac *et al.,* 2009). For a variety of applications (El-Garaihy *et al.,* 2022), such as production, shipping, distribution, warehouse stock, advertising, marketing, and customer service, RFID can be used to incrementally incorporate new barcode reconnaissance systems. This consists of a microchip that stores data and an antenna that transmits it to a reader through an electronic product code (EPC). Following that, the reader reads the tag with radio waves and transmits the EPC to computers in a SC (Usman and Said, 2012). With the introduction of promising technologies such as RFID and web portals, significant improvements in the construction of SC control systems can be felt through the convenient flow of information (Wang *et al.,* 2007). While Sarac et al. (2009) believed that RFID technologies could also

aid in improving SCM operations, such as inventory loss reduction, process efficiency and speed, and information accuracy. (Amade, 2017a; Sarac *et al.* 2009). Unlike bar codes, RFID can identify and monitor goods and equipment in real time without the need for physical contact or line of sight, making it suitable for use in harsh and rugged environments. According to Sarac et al. (2009), RFID's advanced identification and communication capabilities can aid in improving product traceability and visibility among SCs. For example, RFID can improve process accuracy, performance, and speed. Additionally, it will reduce storage, handling, and delivery costs, as well as increase revenue by reducing stock outs. As stated by Elrefaey et al. (2022), RFID, drones, and 3D laser scanning are examples of data collection tools. These technologies are extremely valuable because their output may be used to create as-built BIM models of a building.
Accordingly, the hypothesis below is proposed:

H_4: *Radio frequency & identification (RFID) technology has significant influence on CSCM.*

2.4.5 Utilization of digital technologies-(DIGIT)

In the construction industry, digital technology is seen as the key to increasing productivity as well as the opportunity for rebranding and making themselves providers of smart engineering solutions (Elrefaey *et al.,* 2022; Wang, Wang, Sepasgozar and Zlatanova, 2020). ICT is defined as the framework for electronically organising and incorporating data flows in both directions through the trade SC partners network (El-Garaihy *et al.,* 2022). As a result, ICT facilitates fast access to information by enabling reliable and productive business transactions, resulting in improved customer service, reduced paperwork, improved connectivity, increased efficiency, and time savings. Technology plays a significant role in SCM's development. Digital technologies are a type of ICT that allows you to capture, store, analyse, communicate, visualise, incorporate, and collaborate on data (Cherian and Arun, 2021). Similarly, the use of developing technologies such as email, building information modelling (BIM), CAD, and Web-Based Project Management (WBPM) software has undergone a paradigm shift as a result of digital technology (Elrefaey *et al.,* 2022; Cherian and Arun, 2021). Following the progress of digitalization and automation concepts in Industry 4.0, digital technologies have gotten a lot of attention (Wang *et al.,* 2020). Through the integration of digital technologies, they could be used for logistics management, near-real-time information flows, end-to-end SC transparency, and improvements in human interaction, particularly in labor-intensive activities. According to Cherian and Arun (2021), digital technology evolves in four stages: industry 1.0 (mechanical phase), industry 2.0 (electrification phase), industry 3.0 (telecommunication and digital computer phase), and industry 4.0 (information and communication technology) (information and communication phase). The main requirement for a successful implementation of Industry 4.0, which encompasses the applications of the Internet of Things (IoT), robotics, 3D printing, off-site manufacturing, blockchain, cyber-physical systems, and other relevant technologies, is successful technology adoption (Elrefaey *et al.,* 2022; Liu, Jiang, Osmani and Demian, 2019; Wang *et al.,* 2020). According to Mandicák, Mésáro, and Spiáková (2021), BIM technology is used to control the cost of the entire construction process, including waste costs. It is built on the principles of effective management and the avoidance of out-of-control investments. There are other advantages to using ICTs. Improved industry competitiveness and productivity are among the economic benefits. In the manufacturing and construction industries, it has an equally positive impact on safety. These aspects have been improved, primarily through the use of BIM technology and the Internet of Things (IoT).

Accordingly, the hypothesis below is proposed:

H_5: *Utilization of digital technologies has significant influence on CSCM.*

Fig. 2 shows the 5 proposed research hypotheses alongside the conceptual model of positive influences.

3. Research Methodology

The study employed a quantitative (cross-sectional) research design. The study collected data from selected (targeted) construction firms engaged in SC-related construction activities in Port-Harcourt, Rivers State, Nigeria. To collect data, 214 self-administered questionnaires were distributed using the Krejcie and Morgan sample size determination methods; ultimately, a total of 203 usable questionnaires were retrieved for review (Krejcie & Morgan, 1970). The questionnaire included an introductory segment, a demographic section, and a section on the respondent's ICT knowledge and experience, with a focus on CSCM. A five-point labelled Likert-type scale was used to assess construct agreement with regard to items perceived usage and attitude toward ICT and CSCM. Cronbach Alpha values for each of the five constructs were calculated using IBM Statistics SPSS Version 25.0 in order to assess the reliability of the research instrument's items following data editing. Exploratory factor analysis (EFA) was used to ascertain the underlying relationships between the objects in the study's constructs. The following statistical techniques were used to evaluate the five hypotheses proposed for the study: structural equation modelling (SEM), latent variables and theoretical models that are components of EFA and Confirmatory Factor Analysis (CFA) (Su & Yang, 2010).

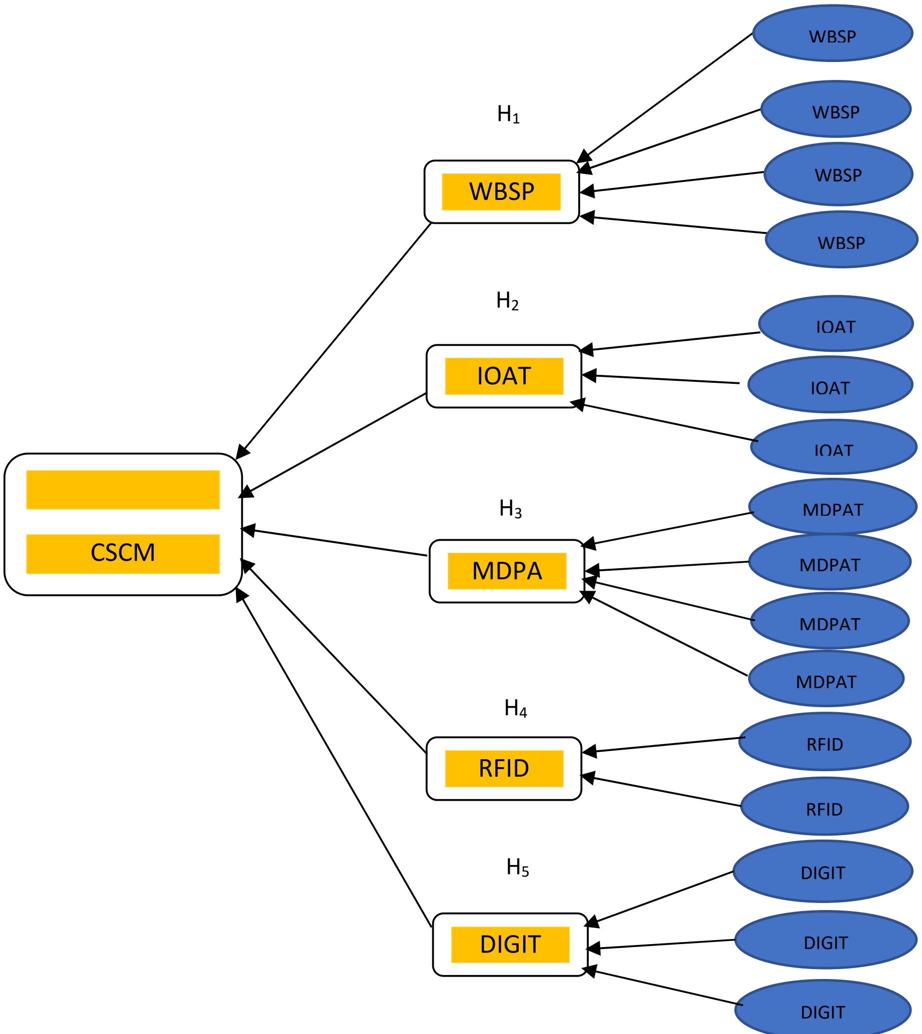
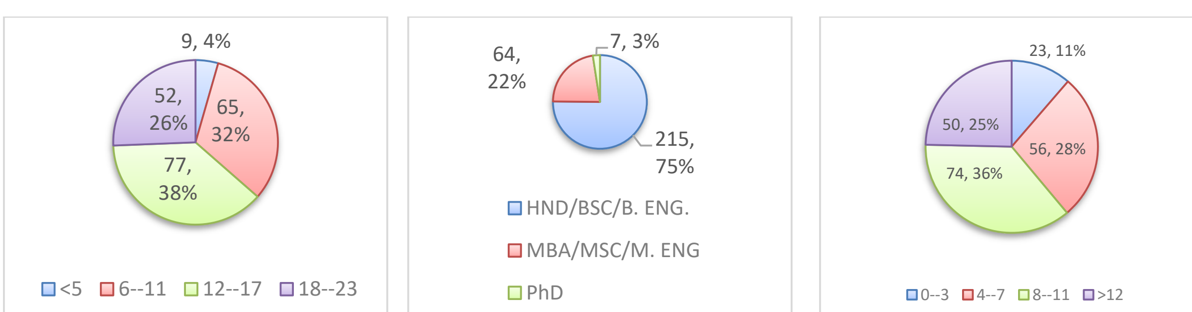


Fig. 2. Conceptual model of positive influences

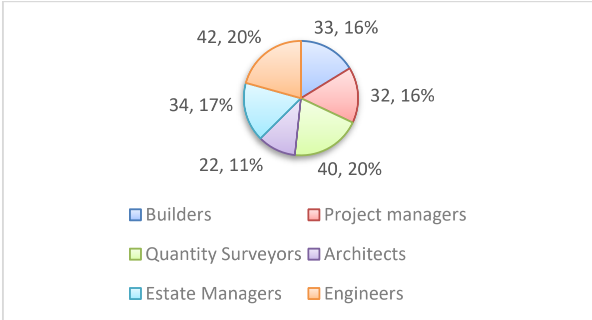
3.1 Results and findings

3.1.1 Descriptive statistics

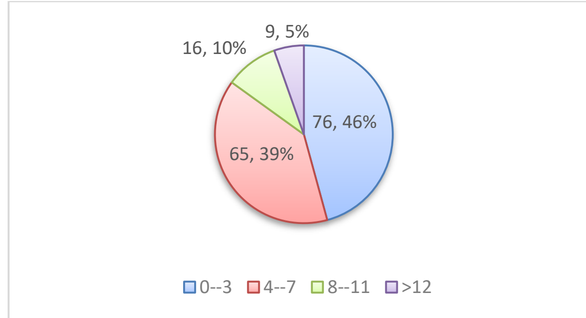
The current research is a quantitative analysis of ICT adoption on CSCM of construction organisations in Rivers state, Nigeria to see how ICT influences CSCM as well as the extent of their relationships. Personnel working in CSC related projects from selected construction firms in Port-Harcourt, Rivers State, Nigeria, with ICT and CSC related activities and functions were included in the study. Data for this study was obtained via email given the recent incident of the COVID-19 pandemic. The information was gathered through formal questionnaires. A total of 208 questionnaire responses were collected from the 214 lots previously distributed, and 203 were found to be available following a data editing procedure and used in the study. In Fig. 3, the demographic profiles of survey participants are summarised as follows.



Professional Experience | Educational Level | Experience in ICT Use (period)



Professionals



Experience in CSCM Activities

Fig. 3. Respondent's profile

3.1.2 Reliability analysis

The Cronbach alpha test was used to determine the instrument's internal accuracy (Ikediashi *et al.,* 2013; Su and Yang, 2010). A coefficient (Alpha test) greater than 0.70 (Table 1) indicates a strong reflection of the instrument's effects depending on the population (Hatcher, 2005; Milijić, Mihajlović and Jovanović, 2017). With a Cronbach alpha coefficient of internal consistency of greater than 0.70 for the collection of questions, one can deduce that the questionnaire on ICT and CSCM is accurate and reliable.

Table 1
Construct's Cronbach's Alpha's, latent variables, composite reliability and average variance extracted tests

Constructs	Items	Cronbach's Alpha (α)	Composite reliability	Average variance extracted (AVE)
Mobile devices, and personal digital assistants- (MDPA)	4	0.894	0.855	0.787
Radio frequency and identification (RFID) technology- (RFID)	2	0.867	0.854	0.672
Internet applications and other technologies- (IAOT)	3	0.773	0.846	0.673
Web-based and other software applications and portals-(WBSP)	4	0.977	0.885	0.897
Utilization of digital technologies-(DIGIT)	3	0.672	0.675	0.663

3.1.3 Factor analysis

The Kaiser-Meyer-Olkin (KMO) and Bartlett tests of sphericity were used to determine the sampling adequacy (Measures of sampling adequacy). For recommendation purposes, the agreed minimum value for KMO is 0.6, and Bartlett's test has a significance level of $p<0.05$ (Bollen and Long, 2010; Hatcher, 2005; Milijić *et al.,* 2017; Singh and Chan, 2022). The KMO coefficient is 0.683, indicating that the data are suitable for factor analysis. The value of the Bartlett sphericity test shows that there are correlations between the objects in the measurement instrument (χ^2 = 154.22, p 0.000), which invariably explains why the correlation matrix is not an identity matrix (Chai *et al.,* 2015).

3.1.4 Correlation matrix of the variables

Correlation coefficients between questionnaire items (variables) and CSCM in construction firms are examined; the correlation coefficients in the matrix in Table 2 meet the 0.05 eligibility threshold. By extension, this indicates that there is a strong association between the items on the questionnaire, justifying the use of factor analysis. Table 2 depicts the correlation matrix for five ICT and CSCM variables.

Table 2
Inter-correlations among five ICT constructs and CSCM within proposed model

Constructs	*(WBSP)*	*(IAOT)*	*(MDPA)*	*(RFID)*	*(DIGIT)*	*(CSCM)*
(WBSP)	1.00					
(IAOT)	0.38	1.00				
(MDPA)	0.30	0.22	1.00			
(RFID)	0.01	0.45	0.33	1.00		
(DIGIT)	0.22	0.02	0.11	0.32	1.00	
(CSCM)	0.65	0.65	0.00	0.27	0.01	1.00

3.1.5 Exploratory factor analysis

An exploratory factor analysis (EFA) was performed to ascertain the primary factors affecting ICT and CSCM in the selected construction firms. The relationship between the variables is such that, using the defined correlations, the variables can be regrouped into a more manageable set of variables in order to reflect a succinct and understandable structure of the variables (Memon *et al.,* 2013; Milijić *et al.,* 2017). The outcome of the EFA analysis was identified, and the factor loadings and communalities of the constructs are shown in Table 3. Correlation coefficients between the original variable and the extracted variables are described by factor loadings. While the communality component denotes the proportion of total variance that can be explained by shared factors (Memon *et al.,* 2013; Milijić *et al.,* 2017).

Table 3
Results of exploratory factor analysis

Constructs		Factor Loadings	Communalities
WBSP	*WBSP 1*	0.822	0.952
	WBSP 2	0.819	0.951
	WBSP 3	0.792	0.967
	WBSP 4	0.791	0.967
IOAT	*IOAT 1*	0.791	0.879
	IOAT 2	0.733	0.861
	IOAT 3	0.654	0.796
MDPA	*MDPA 1*	0.652	0.684
	MDPA 2	0.625	0.848
	MDPA 3	0.605	0.961
	MDPA 4	0.602	0.972
RFID	*RFID 1*	0.587	0.861
	RFID 2	0.509	0.744
DIGIT	*DIGIT 1*	0.453	0.677
	DIGIT 2	0.546	0.721
	DIGIT 3	0.532	0.712

3.1.6 Structural model assessment

The Path Model Analysis was performed in light of the conceptual model's outcome in Fig. 1. Fig. 4 illustrates the outcome of the structural model. The coefficients of regression (-path coefficient) are indicated above the arrow (Milijić *et al.,* 2017).

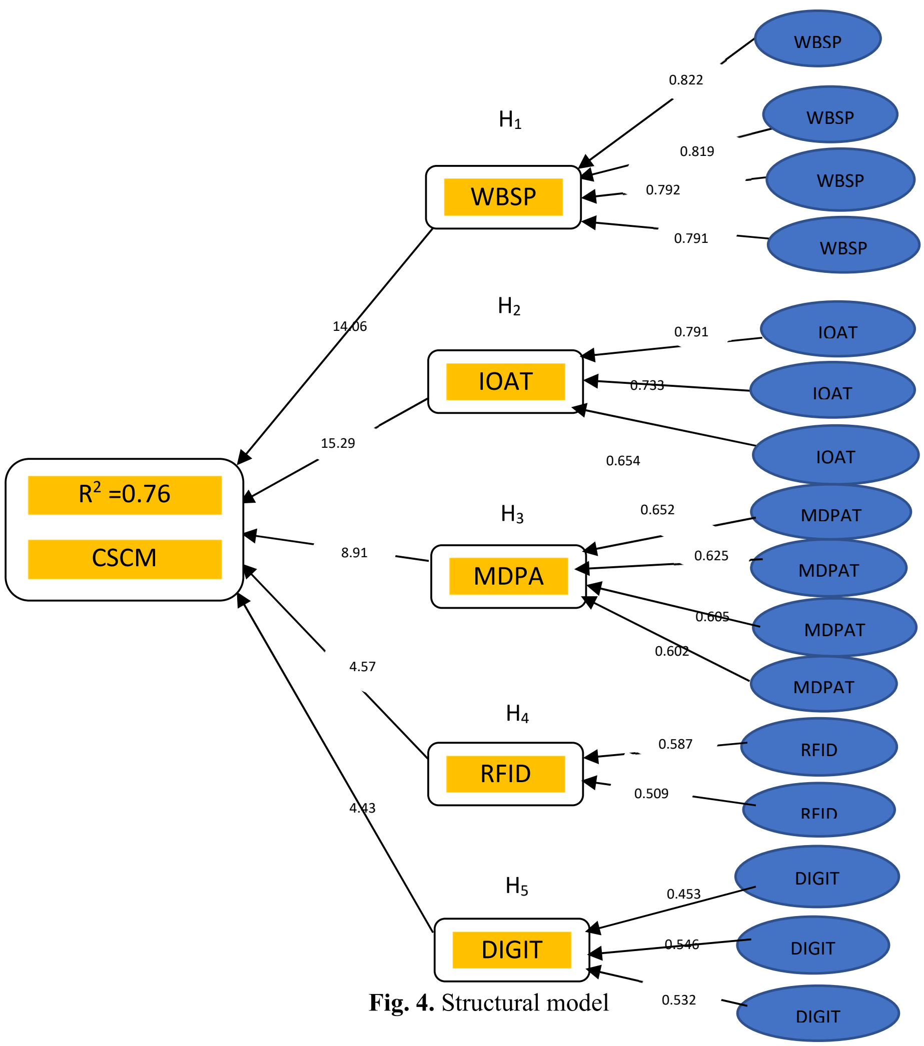


Fig. 4. Structural model

Table 4
Parameter estimates and results of hypotheses

Constructs	VIF	ß-value	t-value	Results
WBSP → CSCM	2.443	0.309	14.057	Supported
IOAT → CSCM	2.675	0.274	15.287	Supported
MDPA →CSCM	2.245	0.183	8.910	Supported
RFID → CSCM	2.315	0.078	4.571	Supported
DIGIT →CSCM	2.322	0.042	4.431	Supported

Significant at $p > 0.05$

It describes the intensity of the relationship between observed and latent variables, and thus the influence of WBSP, IOAT, MDPA, RFID and DIGIT on the dependent variable CSCM. The values shown underneath the arrows represent the t-test value. The R^2 value, which represents the coefficient of determination, is shown next to the dependent variable's sign. It illustrates the total amount of explained variance, that is, the extent to which the observed variable's differences are explained by the predictor variable. The outcome indicates that all ICT variables (constructs) have a mild impact on CSCM. Additionally, it is important to determine the importance of these findings in terms of the hypothesis's acceptance or rejection. The results of the parameter estimations and hypotheses tests are summarised in Table 4. The findings demonstrated that the proposed hypotheses were important. The hypotheses were calculated using a one-tailed test with a confidence interval of 95 percent. As shown in Table 3, WBSP, IOAT, MDPA, RFID and DIGIT all have a positive and statistically relevant influence on CSCM, as all t-values are greater than 1.645 and P-values are greater than 0.05.

3.1.7 Model fit measures

The values of the structural models' most important fits (measure of goodness-of-fit) are shown in Table 5. The fit measure values were evaluated to determine the models fit the initial data satisfactorily or unsatisfactorily by comparing the obtained values to the recommended values. The Root Mean Square Error of Approximation (RMSE) was calculated based on the estimated error introduced by the studied population's predicted degree of freedom. A low RMSEA value indicates a higher degree of correspondence, in other words, the model suits the input data better. As a result, the appropriate congruence value is less than 0.10. (Hatcher, 2005; Milijić *et al.,* 2017; Su & Yang, 2010).

The goodness-of-fit index (GFI) quantifies the degree to which a model is more applicable than it would be in the absence of the model. This indicator falls between the range (0-1), where 0 implies a poor and 1 signifies a perfect match. Acceptable values are those that exceed 0.8. (Hatcher, 2005; Su & Yang, 2010; Milijić *et al.,* 2017).

The Adjusted Goodness-of-Fit Index (AGFI), the CFI (Comparative Fit Index), the IFI (Incremental Fit Index), the NFI (Normalized Fit Index), the NNFI (Non-Normalized Fit Index), and the RFI (Relative Fit Index) all signify a situation under which the considered model exhibits a significant increase in correspondence. If the AGFI, CFI, IFI, NFI, RFI, or NNFI values are greater than 0.9, they are considered suitable (Eybpoosh et al., 2011; Milijić *et al.,* 2017).

The proposed model's parsimony is evaluated using the average value of the chi-square and the degree of freedom (χ^2/d.f.). If the value is greater than 1 and less than 3, the fit is considered satisfactory. Additionally, the procedure verifies that the data are representative (Aibinu *et al.,* 2010; Zainudin, 2012).

Table 5
Summary of model fit measures

Fit Indicators	**Overall Fitness Model**								
	Model Fits			**Model Comparison**					
Measurement fit	**CMI/DF**	**RMSEA**	**GFI**	**AGFI**	**NFI**	**NNFI**	**CFI**	**IFI**	**RFI**
Accepted fit levels	>5.0	0.08-0.10	>0.9	>0.9	>0.9	>0.9	>0.9	>0.9	>0.9
Model Results (SEM)	-	0.087	0.92	0.93	0.90	0.94	0.92	0.91	0.94
Final model (SEM) (χ^2 /d.f)				154.22 (78)					

4. Discussion of Results

The results indicate that the measurement scale's reliability and validity were established using Cronbach's alpha estimates of the instrument used to collect data. Given that the Cronbach alpha coefficients for all five groups of questions are greater than the suggested value of 0.7, it can be inferred that the control model's five groups are internally consistent. These results corroborate similar findings from (Ikediashi *et al.,* 2013; Milijić *et al.,* 2017; Su and Yang, 2010). The KMO and Bartlett tests of sphericity were used to determine the adequacy of sampling when factor analysis was used. The KMO indicator had a value of 0.683. The Bartlett sphericity test suggests a significance level of (χ^2 = 152.22 p<0.000), indicating that there is significant correlation between the objects in the measuring instrument, and therefore that the majority of correlation values are between or above 0.50. (See table 4). It is obvious that the data are ideal for factor analysis based on the outcome of the indicators. As shown in Table 4, five factors were extracted using exploratory factor analysis: WBSP, IOAT, MDPA, RFID and DIGIT and CSCM. These findings demonstrate how the conceptual model for this study was created.

Fig. 4 illustrates a structural model of the outcome of the hypotheses research. The results indicate that the four hypotheses were validated, and that they are both acceptable and statistically important (H_1, H_2, H_3, H_4 and H_5). The regression coefficients had positive values as a result of these hypotheses, and therefore the t-test values were greater than the recommended threshold value of 1.96. The following hypotheses were tested: H_1 (β= 0.309; t=14.057; p<0.05); H_2 (β= 0.274; t = 15.287; p<0.05); H_3 (β = 0.183; t = 8.910; p<0.05); H_4 (β= 0.078; t = 4.571; p <0.05) and H_5 (β= 0.042; t = 4.431; p <0.05). While Hypothesis H_5 (DIGIT) had the lowest -value, despite being statistically important, its t-test value was greater than the recommended 1.96 (β= 0.042; t = 4.431; p<0.05).

The first hypothesis was important; it suggests that the deployment of web-based and other software applications and portals (WBSP) has a significant effect on CSCM. Tarantilis *et al.* (2008) found comparable results in their analysis. They asserted that the majority of web-based technologies are efficient, cost effective, and have recently become the focus of growth efforts.

Additionally, the coefficient of determination (R^2) shows that the latent predictors H_1, H_2, H_3, H_4 and H_5 on the latent endogenous variable CSCM can be determined with 76 percent of the variance. As a result of this finding, the demand for ICT on CSCM may not be the same as in other advanced climes; thus, another analysis is needed to examine the major areas of RFID, as this aspect of the study yielded a low -value. According to Sarac *et al.* (2009), RFID implementations are still limited due to the high costs associated with them. The consequences of these findings are both theoretical and practical. From a theoretical standpoint, the use of RFID introduces a new variable into the analysis of CSCM and ICT applications in the Nigerian construction industry. Although this is a realistic consideration, project managers responsible for construction projects should not neglect RFID's influence. This study confirms that RFID has a beneficial effect on the CSCM of low-value construction firms. Similarly, the findings of this RFID study appear to contradict those of Elrefaey et al. (2022), who felt that fourth industrial revolution technology had a pivotal role in minimising the effects of COVID-19 on construction sites. Also, they talked about how AI-based technologies like RFID have filled in for the lack of workers and how BIM has helped construction professionals follow pandemic rules like physical separation while still simulating construction site activities online-real time.

The results of the model's structural analysis are represented in Figure 3 and Table 6. The RMSEA for the structural model is 0.087, indicating that a desirable congruence exists with the proposed model. The GFI value also indicates a high degree of model correspondence, with a resultant value of 0.92. Thus, based on the RMSE and GFI values, it is possible to deduce that the proposed model is completely consistent. The structural model's metrics are as follows: AGFI = 0.93; NFI = 0.90; NNFI = 0.94; CFI = 0.92; IFI = 0.91; and RFI = 0.94. The values are considered suitable because they exceed 0.90, meaning that the models exhibit a significant increase in concurrency. This result is consistent with Zainudin's (2012) assertion that a model should satisfy at least one of the fitness requirements in terms of total, incremental, or parsimonious suits. The proposed model's parsimony is determined by the relative value of chi-square (χ^2/df), which equals 1.98, which is within the suggested range of 1 to 3, indicating that the initial data are true representatives. It is critical to define the structural model as completely sufficient based on the results of the suitable indicators. The conclusion in broad terms is that all 16 variables can be defined as being responsible for the five groups of variables in a consistent and valid manner using the conceptual model depicted in figure 3.

5. Conclusion

The purpose of this study is to ascertain the influence of ICT on CSCM in Nigeria. The current study contributes to the repository of knowledge in Nigeria regarding CSCM. This research addressed the problems and incorporated a variety of CSCM-related elements, including WBSP, IOAT, MDPA, RFID and DIGIT. The outcomes of this study would assist practitioners in the Nigerian construction sector to gain a better grasp of how to complete their construction projects successfully. The fundamental goal of this analysis is to determine the influence of ICT and to establish a link between CSCM and WBSP, IOAT, MDPA, RFID and DIGIT. The findings indicated that WBSP, IOAT, MDPA, RFID and DIGIT all had a statistically significant effect on CSCM. The study's findings indicate an increase in the use of ICT equipment and services, which ultimately improves the firm's construction SCM's overall efficiency. Thus, the Nigerian construction sector must begin utilising ICT to enhance its CSCM. Because if this study doesn't have any new ICT constructs that are relevant to CSCM, it would be hard to build and test a model with a SEM method.

As a result, this research contributes in a variety of ways to the body of knowledge. To begin with, the topics of ICT and CSCM have received scant attention from the Nigerian construction industry. Second, most of these few studies on ICT and CSCM didn't use a systematic method, like SEM, to come to their conclusions. This research examined the theoretical and practical consequences of ICT's influence on CSCM in the Nigerian construction sector. This study improved the literature on CSCM in the Nigerian construction sector by analysing the significance of various ICT dimensions and CSCM covered in the study. Industry players and practitioners have invested significant sums in preparing their staff for ICT adoption. As a result of this study's findings, practitioners' capacity and performance will be enhanced through the development of an appropriate mentality. Because enhanced performance through the use of ICT and related technologies results in higher profitability, long-term viability, and goodwill for the construction enterprise, hence, the organisations that can learn faster than their competitors will prevail in the twenty-first century. Concerned organisations can use the findings of the study to come up with more effective initiatives that use ICT to get their CSCs going and give them an advantage over their rivals. While this study contributes to our understanding of the influence of ICT on CSCM, it is not without limits. To begin with, the investigation is geographically restricted. The research instrument (questionnaire) was distributed to only construction professionals in Port-Harcourt, Nigeria. To increase the study's generalizability, future research should focus on additional regions. Due to the study's time and budget constraints, doing a longitudinal analysis that requires data to be collected at multiple points in time as well as chronologically is challenging. As a result, a cross-sectional study was conducted to examine specific ICT environments in relation to CSCM at a certain moment. Longitudinal studies should be conducted in the future to collect data from multiple samples in order to examine variations in a particular pattern across time. Additionally, this study used SEM in conjunction with theoretical conceptualization to investigate the influence of ICT on CSCM. Future research could examine how ICT might alter the CSC of small and medium-sized construction enterprises over time using the technology acceptance model (TAM). Finally, while the proposed study's findings may be beneficial in accelerating the country's development through ICT adoption, they do not ensure that the country will be willing to accept and capitalise on future innovative advances in order to maximise socioeconomic benefits for its population. So, the government should play a big role in encouraging the use of ICT in the CSC and its programmes across the country by strengthening the relevant laws.

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