Indian Journal of Economics and Business
Vol. 20 No. 3 (December, 2021)
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Digital Transformation in Supply Chain Management: A conceptual framework for construction industry

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Received:07th July 2021
Revised:21st August 2021
Accepted: 03rd September 2021

Abstract: Digital technology is a powerful tool for storing, analyzing, and integrating data. Despite the construction industry contributes significantly to the economic growth of India, the industry has struggled to make effective use of tools and technology due to low productivity, lack of data, inefficient payment systems, and poor regulations. As a result, successful technology adoption leads to digital transformation in the construction sector. The sector is in an infant stage of technology adoption. Hence, the paper aims to investigate the use digital technology as an enabler to revolutionize the construction supply chain, and to identify the advanced technologies that are used in Construction Supply Chain Management (CSCM). The paper also investigates the factors responsible for adoption of Digital Supply Chain Management (DSCM) in the construction industry using Technology, Organization and Environment theory. An in-depth interview is conducted among construction professionals to determine the adoption factors. The identified factors such as digital transformation enabler, digital infrastructure, digital expertise, Supply Chain (SC) integration, company size, security, and regulatory problems are modulated as a conceptual framework. With this study, the construction professionals and suppliers will benefit and able to get more knowledge on the adoption of digital technology in CSCM. However, to implement DSCM in the construction business, experts require proper coordination and training.

Keywords: Digital Transformation, Supply Chain Management, Technology-Organization-Environment theory, Construction Industry

1. Introduction

The construction is a diversified industry with interdisciplinary construction firms and service providers (Vrijhoef, 2011). It is vital for the development of economies across the world (Bogue, 2018). Because the

sector is fragmented and projects are distributed across the country, supply chain participants are similarly dispersed. In most countries, the construction industry has contributed to economic growth (Dakhil, 2013), and construction accounts for half of a country's investment (Oesterreich and Teuteberg, 2016). Even though this industry is extremely important economically, it also has certain inefficiencies like low productivity, lack of data and inefficient payment systems. Information and Communication Technology (ICT) has recently eased the geographical dispersion of the construction industry, and software such as "Computer-Aided Design" and "Computer Aided Architectural Design" has become a common tool for designing construction works (Papadonikolaki, 2020). Similarly, ICT has brought favorable impact on economic growth (Habibi and Zabardast, 2020) and has touched every aspect of life through substantial shift in Supply Chain (SC). ICT in SC has enabled businesses to share timely information, execute accurate plans, and efficiently conduct various SC operations and activities (Niu, 2010). Even though the industry used ICT, its productivity has barely risen or even deteriorated over previous few decades ('Construction Industry Handbook'). The industry has to embrace advanced ICT and digital technologies like automotive and manufacturing industries for better productivity (Oesterreich and Teuteberg, 2016; Mason, 2017; Barima, 2017).

The unprecedented change of ICT in the automotive and manufacturing industry has led to digital disruption (Alshawi et al. 2003). Similarly, traditional business models' physical operations were disrupted and transformed to digitization. Therefore, the most revolutionary change observed during this industrialized era was that industries had digitized and shifted to digitalization. Digitization means the conversion of analogs to digital format (that is, binary language) whereas, digitalization refers to the usage of digitized information or data to transform a business model for enhanced opportunities and revenue. Despite the negative implications of the digitalization movement, (Buyukozkan and Gocer, 2018) organizations are using digital technology to collect and evaluate data provided by machines (Sarvari et al. 2017).

The SC is composed of a series of processes and procedures that flow from source to the consumers, creating value for goods and services. Traditional SCs were paper and computer based, and have lack of information, transparency, and inventory. Inefficiency and delays ensue as a result. Whereas, Digital SC, on the other hand, improves dependability and efficacy by increasing openness, communication, and cooperation ('Digital Transformation of"). The digital technology has impacted society, the organization's business (World Economic Forum, 2016), and supply chain operations (Holmstrom, and Partanen, 2014). So, using digital applications, Digital Supply Chain Management (DSCM) reduces cost, improves service, time, agility, and inventory through digital applications, and thus enhances operational efficiency. It also boosts the business's flexibility by increasing output to produce high-quality goods at less cost (Scuotto et al. 2016; Maskuriy et al. 2019). As a result, it is critical to comprehend the many sophisticated digital technologies that may be applied to Construction Supply Chain Management (CSCM) and their requirements. Furthermore, there is a succinct overview of current research on the framework and helps both practitioners and academics in CSCM use of digital technologies. Therefore, the study has the following research questions: (1) Will adoption of digital technologies transform the building industry? (2) What emergent digital technologies are being leveraged as transformation facilitators in CSCM? (3) What are the factors that have caused the framework for DSCM adoption in the construction sector to be modulated?

The theory adopted for the adoption of DSCM in the paper is Technology-Organization-Environment (TOE). This paper examines variables such as digital enablers, digital infrastructure, digital expertise, SC integration, firm size, security and legal issues. The study helps the managers and construction professionals to understand the several factors that influences the adoption of DSCM and develop a plan for implementing it in other industry. Thus, the study increases the awareness of digital technology use. On the theoretical side, this study contributes to information system knowledge through the adoption of TOE theory. The study contributes an existing knowledge in testing and developing a conceptual model for digital technology adoption in construction industry. The suggested paradigm provides new perspectives on DSCM for future research and helps decision-makers, practitioners, and experts to obtain a better understanding of digital technologies in CSCM.

The structure of the paper is organized: Section 2 detailed the literature on the current status of the construction industry, as well as the theoretical foundations. It also includes the transformation in the construction industry covering digital technology, Industry 4.0, CSCM and DSCM. Section 3 presents a framework for the adoption digital technology in Supply Chain Management (SCM) for the construction industry using TOE factors. A construction company which has been transformed due to digital technology is explained in section 4. Section 5 details the digital transformation benefits in SCM for the construction industry. Finally, section 6 presents the conclusion, limitations, and further scope of research.

1.1 Literature review

SCM in the construction sector has changed due to the advancement in ICT (Deraman et al. 2012). In the construction sector, technologies widely used were building information modeling (BIM), ICT, a Web-Based Information System (WBIS), and on-site tracking system. Web-based technologies and BIM are utilized to convey a variety of information to many stakeholders while also reducing waste (Singh et al. 2017). BIM also facilitates in performing works in an innovative way (Wong and Fan, 2013; Oh et al. 2015). Similarly, the usage of an on-site tracking system, reduces waste management on the construction site (Singh et al. 2017). The mobile technologies such as the portable computer, Radio Frequency Identification Device (RFID) are employed for efficient information and tracking in Construction Supply Chain (CSC). Likewise, WLAN, 3G and GPRS are used as wireless access networks and Email for information exchange (Froese, 2010). The efficient use of technology enhanced CSC's performance by increasing real-time information and communication with stakeholders (Shi et al., 2016). Also, e-business has resulted in continual development and productivity (Chen et al. 2013; Cherian and Kumaran, 2016). Also, CAD and CADD were used for effective designing and collaboration (Papadonikolaki, 2020).

Despite the adoption and implementation of information technology to exchange information and communication among stakeholders, the industry continues to face challenges such as low performance, poor teamwork, insufficient information, poor regulation, inadequate compliance, and poor accounting processes (Li et al. 2019). In addition, for construction operations such as prefabrication and off-site production, the sector is in high demand for automation and the usage of modern digital technology. Predictive analytics are also required for optimizing inventory allocation and forecasting demand. In smart cities, traffic artificial intelligence systems and Intelligent Transport Systems (ITS) assist in identifying traffic patterns and preventing road congestion ("Dataquest: Digital Revolution"). Furthermore, the adoption of

digital technology results in better productivity in construction activities (Oesterreich and Teuteberg, 2016; Mason, 2017). Hence for advancement in the construction process, the industry needs transformation to digital technologies.

1.1.1 Digital Technologies

Hamelink (1997) in the research addressed that evolution of digital technology occurs in four phases: (1) Industry 1.0 (phase of mechanical), (2) Industry 2.0 (phase of electrification), (3) Industry 3.0 (phase of telecommunication and digital computer) and (4) Industry 4.0 (phase of information and communication). Digital technologies are referred to as an advancement in ICT that supports capturing, storing, analysing, communicating, visualizing, incorporating, and collaborating the data (Hamelink, 1997; Whyte and Lobo, 2010). Likewise, Digital technology, according to Froese (2010), is a paradigm shift in the use of developing technologies such as email, BIM, CAD, and Web-Based Project Management (WBPM) software.

According to Deloitte construction group, the construction industry is a "case of complex disruption" as single technology cannot transform the industry to digitalization. Relatively, it is a combination of technologies that transform the problems of construction companies such as time management, an acquisition of staff, unproductive sites, project management costs and safety (Kelley, 2019). For the execution of construction operations, the digital technologies utilized in the construction sector are web-based (Ibem, and Laryea, 2014). It aids in the procurement of construction supplies and delivery of construction projects (Ibrahim, 2013). Similarly, technologies such as the cloud computing, internet, and other technologies reduce barriers and improve data transmission across geographic boundaries (Underwood and Isikdag, 2011) and provide several benefits ('Innvoations 2050'). The application of digital technology in construction propels the sector to new heights (Alaloul et al. 2020). However, according to research, adoption of digital technology in the construction industry is still in its infancy (Chen et al. 2013), and digital technology adoption is low (Kelley, 2019). Figure 1 shows the difference between traditional and DSCM.

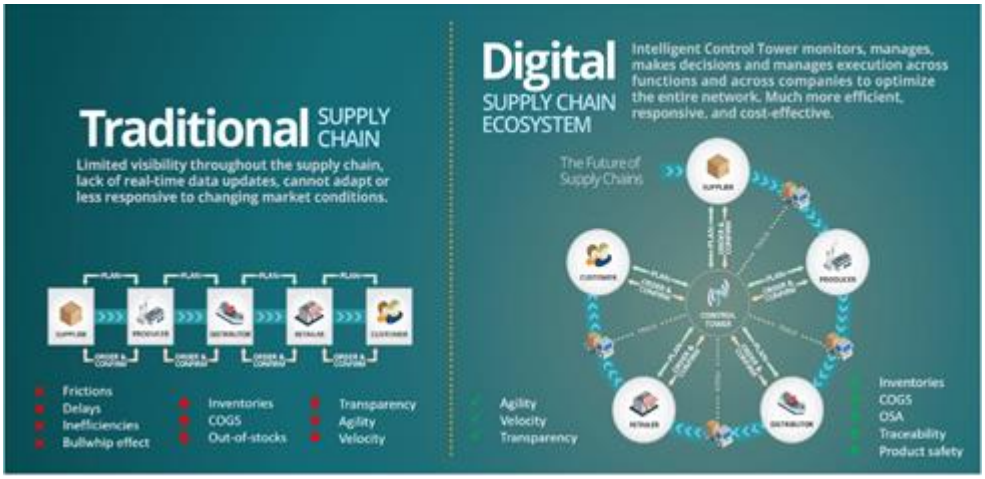

Figure: 1 Traditional SC vs Digital SC (Source: Duckworth, 2019)

1.1.2 Industry 4.0

The industry's fourth revolution referred as Industry 4.0 has a set of 'smart technologies' (Hecklau et al. 2016; Qin et al. 2016) such as Artificial Intelligence (AI), the Internet of Things (IoT), Big Data Analytics (BDA), Cloud Computing (CC), the Cyber-Physical System (CPS) (Lee, 2015; Qin et al. 2016; Schumacher et al. 2016) and other technologies were products and machines interrelate with each other. It aids in decision-making on their own and motivates them to work independently (Lee, 2015). On the other hand, Industry 4.0 has created a new relationship with systems, workers and products (Hecklau et al. 2016). The companies that create high technology product use are likely to develop and implement Industry 4.0 technologies (Yuksel, 2020). Industry 4.0 software is shown in Figure 2.

The lack of technology adoption and implementation in SC has created supply chain problems in businesses. Hence, a transition from traditional to digital SC is required (Queiroz et al. 2019). The important technologies used in SC are artificial intelligence (Blanco, et al., 2018); IoT (Kumar et al. 2016; Bibri, 2018); blockchain technology (Korpela et al. 2018; Li et al. 2018); cloud computing (Korpela et al. 2018; Vazquez-Martinez et al. 2018); BDA (Kache and Seuring, 2017; Strandhagen et al. 2017); CPSs (Yu et al. 2015; Zhong et al. 2017); robotics and automation (Barreto et al. 2017; Oyekan et al. 2017; Delgado et al. 2019). These technologies are necessary for digitization in manufacturing, supply chain management and logistics innovation and deployment (Tu et al. 2018). As a result, these technologies help to improve project performance (Queiroz et al. 2019).

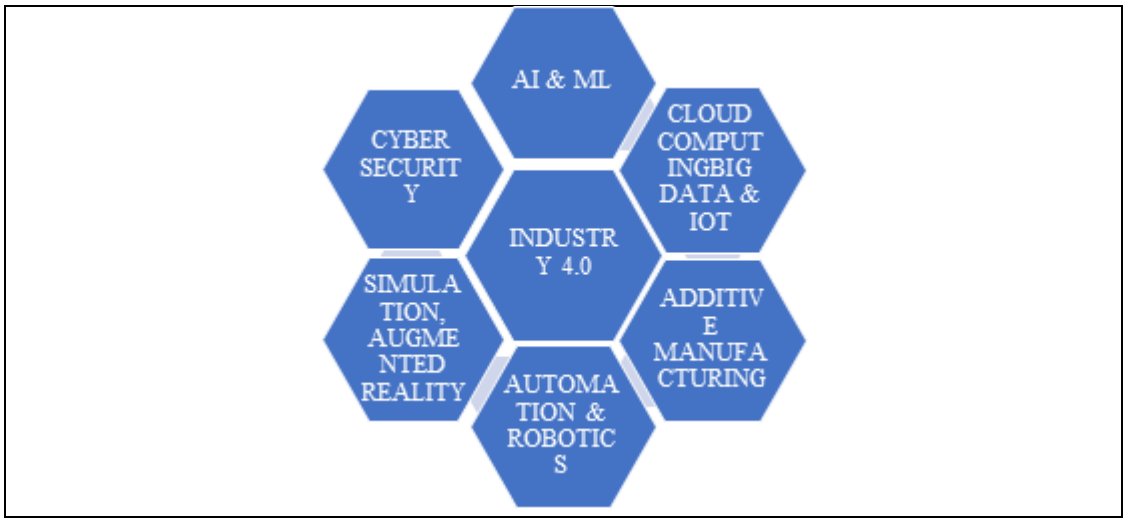

Figure 2. Industry 4.0 (Source: "The Fourth Industrial Revolution")

Although the construction sector has been moving toward Industry 4.0 for some time, the level of digital technology adoption has not been adequate to have a major influence on performance. Construction experts in Europe are less aware of industry 4.0 technology, according to a survey. Technologies such as BIM, modularization, and cloud computing have developed significantly. Even though technology is readily available, industry has yet to adopt digital technologies (Alaloul et al. 2020). In the construction industry there are limited research related to Industry 4.0. As a result, additional research in this area is required.

1.1.3 Construction Supply Chain Management (CSCM)

CSCM is an approach for successful collaboration of internal and external suppliers, clients and other stakeholders. The activities of CSCM are planning, directing and delivering the required quantity of materials to the site for final assembly. CSCM is tedious and time consuming for maintaining the SC activities and the use of digital technology aids in collaboration and integration. According to the report of the "Institute of Civil Engineering" (2017, p 2), DSCM has brought changes to the industry in architecture, service, management and disposal of materials. It also facilitates processing and decision-making.

1.1.4 Digital Supply Chain Management (DSCM)

Digital Supply Chain (DSC) is a smart, value-driven, and efficient process of using advanced and analytical technologies to generate profit, revenue and business value (Alshawi et al. 2003). DSCM means the application of digital technologies in SCM. The historical data, real time and predictive information by digital SC for quick delivery, agility and transparency is shown in Figure 3.

Figure: 3. Digital Supply chain (Source: Duckworth, 2016)

1.1.5 DSCM in Construction Industry

The adoption of digitalization in SCM is slow in the construction industry (Kelley, 2019) and the degree of technology adoption is mostly limited compared to other industries. A study in the European construction industry found that the social factor had greater influence on digital technology adoption than other factors such as technological, environmental, political and economic (Alaloul et al. 2020). Another study argues that even though the industry is slow in adopting innovative technology, automation and robotics helps the sector significantly for future developments (Delgado et al. 2019). BIM has been recently adopted in the industry and operates as a platform for digitalization and a key technology for DSC (Morgan and Papadonikolak, 2018). It aids other technologies to connect with each other and helps in maintaining a relationship with the supplier and customer throughout the supply chain (Morgan and Papadonikolak, 2018; Queiroz et al. 2019). Certain construction companies that have started adopting AI, sensors, automation and thermal imaging have changed the workflow with self-driven trucks, 3D Modeling, digital audits compliance and IoT performance for construction sites (Kelley, 2019). Thus, traditional SC gradually accept the challenge of adopting DSCs to support customer satisfaction, their experience, mode of transportation, production models and information exchange (Queiroz et al. 2019).

Malaysian construction industry reported that IoT adoption in construction industry was in an underdeveloped stage (Mahmud et al. 2018). Similarly, in UK (Woodhead et al. 2018) and Taiwan (Chen, et al., 2020) construction industries the situation remains the same. An inadequate establishment of IoT, lack of standards, awareness, safety and security are the major challenges identified in Malaysian construction industry (Gamil et al. 2020). The big data technology

adoption was very less in Australian construction industry (Leviakangas et al. 2017). Similarly, a study identified that 75% of professionals in "Architecture, Engineering and Construction" (AEC) were aware of big data technology (Sage, 2014). Another study claimed that big data technology was very slowly adopted in the construction industry (AbouniaOmran, 2016). Whereas a study conducted in the European construction industry reported that construction was ahead of the adoption of Industry 4.0 (Klinc and Turk, 2019). It is apparent from this study that ICT and Industry 4.0 have a major beneficial influence on the construction industry's development.

In construction projects, 3D printing, drones, AI, SC optimization and robotics were employed in site, as a collaborative platform. Drones were used for inspection on the site, to locate hazards, to take pictures and to track progress. Robots aid to perform better than humans, thus saving time. Similarly, autonomous equipment in construction such as self-driven trucks reduce the workforce and solve shortages of construction activities using computerized machines. They also use GPS and sensors in construction sites with 3D models for better precision. Mobile apps and RFID facilitate collaboration between offices and construction sites as they enable real time communication (Kelley, 2019). The use of software for recruiting employees, procuring materials and equipment has improved SCM in the construction sector. By predicting supply and demand, construction companies optimize SC and increase efficiency, resulting in transparency in competitive bidding.

Construction SC has a complicated network of relationships, goods, logistics, materials, information, and cash flow. For proper SC administration, CSC synchronization and integration are required. In SC, disruptions and hazards result in waste, material damage, inefficiencies, and significant downtime. Traditional pre-digital CSC procedures, which are manual, paper-based, semi-automated, and conducted over the phone, have major difficulties. Similarly, in the construction sector, real-time coordination and integration of SC limits the capacity to anticipate the supplies and equipment required. Hence it is vital for construction companies to take part in the adoption of digital technology for better visibility and optimization of SC. In this perspective, all construction professionals and decision makers are challenged to recognize the digital transformation of SC in construction industry. The construction sector has to identify the areas that need to be digitally changed to increase efficiency. Regulations, contract changes, on-site execution, design rethinking and labor retraining are few of the sectors that need to be digitized. Furthermore, it is necessary to investigate the necessity for digital technology adoption in CSCM. Consequently, the concept digital SC was neither organized nor discussed in pervious literature for construction industry. Moreover, there is scant literature in DSCM concept and emerging technologies adopted in the construction industry. There are only limited studies that enable for the adoption of DSCM for SC in construction perspective. Hence, the construction practitioners need to perform more studies on advanced ICT technologies to enhance automation in construction works ('Digital Transformation of') and safety of the workplace (Nnaji et al. 2019). Also, the factors of DSCM adoption need to be studied.

1.1.6 Objectives

The purpose of the paper is to help researchers and professionals in the construction industry:

1. To recognize the adoption of digital technology as an enabler of transformation.
2. To understand the concept of DSCM and to identify the emerging technologies in the construction industry.
3. To find the factors responsible for digital technology adoption in the construction industry, and to modulate a framework.

1.1.7Theoretical Foundations

The existing literature on theories for technology adoption includes Theory of Planned Behavior (TPB), Technology- Organization- Environment (TOE) theory, Theory of Reasoned Action (TRA), Diffusion of Innovation Theory (DOI), Technology Acceptance Model (TAM) and Technology Readiness Index (TRI). A study on the adoption of block chain technology in SC implemented TPB and TAM theory (Kamble et al. 2019) whereas the adoption of AI in construction industry used TOE and DOI (Alsheibani et al. 2018). Similarly, e-business technology adoption in the construction industry has supported TOE theory (Cherian et al. 2019), while IoT adoption in the Taiwan construction industry has adopted UTAUT theory (Unified Theory of Acceptance and Use of Technology) (Chen et al. 2020). As a result, the previous research shows that Tornatzky and Fleischer's TOE paradigm can be used to technology adoption. Therefore, this paper adopts the theory of TOE to determine the factors responsible for the adoption of DSCM in construction industry.

The framework of TOE facilitates to understand the factors responsible for technology adoption at an organizational level for the construction industry. It is a systematic and valuable framework established by Tornatzky and Fleischer (1990) that explains the factors for technology adoption and innovation. It analyzes the factors of an organization in terms of technology, organization and environment. The factors of technology involve all the relevant available technologies for the firm, organizational factors include resources and business attributes that influence the adoption such as management's support, firm size, communication and collaboration. The environment factors describe the industry's structure such as competition, external pressure, security and legal issues (Tornatzky et al. 1990).

The factors identified for the adoption of blockchain in Indian SCM industries were insecurity, discomfort, attitude, usefulness, and behaviour control (Kamble et al. 2019). Similarly, M-Internet in CSCM adopted factors like sharing of information and communication, material flow, integration, coordination, technological support and security (Oh et al. 2015). Likewise, ICT infrastructure (Bordonaba-Juste et al. 2012), firm size (Mohamed, 2010; Oh et al. 2015) are few factors identified in previous studies.

2. Methodology

In order to accomplish the objectives, an interview (qualitative study) was performed to determine the factors of technology, organization, and environment that influence the digital technology

adoption in SCM. This research aids in obtaining knowledge of advanced technologies and its trends in the construction industry (Garcia and Gluesing, 2013). The sort of digital technologies utilized in construction, the digital expertise required, infrastructural facilities, laws and regulations, the firm size for technology adoption, and SC integration were all assessed using the Delphi interview approach. A semi-structured questionnaire was utilized to gather in-depth information from construction experts, and comments was recorded. Details such as technology utilization and its advantages, infrastructural facilities, and digital technology training were examined in the first round. The second set of interviews focused on laws and regulations, company size, and SC integration. In the third stage, all the factors were consolidated and discussed. As a result, six variables were finalized for the study.

2.1 Details of construction Professionals

Through a Delphi interview, data was obtained from three construction experts regarding the usage of digital technology, infrastructure, firm size, SC integration, and regulations in the construction sector. The major highlights are explained below. From Company A, a senior construction project manager with 20 years of experience, CEO of the company with 10 years of experience from company B and project manager of company C (8 years' experience) are interviewed virtually.

Based on Company A, a senior construction project manager's information the company was using technology for the last 10 years and has adopted drone and other based technologies in business. The size of the company is large (greater than 250 employees). The employees have to be given adequate training for future growth and external suppliers and government are willing to support.

As per information from CEO of the construction company (company B), they have adopted technology for last 5 years for faster construction works. It is a medium sized company (50 to 250 employees). They are using RFID for tracking materials and blockchain technology in logistics and SCM. Government support and training is required for further business. Due to digitalization, response time and production time were able to meet.

From company C, project manager information, they are using e-business technologies and web technologies for SC tracking and communication respectively for last 3 years. The company falls under small size (10 to 49 employees). As a result, the company has not implemented advanced technologies. The size of the firm plays a major role in technology adoption hence difficult to get government support in terms of monetary. Better infrastructure facility is needed to support technology.

Based on the interview, the factors responsible for adoption of technology identified are the firm size, skilled and trained professionals, SC integration, technology enabler, security and legal issues are the factors identified.

3 Conceptual Framework

From the existing literatures, objectives of study and factors obtained from the interview, a conceptual framework is proposed for the adoption of DSCM in construction industry. Figure 4 represents the proposed framework. The factors are described below:

3.1 Digital transformation enablers

Digital transformation enablers are technology enablers that are novel technological solutions and business processes that offer outstanding value and sustainable competitive advantages (Maditinos et al. 2014). Digital transformation enabler has to be enabled in the organization to support the organization's strategy within the timescale for productivity (Ibem and Laryea, 2014). The digital enablers for construction industry include theArtificial Intelligence (AI), Internet of Things (IoT), Blockchain Technology (BT), and Big Data Analytics (BDA).

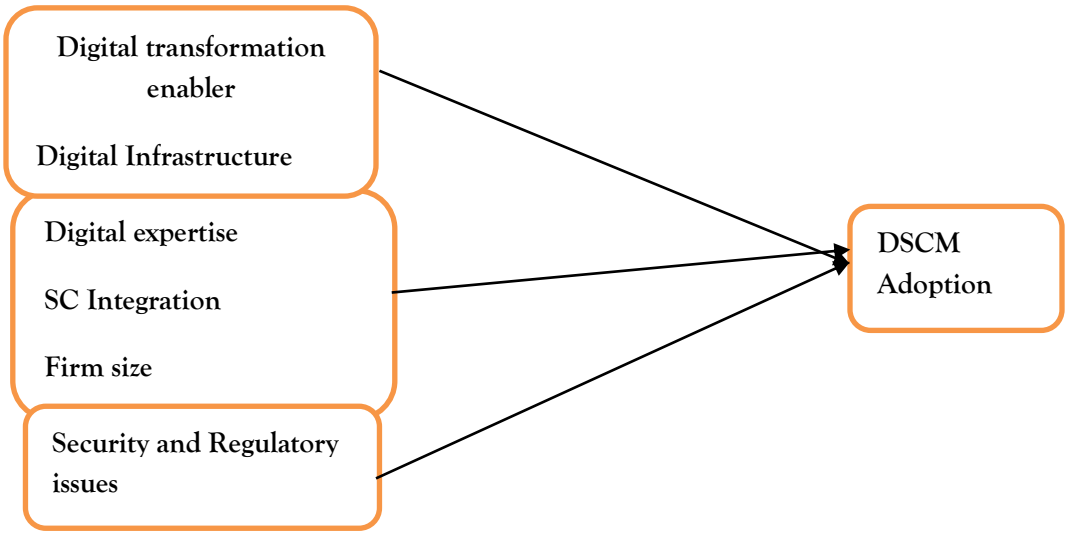

Figure 4: The proposed conceptual framework [Source: Author]

3.2 Digital Infrastructure

Digital Infrastructure refers to information, communication, technology, infrastructure, and systems such as both hardware and software for configuring, monitoring and maintaining network equipment and devices. In the modern business world, digital infrastructure is undeniably important in SCM, business to business, and rapid fund transfer. Thus, it plays a significant role in the industry's economic growth (Leekha, 2018). The ICT system facilitated the shift of paper-based communication to electronic communication (Pradhan et al. 2018). On the other side, research on Industry 4.0 and DSCM have shown that the ICT system was still not equipped to support digital SCM (Queiroz et al. 2019). While the cost and quality of infrastructure are found to be the major factors contributing to performance of construction industry in Nigeria (Varma,

2017). Another study found that the adoption of AI has a positive correlation between IT infrastructure and AI adoption (Alsheibani et al. 2018). Therefore, digital infrastructure is very essential in DSCM adoption.

3.3 Digital expertise

The major driver for adoption of technology in supply chain activities is digital knowledge (Ikediashi and Ogwueleka, 2016). Technology and humans go hand in hand and the dependency of humans on technology was increasing day by day. New entrants of construction professionals are aware of technology, but lags in technical skills on the execution of construction activities. Lack of digital expertise has become a serious competitive issue for the future of companies (Yuksel, 2020) especially, construction companies (Daugherty, 2015). Digital expertise facilitates transforming the construction industry**.**

3.4 Supply Chain Integration

Integration is important among the suppliers for proper sharing of information and coordination. The two stages of SC integration are information sharing and coordination in decision making (Sahin and Robinson, 2002; Berger, 2016). Whereas Lee (2015) summarized that there are three stages: information and sharing, resource sharing and coordination. An integrated SC improve the coordination and collaboration among the stakeholders and partners (Alshawi et al. 2003). M-internet technologies like wireless sensor, RFID, web based, and agent base technology improve the integration and collaboration of CSCM (Oh et al. 2015). The SC integration includes information sharing, coordination and collaboration relationships.

3.5 Firm Size

The size of the firm is one of the significant roles in the adoption of DSCM as construction projects are distributed in different places. Construction industries include small, medium, and large enterprises. Small firms have limited resources to digitalize compared to large firms (Ahuja et al. 2009).

3.6 Security and regulatory issues

The factor, security and regulatory issues are the environmental factors for adoption of DSCM. Regulatory issues are the assistance for the adoption of digital technology in SCM by the government authority at organization level (Alsheibani et al. 2018). Government rules are regulations that play a majorpart in the firm. The issues faced in the construction industry are system and data security (Oh et al. 2015). The industry should take precautionary steps for the security of software and hardware. Table 1 shows the factors identified for each factor.

Table 1: Factors for adoption of DSCM

Constructs	Variables	Description	References
Technological factors	Digital Transformation enablers	Less usage of technology	((Ibem and Laryea, 2014; Cherian et al. 2019)
	Digital infrastructure	Lack of infrastructure	(Pradhan et al. 2018)
Organizational factors	Digital Expertise	Lack of skilled professionals	(Yuksel, 2020)
	Firm size	More number of small firms	(Cherian et al. 2019)
	SC Integration	Improper coordination and collaboration	(Oh et al. 2015).
Environmental factors	Security and legal issues	Regulatory issues by the government	(Alsheibani et al. 2018).

Source: Author

The next section shows an example of an off-site construction company that had been successful by the usage of digital technologies in construction SCM.

Katerra: Technology transformation

Katerra is a Japanese-funded off-site construction firm and a building service provider powered by American technology. In 2015, the firm began as an architectural company, an off-site manufacturer, and contractor. By integrating with technology and SCM into building processes, it interacts directly with contractors, clients and owners. The company employs sophisticated technologies like SAP, mobile apps, IoT, BDA and machine learning for optimization, communication between site and office, resource tracking and construction designs. The use of technology has resulted in significant changes in building procedures, like inventory tracking of raw materials, which has assisted the firm in determining the time and number of supplies to be ordered. This allowed the firm to save material costs by reducing waste, as well as order huge quantities of items from suppliers, boosting the company's environmental impact. Katerra is using other technologies like cloud computing to run applications of SC and to store data; IoT devices to track the materials, supplies and equipment; Mobile apps to get universal information. Katerra's investment has increased by more than $200 million owing to the usage of digital technologies in SCM.

Benefits of Digital SCM in construction industry

The following are the benefits of digital transformation in SCM for the construction industry:

1. Reduces inventory because of just-in-time procurement (Hardie, 2010).
2. Better decision making as a result of transparency (Cherian et al. 2019).
3. Inventory visibility due to integration of the entire value chain (Hardie, 2010).
4. Delivery times have been shortened because of more dispersed warehouses and a reduction in the number of selling chain steps (Hardie, 2010)
5. Availability of more alternatives in the decision-making process (Hardie, 2010).
6. Better SC flexibility and risk reduction (Hardie, 2010).
7. Enhanced relationship with stakeholders, high profit and revenue (Agrawal and Narain, 2018).
8. Cost reduction (Cherian et al. 2019).
9. Demand sensing and real-time data of sales aids to grasp the customer's requirements (Hardie, 2010).
10. Enhanced quality of workmanship and improved competitive advantage (Meier, 2016; Agrawal and Narain, 2018).

4. Conclusion

According to the extant research, sophisticated technology adoption in CSCM is in infancy state in both developing and developed countries. The construction sector will be transformed as a result of adoption of DSCM. Digital technologies in SCM help in better integration, collaboration, and communication with the stakeholders. Also, DSCM helps in global transactions and partnership. The study addresses the factors influencing the adoption of DSCM for construction industry. The TOE framework provides an understanding of digital technology adoption in CSCM. This framework is like a capability maturity model for an organization. Factors such as digital transformation enabler, digital infrastructure, digital expertise, SC integration, firm size, security, and regulatory issues are essential for DSCM adoption in the construction sector. The current literature specifies that construction professionals require more training and understanding about the technology and the methods to implement it. As a result, it boosts productivity by decreasing time, expenses, and profit. The government's technology adoption strategy has opened the ground for the development of smart construction sectors. In the current scenario, technological environment is significant for all activities in the industry, but it has not been implemented in construction industries.

This study helps the managers and construction professionals to recognize the various factors that influences the adoption of DSCM and develop a plan for implementing it in other industry. The study increases the awareness of digital technology use. On the theoretical side, this study contributes to information system knowledge through the adoption of TOE theory. The study contributes an existing knowledge in testing and developing a conceptual model for the adoption of digital technology in the construction industry. The research also provides a detailed literature review on digital technology adoption in construction industry as there is lack of study in India.

It is purely a conceptual study and only a few construction professionals are interviewed due to COVID-19 restrictions are the study constraints. Only 3 construction professionals were taken for the study. In future research, the present study could be tested empirically by studying a set of construction companies.

REFERENCES

Abounia Omran, B. (2016). *Application of Data Mining and Big Data Analytics in the Construction Industry* (Doctoral dissertation, The Ohio State University).

Agrawal, P., &Narain, R. (2018). Digital supply chain management: An Overview. *In IOP Conference Series: Materials Science and Engineering,* 455(1), 012074.

Ahuja, V., Yang, J., & Shankar, R. (2009). Study of ICT adoption for building project management in the Indian construction industry. *Automation in construction,* 18(4), 415-423.

Alaloul, W. S., Liew, M. S., Zawawi, N. A. W. A., & Kennedy, I. B. (2020). Industrial Revolution 4.0 in the construction industry: Challenges and opportunities for stakeholders. *Ain shams engineering journal*, 11(1), 225-230.

Alshawi, S., Irani, Z., & Baldwin, L. (2003). Benchmarking information technology investment and benefits extraction. *Benchmarking: An International Journal*, 10(4), 414-423.

Alsheibani, S., Cheung, Y., & Messom, C. (2018). *Artificial Intelligence Adoption: AI-readiness at Firm-Level.* In PACIS, 37.

Barima, O. (2017). Leveraging the blockchain technology to improve construction value delivery: the opportunities, benefits and challenges. *Construction Projects*, 93-112.

Barreto, L., Amaral, A., & Pereira, T. (2017). Industry 4.0 implications in logistics: an overview. *Procedia Manufacturing*, 13(1), 1245-1252.

Berger, R. (2016). *Digitization in the construction industry*. Roland Berger GmbH, Competence Center Civil Economics.

Bibri, S. E. (2018). The IoT for smart sustainable cities of the future: An analytical framework for sensor-based big data applications for environmental sustainability. *Sustainable cities and society*, 38, 230-253.

Blanco, J. L., Fuchs, S., Parsons, M., & Ribeirinho, M. J. (2018). Artificial intelligence: Construction technology's next frontier. *Building Economist, The, (Sep 2018)*, 7-13.

Bogue, R. (2018). What are the prospects for robots in the construction industry? Industrial *Robot: An International Journal*, 45(1), 1-6.

Bordonaba-Juste, V., Lucia-Palacios, L., & Polo-Redondo, Y. (2012). Antecedents and consequences of e-business adoption for European retailers. *Internet Research*, 22(5), 532-550.

Buyukozkan, G., & Goçer, F. (2018). Digital Supply Chain: Literature review and a proposed framework for future research. *Computers in Industry*, 97, 157-177.

Chen, J. H., Ha, N. T. T., Tai, H. W., & Chang, C. A. (2020). The willingness to adopt the Internet of Things conception in Taiwan's construction industry. Journal of Civil Engineering and Management, 26(6), 534-550.

Chen, Y., Ruikar, K. D., & Carrillo, P. M. (2013). Strategic e-business framework: a holistic approach for organisations in the construction industry. *Journal of Information Technology in Construction (ITcon)*, 18(15), 306-320.

Cherian, T. M., & Kumaran, L. A. (2016). E-business in construction industry: Opportunities and challenges. *Indian Journal of Science and Technology*, *9*(32), 1-6.

Cherian, T. M., Shanmugam, M., &Kumaran, A. (2019). Adoption of E business in Indian Construction industry: Conceptual framework. *Restaurant Business*, 118(2), 54–66.

Dakhil, A. (2013). *The contribution of the construction industry to economic development in Libya*. Liverpool John Moores University, United Kingdom.

Dataquest. Digital Revolution 4.0 – Information and Communication Technology (ICT) in Construction Industry. Available at: https://www.dqindia.com/digital-revolution-4-0-information-and-communication-technology-ict-in-construction-industry/ Accessed on 5 September, 2020.

Daugherty, P. (2015). *Blending humans and technology in the workforce*, Computerweekly.com. Available at: http://www.computerweekly.com/ opinion/Blending-humans-and-technology-in-the-workforce. Accessed on 26, August 2020.

Delgado, J. M. D., Oyedele, L., Ajayi, A., Akanbi, L., Akinade, O., Bilal, M., &Owolabi, H. (2019). Robotics and automated systems in construction: Understanding industry-specific challenges for adoption. *Journal of Building Engineering*, 26, 100868.

Deraman, R., Salleh, H., Beksin, A. M., Alashwal, A. M., Abdullahi, B. C., & Abdullah, A. A. (2012). The roles of information and communication technology (ICT) systems in construction supply chain management and barriers to their implementation. *African Journal of Business Management*, 6(7), 2403-2411.

Digital Transformation of Supply Chains, Capgemini Consulting. pp.3, Available at https://www.capgemini-consulting.com/resource-file-access/resource/pdf/Digital_Transformation_of_Supply_Chains.pdf. Accessed on 1 September 2020.

Duckworth, N. (2019), *The network effect beyond supply chains, Traditional-supply-chains-vs-digital-supply-chains*. Available at: https://supplychainbeyond.com/gartner-supply-chain-conference-trends-2019/traditional-supply-chains-vs-digital-supply-chains/. Accessed on 12 September 2020.

Evtodieva, T. E., Chernova, D. V., Ivanova, N. V., & Wirth, J. (2020). The internet of things: possibilities of application in intelligent supply chain management. *Digital transformation of the economy: Challenges, trends and new opportunities*, 395-403.

Froese, T. M. (2010). The impact of emerging information technology on project management for construction. *Automation in Construction*, 19(5), 531-538.

Gamil, Y., A. Abdullah, M., Abd Rahman, I., &Asad, M. M. (2020). Internet of things in construction industry revolution 4.0. *Journal of Engineering, Design and Technology*, 18(5), 1091–1102.

Habibi, F., &Zabardast, M. A. (2020). Digitalization, education and economic growth: A comparative analysis of Middle East and OECD countries. *Technology in Society*, *63*, 101370.

Hamelink, C. J. (1997). *New information and communication technologies, social development and cultural change* (86). Geneva: United Nations Research Institute for Social Development.

Hardie, M. (2010). Influences on innovation in small Australian construction businesses. *Journal of Small Business and Enterprise Development*, 17(3), 387-402.

Hecklau, F., Galeitzke, M., Flachs, S., & Kohl, H. (2016). Holistic approach for human resource management in Industry 4.0. *Procedia Cirp*, *54*, 1-6.

Holmström, J., &Partanen, J. (2014). Digital manufacturing-driven transformations of service supply chains for complex products. *Supply Chain Management: An International Journal*, 19(4), 421-430.

Ibem, E. O., &Laryea, S. (2014). Survey of digital technologies in procurement of construction projects. *Automation in Construction*, 46, 11-21.

Ibrahim, N. H. (2013). Reviewing the evidence: use of digital collaboration technologies in major building and infrastructure projects. *Journal of information technology in construction (ITcon)*, 18(3), 40-63.

Ikediashi, D. I., &Ogwueleka, A. C. (2016). Assessing the use of ICT systems and their impact on construction project performance in the Nigerian construction industry. *Journal of Engineering, Design and Technology*, 14(2), 252-276.

Innovations 2050: A Digital Future for the Infrastructure Industry. Balfour Beatty. 2017. Available at: https://www.balfourbeatty.com/how-we-work/public-policy/innovation-2050-a-digital-future-for-the-infrastructure-industry/. Accessed on 10 September 2020.

JFCC. Construction Industry Handbook 2012. Tokyo, 2012.

Kache, F., & Seuring, S. (2017). Challenges and opportunities of digital information at the intersection of Big Data Analytics and supply chain management. *International Journal of Operations & Production Management*, 37(1), 10-36.

Kamble, S., Gunasekaran, A., &Arha, H. (2019). Understanding the Blockchain technology adoption in supply chains-Indian context. *International Journal of Production Research*, 57(7), 2009-2033.

Kelley, M. (2019). *How digital transformation has changed in the past year in construction. Constructible*. Available at: https://constructible.trimble.com/construction-industry/how-digital-transformation-has-changed-in-the-past-year-in-construction Accessed on 10 September 2020.

Klinc, R., & Turk, Z. (2019). Construction 4.0–digital transformation of one of the oldest industries. *Economic and Business Review*, 21(3), 393-410.

Korpela, K., Hallikas, J., & Dahlberg, T. (2017, January). Digital supply chain transformation toward blockchain integration. *In proceedings of the 50th Hawaii international conference on system sciences.*

Kumar, M., Graham, G., Hennelly, P., & Srai, J. (2016). How will smart city production systems transform supply chain design: a product-level investigation. *International Journal of Production Research*, 54(23), 7181-7192.

Lee, J. (2015). Smart factory systems. *Informatik-Spektrum*, 38(3), 230-235.

Leekha, S. (2018). Book Review: Don Tapscott and Alex Tapscott, Blockchain Revolution: How the Technology Behind Bitcoin Is Changing Money, Business, and the World. *FIIB Business Review*, 7(4), 275-276.

Leviakangas, P., Paik, S. M., & Moon, S. (2017). Keeping up with the pace of digitization: The case of the Australian construction industry. *Technology in Society*, 50, 33-43.

Li, J., Greenwood, D., & Kassem, M. (2019). Blockchain in the built environment and construction industry: A systematic review, conceptual models and practical use cases. *Automation in Construction*, *102*, 288-307.

Li, Z., Wang, W. M., Liu, G., Liu, L., He, J., & Huang, G. Q. (2018). Toward open manufacturing. *Industrial Management & Data Systems,* 118(1), 303-320.

Maditinos, D., Chatzoudes, D., & Sarigiannidis, L. (2014). Factors affecting e-business successful implementation. *International Journal of Commerce and Management*, 24(4), 300-320.

Mahmud, S. H., Assan, L., & Islam, R. (2018). Potentials of Internet of Things (IoT) in Malaysian Construction Industry. *Annals of Emerging Technologies in Computing*, 2(4), 44-52.

Maskuriy, R., Selamat, A., Maresova, P., Krejcar, O., &David, O. O. (2019). Industry 4.0 for the construction industry: Review of management perspective. *Economies*, 7(3), 68.

Mason, J. (2017). Intelligent contracts and the construction industry. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, 9(3), 04517012.

Meier, C. (2016). 'Digital supply chain management.' *Digital Enterprise Transformation: A Business-Driven Approach to Leveraging Innovative IT*, Ch. 9, Routledge, London and Newyork, 231.

Mohamed, I. S. (2010). *Empirical Study on Factors Determining E-Business Usage on Business Performance in Malaysian Service Industry* (Doctoral dissertation, University of Multimedia).

Morgan, B., & Papadonikolak, E. (2018). Organising for Digitisation: A Balancing Act. *Academy of Management Global Proceedings*, pp. 92.

Niu, Y. (2010). *The impact of information technology on supply chain performance: A knowledge management perspective* (Doctoral dissertation, The University of North Carolina at Charlotte).

Nnaji, C., Gambatese, J., Karakhan, A., &Eseonu, C. (2019). Influential safety technology adoption predictors in construction. *Engineering, Construction and Architectural Management,* 26(11), 2655-2681.

Oesterreich, T. D., &Teuteberg, F. (2016). Understanding the implications of digitisation and automation in the context of Industry 4.0: A triangulation approach and elements of a research agenda for the construction industry. *Computers in industry,* 83, 121-139.

Oh, M., Lee, J., Hong, S. W., &Jeong, Y. (2015). Integrated system for BIM-based collaborative design. *Automation in Construction*, 58, 196-206.

Oyekan, J., Prabhu, V., Tiwari, A., Baskaran, V., Burgess, M., &Mcnally, R. (2017). Remote real-time collaboration through synchronous exchange of digitised human–workpiece interactions. *Future Generation Computer Systems*, 67, 83-93.

Palka, D., &Ciukaj, J. (2019). Prospects for development movement in the industry concept 4.0. *Multidisciplinary Aspects of Production Engineering*, 2(1), 315-326.

Papadonikolaki, E. (2020). The digital supply chain: mobilising supply chain management philosophy to reconceptualise digital technologies and building information modelling (BIM). *Successful Construction Supply Chain Management: Concepts and Case Studies*, 13-41.

Pradhan, R. P., Mallik, G., &Bagchi, T. P. (2018). Information communication technology (ICT) infrastructure and economic growth: A causality evinced by cross-country panel data. IIMB Management Review, 30(1), 91-103.

Qin, J., Liu, Y., & Grosvenor, R. (2016). A categorical framework of manufacturing for industry 4.0 and beyond. *Procedia cirp*, 52, 173-178.

Queiroz, M. M., Pereira, S. C. F., Telles, R., &Machado, M. C. (2019). Industry 4.0 and digital supply chain capabilities. *Benchmarking: An International Journal,* 1463-5771.

Sage. (2014).*construction IT survey*. Available at: https://www.sage.com/na/~/media/sage-job-ready/assets/2014_construction_it-survey_infographic-1. Accessed on 15 September 2020

Sarvari, P. A., Ustundag, A., Cevikcan, E., Kaya, I. and Cebi, S. (2017). Technology Roadmap for Industry 4.0. *Industry 4.0: Managing the Digital Transformation, Springer International Publishing*,Switzerland, 95-103.

Schumacher, A., Erol, S., &Sihn, W. (2016). A maturity model for assessing Industry 4.0 readiness and maturity of manufacturing enterprises. *Procedia Cirp*, 52, 161-166.

Scuotto, V., Del Giudice, M., &Carayannis, E. G. (2016). The effect of social networking sites and absorptive capacity on SMES' innovation performance. *The Journal of Technology Transfer*, 42(2), 409-424.

Shi, Q., Ding, X., Zuo, J., &Zillante, G. (2016). Mobile Internet based construction supply chain management: A critical review. *Automation in Construction*, 72, 143-154.

Singh, J., Mangal, M., & Cheng, J. C. P. (2017). It for lean construction-A survey in India. *In Proceedings of the 25th Annual Conference of the International Group for Lean Construction 2017*. Walsh, K., Sacks, R., Brilakis, I. (eds.), Heraklion, Greece, 2, 119-126.

Strandhagen, J. O., Vallandingham, L. R., Fragapane, G., Strandhagen, J. W., Stangeland, A. B. H., & Sharma, N. (2017). Logistics 4.0 and emerging sustainable business models. *Advances in Manufacturing*, 5(4), 359-369.

Tornatzky, L. G., Fleischer, M., &Chakrabarti, A. K. (1990). Processes of technological innovation. *Lexington books*.

Tu, M., K. Lim, M., & Yang, M.-F. (2018). IoT-based production logistics and supply chain system – Part 2. Industrial Management & Data Systems, 118(1), 96-125.

Underwood, J., &Isikdag, U. (2011). Emerging technologies for BIM 2.0. *Construction Innovation,* 11(3), 252-258.

Varma, T. N. (2017). Curbing Cyber Crimes by Indian Law. *SSRN Electronic Journal.* Available at SSRN 2922365.

Vazquez-Martinez, G. A., Gonzalez-Compean, J. L., Sosa-Sosa, V. J., Morales-Sandoval, M., & Perez, J. C. (2018). CloudChain: A novel distribution model for digital products based on supply chain principles. *International Journal of Information Management*, 39, 90-103.

Vrijhoef, R. (2011). Supply chain integration in the building industry: The emergence of integrated and repetitive strategies in a fragmented and project-driven industry. *Ios Press*.

Whyte, J., & Lobo, S. (2010). Coordination and control in project-based work: digital objects and infrastructures for delivery. Construction management and economics, 28(6), 557-567.

Wong, K., & Fan, Q. (2013). Building information modelling (BIM) for sustainable building design. Facilities, 31(3/4), 138–157.

Woodhead, R., Stephenson, P., & Morrey, D. (2018). Digital construction: From point solutions to IoT ecosystem. Automation in Construction, 93, 35-46.

Yu, C., Xu, X., & Lu, Y. (2015). Computer-integrated manufacturing, cyber-physical systems and cloud manufacturing–concepts and relationships. *Manufacturing letters*, 6, 5-9.

Yuksel, H. (2020). An empirical evaluation of industry 4.0 applications of companies in Turkey: The case of a developing country. *Technology in Society*, 63, 101364.

Zhong, R. Y., Xu, X., Klotz, E., & Newman, S. T. (2017). Intelligent manufacturing in the context of industry 4.0: A review. Engineering, 3(5), 616-630.