CONSTRUCTION SUPPLY CHAIN MANAGEMENT IN THE FOURTH INDUSTRIAL REVOLUTION ERA

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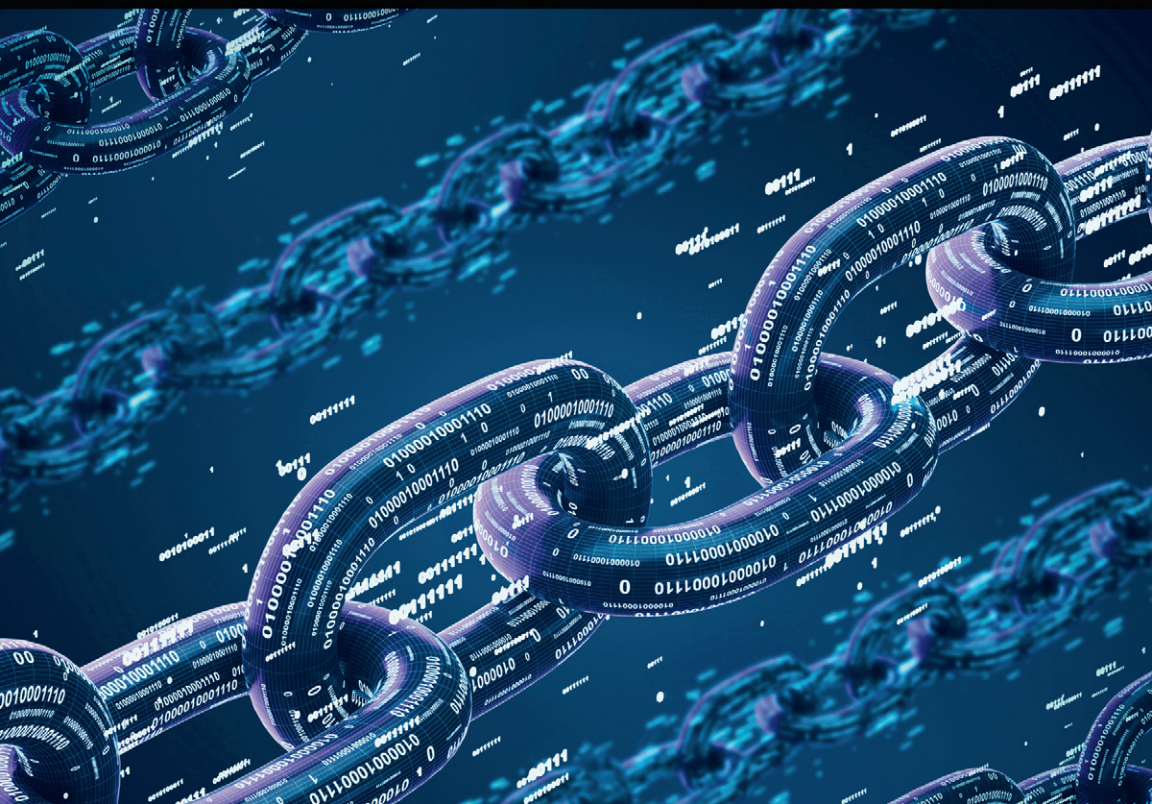

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Preface

The Fourth Industrial Revolution (4IR) originated from the manufacturing sector and is based on the premise that the manufacturing industry has gone through three revolutions: mechanisation, electrification and digitalisation. Evidence from literature and practice revealed that we are currently in the 4IR, which describes the blurring of boundaries between the physical, digital and biological worlds. The present revolution seeks a fusion of advances in artificial intelligence, robotics, the internet of things and other technologies that can alter the management of the construction supply chain (CSC). Unfortunately, most construction stakeholders do not know how to align their supply chain activities following the technologies and principles driven by the 4IR. This led to failure and underperformance, which is evident in the delay, fragmentation, corruption and other Gordian Knots of the CSC.

Towards positioning the management of CSC as the lynchpin of the Nigerian economy, this book presented the model for construction supply chain management (CSCM) practice in the 4IR era. Prior to developing the model, this book recognised some existing factors or behaviour capable of impeding the administration of CSC following the tenets and principles of 4IR. For instance, the CSC stakeholders as a culture for hoarding financial information. This culture contradicts the principles and belief of managing CSC in the 4IR era that encourages seamless information synchronisation across the supply chain. Another crucial belief for CSCM in the 4IR era is the principle of interoperability. This principle supports seamless communication and the usage of the functions of one another. The focus of interoperability performs effectively in a trusted environment. Unfortunately, the CSC is not a trusted environment due to the heavy sub-contracting within the construction industry.

In ensuring the practical application of 4IR beliefs like interoperability, this book introduced the drivers of trust, 4IR components and organisational culture to the existing variables for modelling CSCM. Trust drivers encompass the factors that eliminate opportunistic behaviour within the CSC. At the same time, organisational culture was perceived as the indicator supporting the adoption of 4IR components for CSCM. The 4IR components are divided into the cyber-physical system, virtualisation and smart management. The existing variables for modelling CSCM before the rise of 4IR are collaboration, integration and supply chain structure. The model was developed from a rich and robust existing theoretical and SCM model. The book discusses how theories such as the resource-based view, resource dependency theory, transaction cost theory, social

identity theory and change theory shaped the CSCM in the 4IR era. Also, a two-stage Delphi study regarding the future trends likely to occur within the CSC of developing economies was presented in this book. The book's content is crucial for academia, construction stakeholders and the construction regulatory bodies.

The findings from this book will enable the construction stakeholders to realign their activities with the principle and tenets of the 4IR era. Knowing the influence or impact of the model's constructs could assist construction stakeholders in planning better during the management of CSC activities. The book's content will also be significant to academia in the following areas: it serves as a road map for researchers interested in expanding the frontiers of knowledge regarding CSCM in the 4IR era. Furthermore, it will provide literature for students researching the SCM concept in the construction industry in the era of the 4IR. The book provides an operational definition of CSCM from the theoretical perspectives, thereby providing a further basis for studying CSCM. The findings from the study serve as a guide for training students on SCM practice on construction sites in the 4IR era. The robust literature review emanating from this book assists in exposing the readers to CSCM practice in developed countries such as the United Kingdom and Australia.

The book will provide tremendous support for construction regulatory bodies in determining the acceptable practice and standard for managing the CSC in the 4IR era. The regulatory bodies for construction professionals and stakeholders in conjunction with the Government can create software using the construct extracted from this study. The software will function as a pre-test in predicting the performance of CSCM in the 4IR era. Finally, the outcome of this thesis is of great significance to developing countries and their regulatory agencies through the provision of innovative ideas to improve the CSC. The book provides a guide regarding essential factors to consider for achieving efficient CSC practice in the 4IR era.

This book is divided into three parts and nine chapters for guidance and ease of use for construction stakeholders and researchers. Each chapter commences with a brief introduction describing the objective of the chapter and concludes with a summary highlighting the significant issues and their solutions. Since this is a research book, each chapter has a reference for further reading and broadening of the knowledge and scope of this book. An index of significant keywords was also provided for prompt reference to areas of interest for the readers.

The anticipated readers of this book include postgraduate students in the built environment, researchers with an interest in CSCM in the 4IR era and construction and project managers. Other potential readers are government departments that are responsible for construction project delivery as well as corporate agencies shouldered with construction management agenda including clients and contractors of construction projects. The book will also attract built environment professionals, such as operations managers, quantity surveyors, civil engineers,

estate managers, etc. It will also attract a reading audience from stakeholders in the construction educational sectors, owing to the ability of the book to function as an educational research guide, framework or material for topics related to CSCM. Finally, we hope that the readers of this book find it interesting, intuitive, and impacting and vital in improving their understanding of CSCM in the 4IR era.

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Part I
Background Information of the Book

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Chapter 1

General Introduction

Introduction

The construction industry is confronted with many challenges such as low-profit margin, budget overruns and delays (Ansah, Sorooshian, & Mustafa, 2018; Koskela, Bølviken, & Rooke, 2013). These challenges facing the construction industry are responsible for the sector's underperformance. Mustafa Kamal and Irani (2014) related these challenges to poor integration among different construction professionals within the construction industry. Supply chain management (SCM) has been recognised within the construction industry as a tool that integrates various parties involved with a construction project (Forbes & Ahmed, 2003; Koolwijk, Oel, Wamelink, & Vrijhoef, 2018). Despite the benefits posed by SCM, its application in construction is still confronted with some challenges. Several studies have indicated that the difficulties experienced in the construction supply chain (CSC) can be attributed to waste and late delivery of construction materials on the site (Ojo, Mbohwa, & Akinlabi, 2013; Vrijhoef & Koskela, 2000). Saka and Mudi (2007) discovered that the challenges confronting SCM in the construction industry occur at the material procurement stage owing to import tariff, sharp practice and inflation. However, Segerstedt and Olofsson (2010) reported that the challenge experienced in applying SCM for the construction industry does not guarantee the failure of CSCM (construction supply chain management). The failure could be attributed to numerous factors. The most crucial amongst them are adopting management ideas rooted in the second and third industrial revolution without taking consideration of the present industrial revolution.

Evidence from literature and practice revealed that we are presently in the fourth industrial revolution (4IR) or industry 4.0. This book believes that the present revolution is not just about integrating technologies into the CSC. It also includes how CSC resources and data are shared, exploited and organised to deliver faster, cost-effective and sustainable construction projects. Thus, the management of the CSC in the 4IR era requires a paradigm shift in the mindset of construction stakeholders concerning the management of the supply chain. Unfortunately, most stakeholders within the CSC do not know how to align their management philosophy with the tenets and beliefs of the 4IR. This led to a gap regarding the management of the CSC in the era of the 4IR.

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Another gap associated with the management of the CSC in the 4IR era is the creation of enabling organisational culture and trust. Willar, Trigunarsyah, and Coffey (2016) opined that the supply chain in the construction industry is dominated by the traditional culture in which each project team member is concerned about maximising their functions. Another culture affiliated with the CSC is hoarding financial information. This culture contradicts the idea of managing CSC management in the 4IR era that encourages seamless information synchronisation across the supply chain (Manavalan & Jayakrishna, 2019; Osunsanmi, Aigbavboa, Thwala, & Molusiwa, 2021). Thus, creating an enabling culture towards effective management of the CSC in the 4IR era is crucial. This suggests that the organisational culture adopted by a construction firm can affect the practice of CSCM in the 4IR era. Therefore, the impact of organisational culture dimensions on the performance of CSCM in the 4IR era was examined in this book. Unfortunately, few studies have been conducted in the construction industry relating CSC with organisation cultures, especially in the 4IR era. The majority of them examine the impact of the construction supply chain on other parameters such as collaboration (Hatmoko, 2008), delay (Riazi & Riazi, 2014) and risk (Soe, 2017). Thus, a gap exists in examining the impact of organisational culture on the management of CSCM in the 4IR era.

This book also discovers a gap or impediment regarding the management of the CSC in the 4IR era is a need to create trust among stakeholders owing to the interoperability nature of industry 4.0. Qin, Liu, and Grosvenor (2016) submitted that interoperability is the primary principle of 4IR which supports the seamless communication and the usage of the functions of one another. Lu (2017) and Koh, Orzes, and Jia (2019) discovered that the principle of interoperability performs effectively in a trusted environment. Unfortunately, the CSC is not a trusted environment due to the heavy sub-contracting within the construction industry (Chou, Irawan, & Pham, 2013). Broft, Badi, and Pryke (2016) and Hall (2018) submitted that the sub-contracting experienced within the industry is responsible for opportunistic behaviour, fragmentation and adversarial relationships. The fragmented nature of the CSC challenges the interoperability nature of the 4IR. Towards enhancing the management of CSC in the 4IR era, this chapter will present the factors that guarantee trust and in return support interoperability. The subsequent sections explain the SCM in the construction industry and the 4IR and SCM.

Supply Chain Management in the Construction Industry

All over the world, the construction industry functions as a nations' economic backbone owing to its capacity for affecting all areas of human life (Choong Kog, 2018). The construction industry of developing countries is not an exception as it is one of the vital sectors in the country (Aghimien, Fadeke, Aghimien, & Awodele, 2018; Anny, Anthony, & Kehinde, 2015). Fapohunda (2012) indicated that the industry provides direct employment through the employment of construction professionals whereas indirect employment occurs from the purchase of

construction materials. Ayangade, Wahab, and Alake (2009) noted that the construction industry is vital because other sectors cannot function effectively in its absence. For instance, it will not be possible for the manufacturing sector to thrive without buildings to house their plants and infrastructure such as the road to transport their raw materials. The construction industry is also responsible for the development and maintenance of infrastructural projects such as roads, bridges and residential and commercial housing. Despite the sacrosanct role performed by the construction industry of developing nations in infrastructure provision, it is still confronted with the problem of late delivery of construction projects.

Khlaifat, Alyagoub, Sweis, and Sweis (2019) and Khalfan and McDermott (2006) opined that many factors cause the late delivery of construction projects in the construction industry. They include poor project planning, risk, late delivery of construction materials and fragmentation. Among all the factors responsible for the late delivery of construction projects, Alashwal, Rahman, and Beksin (2011) recognised that fragmentation poses a significant impediment to the prompt delivery of construction projects. However, Amade (2017) contended that fragmentation affects the construction industry of developing nations and poses a problem in other developed countries. Fragmentation in developed nations such as the United Kingdom and Germany has been tackled by encouraging SCM practices (Geoffrey & Andrew, 2005; Meng, 2013). In the United Kingdom, for instance, the Latham and Egan report emphasises the importance of collaboration among construction stakeholders. Ever since the report of Latham and subsequent construction report in the United Kingdom encouraging supply chain practices such as collaboration and integration, there has been a significant improvement in the construction industry (Mandeep, Mohammed, & Kulonda, 2018; Morledge, Knight, Grada, & Pryke, 2009). In Australia, Petrovic-Lazarevic, Matanda, and Worth (2018) indicated that SCM practices had improved the overall performance of the construction industry. This opinion recognises the importance of adopting the construction industry's SCM concept.

Adopting SCM in the construction industry creates a collaborative working relationship for the prompt delivery of construction projects (Emuze & Smallwood, 2014; Xue, Shen, & Ren, 2010). The concept of SCM originated from the manufacturing sector, and it has witnessed an enormous contribution to the sector (Fernie & Tennant, 2013). Chileshe, Rameezdeen, and Hosseini (2016) asserted that SCM was adopted to ensure prompt delivery of car parts to the production site in the manufacturing of Toyota cars. Vrijhoef and Koskela (2000) and Vrijhoef and London (2008) opined that numerous manufacturing industry firms had utilised SCM to reduce their inventory level, achieve profit, reduce supplier cost and many others. This opinion revealed that SCM has a positive impact on the manufacturing sector by enhancing the sector's performance.

Meng, Sun, and Jones (2011) noted that the performance of SCM in the manufacturing sector could be attributed to numerous models that have been established in the industry over the years. Also, to enhance SCM's performance in the construction industry, innumerable models were developed. Aside from guaranteeing the performance of SCM in the construction industry, these models

were driven by the change in relationship within the CSC. The changes originated from the publication of the Egan and Latham report. Some models have been developed to evaluate this change for analysing, measuring and enhancing CSC relationships. Despite this, there are some noticeable insufficiencies in this model for the construction industry.

Lockamy and McCormack (2004) and Meng et al. (2011) developed a maturity model for explaining the CSC. Their model provided the ways and means for measuring CSC. Unfortunately, CSC is still a growing phenomenon for the construction industry of most developing countries; therefore, a model showing the measurement of its practice may not be sufficient. Wang, Zhang, Chong, and Wang (2017) established a model centred around supplier selection. This model only focused on a specific section of the CSCM, such as material delivery. Stamatiou, Kirytopoulos, Ponis, Gayialis, and Tatsiopoulos (2018) developed a CSCM model for claims management in Australia. The model also focuses on a specific section of CSCM (claims management) and thus provides SCM variables that support claims management. The model also assumes that CSC is developed in Australia, thereby not making it suitable for developing nations like the Nigerian construction industry characterised by undeveloped CSC practices. This, therefore, creates the need to develop a model that will show the variables supporting the practice of CSCM while incorporating all the areas of CSCM processes.

Although some existing models incorporate all the areas of CSCM processes. Further research into the current models showed some inherent weaknesses that will hinder its adoption for the construction industry in developing countries. Such models include the model developed by Love, Irani, and Edwards (2004) that created a client-based SCM model. Love et al. (2004) opined that the client will always be the one to control the CSC. Relating the model's assumptions to the construction industry of most developing nations like Nigeria, South Africa and others that a few large clients characterise to drive the supply chain, the model may not be sufficient for the country. Also, the model failed to incorporate the technologies driven by the 4IR, making the model not fit for the current industrial revolution. Against this background, this chapter presents the model for the effective management of the CSC in the 4IR era.

Fourth Industrial Revolution and Supply Chain Management

It is worthy to note that all the previous industrial revolutions were propelled by altering the production system made possible by a specific emerging technology. The first industrial revolution witnessed a change in production through the power of a steam engine. The second revolution was powered by electricity, while the third revolution was driven by information technology (Liao, Deschamps, Loures, & Ramos, 2017). The present revolution powered by the internet of things (IOT) and the cyber-physical system is referred to as the 4IR, also known as the industry 4.0. Marques, Agostinho, Zacharewicz, and Jardim-Gonçalves (2017) describes industry 4.0 as an integrated, optimised and interoperable manufacturing

process that includes the application of algorithms and high technologies. Osunsanmi, Aigbavboa, Oke, and Liphadzi (2020) indicated that technologies are the heartbeat of industry 4.0 as the connectivity under this revolution is supported using software, sensor and advanced communication technologies. Lu (2017) submitted that in industry 4.0, five technologies are the central point of discussions: big data analytics, cloud, 3D printing, IOT and robotics.

The application of this technology has attracted academics and enterprises owing to its capacity of ensuring a higher level of connection between products, activities and people (Bloem et al., 2014). The connection is facilitated by using smart machines equipped with cognitive computing technologies (Koh et al., 2019; Mittal, Khan, Romero, & Wuest, 2018). Using this technology's machines can reason, solve problems and take independently. These machines created a decentralised system that replaced the traditional hierarchy of production system. In the 4IR era, the production system was driven by open networks that support the communication among autonomic components, enhancing flexibility within the production line (Fragapane, Ivanov, Peron, Sgarbossa, & Strandhagen, 2020). Thus, it can be inferred that the rise of the 4IR has transformed the existing production system.

In support of the statement mentioned above, Dallasega, Rauch, and Linder (2018) avowed that industry 4.0 could transform the supply chain as it supports the disruption of activities within the chain. The disruption is experienced by decentralising and digitalising of supply chain stakeholders' activities (Barata, 2021). Another primary function performed by industry 4.0 for the supply chain is the enhancement of product and process integration. On the other hand, Frazzon, Rodriguez, Pereira, Pires, and Uhlmann (2019) affirmed that the 4IR increases flexibility and resource efficiency during the SCM in the manufacturing industry. Unfortunately, most of the benefits and significance of adopting the 4IR in SCM are experienced in other sectors like manufacturing, banking, transportation and others. Few or little benefits regarding adopting 4IR for CSCM have been recorded in the literature. This could be related to the little or no literature related to 4IR and the CSC.

Although some literature, such as (Chen & Kamara, 2011; Osunsanmi et al., 2021; Wang et al., 2020), have examined the benefits of adopting the 4IR technology for the CSC. Wang et al. (2020) discovered that implanting the 4IR technologies in the CSCM is a promising strategy for overcoming integration challenges associated with CSCM. They assist in overcoming the challenges by creating advanced levels of connectivity among the CSC stakeholders. Recently, Osunsanmi et al. (2021) discovered that the application of industry 4.0 technologies could enhance CSC resilience. The majority of the literature related to CSC and industry 4.0 provided helpful insight for applying technologies driven by the 4IR. Unfortunately, the existing studies failed to fully explain the operation and variables needed for consideration in the management of CSC in the 4IR era. This is because meaningful explanations cannot solely come from an attempt to apply the 4IR practice rooted in the manufacturing industry to a diverse, complex and project-driven industrial environment such as the construction industry. Towards the proper application of 4IR technologies and principles for the management of

CSC, this chapter presents the model showing the variables and constructs supporting the application of CSCM in the 4IR era.

Background and Significance

The SCM in the construction industry has passed through different eras. In all these eras, the construction industry has experienced fragmentation, late project delivery and other Gordian Knots due to its slow adoption of modern technologies and principles for its supply chain. With the 4IR era upon us, we need to re-align the CSC to position the industry as the lynchpin of the economy. It is also believed the CSC will benefit from the disruptive power of the 4IR. The benefit and the disruptive power of the 4IR have been adequately documented in other industries' supply chains. Unfortunately, little evidence has been gathered regarding the benefit and disruptive potentials of the 4IR within the CSCM domain. This could be attributed to the heavy adoption of the traditional method of managing the supply chain in the construction industry. Evidence from existing literature has revealed that the adoption of the traditional method of CSCM has hindered the synchronisation of the activities of CSC stakeholders. While some stakeholders are willing to manage their CSC under the 4IR era, most have no clue how to go about it. This chapter will provide readers and construction stakeholders with the current practice of managing the CSC in the 4IR era. The book will also investigate and model the variables capable of ensuring the performance of CSCM in the fourth industrial era. It will also establish the impact of each SCM variable classified as independent on the dependent variable (construction SCM performance). The book assists in identifying the variables that determine an efficient CSCM management practice in the era of the 4IR. The developed model will establish the influence of collaboration, integration, supply chain structure, organisational culture and trust in predicting the performance of SCM in the construction industry in the 4IR era.

The model will be developed from a rich and robust existing theoretical and SCM model. The book will discuss how theories such as the resource-based view, resource dependency theory, transaction cost theory and social identity theory shape and support the CSCM in the 4IR era. Also, a two-stage Delphi study regarding the future trends likely to occur within the CSC of developing economies was presented in this book. This research book will be of utmost importance to readers as it will serve as a roadmap for navigating the CSCM in the 4IR era. This book will allow re-aligning the activities of the CSC stakeholders with the principle and tenets of the 4IR era. The book will provide tremendous support for construction regulatory bodies in determining the acceptable practice and standard for managing the CSC in the 4IR era.

The book's content will also be significant to academia in the following areas: it serves as a road map for researchers interested in expanding the frontiers of knowledge regarding CSCM in the 4IR era. Furthermore, it will provide literature for students researching the SCM concept in the construction industry in the era of the 4IR. The book provides an operational definition of CSCM from the