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A Conceptual Model on Industry 4.0 and Construction Performance: Resource-Based View

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Abstract: Despite the promising future of industry 4.0 to be integrated successfully within the construction industry, researchers, stakeholders and project managers are still struggling with how to link industry 4.0 with the construction industry. A review of the literature revealed that there is still a lack of research on the benefits of industry 4.0 in the construction industry context, particularly concerning the impact on performance. Therefore, the main objective of this study is to develop a conceptual model underpinned by the resource-based view theory and also via applying the CIMO logic. This study seeks to understand the impact of industry 4.0 technologies as resources and the mediating role of IT and operations capabilities considering the construction industry complex context through the integration challenges.

INTRODUCTION

Industry 4.0 term was first introduced by Germany as a proposal for a new concept of German economic strategy that relies on modern technologies (Mosconi, 2015). The concept has developed to express the fourth technology revolution which is based on multiple technologies including Cyber-Physical Systems (CPS), the Internet of Things (IoT), cloud computing and mobile computing among many other technologies. Industry 4.0 refers to the growing automation and digitisation of the manufacturing environment (Lasi *et al*., 2014). Although, industry 4.0 was initially applied to the manufacturing sector, it is slowly but strongly influencing and changing the construction sector (Dallasega *et al*., 2018).

However, the construction industry which is one of the significant contributors to the countrie's Gross Domestic Product (GDP) has not managed to integrate industry 4.0 technologies (Oesterreich and Teuteberg, 2016). The construction sector has a more complex environment compared to the manufacturing sector. For an instant having a large number of processes, sub-processes and participants acting at different stages and location increases the complexity of the construction industry (Arayici and Coates, 2012). Osunsanmi *et al*. (2018) asserted that the evaluation of the construction into a fully digital industry is difficult due to the segmented nature, site-based activity and resistance to change of the construction industry.

To overcome these difficulties, the industry view towards industry 4.0 must be transformed by illustrating the impact of its technologies on construction performance. The main objective of this paper then is to propose a conceptual model for the industry 4.0 integration within the construction industry by applying the Resource-Based View (RBV) theory and CIMO logic.

Literature review

Industry 4.0 overview: Industry 4.0 is a term/concept used to relate to the idea of the fourth industrial revolution. The main objective of industry 4.0 is to integrate modern technologies with the production

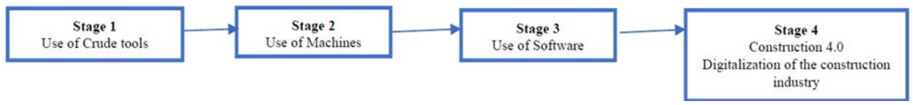

Fig. 1: Evolution of construction technologies (Osunsanmi *et al*., 2018)

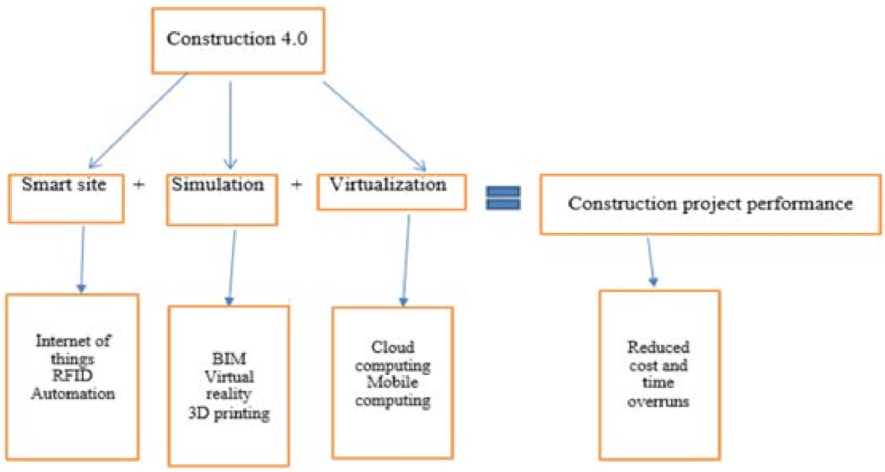

Fig. 2: Construction 4.0 conceptual framework (Osunsanmi *et al*., 2018)

process. One of its assumptions is that the product can be customised with the individual needs of the user, for example, individually customised sneakers, cars or furniture. Industry 4.0 grants the possibility to produce customised products with excellent quality and reasonable prices. Smart, visualisation, simulation and digitisation are the technical basis of industry 4.0.Moreover, industry 4.0 influence the entire life cycle of a product; development, manufacturing, use and maintenance. (Alaloul *et al*., 2018).

Germany proposed term industry 4.0 in 2011, German government developed industry 4.0 as a concept to define coherent policy framework in order to maintain competitiveness on the global market, then was formally put forward as a concept at the Hannover Industrial Expo in April 2013 (Li and Yang, 2017). Since then, the research efforts to examine industry 4.0 technologies, applications, benefits and challenges started.

Essentially, Rylnikova *et al*. (2017) indicated that the main components of industry 4.0 are: Cyber-Physical Systems (CPS), the Internet of Things (IoT), the Internet of Service (IoS) and smart units. Nevertheless, communication between machines (M2M) and smart products are not considered as a self-determining portion. They indicated that M2M is considered as a part of IoT and smart products as a part of CPS.

Industry 4.0 and construction industry: The complex nature of the construction industry, site-based, large number of participants and low IT investment capabilities, leads to difficult integration of industry 4.0. Oesterreich and Teuteberg (2016) reported that the lack of innovation and technology implementation in the construction industry is reasoned by the low investment in Research and Development (R&D). However, despite this complexity, Fig. 1 shows how technologies are evolved through various stages of construction through history.

Recently, the term construction 4.0 has been used by researchers to indicate for the integration of industry 4.0 to the construction industry. A review of the literature shows many research efforts to examine industry 4.0 in construction. In particular, Oesterreich and Teuteberg (2016) who was among the first to review industry 4.0 concept, application, state of the art, state of practice, benefits and challenges among construction companies. Subsequently, Osunsanmi *et al*. (2018) provided a framework for construction 4.0 based on the results of Oesterreich and Teuteberg (2016) (Fig. 2).

Past research on construction 4.0: Generally, construction 4.0 research mainly focuses on applications of industry 4.0 in construction, industry 4.0 readiness and construction industry challenges (Soto *et al*., 2019; Maskuriy *et al*., 2019). However, some researchers were interested in the benefits of construction 4.0 and its role in enhancing performance. They argued that the integration of industry 4.0 technologies with the construction industry would enhance construction project performance. Among previous studies focusing on industry 4.0 benefits to the construction industry are the following:

Table 1: CIMO logic implementation

Component	Construct in this study	Explanation
	Context	Integration challenges “The surrounding and human nature factors that influence the behaviour change; such as experience, age, organisational politics, firm nature, stability, and system. Interventions are affected by four contextual layers (individual, relationships, institutional setting and infrastructure system)” *
	Interventions	Industry 4.0 technologies “The interventions managers have at their disposal to influencebehaviour. Such as planning, control systems, training, leadership style. It is important to examine the nature of the intervention and how it is implemented. Also, hypotheses are carried by interventions” *
Mechanisms	IT and operations capabilities	“The mechanism that is triggered by the interventions in a certain context” *
	Outcome	Performance and SCA“The outcome of the intervention in its several aspects, such as performance improvement, costreduction or low error rates” *

Denyer *et al*. (2008)

Oesterreich and Teuteberg (2016) conducted a review to understand the implication of industry 4.0 for the construction industry. Using the PESTEL framework (political, economic, social, environmental and legal) to point out the benefits of its adoption, they found its potential benefits in terms of improvements in productivity and quality. Osunsanmi *et al*. (2018) research focused on industry 4.0 adoption among construction industry in South Africa by using a questionnaire to evaluate the awareness and readiness of construction professionals towards construction 4.0. The findings indicated that the adoption of construction 4.0 would enhance the performance regarding cost and time saving and also create sustainable buildings.

Underlying theory and logic

Resource-Based View (RBV): RBV theory has been highlighted in the literature to link the firm’s resources with performance. RBV theory was introduced by Werener felt in 1984, stating that the competitive advantage/performance of any organisations relies mainly on the use and adoption of tangible and intangible resources. Tangible resources are physical assets such as equipment and machines while intangible resources are the ones with no physical presence such as skills and reputation. Consequently, the company chooses their strategies based on their resources (Barney and Hesterly, 2011). Competitive advantages were defined as having more economic value than competitors in the product market.

The main argument of the RBV theory is that firm/organisation holds resources in order to achieve competitive advantage and enhance performance (Barney and Arikan, 2001). RBV assumes that resources should be economically valuable, relatively scare, difficult to imitate and immobile across companies; to be a valuable resource. RVB has three primary constructs; firm performance, resources and capabilities where the dependent construct is firm performance. RBV argues that a firm’s performance can be enhanced by the proper use of resources.

Daowd (2016) refer to resources as something that firms could employ to achieve its goals and capabilities as subsets of the resources. Resources were classified into four categories: physical, financial, human and organisational (Barney and Hesterly, 2011). Consequently, RBV theory was applied in various sectors including human resources, marketing, IT management and construction management.

Dynamic Capability View (DCV) was derived from RBV. This view argues that firms’ resources need other factors to create a significant impact on performance. Teece *et al*. (1997) referred to those factors as ‘Dynamic Capabilities’, defined as “the firm’s ability to integrate, build and reconfigure internal and external competences to address rapidly changing environments”. According to this approach the relationship between resources and performance must be mediated by capabilities (Carrick, 2016). The rationale of that approach is that firm’s resources can enhance specific firm’s capabilities through the implementation and integration of these resources (Liang and You, 2009).

CIMO logic: Based on Bunge’s rule “In Context, use Intervention to invoke generative Mechanisms that produces Outcome” (Denyer *et al*., 2008), the CIMO (Context, Intervention, Mechanism and Outcome) logic was developed. Subsequently, based on the CIMO logic, the framework of this research was developed. The CIMO approach has been adopted recently to CMR to evaluate the relationship between technology and performance (Da Silva *et al*., 2018). The context of the model is the complexity in the construction environment and the challenges of industry 4.0 integration. Industry 4.0 technologies are considered as an intervention. Outcomes of industry 4.0 integration are sustainable Competitive Advantage (SCA) and performance. The mechanisms that mediate these impacts are industry 4.0 readiness and DEA. Table 1 summarizes CIMO approach implementation.

MATERIALS AND METHODS

Proposed research model: Currently, there are several studies relating the RBV theory to construction management research and IT use. For example,

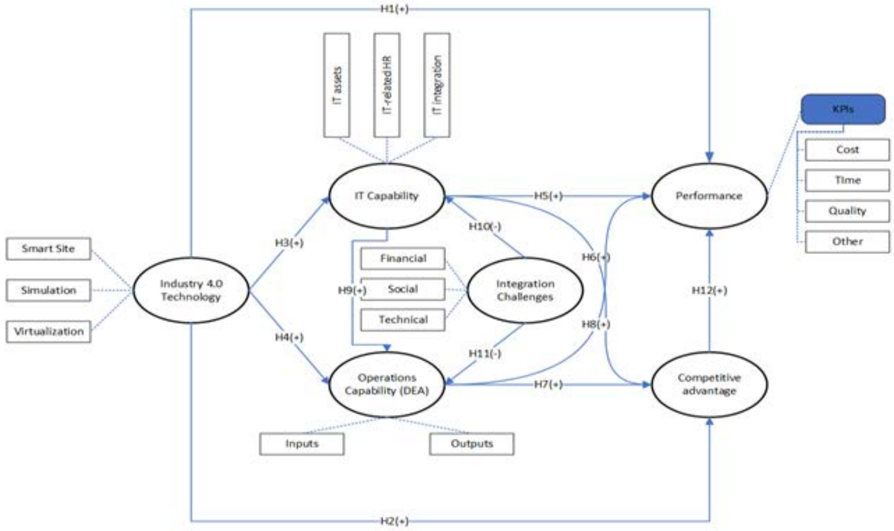

Fig. 3: Proposed industry 4.0 model for construction companies

Olanipekun and Xia (2017) review found that RBV is the most used model in construction management research between 2005-2014. Razak *et al*. (2015) used RBV as the underpinning theory to explain the relationship between IT and operational performance in the Malaysian construction industry. Similarly, Li *et al*. (2019) and Hazarika and Zhang (2019) adopted RBV in their research in the construction management field.

Based on the RBV, this research model is derived to understand the relationship between industry 4.0 technologies and construction performance. This model has been adapted to suit the construction industry context, where new variables such as IT capabilities and DEA are included to represent the capabilities. The model consists of six key variables, namely: industry 4.0 technologies; IT Capabilities; operation capability (DEA); performance; competitive advantage and integration challenges. This model is shown in Fig. 3.

This research identifies several constructs that are considered relevant to the research problem and construction context:

- Dependent variable: construction performance
- Mediating variables: IT capabilities, operations capabilities and competitive advantage
- Independent variable: industry 4.0 technologies

The following section will describe each variable in detail.

RESULTS AND DISCUSSION

Hypothesis development: To advance the literature on the impact of industry 4.0 of construction companies, the research framework was developed, based on RBV and CIMO logic. Consequently, research hypotheses are proposed in this section. Relative studies are also provided to support hypothesis.

Impact of industry 4.0 technology: The integration of industry 4.0 in the construction industry have been actively discussed by researchers (Alaloul *et al*., 2018; Soto *et al*., 2019; Nowotarski and Paslawski, 2017; Oesterreich and Teuteberg, 2016; Osunsanmi *et al*., 2018). Even various industries have benefited from industry 4.0 technologies, construction companies have found industry 4.0 integration difficult or may even fail to integrate (Osunsanmi *et al*., 2018). This issue could be a result of the misunderstanding of the benefits of industry 4.0 integrations and the mechanisms in which industry 4.0 makes an impact.

Many researchers have addressed industry 4.0 technologie’s impact and benefits to construction companies. Construction companies could benefit from industry 4.0 in terms of cost savings; labour costs are reduced through the use of robotics (Pan *et al*., 2018) and material costs could be reduced through the use of RFID technology to track equipment and materials (Niu *et al*., 2018). Moreover, construction companies could benefit from the time saving provided by industry 4.0; construction time is reduced through the use of prefabrication and additive manufacturing (Bamana *et al*., 2019). Similarly, industry 4.0 improves quality for construction companies; simulating the whole construction process and the use of BIM leads to avoid errors (Kelly and Ilozor, 2019), decision making is enhanced due to big data analytics (Dubey *et al*., 2019).

Likewise, industry 4.0 implementation in construction companies leads to communication and collaboration enhancement; through the use of cloud, BIM and social media apps among the high amount of project participants (Ahmad *et al*., 2019; Chen *et al*., 2019). Moreover, Alizadehsalehi *et al*. (2019) indicated that the satisfaction of project stakeholders would be improved through the application of VR, AR and mobile computing. Notably, the performance indicators are impacted by industry 4.0 technologies. Hence the following hypothesis was proposed.

- H_1: Industry 4.0 technologies have a positive impact on firm performance

The RBV theory suggests that integrating industry 4.0 as physical resources enhances the competitive advantage of the construction companies (Barney and Hesterly, 2011). In addition to the economic impact by increasing productivity, performance and efficiency, the integration of industry 4.0 in construction companies can improve safety and sustainability which leads to enhancing the image of the construction industry in the long run. Basically, the implementation of industry 4.0 technologies transfers the construction industry to a technology-driven industry that can keep up with other industries in terms of competitive advantage (Oesterreich and Teuteberg, 2016). Hence the following hypothesis were proposed.

- H_{1a}: sustainable competitive advantage mediates the relationship between industry 4.0 and performance
- $_{H2}$: Industry 4.0 technologies have a positive impact on Sustained Competitive Advantage

Bipat and Sneller (2015) conducted a review in order to conceptualise the IT capabilities' constructs. In their research, IT technical resources were one of the IT capabilities defined construct which supports Bharadwaj (2000) classification. Similarly, Ross *et al*. (1996) emphasised the role of IT resources in their explanation of IT capabilities (Zhao and Priporas, 2017). Hence and based on RBV and DCV the following hypothesis were proposed.

- H_{1a}: IT capabilities mediates the relationship between industry 4.0 and performance
- H_3: Industry 4.0 technologies have a positive impact on firm's IT capabilities

Operations capability is a key dynamic capability in both RBVand DCV (Yu *et al*., 2018). Data Envelopment Analysis (DEA) is applied to assess the relative efficiency of decision-making units (DMU). DMU is defined as the organisation responsible for converting inputs (i.e., people, cash, resources) into outputs (i.e., satisfaction, revenues, performance metrics) and whose performance is to be examined (Emrouznejad and Yang, 2018). According to RBV, firms diversify for using resources to generate synergy, that is, to minimise inputs and maximise outputs for higher performance which could be analysed by DEA (Jiang *et al*., 2019). Thus, in this research, DEA will be deployed to measure operational capabilities by using industry 4.0 as the input following Yu *et al*. (2018). Hence, the following hypothesis were proposed.

- H_{1c}: Operational capabilities mediates the relationship between industry 4.0 and performance
- H_4: Industry 4.0 technologies have a positive impact on operational capabilities (DEA)

Impact of IT capabilities: IT capabilities, defined as, the firm's ability to integrate and manage IT, serve as a source of SCA when combined with other resources and capabilities (Bharadwaj, 2000). Many scholars have discussed IT capabilities and its constructs (Zhao and Priporas, 2017). Following Ross *et al*. (1996) research, IT capabilities were classified into three categories; IT assets, IT-related human resource and IT integration.

IT assets are defined as hardware and software resources that are possessed by the firm. Moreover, since IT assets does not function by itself, IT-related human resources are defined as technical and managerial skills needed to build and maintain IT applications using the available technology. Similarly, without a system and infrastructure that supports IT integration, IT will not be distinctive enough to create SCA (Zhao and Priporas, 2017). Hence by considering IT capabilities as a combination of tangible (hardware, software and infrastructure) and intangible (Skills, knowledge and system) resources and by applying the RBV the following hypothesis were proposed.

- H_5: IT Capabilities have a positive impact on firm performance
- H_6: IT capabilities have a positive impact on Sustained Competitive Advantage

Impact of operations capabilities: Operations capabilities are defined as the synergy of tasks a firm deploys to enhance its output (service or product) by efficiently using the available technology and process (Wan *et al*., 2016). Consequently, RBV and DCV asserted that operations capabilities could achieve a SCA through the efficient management of knowledge and IT (Yu *et al*., 2018) additionally, as mentioned, DEA is used to assess the relative efficiency of organisations (Emrouznejad and Yang, 2018). In recent efforts, researchers are using DEA combined with theories to explore the organisation's operations capabilities (Tsai and Chang, 2018). However, the level of integration related to establishing relative efficiency can be identified by DEA; then different strategies could be compared to improve efficiency (Cioaca *et al*., 2017). Hence, the following hypothesis were proposed.

- H_7: Operations Capabilities (DEA) have a positive impact on SCA
- H_8: Operations Capabilities (DEA) have a positive impact on firm performance

Bharadwaj (2000), Bipat and Sneller (2015), Salleh and Hussin (2016) and Zhao and Priporas (2017) indicated that IT capabilities should be combined with other resources and capabilities to enhance the performance and create a SCA. Hence, the following hypothesis was proposed.

- H_9: Operational capabilities mediate the relationship between IT capabilities and firms performance

Impact of integration challenges: There are financial, technical and social challenges that must be considered before the transformation of industry 4.0 (such as the implementation cost, the organisation changes, technology acceptance, data security) (Oesterreich and Teuteberg, 2016). The complex nature and environment of the construction industry result in many challenges that slow and impact the implementation of industry 4.0; thus, lowering both IT and operational capabilities (García de Soto *et al*., 2019). Hence, the following hypothesis were proposed.

- H_{10}: Integration challenges have a negative impact onIT capabilities
- H_{11}: Integration challenges have a negative impact onoperational capabilities

Impact of sustained competitive advantage: RBV theory significantly explains how sustained competitive advantage can enhance performance (Barney and Hesterly, 2011). Most of the studies applying RVB have investigated the impact of sustained competitive advantage on firm's performance (Piboonrungroj, 2012). In a recent effort, Oyewobi *et al*. (2019) concluded that technological resources in construction companies do not have a direct significant impact on companie's performance. On the other hand, when technological resources are mediated by competitive strategy, a significant relationship with performance was indicated. Hence, the following hypothesis was proposed.

- H_{12}: Sustained competitive advantage has a positive impact on firm performance

CONCLUSION

This study has a favourable implication both for the academics as well as the construction industry professionals because of its robust theoretical framework which is underpinned by the RBV theory and CIMO logic. This model is multi-dimensional,which utilise resources and capabilities that affect industry 4.0 impacts on construction performance. For construction professionals, the findings will increase their awareness, knowledge and strategies to achieve a proper integration of industry 4.0 technologies in their companies.

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