2021 European Conference on Computing in Construction
Online eConference
July 26-28, 2021

DEVELOPING COMPETENT PROJECT MANAGERS FOR MEGA INFRASTRUCTURE CONSTRUCTION: A DIGITAL CONSTRUCTION APPROACH

Iliyasu Abdullahi[1], Georgios Kapogiannis[1], Michal Lemanski[1], and Carlos Bescos[2]
[1] University of Nottingham Ningbo, China
[2] University of Nottingham, United Kingdom

ABSTRACT

Recent studies implied that exhibiting competence remains impracticable for project managers during infrastructure construction due to project strategies shortfall to augment their competence, handle complexity. The paper adopted an exploratory case study technique to report how integrating various digital tools to form a strategy augments managers' competence during construction. Findings depicted that adopting digital construction approach enabled managers to perform due to its pluralism to reinforce human sensation and evolve complex processes to maximize human capabilities. Practically, the study proposes to practicing managers a proactive medium towards competence development and provides companies insights into digital tools utilization to improve performance.

INTRODUCTION

Project managers' inability to manage complexity during mega infrastructure construction is attributed to this project type's underperformance in terms of cost and ontime delivery globally (Patmore, 2016, Siemiatycki, 2015). According to Remington and Pollack (2016), one common reason for this occurrence lies in traditional project management strategies (i.e., methodologies) inadequacy to augment managers' competence to handle complexity inherent in megaprojects. Consequently, when complexity occurs due to its difficulty and uncertainty, project managers become helpless with little to no solution to what actions they could implement to manage complexity (Kermanshachi and Safapour, 2019, Maylor and Turner, 2017).

Competence depicts the knowledge, traits, and skills effective project managers exude to perform during construction optimally (Chen, Partington and Wang, 2008). Spencer and Spencer (2008) described competence as an individual's inherent characteristics that depict the epitome of superior and effective performance in various situations or on a specific job. Along these lines, the International Centre for Complex Project Management (2012) opined that only competent project managers could manage complexity on infrastructure projects. This points to the importance of competence towards complexity management and raises concern about how project managers could perform competently during the construction phase that is maimed by complexity.

The International Project Management Association [IPMA] (2015) suggested self development, peer development, education and training; coaching and mentoring, and simulation and gaming as plausible approaches that individual managers could adhere to in developing their competence. However, this study reiterates that how can managers build competence from these suggestions considering each project type is entirely distinct in its characteristics (Shenhar and Dvir, 2008). Moreover, these content outlines were designed to fit the needs of a particular project type.

Although, Love et al. (2015) indicated that adopting technological computing tools could be the impetus for performance improvement on mega infrastructure projects. However, field experts suggested these tools should be integrated to complement each other to attain their full potential during construction (Chi and Caldas, 2011). In general, integrating tools to form a strategy is indicative of the far-reaching effects that digital systems had on the manufacturing sector (Brettel et al., 2014), an industry where trends have been enormously transferred and observed in the construction industry over the years. Production managers exploited computing technology to operate in real-time by transforming into integrated networks and uniting their core competence (Brettel et al., 2014).

Drawing from the positive benefits of combining digital tools in manufacturing, this study highlights how integrating technological computing tools to form a digital construction strategy could effectively develop project managers' competence to handle complexity exacerbated challenges during construction. Findings would bring a distinct and practical perspective to the study of project management competence development in managing complexity-associated challenges during infrastructure construction. The paper presents an observational survey of digital construction depiction through the researcher's direct observation of various construction sites over three months. Specifically, findings would provide insights for future studies on digital construction as a strategy, its concepts, and its overall impact on project management competence development during infrastructure construction to further the Architectural, Engineering, and Construction (AEC) industry digital transformation. In the same vein, it shall bring forth advances made applying digital tools during construction, and this shall inspire confidence to adopt digital construction into practice further.

LITERATURE REVIEW

The section discusses the study key terms – project complexity, complexity challenges, and project management competence – to provide more insights on how they relate to its context**.**

Project Complexity in Construction Terminology

The project management literature had inconsistently described project complexity due to different conventions on its characterization and classification (Geraldi, Maylor and Williams, 2011). Despite these divergent views, Baccarini (1996) defined complexity in construction as "consisting of many varied interrelated parts," which are characterized in terms of differentiation and interdependency. Differentiation being the number of varied components on a project (e.g., tasks, specialists, subsystems, and parts), and interdependency is the degree of integration between these components.

According to Xia and Chan (2012), complexity is a critical property of construction projects, emancipating from the interaction between the project elements that depicts structural, dynamic, and uncertain characteristics. More so, the Project Management Institute highlighted complexity as a critical project factor, crucial to effective planning and control that determines the project goals and objectives and influences overall project performance (Cicmil et al., 2009). Summarily, from these complexity definitions, it is apparent complexity is perceived as project elements - seen from Table 1 - that interact to trigger complex challenges, limiting project managers from performing during construction.

These challenges were extensively researched in the literature. However, most studies have failed to address the root cause, illustrating how managers could better manage this occurrence. Accordingly, this study suggests that by adopting responsive complexity management strategies as digital construction, project managers' competence could be better augmented to handle complexity-associated challenges during mega infrastructure construction.

Table 1: Structural and Dynamic Complexity Element

Constructs	Description	Elements
Structural		
Size	Overall project dimension and scale	Structure height Structure type Site area Density Number of elements Number of participants Number of engineering hours Budget
Task	Piece of work\activity undertaken during the project duration	High number of tasks High variety of task Difficulty of task Scheduling Rigidity of sequence Quality requirement Construction method Lack of technical methods Availability of skilled workforce
Design complexity	Difficulty understanding and translating project drawings	Level of detailing Structural elements Clarity of functions Variety of drawings
Project Characteristic	Features and attributes belonging to individual projects	Project scope Disperse teams. Multiple locations Multiple time zones Site topography
Dynamic		
Project Features	Distinctive project attributes	Project duration Project tempo Construction methods Uncertainty in methods Reliance on other projects Project team's capability Geological conditions Immediate environment Deployment of plants Deployment of workers Regulations Disperse team Multiple locations Multiple time zone Form of contract
Project Goals	Project desired results	High number of goals Lack of clear project goal Multiple project goals(multidisciplinary members) Variety of perspective Form of contract
Project Scope	Amount of work needed to complete a project	Scope ambiguity Scope uncertainty Change in project scope. Change in the project specification. Inability to estimate accurately (timeline and budget) Quantity of information to analyse Quantity of information source

Complexity Challenges during Mega Infrastructure Construction

Mega infrastructure projects command a budget above a billion US dollars and are inherently characterized by complexity surging from its large size, scope, numerous task and components, high uncertainty occurrence springing from more extended project periods, scope change, and contravening political interest (Siemiatycki, 2015). Hu et al. (2013) objected that the construction sum in tandem with a nation's GDP was a more befitting megaproject description, which this study subscribes. The construction of this project type often faces severe and very complex problems of implementation and management. This requires high technical and experienced professionals, abundant resources, high capital, various stakeholders, and most importantly, competent and effective management to achieve the strategic project goals (Flyvbjerg, 2017).

Challenges on construction sites begin with experienced workers' absence during mega infrastructure construction as workers find it difficult to interpret complex construction information and comprehend their roles on site (Kermanshachi, Rouhanizadeh and Dao, 2020).

Procaccini, Lea-Cox and Scheffer (2012) and Kerzner (2018) highlighted how poor communication and inadequate coordination at all levels, ineffective supervision and monitoring, and poor planning and management of the massive project resource influence underperformance. Kermanshachi, Rouhanizadeh and Dao (2020) identified scope definition, project resources, and a high number of project participants as the highest-ranked complexity indicators during mega infrastructure construction. The project size, number of participants, number of plants, and the number of tasks to be performed are complexity elements that limit project managers from effectively coordinating, communicating and monitoring during infrastructure construction

Furthermore, Othman and Ahmed (2013) suggested that infrastructure projects fail due to 10 broad reasons, and critical to this study context are poor decision-making, fragmented supply chain, and cumbersome construction methodology. The study further showed how most project challenges occur due to poor health and safety practices. Besides, naive risk analysis and inappropriate identification of project consequences in areas of safety concern were amongst critical challenges constraining project managers from competently performing during mega infrastructure construction (Zannah et al., 2017).

Agreeably, numerous measures were suggested to support managers handle complexity-associated challenges, yet recent studies indicated that project managers could not influence mega construction performance positively. As such, this study aims to address this backdrop by suggesting a conventional and responsive approach through digital construction adoption.

Project Manager's Competence

A well-conceived project might end up going above its initial budget, fail to meet the setout timeline, and falls short of technical and functional specifications if project resources are not effectively coordinated and managed (Roth et al., 2016). In the project management area, project success is requisite to numerous intertwined factors acting concurrently, and most critical on mega infrastructure construction is selecting a competent project manager (Ding, 2016). Project managers are the foundation upon which projects blossom, and they are expected to exude certain competence traits, distinguishing them from other participants (Larson and Gray 2017).

Past studies established a direct correlation on how competence impacts project outcomes, as it influences managers to coordinate, manage, motivate, and maintain a perfect balance between the project and its people(Dias et al., 2014, Müller and Turner, 2007). Nguyen, Ogunlana and Thi Xuan Lan (2004) established competence to be a critical success factor for large engineering construction projects. This forms a basis to why having competent project managers is a prerequisite to infrastructure construction.

Crawford (2005) described project management competence as "more than just a project success factor" but also as development standards defining a usable guide to develop and assess project teams. The study showed planning as a vital factor for project management competence and a project success factor. Along with this premise, various professional bodies defining project management practice proposed competence development frameworks, which outlined competence development and expected standards that illustrate best practice (Association for Project Management, 2008, International Project Management Association [IPMA], 2015)

Despite these proposed frameworks, a new dimension of competence development research ushered studies, which believed by categorizing and identifying the salient competence factors for each project type, project managers would be better able to improve their competence level and positively influence project performance (Chen, Partington and Wang, 2008). However, due to the various divergent and competing views of what competence entails, the researcher identified competence factors through an extensive literature review (seen from Table 2.). Although, this study emphasises the technical inclined competence factors because the construction stage is technically oriented, and developing this competence dimension is more crucial for optimum performance (Chen, Partington and Wang, 2008). Subsequently, the study proposed why adopting digital construction for mega infrastructure construction is the most responsive measure to project management competence development to manage complexity-associated challenges during construction.

Table 2. Project Manager's Competence (Literature Review)

Competence	Description
Leadership	Possess the ability to evaluate technical concepts needed to make the right decisions to keep a project on track and effectively involve all stakeholders.
Planning	Has an awareness of the definite project scope and design schedule, ensuring the project performs to its expected goals.
Communication	Ability to provide clear and concise information to clarify work direction and pass such in a timely fashion amongst project participants.
Effective decision-making	Possess the ability to identify the best choice among alternatives in the face of uncertainty.
Supervision and monitoring	Ensure strict compliance at work and keep track of project team performance to ensure they are working towards the project goal.
Interfacing and Coordinating	Meeting and working with line management, external contractors, subcontractors, and management.
Directing	Being able to dictate the most prudent way to implement tasks and manage project resources efficiently.
Motivates team	Can motivate the project team in the presence of normal work pressure as well as political realities and pressures.
Issues and conflict resolution	He or she understands that conflicts are inevitable, and when such occurs, he could analyse the cause and respond appropriately to resolve them
Administering	Project managers are expected to perform various administrative tasks without support.
Negotiation	Possess the demeanour to persuade project stakeholders and participants by providing convincing rationale to obtain their support to foster project performance.
Aptitude	Able to adapt to scope change and be flexible to fit into new cultural realities in the project environment.
Confidence and commitment	Possess firm belief in himself and is fully committed to the project goals and objective.
Proactive	Keeps an eagle eye on project outcomes rather than waiting on a situation to occur before reacting.
Open-mindedness	Open to new ideas without prejudice.
Trustworthy	His traits portray that of someone to be relied on as an honest and truthful person.
Analytical thinking	Has a strong acumen to improvise in times of uncertainty and complexity?

RESEARCH METHODOLOGY

The study adopted an exploratory case study technique using structured observation method to monitor project managers' construction roles. This approach enabled data gathering through direct observation without intruding on the subject and eliminated any risk of bias compared to using a different method, say interview. Project managers could provide contrary accounts, majorly due to their affliction or conviction to the use of digital tools on construction sites. The researcher objectively observed how project managers interact with digital tools on-site and how they were used to support project managers in performing their job roles while managing complexity competently.

The adoption of at minimum two digital tools formed the criteria for selecting a construction site as a study sample. A consent letter was written to various construction sites, stating the researcher's intent to observe managers randomly. Further, based on accessibility and attaining the mega infrastructure description, twelve construction sites were selected as depicted in Table 3.

The researcher gathered data through direct observation to form the initial phase of a doctoral study. The project findings were summated and compiled as a report, as seen in the next section. Furthermore, the findings were classified into themes of the most salient complexity-induced challenges on construction sites that require competent project managers to manage complexity adequately: Communication, Planning and Coordination, and Supervision and Monitoring. It is worth mentioning that regardless of the theme classification adopted, digital tools augment project manager's competence in various dimensions, not limited to the categorisation adopted in this study. Different challenges earlier mentioned were not covered in this study but form part of future research that empirically establishes how digital construction redefines and supports the project manager's role during construction.

Table 3. Observed project site.

Project Site	Project Description
A	A maritime university development, estimated at $1.5 billion.
B	200km Road with ancillary bridge construction costing $750 million.
C	Erosion Control Project under the UN ecological fund initiative.
D	156km rail line valued at $1.5 billion
E	2733km standard gauge rail line construction at $11.1 billion.
F	284km single-track rail line valued at $1.96 billion.
G	Hydropower plant construction with a contract sum of $5.5 billion.
H	1.7km Bridge valued at $1.2billion.
I	550-meter long Gravity Dam construction

DISCUSSION

This section discusses the concept of digital construction during infrastructure development and illustrates how this practice is fostered on construction sites to manage project complexity. Besides, the researcher reiterates the need to adopt digital construction for project management competence development.

Digital Construction influence on Project Managers Competence

The last decade witnessed an advent uptake in using various digital tools during construction to eliminate and control complex challenges in the industry. This revolution was made possible through a paradigm shift to a more collaborative approach, adopting Building Information Modelling (BIM) initiatives (Walker and Lloyd-Walker, 2016). Subsequently, certain national governments mandate enforcing its usage (Redwood et al. 2017). BIM 3D information model serves a central role as the control layer that harmonizes and facilitates the use of various digital tools in construction (Catlin et al., 2018). BIM adoption enabled companies to boost productivity, manage complexity, ensure predictability**,** improve client satisfaction, and archive project information through its life cycle (Whyte and Hartmann, 2017, Kapogiannis, 2019).

As an illustration, employing collaborative software and BIM models equipped managers with resources to identify the possible causes of inefficiency during construction planning, using clash detection features to recommend mitigating actions (Tixier et al., 2017).

Digital tools adoption completely revolutionized the infrastructure planning phase to be more effective and collaborative. However, the congested nature present during mega construction rendered the use of individual tools to be ineffective. It was against this backdrop that the researcher suggests numerous digital tools (Table 3) integration to form the digital construction strategy. This, the researcher argues, is the most responsive approach to augment project managers' competence for complexity management. The following section highlights the researcher's findings from a cross-sectional study observing managers on mega infrastructure construction sites.

Table 4: Prominent Digitals tools in the Construction Industry

Category	Digital Tool
Higher definition surveying and Geospatial Technologies	Barcoding Radiofrequency Identification (RFID) Geographic information system (GIS) Global positioning system (GPS) Ultra-wideband (UWB) Light detection and ranging (LIDAR) Unmanned Aerial Vehicle (Drone)
Imaging Technology	Photogrammetry Remote Sensing 3D laser scanning Videogrammetry Range Images
Advanced Construction Technology	Prefabrication 3D printing Robotics Wearable technology
Enhanced technological tools	Augmented reality (AR) Virtual reality BIM nD Modelling tools Mobile computing Blockchain Internet of things (IoT) Digital twin

Communication

Mega infrastructure development involves various professionals collaborating to deliver the final product. However, a significant setback project managers encounter on these projects is clearly and effectively communicating with the various participants (Senescu et al., 2013). Project managers' failure to share project information effectively has been identified as the primary root cause of poor project performance (Ruqaishi and Bashir, 2015). This gives leeway to avoidable change orders, rework, variation, and claims, and in certain instances, it creates adversarial relationships leading to litigation (Dainty, Moore and Murray, 2007).

Through direct observation, the researcher found the use of walkie-talkies to communicate verbal instruction and BIM models to visualise the project as ubiquitous during mega infrastructure construction. This enabled the project manager to communicate with the project and its people competently despite the complexity that might emancipate from the project size, numerous participants, dispersed teams, and the project type. At project A, the BIM model was integrated into a collaborative work environment tablet device to foster communication between the project participants on-site. Site supervisors contacted the project manager through this medium to clarify drawing details and report challenges from the vast construction site. Apparently, the project perimeter, the quantity of information to analyze, the number of specialist contractors present on-site, and disperse project teams are complex elements that create complex communication challenges on this construction site. However, the project manager effectively coordinated and communicated project schedules and details in real-time due to digital tools' positive influence.

In one instance, the elevator contractor faced difficulties when installing the lift shaft. The installation point was 2km away from the project office. Typically, using conventional project management practice, the manager would have to travel to the elevator site, losing considerable time and effort to inspect the challenge and decide on the best approach to solving it. In this instance, the specialist contractor used the project tablet to send a video clip of the area that required the project manager's input. The foreman, the project manager, the subcontractor, and the structural consultant discussed within the digital collaborative environment and decided on the needed action to rectify the challenge without having to travel.

On project H, due to sociocultural tension from various stakeholders and the immediate community residents disrupting work progress, project output was transmitted using CCTV and augmented reality integrated into a mobile app to provide real-time project progress. The app offers a comparison of the project 3D model in contrast to the actual work achieved. Adopting this medium ensured the manager could solve an exigent challenge and communicate the project progress to a broader audience seamlessly to manage political tensions, in contrast to the convention of holding a regular press conference to quell tensions (Lundell, 2010).

Indicatively, adopting a wholesome strategy that integrates various digital technology tools could be more responsive in achieving timely gathering and distributing information between the manager and the project and its people (Kapogiannis, 2019). As a case point, using LIDAR, GIS, and UAV's have enabled project managers to gather and manage information on a large project momentarily and distribute project updates and detail within seconds through mobile communication devices and cloud computing, fostering an integrated project environment. Conventionally, it is only appropriate for project managers to rely more on digital tools on construction sites as a plausible medium to augment their competence to manage complexity during construction.

Digital tools harmonized to form a digital construction strategy have the efficacy to support the project manager's competence in communication, information management, planning, program management, and problem-solving during construction. Tellingly, integrating digital tools enabled project managers to communicate competently, take incisive decisions, manage information, and coordinate work on-site, ensuring complexity is managed competently. In the same vein, digital tools can enable project managers to curtail complexity-associated challenges, improving overall project productivity and performance output.

Planning and Coordination

Mega infrastructure construction is subject to input from various professionals and the consumption of copious resources. Hence, it is imperative for project managers to effectively plan project schedules and allocate resources (i.e., budget, resources, and human capital) between dependent activities in a coordinated manner to attain the project's desired goals (Andy and Price, 2010).

During the researcher's observation at project B, work began from three strategic points, at both extreme ends and equidistant of the road construction project to ensure timely completion. The project scope, material and labour scheduling, disperse teams, multiple locations, deployment of plants, and workers' deployment were complexity sources for the manager, which borne planning and coordination challenges. Indeed, how effectively the project manager coordinates these elements crucially determines performance and productivity during infrastructure construction (Ochieng and Hughes, 2013, Andy and Price, 2010).

The main contractor provided drones (UAVs), BIM 3D modelling, equipment routing software using cloud computing, mobile devices, GIS, and RFID to support the project manager. The researcher established that equipment were perfectly coordinated and delegated all through the 200km road stretch. The project manager handled complexity by visualising and simulating equipment usage on a BIM 3D enabled GIS model to augment his/her planning and decision-making competence. Further, the agreed-upon equipment schedule concept from the simulation process was uploaded to the cloud routing software for participants to know where and when each piece of equipment is expected. Subsequently, the manager monitors compliance using RFID tag placed on each piece of equipment, and their positioning was established using GPS. Harmonizing these tools enabled the manager to plan and coordinate equipment usage.

Additionally, adopting these tools curtails unproductivity on-site, as research showed that locating equipment, scheduling, and delegating its usage is a significant source of task complexity on large engineering projects (Nasir et al., 2010). Importantly, through digital tool integration, managers could competently manage task complexity within this project in a coordinated manner.

Observing project C, due to the vast land area surveyed, the PM employed UAVs and remote sensing to identify eroded areas, track actual work done, and plan future work programme to ensure compliance with the project baseline. Combining these tools ensured the manager could plan and coordinate work on a vast project without physically surveying the project site. Undoubtedly, it might take years to physically assess the project site, which new areas must have eroded in the process.

Rightly so, managers on projects E and F employed integrated collaborative software using mobile computing to coordinate various supervisors and transmit work schedule change in real-time. Given these points, it is only suitable for active project managers to further implement digital tools integration. This approach could augment their planning, project management, information management, and problem-solving competence to ensure successful mega infrastructure delivery. Digital construction could be the panacea that addresses complexity-associated challenges during construction to improve overall project delivery.

Supervision and Monitoring

The act of supervision and monitoring have been used interchangeably to mean overseeing a task or activity in the construction project management area. However, both differ. Supervision involves direct observation of the work process and the crew performing it. On the other hand, monitoring entails passive observation of the work process that requires project resource (i.e., materials, human resources, machine, and money) performance evaluation to ensure conformance with the project baseline (Yu et al., 2007). The project floor area, the number of workers involved, and the number and variety of tasks performed daily during mega infrastructure construction hinder project managers from effectively overseeing their supervisory and monitoring roles (Gidado, 1996).

Envisage a manager overseeing more than one hundred interrelated activities simultaneously on a project daily. Certainly, the manager would be overwhelmed, and this could turn out counterproductive on performance. McCullouch (1997) showed that project managers spend approximately 50% of their productive time daily performing on-site data collection and analysis. Further, this conventional monitoring system was found to be error-prone, cumbersome, and ineffective when adopted on mega infrastructure construction because numerous concurrent activities need to be assessed. In most instances, the gathered data becomes obsolete before project managers proffer corrective measures that ensure the project aligns to its performance baseline. It was against this backdrop; studies recommended structured training (Dias et al., 2014) and technological tools to improve project management competence to perform these roles effectively (Panas, Pantouvakis and Lambropoulos, 2014). As earlier mentioned, training is ineffective during infrastructure construction, as each training resume is designed on the tenets that projects are predictable, which contradicts the reality during complex construction management.

Notwithstanding suggestions to use digital tools, this study opined that managers could better manage complexity effects on every project type by adopting digital construction. As an illustration, the projects observed employed one digital tool or the other to conduct supervision and monitoring during construction. At project G, drone and LIDAR technology were used. The manager employed drones to conduct his supervisory role because the site perimeter, topography, and disperse project teams were complex elements that constrained him/her from competently performing this role. However, using these tools supported the project manager to perform his functions. At a two-hourly interval, 6 of the project drones were dispersed to survey the project site, and LIDAR was used every other day to estimate the work executed thus far. On projects B, D, E, and F, the managers relied mainly on drones, GIS, and LIDAR to supervise and monitor work output during construction. Combining these tools ensured they could survey a vast project seamlessly and ensure the project was in tandem with the setout baseline. Observing Project B, C, D, E, G, the researcher observed that younger project managers tend to rely more on digital tools to perform their roles than project managers, mainly from the baby boomer generation. This is primarily due to distinct orientations between the two generations. The younger generation grew at the advent of the technological revolution, making them more inclined to use computing.

CONCLUSION

This study findings bring forth to practicing project managers a proactive and evolving dimension towards competence development. Further, it captures and proposes a novel perspective on how project management competence could be augmented by introducing an information-driven strategy through various digital tools integration. The proposed approach exhibited how digital technology could reinforce human sensation to perform complex tasks on construction sites due to its ability to evolve entirely to maximize human understanding and capabilities.

Furthermore, the study highlighted that through digital construction, structural complexity is addressed holistically during construction. However, the study could not establish if adoption handled dynamic complexity prompted by uncertainty due to the adopted data-gathering technique. Undoubtedly, the project managers have to be asked directly, or this could be empirically established.

Similarly, digital construction was found to support project managers in proactively gathering and managing information and making prompt decisions on various infrastructure project types with no limitations to a specific project environment than other suggested construction industry strategies as lean construction and concurrent engineering. More so, the adoption of digital construction could enhance other project management strategies' inadequacies due to its pluralism to serve different functions during project development.

The study provides construction companies insights on how to better utilize digital tools at the construction stage by integrating various tools to complement each other – more evident benefits could be attained. Besides, construction project management academic learning centers could benefit from this study by introducing digital construction syllables into their academic curriculum to better prepare future professionals with advancements found on contemporary construction sites. Further, the authors are confident with the advent gains from BIM ISO 19650 implementation, the practice of digital construction amongst project managers would become ubiquitous within the next decade.

Despite the study findings, the observational technique's significant limitation is that underlying factors interrelationship of the behaviour and motives observed cannot be elucidated. This limitation shall be addressed in a further study where the researchers would empirically ascertain if adoption augments project managers' competence. If it does, which competence was better augmented, and on what infrastructure type. The paper forms the initial phase of doctoral research to ascertain if adopting a digital construction strategy increases project managers competence to manage complexity during mega infrastructure construction

REFERENCES

Andy, K. & Price, D. 2010. Causes Leading to poor site coordination in building projects. *Organization, technology & management in construction: an international journal,* 2**,** 167-172.

Association for Project Management. 2008. *Competency Framework* [Online]. [Accessed].

Baccarini, D. 1996. The concept of project complexity—a review. *International journal of project management,* 14**,** 201-204.

Brettel, M., Friederichsen, N., Keller, M. & Rosenberg, M. 2014. How virtualization, decentralization and network building change the manufacturing landscape: An Industry 4.0 Perspective. *International journal of mechanical, industrial science and engineering,* 8**,** 37-44.

Catlin, T., Laberge, L., Varney, S., Bradley, C., Hirt, M. & Smit, S. 2018. Digital strategy: The four fights you have to win.

Chen, P., Partington, D. & Wang, J. N. 2008. Conceptual determinants of construction project management competence: A Chinese perspective. *International Journal of Project Management,* 26**,** 655-664.

Chi, S. & Caldas, C. H. 2011. Automated object identification using optical video cameras on construction sites. *Computer-Aided Civil and Infrastructure Engineering,* 26**,** 368-380.

Cicmil, S., Cooke-Davies, T., Crawford, L. & Antony, K. 2009. Exploring the complexity of projects: Implications of complexity theory for project management practice. *PMBOK Guide*

Crawford, L. 2005. Senior management perceptions of project management competence. *International journal of project management,* 23**,** 7-16.

Dainty, A., Moore, D. & Murray, M. 2007. *Communication in construction: Theory and practice*, Routledge.

Dias, M., Tereso, A., Braga, A. C. & Fernandes, A. G. 2014. The key project managers' competences for different types of projects. *New Perspectives in Information Systems and Technologies, Volume 1.* Springer.

Ding, R. 2016. Being a Highly Effective Project Manager. *Key Project Management Based on Effective Project Thinking.* Springer.

Flyvbjerg, B. 2017. Introduction: The Iron Law of Megaproject Management. *The Oxford Handbook of Megaproject Management* Oxford Oxford University Press

Geraldi, J., Maylor, H. & Williams, T. 2011. Now, let's make it really complex (complicated) A systematic review of the complexities of projects. *International Journal of Operations & Production Management,* 31**,** 966-990.

Gidado, K. 1996. Project complexity: The focal point of construction production planning. *Construction Management & Economics,* 14**,** 213-225.

Hu, Y., Chan, A. P., Le, Y. & Jin, R.-Z. 2013. From construction megaproject management to complex project management: Bibliographic analysis. *Journal of management in engineering,* 31**,** 04014052.

International Centre for Complex Project Management 2012. Complex Project Manager Competency Standards. *In:* STEPHEN, H. (ed.) *Complex Project Management Leadership and Excellence.* Commonwealth of Australia (Department of Defence: Department of Defence

International Project Management Association [Ipma] 2015. Individual Competence Baseline for Project, Programme and Portfolio Management *In:* MARTIN, S. (ed.) *IPMA Global Standards Series 4.0.* Netherlands IPMA.

Kapogiannis, G. 2019. Digital Construction *Construction Project Management: an Integrated Approach.* Third ed. London Routledge.

Kermanshachi, S., Rouhanizadeh, B. & Dao, B. 2020. Application of Delphi Method in Identifying, Ranking, and Weighting Project Complexity Indicators for Construction Projects. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction,* 12**,** 04519033.

Kermanshachi, S. & Safapour, E. 2019. Identification and quantification of project complexity from perspective of primary stakeholders in US construction projects. *Journal of Civil Engineering and Management,* 25**,** 380-398.

Kerzner, H. 2018. *Project management best practices: Achieving global excellence,* John Wiley & Sons.

Love, P. E., Smith, J., Simpson, I., Regan, M. & Olatunji, O. 2015. Understanding the landscape of overruns in transport infrastructure projects. *Environment and Planning B: Planning and Design,* 42**,** 490-509.

Lundell, Å. K. 2010. The fragility of visuals: How politicians manage their mediated visibility in the press. *Journal of Language and Politics,* 9**,** 219-236.

Maylor, H. & Turner, N. 2017. Understand, reduce, respond: project complexity management theory and practice. *International Journal of Operations & Production Management,* 37**,** 1076-1093.

Mcculloch, B. G. 1997. Automating Field Data Collection in Maintenance Operations. *Joint Transportation Research Program***,** 342.

Müller, R. & Turner, J. R. 2007. Matching the project manager's leadership style to project type. *International journal of project management,* 25**,** 21-32.

Nasir, H., Haas, C. T., Young, D. A., Razavi, S. N., Caldas, C. & Goodrum, P. 2010. An implementation model for automated construction materials tracking and locating. *Canadian Journal of Civil Engineering,* 37**,** 588-599.

Nguyen, L., Ogunlana, S. O. & Thi Xuan Lan, D. 2004. A study on project success factors in large construction projects in Vietnam. *Engineering, Construction and Architectural Management,* 11**,** 404-413.

Ochieng , E. & Hughes, L. 2013. Managing project complexity in construction projects: The way forward. *Journal of Architecture Engineering Technology,* 2.

Othman, E. & Ahmed, A. 2013. Challenges of mega construction projects in developing countries. *Organization, technology & management in construction: an international journal,* 5**,** 730-746.

Panas, A., Pantouvakis, J.-P. & Lambropoulos, S. 2014. A simulation environment for construction project manager competence development in construction management. *Procedia-Social and Behavioral Sciences,* 119**,** 739-747.

Patmore, A. 2016. Rising Above: Increasing due to diligence to reduce cost variances in infrastructure megaprojects. *Foresight*.

Procaccini, C., Lea-Cox, A. & Scheffer, W. 2012. Challenges of E&P megaproject delivery. *SBC Capital Projects Research*.

Remington, K. & Pollack, J. 2016. *Tools for complex projects*, Routledge.

Roth, H., Suhonen, S., Macaulay, N. & Ho, R. 2016. Megaproject leaders: Shifting the focus from technical to people leaders. Houston Russell And Reynolds Associates

Ruqaishi, M. & Bashir, H. A. 2015. Causes of delay in construction projects in the oil and gas industry in the gulf cooperation council countries: a case study. *Journal of Management in Engineering,* 31**,** 05014017.

Senescu, R. R., Haymaker, J. R., Meža, S. & Fischer, M. A. 2013. Design process communication methodology: Improving the effectiveness and efficiency of collaboration, sharing, and understanding. *Journal of Architectural Engineering,* 20**,** 05013001.

Shenhar, A. J. & Dvir, D. 2008. *Reinventing project management: the diamond approach to successful growth and innovation*, Harvard Business Review Press.

Siemiatycki, M. 2015. Cost Overruns on Infrastructure Projects: Patterns, Causes and Cures. Toronto: IMFG Perspectives

Spencer, L. M. & Spencer, P. S. M. 2008. *Competence at Work models for superior performance*, John Wiley & Sons.

Tixier, A. J.-P., Hallowell, M. R., Rajagopalan, B. & Bowman, D. 2017. Construction safety clash detection: identifying safety incompatibilities among fundamental attributes using data mining. *Automation in Construction,* 74**,** 39-54.

Walker, D. & Lloyd-Walker, B. 2016. Rethinking project management: Its influence on papers published in the international journal of managing projects in business. *International Journal of Managing Projects in Business,* 9**,** 716-743.

Whyte, J. K. & Hartmann, T. 2017. Building Research & Information How digitizing building information transforms the built environment.

Xia, B. & Chan, A. P. 2012. Measuring complexity for building projects: a Delphi study. *Engineering, Construction and Architectural Management,* 19**,** 7-24.

Yu, I., Kim, K., Jung, Y. & Chin, S. 2007. Comparable performance measurement system for construction companies. *Journal of Management in Engineering,* 23**,** 131-139.

Zannah, A. A., Latiffi, A. A., Raji, A. U., Waziri, A. A. & Mohammed, U. 2017. Causes of Low-Skilled Workers' Performance in Construction Projects. *Path of Science,* 3**,** 4.1-4.15.