TOWARDS SMART CONSTRUCTION SITES FOR EFFECTIVE PROJECT DELIVERY

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The pursuit of effective delivery of construction projects still appears to be a mirage due to challenges associated with project management. Several of these encumbrances are encountered due to outdated and uncoordinated methods deployed for construction projects. Implementing smart construction sites (SCS) is a panacea to some of these hurdles. This study empirically evaluates the propelling measures toward the uptake of SCS in South Africa. This was attained by using a quantitative technique that propagated the collection of data from construction professionals and subsequently analyzed using exploratory factor analysis using the principal component analysis extraction method. The findings from the study show that the significant drivers for the implementation of SCS in the South African construction industry are optimizing project delivery processes, stakeholders’ interest, and the synergy of digital technologies. The study’s outcome contributes theoretically to the conversation of construction digitalization which has been touted to be the silver lining in the abatement of the challenges plaguing the construction industry.

Keywords: Drivers, South Africa, Project management, Digital technologies.

1 INTRODUCTION

The increase in complexities of systems and methods for service delivery has reinforced the need for embracing innovative technologies. For the construction industry, the initiative for the attainment of a plethora of demands has ushered in a window for seeking alternative solution systems driven by the uptake of digital technologies (Aghimien et al. 2022, Ikuabe et al. 2022). Some of the demands are but not limited to the ever-evolving clients’ sophisticated wants, targeted timely completion of projects, abatement of health and safety challenges, negating project cost overrun, improving service delivery, surmounting supply chain challenges, etc. (Sultan and Kajewski 2003, Ikuabe et al. 2020). To achieve the aforementioned, the uptake of digital technologies for construction project delivery must be pursued. Evidence from sectors such as healthcare, banking, and manufacturing indicates that the espousal of digital technologies would help in meeting the yearnings of the digital era (Barbosa et al. 2017). Therefore, one of the advancements in the digital revolution to yield improvement in construction project delivery is the smart construction site (SCS).

According to Edirisinghe (2017), SCS also referred to as an intelligent construction site, is an assemblage of computational elements, networked sensors, and displays with enhanced digital application and embedded intelligence. This approach to project management yields smart construction, which is the building operation and construction, which through collaborative partnership makes full use of digital technologies and industrialized manufacturing techniques

(2017). Consequently, yielding optimum use of the implementation of advanced digital technologies serving as vehicles of the fourth industrial revolution. Some of such digital technologies include cyber-physical systems, artificial intelligence, digital twin, virtual reality, augmented reality, 3D printing, etc. Hence, the benefits derived from the espousal of SCS would fall under the coverage of early warnings against site accidents, resourceful management of assets, project monitoring, position detection of construction elements, time and cost savings, productivity improvement, etc. (Hwang 2012, Stefanic and Stankovski 2019). Considering outlined benefits of the use of SCS for project delivery, it becomes imperative to explore the driving factors for its implementation in South African construction. The outcome of the study makes a practical and theoretical contribution to the body of knowledge as it unravels the propelling measures for the embracement of SCS by stakeholders in the South African construction industry.

2 LITERATURE REVIEW

Smart construction involves the process of development through the use of technological applications that seek to improve the planning and management of construction projects (Zhou et al. 2018). This is aided by collaborative tools whose technological applications result in the improved delivery of construction projects. According to Layton-Matthews and Landsberg (2022), the attainment of improved project delivery is a propelling measure for the use of technological applications whose enhanced communication networks and sophisticated information management is a core element of SCS. For example, tracking technologies can provide the enablement of improved safety through the provision of on-site data capturing and decision-making using real-time location systems (Lim et al. 2016). Furthermore, safety risk management aids the implementation of SCS. Jiang et al. (2020) noted that the advancement of safety tenets in construction sites is a fundamental yardstick for project success. Since the construction industry is still faced with safety challenges due to the dynamic complexity of projects and the continued use of outdated methods, the deployment of innovative technology for the abatement of the daunting challenge is receiving due attention. Moreover, the improvement in material selection and use is a driving measure for smart construction. The contribution of smart materials has aided in energy and performance efficiency in structures (Mukherjee et al. 2023). Advancement in technology has helped in the deployment of smart materials for construction projects.

Construction project execution involves the collaborative efforts of several stakeholders whose duties vary from each other. In ensuring the successful execution of construction projects, an alignment of project goals by all stakeholders is required (Guo et al. 2022). Therefore, for a seamless implementation of SCS, the effective collaboration of stakeholders is a vital element. Also, due to the practical nature of construction project delivery that is associated with enormous challenges, the provision of insights to solve most of these encounters is very important. Since SCS gives enablement for proffering technical solutions (Lundeen et al. 2016), this attribute becomes important for its implementation. Furthermore, policies formulated by the government go a long way in influencing the adoption of technological use. Consequently, the development of suitable guidelines is needed for their effective adoption of a wide range of construction technologies. It can also be noted that the lack of government incentives and tariffs to promote the application of new technologies to be implemented on construction sites has also contributed to their limited use (Yap et al. 2022). There is some level of importance when it comes to the creation, stabilizing, and upgrading of knowledge networks. An organization’s capacity to gather and process information about new technology contributes to the firm’s innovativeness. Beyond the level of awareness, the aspirations demonstrated by stakeholders by giving priority to a more efficient construction process through the broader deployment of new technologies is a significant factor (Parusheva and Aleksandrova 2021).
3 METHODOLOGY

Establishing the propelling measures for the implementation of SCS in the South African construction industry is the aim of the study. A quantitative research design was adopted which necessitated the use of a questionnaire survey to elicit responses from construction professionals. The choice of the questionnaire is facilitated due to its ability to reach out to a large pool of respondents within a given time frame, while also having the attribute of quantifiability and objectivity in research (Tan 2011). The target respondents were construction professionals domiciled in Gauteng province, South Africa. The choice of the research area results from the province’s characterization of playing host to a large number of construction professionals, while also accommodating a large number of construction projects. The target respondents of the study are architects, quantity surveyors, engineers, construction managers, and construction project managers, whereas convenience sampling was employed due to time constraints. A total of eighty-three questionnaires were distributed and passed as being appropriate for analysis upon retrieval. To ascertain the reliability and validity of the research instrument, Cronbach’s alpha was used and gave a value of 0.883. This portrays the good reliability of the research instrument since the value is above the threshold of 0.7 and closer to 1.0 (Tavakol and Dennick 2011). Exploratory factor analysis (EFA) was deployed as the method of data analysis for the study using the principal component analysis extraction method. This approach helps in converting comparable related variables attributed with underlying features that are linear correlated and resulting in constructs that are projected in variation given in the original variable (Jolliffe 2002).

4 RESULTS

4.1 Exploratory Factor Analysis

With the aim of establishing clusters of variables having similar underlying dimensions, the study employed exploratory factor analysis (EFA) as the method of data analysis. This led to the identification of variables with similar attributes which formed constructs, thereby leading to the reduction of the number of variables into a simpler and better-understood framework. The suitability of the data retrieved from the target respondents for the proposed analysis was conducted. The output given had an inter-item correlation of 0.15 to 0.50 which is deemed suitable (Phelan and Wren 2007). The given correlated values from the analysis for the variables gave a coefficient above 0.3, thereby affirming the suitability for factor analysis. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett’s test of sphericity were employed in evaluating the factorability of the data gathered from the survey. As recommended by Pallant (2005), Bartlett’s test of sphericity should be significant (p < 0.05) to uphold the suitability for factor analysis. Table 1 shows that the value of the analysis for the KMO is 0.862, while Bartlett’s test indicates that that is significant with a p-value of 0.00. This is with the threshold of 0.6 as stipulated by previous studies (Ikuabe and Oke 2019, Akinradewo et al. 2022). These results in combination with the validity test conducted using Cronbach alpha which gave a value of 0.883 affirms the suitability of the data set collected for EFA.

The result of the rotated component matrix and the extracted communalities of the EFA are presented in Table 2. Employing the principal component analysis (PCA) extraction technique using the varimax rotation, the variables converged in six iterations. Also, the outcome gave three components whose eigenvalue ≥ 1.00 and having a total cumulative variance of 61.12%. The result shows that the first component is made up of seven variables with factor loadings ranging from 0.882 to 0.632, while it accounts for 41.22% of the variance given and is labeled as optimizing project delivery processes. The second component is made up of four variables with factor loadings ranging from 0.688 to 0.548, while it accounts for 11.85% of the variance given and is labeled as
stakeholders’ interest. The third component has two variables with factor loadings of 0.626 and 0.572, while it accounts for 8.05% of the variance given and is labeled as synergy of digital technologies. The names of the components are informed by their intrinsic features and the nomenclature of the variables making up the components.

Table 1. KMO and Bartlett’s test.

| Kaiser-Meyer-Olkin Measure of Sampling Adequacy | 0.862 |
| Bartlett’s Test of Sphericity | Approx. Chi-Square | 1356.771 |
| DF | 151 |
| Sig. | 0.000 |

Table 2. Rotated component matrix and variance explained.

<table>
<thead>
<tr>
<th>Drivers</th>
<th>Component</th>
<th>Extracted Communalities</th>
<th>% of Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Efficient safety management</td>
<td>0.882</td>
<td>0.624</td>
<td>41.22</td>
</tr>
<tr>
<td>Improved project delivery</td>
<td>0.813</td>
<td>0.571</td>
<td></td>
</tr>
<tr>
<td>Total cost management</td>
<td>0.771</td>
<td>0.772</td>
<td></td>
</tr>
<tr>
<td>Improved material selection</td>
<td>0.759</td>
<td>0.477</td>
<td></td>
</tr>
<tr>
<td>Smart construction administration</td>
<td>0.713</td>
<td>0.539</td>
<td></td>
</tr>
<tr>
<td>Provision of technical solutions</td>
<td>0.693</td>
<td>0.728</td>
<td></td>
</tr>
<tr>
<td>Creation of asset value</td>
<td>0.632</td>
<td>0.839</td>
<td></td>
</tr>
<tr>
<td>Government policies</td>
<td>0.688</td>
<td>0.696</td>
<td>11.85</td>
</tr>
<tr>
<td>Effective stakeholders’ collaboration</td>
<td>0.623</td>
<td>0.627</td>
<td></td>
</tr>
<tr>
<td>Level of awareness</td>
<td>0.572</td>
<td>0.571</td>
<td></td>
</tr>
<tr>
<td>Knowledge exchange</td>
<td>0.548</td>
<td>0.779</td>
<td></td>
</tr>
<tr>
<td>Integration of design and build</td>
<td>0.626</td>
<td>0.639</td>
<td>8.05</td>
</tr>
<tr>
<td>Collaborative intelligence</td>
<td>0.572</td>
<td>0.582</td>
<td></td>
</tr>
</tbody>
</table>

Extraction Method: Principal Component Analysis
a.3 components extracted

5 DISCUSSION OF FINDINGS

5.1 Optimizing Project Delivery Processes

The outcome of the EFA indicates that the first component has seven variables which are efficient safety management, improved project delivery, total cost management, improved material selection, smart construction administration, provision of technical solutions, and creation of asset value. This component is labeled as optimizing project delivery processes. This finding portrays that the pursuit of improving the engagements associated with construction project delivery is a significant driver for implementing SCS in the South African construction industry. This is affirmed by Layton-Matthews and Landsberg (2022) who noted that the attainment of improved project delivery is a propelling measure for the use of technological applications whose enhanced communication networks and sophisticated information management is a core element of SCS. For example, Lim et al. (2016) stated that tracking technologies could provide enablement of improved safety through the provision of on-site data capturing and decision-making using real-time location systems. These potentiality of enhancing delivery systems in construction project delivery is a driver for SCS espousal.
5.2 Stakeholders’ Interest

The second component entails four variables which are government policies, effective stakeholders’ collaboration, level of awareness, and knowledge exchange. This component is labeled as stakeholders’ interest. The successful implementation of digital technologies in the construction industry is largely influenced by various stakeholders such as top management of organizations, policymakers in government, and construction professionals. This is corroborated by Yap et al. (2022) who opined that the lack of government incentives and tariffs to promote the application of new technologies to be implemented on construction sites has also contributed to their limited use. Hence, policies formulated by the government go a long way in influencing the adoption of technological use. Also, beyond the level of awareness, the aspirations demonstrated by stakeholders by giving priority to a more efficient construction process through

5.3 Synergy of Digital Technologies

The third component comprises two variables which are integration of design and build and collaborative intelligence. It is labeled as synergy of digital technologies. The collaborative delivery system of different digital technologies is a propelling measure for the uptake of SCS. This approach to project management yields smart construction, which is the building operation and construction, which through collaborative partnership makes full use of digital technologies and industrialized manufacturing techniques (Kim et al. 2017). Consequently, to push for the use of SCS, the synergy of several digital technologies for project execution is a significant determinant.

6 CONCLUSION AND RECOMMENDATIONS

The study evaluated the propelling measures for the implementation of SCS in the South African construction industry. A review of relevant literature was conducted which unraveled the relevant variables. This led to the formulation of the research questionnaire used in eliciting responses from the target respondents of the study. Retrieved data was analyzed using EFA which developed three components that serve as significant drivers for the use of SCS. The three components are optimizing project delivery processes, stakeholders’ interest, and synergy of digital technologies. The construction industry has long been associated with challenges that hinder the efficient delivery of projects. By proffering solutions to some of the challenges, embracing the utilization of emerging technologies such as SCS would be highly encouraged. Furthermore, the relevant stakeholders in the construction industry have varying roles to play in propagating the use of innovative technologies such as SCS. Hence, government functionaries, construction professionals, and top management executives of construction organizations should lend their voices to the call for the digital transformation of the construction industry through the encouragement of the uptake of innovative technologies such as SCS. It is worthy to state that the study was limited to the Gauteng province of South Africa. Other studies can be conducted in other provinces for a more robust outcome.

References


