

Significant barriers to smart computing adoption on construction projects in a developing nation

Lekan D. Ojo^{1*}, Ayodeji E. Oke², Victor A. Arowoia³, Modupe C. Mewomo⁴ and
Olaoluwa J. Opeoluwa²

^{1*}Department of Architecture and Civil Engineering, City University of Hong Kong,
ldojo2-c@my.cityu.edu.hk

²Department of Quantity Surveying, Federal University of Technology, Akure, Ondo,
Nigeria, emayok@gmail.com, olaoluwajopeoluwa1212@gmail.com

³Department of Civil Engineering, Monash University, Australia,
victor.arowoiya@monash.edu

⁴Department of Construction Management and Quantity Surveying, Durban University
of Technology, Durban, South Africa,
ModupeM@dut.ac.za

Abstract:

The construction industry in developing countries is characterised by ineffective decision-making, which contributes to poor project performance and stakeholder dissatisfaction. Meanwhile, smart computing (SC) proffers solutions to these problems with proven benefits; however, some barriers continually hinder its applications in construction projects. Therefore, this study investigated the barriers to SC applications on construction projects in a developing nation through a survey to determine the significant ones. Data were retrieved from construction professionals while descriptive and inferential statistical analyses such as mean score, standard deviation, normality test, and Kruskal-Wallis H-test were conducted accordingly. Five significant barriers were identified: inadequate technological knowledge, clients' unwillingness, professional complacencies, protection monopoly, and lack of government policies. The main barriers deduced are construction-related, client-related, and government-related. Therefore, practical recommendations were posited for the three key actors in the construction industry, i.e., construction professionals, clients, and government agencies. Training is recommended for construction professionals to update their technological competencies and skills. The client's willingness can be improved through convincing proof of the importance of SC to project owners. At the same time, the government is advised to implement and enforce policies that encourage digitalisation in the construction industry. Therefore, giving careful attention to the barriers to SC on construction projects is essential to enhance timely decision-making by the construction team.

Keywords:

Construction industry, construction management, decision-making, digitalisation, smart computing

1 Introduction

Construction projects involve multidisciplinary stakeholders' decision-making to deliver projects to the client's requirements (Yu & Leung, 2018). Traditionally, the decision-making process and updating information on construction projects are carried out physically. Meanwhile, the advancement in information technology and the coronavirus pandemic have necessitated embracing dynamic methods of updating construction information and data. Through smart computing (SC) technologies such as proximity sensors, global positioning systems, communication networks, machine-to-machine (M2M), and other related technologies, construction data are updated with better precision (Zhu *et al.*, 2012; Farooqi *et al.*, 2018; Liu *et al.*, 2019). In addition, outcomes of construction projects such as project performance, sustainability, organisational reputation, and other metrics are simultaneously enhanced by adopting innovative and intelligent technologies (Nižetić *et al.*, 2019; Mewomo & Ejidike, 2021; Zhu *et al.*, 2022). Meanwhile, the applications of these SC technologies on construction projects in developing countries are limited.

Construction projects in developing nations are characterised by poor project performance, stakeholder dissatisfaction, and project abandonment (Aibinu & Jagboro, 2002). For example, in the Nigerian construction industry, seventy per cent or more of construction projects are not delivered on time (Aibinu & Jagboro, 2002; Akinradewo *et al.*, 2017). Other adverse circumstances bedevilled the Nigerian construction projects, from which other developing nations are not exempted. It is important to note that the outcomes (project-related, organisational-related, social-related, or government-related.) of construction outputs are a function of the team decision-making process of the stakeholders. Sadly, the construction industry in developing nations does not apply a systematic and logical team decision-making process (Oke & Aigbavboa, 2017; Ojo & Leung, 2021). Adopting a systematic decision-making process on construction projects is vital to achieving the desired objectives. Therefore, to avoid poor outcomes on construction projects and enhance the decision-making process fitting for the twenty-first century, a survey needs to investigate the barriers to SC adoption. Understanding SC's underlying issues in the team decision-making process is vital to provide the necessary solutions to poor project outcomes.

This research will benefit stakeholders such as clients, government, workers, and construction professionals in the built environment by identifying the significant impediments to real-time information and communication updating for effective team decision-making. Also, the next part of the paper reviewed SC and several barriers highlighted by previous researchers. The third section discusses the research approach used to garner data and the analysis adopted. Section four revealed the results from the survey and the implications of the research, while the last section was the conclusion, recommendations, and area for further studies.

2 Literature Review

According to Bartels (2009), SC is a new generation of embedded hardware, software, and networking protocols that give information technology systems with real-time awareness of the real world and advanced analytics to help people make better

intelligent decisions about options and actions that improve business processes. On the part of (Lee *et al.*, 2012), SC is defined as a personalised user-oriented computing through the application of intelligent and lightweight of computing resources, including hardware, software, and user service. Through SC, team members provide accurate information tailored to the user's current situation for effective management (Lee *et al.*, 2012).

SC techniques have been used to solve notable problems in manufacturing organisations (Weilin *et al.*, 2014), energy (Bharti & Dubey, 2018), healthcare (Cai, 2021), and a lot more. However, the application in the construction industry is very minimal. Thus, the limited applications on construction projects could be linked to some barriers. Generally, one of the key hindrances to applying technological techniques is the lack of technical know-how (McNamara & Sepasgozar, 2018). Logically, construction projects would not benefit from SC when the practitioners have limited or no knowledge of it. Besides, the lack of knowledge on the benefits may hinder engaging experts from developing nations to educate construction practitioners in developing countries. However, the application of SC technologies may be limited to the projects handled by experts in big multinational companies. Therefore, inadequate professional expertise in SC would hinder most construction projects from achieving the expected advantages (Zhao *et al.*, 2017). On the other hand, a lack of capital to enrol in training for construction professionals or apply SC to construction projects may also be a barrier (Ojo *et al.*, 2021).

The inertia to change of professionals is also a major barrier to technological innovation acceptance by stakeholders (Olawumi *et al.*, 2018). In most situations, most aged professionals who are primarily used to undertaking construction projects with traditional methods may be reluctant to embrace innovative methods, especially when such smart techniques require a financial outlay of the organisation. Meanwhile an organisation may experience itch-free obstruction to SC adoption when the senior officials of the establishment are aware of the advantages of the smart methodologies to the delivery of construction projects, project performance and organisational reputation (Zakara *et al.*, 2013; Olawumi *et al.*, 2018). The problem associated with the unwillingness of clients to pay for additional services of using innovative techniques on their projects may be reduced when senior officers in construction organisations are not oblivious of SC techniques. For instance, some organisations with reputable stand-through timely delivery of mega projects to required outcomes can easily convince construction clients and assure them of the value-adding capabilities of the techniques. In addition, professional complacency that younger construction professionals may want to display can be overcome when senior management is well informed on latest intelligent technologies.

Another common obstacle to the adoption of smart technologies is the uncertainty of data security on web platforms (Berglund *et al.*, 2020; Oke *et al.*, 2020). Establishments are very cautious of confidential documents and information because of the need to protect their image and remain competitive in the global market. Considering construction projects where vital information such as 'cost' are often kept secretive from other bidders at the tendering stage or other stages of the project, updating such confidential information using smart technologies may be a threat. Meanwhile, such

fear of data insecurity may be abated when the stakeholders ensure optimum ethical practices (Lu *et al.*, 2011). Besides, the government can also provide policies that frown at the infringement of data while simultaneously encouraging the use of SC techniques (Abubakar *et al.*, 2014). The inputs of the governments would be a key driver to the adoption of smart technology methodologies by other construction clients.

3 Research Methodology

Through a survey research design, this study investigated the barriers to SC on construction projects in the Nigerian construction industry. The survey research design helps to source opinions of multiple stakeholders, obtain a large response, and compare their perceptions (Flynn *et al.*, 2018). In this study, the opinions of quantity surveyors, architects, builders, and engineers in Lagos State, Nigeria were purposely solicited because of their critical roles in construction project development. Lagos State was also selected because it is a commercial hub of Nigeria and the seat of many construction firms (Oke & Ogunsemi, 2013). With Yamane's formula at a 5% precision level, 372 sample sizes of the four construction professionals were determined from a population of 5,330 registered construction practitioners sourced from Lagos State chapters of the respective professional institutions. A structured questionnaire comprising the respondents' background information, and the barriers to SC on construction projects in which the professionals are required to indicate their level of agreement on a five-point rating scale was designed. Of the 250 questionnaires that were successfully distributed through convenient sampling, 94 were returned, representing a 37.6% response rate. Although the response rate is limited, it is above the 20% threshold that is commonly adopted in quantitative research (Fosnacht *et al.*, 2017). Therefore, analysis can be conducted on the limited questionnaire retrieved. Descriptive and inferential analysis using Statistical Package for Social Sciences (SPSS version 25) were conducted to achieve the aim of the study. The normality of the dataset was determined using the Shapiro-Wilk test. The results of the Shapiro-Wilk test indicated that the data is not normally distributed with p-values of the barriers that are less than 0.05 (Corder & Foreman, 2014). Therefore, the Kruskal-Wallis H test, a non-parametric test, was used to determine the differences in the opinions of the respondents.

4 Findings and Discussion

The respondents to this study comprised architects (27.7%), builders (6.4%), quantity surveyors (23.4%), and engineers (42.6%), all of which are registered members of their respective professional institutions. Most respondents (71.3%) have more than five years of working experience in the construction industry. The academic qualifications of the respondents are ordinary national diploma (4.3%), higher national diploma (53.2%), bachelor's degree (6.4%), master's degree (24.5%), and doctoral degree (11.7%). Based on the respondents' background information, it can be inferred that they are professionally and academically qualified to provide a valid response to the survey.

Table 1 shows the results of the mean score, standard deviation, and Kruskal-Wallis H test on the barriers to SC on construction projects. According to the architects' group, the mean score on the twelve barriers ranges from 3.69 (inadequate technical knowledge) to 4.65 (client's unwillingness). To the quantity surveyors, the barrier with the highest mean value is social and political non-motivation (M=4.32), while

inadequate technical knowledge ranked highest among the builders with a mean score of 4.67. On the part of the engineers, the client's unwillingness has the highest mean score of 4.83. The mean scores of all the barriers in the four categories are above the threshold of 3.50 with which an item can be denoted critical (Harada *et al.*, 2015). Besides, the standard deviations of most of the barriers in all the groups are below 1.00. The standard deviation values indicated that the variability of the respondents' opinions in each group is minimal (Aghimien *et al.*, 2018). The Shapiro-Wilk test reveals p-values that are less than 0.05, indicating that the data is not normally distributed. Therefore, a non-parametric test was employed to check the difference in the opinions of all the categories of the respondents on the barriers. The results of the Kruskal-Wallis H test indicated that significant differences occurred in five barriers namely *inadequate technical knowledge* (0.018), *client's unwillingness* (0.001), *professional complacencies* (0.001), *protection monopoly* (0.001), and *lack of government policies* (0.0018). It implies that the respondents have similar views on the remaining seven barriers to SC on construction projects.

Table 1: Barriers to smart computing on construction projects in a developing nation

Barriers	S-W (Sig.)	AR (N=26)		QS (N=22)		BLD (N=6)		ENG (N=40)		K-W (Sig.)
		M	SD	M	SD	M	SD	M	SD	
Inadequate technical knowledge	0.000*	3.69	0.79	4.14	0.99	4.67	0.52	4.25	0.78	0.018*
Data insecurity	0.000*	3.85	0.83	4.18	0.73	4.00	0.89	4.15	0.77	0.409
Awareness level	0.000*	3.85	0.83	3.95	0.95	4.17	0.41	4.10	0.78	0.616
Lack of professional expertise	0.000*	3.92	0.74	4.00	0.93	3.83	0.41	4.18	0.75	0.493
Older professional resistance to change	0.000*	3.77	0.76	4.27	0.77	4.17	0.41	4.13	0.72	0.107
Client's unwillingness	0.000*	4.65	0.49	4.23	0.69	4.67	0.82	4.83	0.38	0.001*
Professional complacencies	0.000*	4.31	0.68	4.00	0.87	4.33	0.82	4.78	0.42	0.001*
Protection monopoly	0.000*	4.31	0.74	4.09	0.81	4.67	0.82	4.78	0.48	0.001*
Lack of initial capital	0.000*	4.58	0.64	4.00	1.11	4.33	0.82	4.60	0.59	0.101
Lack of market familiarity	0.000*	4.12	0.82	4.23	0.97	4.50	0.55	4.40	0.63	0.526
Social and political non-motivation	0.000*	4.04	0.87	4.32	1.09	3.83	1.47	4.38	0.63	0.325
Lack of government policies	0.000*	3.88	0.71	4.22	0.72	4.33	0.82	4.45	0.60	0.018*

Note: M = Mean, S.D. = Standard deviation, AR = Architect, QS = Quantity surveyor, BLD = Builder, ENG = Engineer, S-W = Shapiro-Wilk test, K-W = Kruskal-Wallis H test, * = Significant at 0.05.

Based on the results of the Kruskal-Wallis H test, there is a need to conduct further analysis to determine the group of construction professionals where the significant difference occurs. Therefore, a posteriori analysis using a pairwise Mann-Whitney test with the application of Bonferroni adjustment for the controlling of Type 1 errors was conducted (Bowen *et al.*, 2021; Cohen, 1988). The results with adjusted significant value are mainly considered in Table 2. The significant difference noticed in *inadequate technical knowledge* between the 'architects-engineers', and 'architects-builders' groups with the values of 0.010 and 0.011 were not later considered vital through the Bonferroni adjustment. The significant difference on the *client's unwillingness* mainly occurred between the quantity surveyors and engineers, while the significant difference

of *lack of government policies* existed between the architect and engineers only. In addition, the significant difference in *professional complacencies*, and *protection monopoly* occurred between the quantity surveyors and engineers, and architects and engineers. Considering the results of the post hoc test on the client's unwillingness, quantity surveyors are usually prudent with cost and thereby give financial advice to the client. Meanwhile, engineers are not detailed in cost preparation for construction projects (Oladinrin and Ojo, 2021). Since quantity surveyors are the principal cost advisers on construction projects to clients with professional skills of cost-saving, the clients can be unwilling to invest in additional expenses that SC may require.

Although a detailed discussion based on the significant difference between the professionals is not provided, an explanation of the five barriers with significant value is presented.

Table 2: Post Hoc Test of Barriers with Significant Difference

Barriers		Test statistic	SE	Std. test statistics	Sig.	Adj. Sig.
Inadequate technical knowledge	Architects - Engineers	-16.754	6.461	-2.593	0.010*	0.057
	Architects - Builders	-29.404	11.616	-2.531	0.011*	0.068
Client's unwillingness	Quantity surveyors - Engineers	-24.064	5.974	-4.028	0.000*	0.000*
Professional complacency	Quantity surveyors - Engineers	-25.005	6.438	-3.884	0.000*	0.001*
	Architects - Engineers	-17.146	6.110	-2.806	0.005*	0.030*
Protection monopoly	Quantity surveyors - Engineers	-22.220	6.297	-3.569	0.000*	0.002*
	Architects - Engineers	-16.261	5.976	-2.721	0.007*	0.039*
Lack of government policies	Architects - Engineers	-19.523	6.304	-3.097	0.002*	0.012*

Note: SE = standard error, * = Significant at 0.05.

Inadequate technical knowledge connotes the prowess of construction professionals in SC. Applying innovative methodologies to construction projects is primarily hinged on the technical expertise possessed by the professional (Frame, 2003). Technical know-how in using smart technologies of the twenty-first century is important for construction professionals to remain relevant in the global competitive market. Besides, the delivery of construction projects on time and the satisfaction of the stakeholders.

The client's unwillingness is also a significant hindrance to SC on construction projects. To a large extent, construction clients (private, corporate, or public) are the great determinant of the construction process and progress. Besides, clients are the major determinant of the kind of professional services practitioners should render on the construction project. Past studies have revealed that the unwillingness of clients in developing countries to pay beyond the traditional services of construction professionals is an obstacle to providing innovative services on construction projects (Oke & Aigbavboa, 2017). In contrast, clients in developed nations are often willing to pay for additional services for innovative and technological approaches for better delivery and quality standard of construction projects. The inadequate knowledge of construction professionals in developing countries may also be attributed to the reason why the clients can be convinced. Client's willingness to pay a premium for SC must be

considered before a professional used it on a construction project (Ben-Yehuda *et al.*, 2014).

In the analysis, *professionals' complacency* is another significant barrier to SC on construction projects in developing countries. Professional complacency depicts a sense of satisfaction with the present capabilities in discharging their duties to construction clients. Meanwhile, construction practitioners in developing countries predominantly employed traditional methods in undertaking their professional services. The present perceived satisfaction of the professionals creates an obstacle to the unwillingness to engage technological approaches on construction projects. Through the professional's complacency, the construction clients could not be convinced of the importance of technology to the delivery of construction projects.

Significant value was also obtained in *protection monopoly* based on the analysis results. Due to the dynamic nature of the construction industry in which multidisciplinary stakeholders work as a team to undertake construction projects, some level of ego-driven mindset is often noticed to protect individual professional status (Tang & Liao, 2021). The traditional mindset of professional hierarchy and communication often causes a monopoly of ideas that may benefit the project. Thus, construction projects may suffer the applications of innovative methodology if the team leader does not appropriately control the protection monopoly of professionals.

Based on the analysis results, *lack of government policies* is also of significant value in the study. The government's input is indispensable in setting the construction industry and other sectors on course. Lack of government involvement in providing guiding policies and their implementation is often a major hindrance to embracing new changes in the construction industry (Ojo *et al.*, 2021; Toyin & Mewomo 2021). Besides, lack of enforcement of the government policies is also a critical obstacle in a situation where policies exist. The construction practitioners and other clients often respond quickly when the government puts policies in place and enforces them. Therefore, a swift response from the government in providing policies that enforce SC would encourage construction organisations and other clients.

The findings from this study make three major contributions to theory. First, an empirical study on the barriers to SC in construction projects was provided in this study. Secondly, the significant barriers that demand quick attention of construction stakeholders were identified through statistical analysis. Lastly, this study adds to the limited literature on SC in the construction industry.

5 Conclusion and Further Research

This study investigated the barriers to SC adoption in a developing nation to determine the critical ones. Descriptive and inferential statistics were conducted based on the data collected from construction practitioners on the barriers to SC in construction projects. The analysis shows that inadequate technical knowledge, client unwillingness, professional complacency, protection monopoly, and lack of government policies were the barriers to SC adoption with a significant difference. The analysis shows that the five barriers are professional-related (*inadequate technical knowledge, professional's complacency, and protection monopoly*), client-related (*client's unwillingness*), and

government-related (*lack of government policies*). Interestingly, construction professionals, clients, and government are key project stakeholders. Therefore, proposing solutions to lessen these obvious barriers to the adoption of SC on construction projects is important.

To reduce the professional-related problems to the adoption of SC on construction projects, it is advised that construction practitioners be trained on the use of SC technologies, and its immense benefits to project delivery. The client's unwillingness can be reduced through the knowledge of construction professionals in stating the importance of SC to project performance and other outcome metrics. Finally, it is recommended that the government provide policies that support the use of SC technologies on construction projects. Besides, enforcement of such policies by placing sanctions on defaulting organisations is also vital.

Although this study achieved the objectives through the various statistical analyses, the results may not be generalisable for some factors. First, the chosen area for this study is a major city with constant ongoing construction projects and the seat of construction companies in Nigeria. However, the opinions of the construction professionals in other countries may differ, resulting in different results. Secondly, the barriers used in the study were sourced from extant literature, there may be other unique barriers that are not captured in this study. Therefore, a qualitative study can be conducted to identify other hindrances to adopting SC technologies for construction projects. Lastly, investigating the opinions of construction professionals on the barriers to SC adoption can be conducted in other developing nations.

6 References

- Abubakar, M., Ibrahim, Y. M., Kado, D., & Bala, K. (2014), 'Contractors' perception of the factors affecting Building Information Modelling (BIM) adoption in the Nigerian construction industry', *Computing in Civil and Building Engineering*, pp. 167-178.
- Aghimien, D. O., Oke, A. E., & Aigbavboa, C. O. (2018), 'Barriers to the adoption of value management in developing countries', *Engineering, Construction and Architectural Management*, 25(7), pp. 818-834.
- Aibinu, A. A., & Jagboro, G. O. (2002), 'The effect of construction delay on project delivery in Nigerian construction industry', *International Journal of Project Management*, 20(8), pp. 593-599.
- Akinradewo, O. F., Akinola, J. A., & Ojo, L. D. (2017), 'A regression equation for determining completion period of construction projects in Ondo state, Nigeria', *The Quantity Surveyors*, 63, pp. 13-23.
- Bartels, A. H. (2009), 'Smart computing drives the new era of IT growth', *Forrester Research, Inc.*, pp. 1-42.
- Ben-Yehuda, A. O., Ben-Yehuda, M., Schuster, A., & Tsafirir, D. (2014), 'The rise of RaaS: the resource-as-a-service cloud', *Communications of the ACM*, 57(7), pp. 76-84.
- Berglund, E. Z., Monroe, J. G., Ahmed, I., Noghabaei, M., Do, J., Pesantez, J. E., Fasaee, M. A. K., Bardaka, E., Han, K., Proestos, G. T., & Levis, J. (2020), 'Smart infrastructure: A vision for the role of the civil engineering profession in smart cities', *Journal of Infrastructure Systems*, 26(2), 03120001.

- Bharti, S., & Dubey, S. P. (2018), 'Application of smart computing techniques in cost optimisation of 1200 KV autotransformer', *Journal of Information and Optimisation Sciences*, 39(1), pp. 249-262.
- Bowen, P., Zhang, R. P., & Edwards, P. (2021), 'An investigation of work-related strain effects and coping mechanisms among South African construction professionals', *Construction Management and Economics*, 39(4), pp. 298-322
- Cai, Y. (2021), *Integrated wearable sensing and smart computing for mobile parkinsonian healthcare*. An Unpublished Ph.D. Thesis of Case Western Reserve University, USA.
- Cohen, J. (1988), *Statistical power analysis for the behavioural science*, 2nd ed., Lawrence Erlbaum Associates, Hillsdale, NJ.
- Corder, G.W., & Foreman, D.I. (2014), *Non-parametric statistics: A step-by-step approach*, Hoboken, NJ: Wiley.
- Farooqi, N., Gutub, A., & Khozium, M. O. (2019), 'Smart community challenges: enabling IoT/M2M technology case study', *Life Science Journal*, 16(7), pp. 11-17.
- Flynn, B., Pagell, M., & Fugate, B. (2018), 'Survey research design in supply chain management: the need for evolution in our expectations', *Journal of Supply Chain Management*, 54(1), pp. 1-15.
- Fosnacht, K., Sarraf, S., Howe, E., & Peck, L. K. (2017), 'How important are high response rates for college surveys?', *The Review of Higher Education*, 40(2), pp. 245-265.
- Frame, J. D. (2003). *Managing projects in organisations: how to make the best use of time, techniques, and people*. John Wiley & Sons.
- Harada, T., Abe, T., Kato, F., Matsumoto, R., Fujita, H., Murai, S., Miyajima, N., Tsuchiya, K., Maruyama, S., Kudo, K., & Shinohara, N. (2015), 'Five-point Likert scaling on MRI predicts clinically significant prostate carcinoma', *BMC Urology*, 15(1), pp. 1-7.
- Lee, T. G., Lee, S. H., & Chung, G. S. (2012), 'An interaction system architecture and design between smart computing and cloud computing', *Proceedings of 4th FTRA International Conference on Computer Science and its Application*, November 22-25, Jeju Island, Korea, Springer, pp. 197-205.
- Liu, S., Qiu, T., Qian, Y., Huang, H., Tutumluer, E., & Shen, S. (2019), 'Simulations of large-scale triaxial shear tests on ballast aggregates using sensing mechanism and real-time (SMART) computing', *Computers and Geotechnics*, 110, pp. 184-198.
- Lu, W., Huang, G. Q., & Li, H. (2011), 'Scenarios for applying RFID technology in construction project management', *Automation in construction*, 20(2), pp. 101-106.
- McNamara, A., & Sepasgozar, S. (2018), 'Barriers and drivers of Intelligent Contract implementation in construction', *Management*, 143, pp. 281-293.
- Mewomo, M., & Ejidike, C. (2021), 'Smart building as key driver in the elimination of greenhouse gas emission in the less economically developing country (LEDC)'. *Proceedings of 5th CU Construction Conference on Exploring Contemporary Issues and Challenges in the Construction Industry*, March 17, Coventry, United Kingdom.
- Nižetić, S., Djilali, N., Papadopoulos, A., & Rodrigues, J. J. (2019), 'Smart technologies for promotion of energy efficiency, utilisation of sustainable resources and waste management', *Journal of cleaner production*, 231, pp. 565-591.
- Ojo, L. D., & Leung, M. Y. (2021), 'Value management in Africa: A literature review',

- Proceedings of the Society of American Value Engineers (SAVE) International*, Virtual Conference, June 5-9, SAVE International, pp. 226-233.
- Ojo, L. D., Oladinrin, O. T., & Obi, L. (2021), 'Critical barriers to environmental management system implementation in the Nigerian construction industry', *Environmental Management*, 68(2), pp. 147-159.
- Oke, A. E., & Aigbavboa, C. O. (2017), *Sustainable value management for construction projects*, Switzerland: Springer.
- Oke, A. E., & Ogunsemi, D. R. (2013), 'Key competencies of value managers in Lagos state, Nigeria', *Proceedings of 5th West Africa Built Environment Research Conference*, August 12-14, Accra, Ghana, WABER Conference, pp. 773-778.
- Oke, A. E., Aghimien, D. O., Akinradewo, O. & Aigbavboa, C. O. (2020). Improving resilience of cities through smart city drivers, *Construction Economics and Building*, 20(2), 45-64.
- Oladinrin, O. T., & Ojo, L. D. (2021), 'Characterisation of the drivers of environmental management system implementation', *Engineering, Construction, and Architectural Management*. Doi:10.1108/ECAM-04-2021-0356
- Olawumi, T. O., Chan, D. W., Wong, J. K., & Chan, A. P. (2018), 'Barriers to the integration of BIM and sustainability practices in construction projects: A Delphi survey of international experts', *Journal of Building Engineering*, 20, pp. 60-71.
- Tang, M., & Liao, H. (2021), 'From conventional group decision making to large-scale group decision making: What are the challenges and how to meet them in big data era? A state-of-the-art survey', *Omega*, 100, 102141.
- Toyin, J. O., & Mewomo M. C. (2021), 'Barriers to successful BIM applications: A literature review', *Proceedings of the Development and Investment in Infrastructure (DII) Building Smart, Resilient and Sustainable Infrastructure in Developing Countries Conference*, October 6-7, Virtual Conference.
- Weilin, L., Xiaobin, Z., & Huimin, L. (2014), 'Design of star-connected autotransformer based 24-pulse rectifier and its application in the more electric aircraft', *EPE Journal*, 24(1), pp. 37-44.
- Yu, J., & Leung, M. Y. (2018), 'Structural stakeholder model in public engagement for construction development projects', *Journal of Construction Engineering and Management*, 144(6), 04018046.
- Zahrizan, Z., Ali, N. M., Haron, A. T., Marshall-Ponting, A., & Hamid, Z. A. (2013), 'Exploring the adoption of Building Information Modelling (BIM) in the Malaysian construction industry: A qualitative approach', *International Journal of Research in Engineering and Technology*, 2(8), pp. 384-395.
- Zhao, X., Feng, Y., Pienaar, J., & O'Brien, D. (2017), 'Modelling paths of risks associated with BIM implementation in architectural, engineering and construction projects', *Architectural Science Review*, 60(6), pp. 472-482.
- Zhu, H., Hwang, B. G., Ngo, J., & Tan, J. P. S. (2022), 'Applications of smart technologies in construction project management', *Journal of Construction Engineering and Management*, 148(4), 04022010.
- Zhu, X., Mukhopadhyay, S. K., & Kurata, H. (2012), 'A review of RFID technology and its managerial applications in different industries', *Journal of Engineering and Technology Management*, 29(1), pp. 152-167.