CITC GLOBAL Construction in the 21st Century

The Thirteenth International Conference on Construction in the 21st Century (CITC-13)

Arnhem, The Netherlands| May 8 – 11, 2023

Synthesizing Construction Professionals' Perception of Construction 4.0 in South Africa

Matthew Ikuabe[1], Clinton Aigbavboa[1], Samuel Adekunle[1] and Opeoluwa Akinradewo[1]

[1] SARChI in Sustainable Construction Management and Leadership in the Built Environment, Faculty of Engineering and Built Environment, University of Johannesburg, South Africa

ikuabematthew@gmail.com

Abstract

The construction industry is attributed to its slow compliance with the uptake of technological innovations. This has inhibited the industry from attaining projected heights characterised by these technologies' espousal. Construction 4.0 serves as a vehicle for the digital transformation of the methods and processes involved in construction project delivery. Therefore, this study seeks to present the viewpoints of construction professionals on the impacts of construction 4.0 in South Africa. Using a quantitative approach, a questionnaire survey was employed to elicit responses from target respondents. The retrieved data were subjected to statistical analysis using methods which included mean item score, standard deviation, and one-sample *t*-test. Findings from the study showed that the professionals' views indicate that the most significant impacts of the implementation of construction 4.0 are improved delivery time of projects, more accurate construction methods and increased customer satisfaction. It was also shown that all the identified impacts were proven to be significant. Conclusively, the study made recommendations that would aid in propagating the concept of digital transformation in project delivery using construction 4.0 as a viable vehicle. The study's outcome makes insightful contributions to the body of knowledge on the digitalisation of construction processes for effective project delivery.

Keywords

Construction 4.0, Construction Professionals, Digitalisation, Project Delivery, South Africa.

1. Introduction

Activities such as the erection of buildings and civil engineering projects and the maintenance and repair of existing structures characterise the mandates of the construction industry. According to the CIDB (2017), the construction industry plays a crucial role in job creation in South Africa, not only in the construction sector but also in other industries (e.g. material manufacturing, mining quarrying, and transport sector) that contribute to the South African economy. The importance of this sector cannot be over-emphasized as it significantly contributes to the nation's economy. However, in previous years, the South African construction industry has been viewed and criticised for its deprived performance and low success rates compared to other sectors (Ikuabe *et al*., 2022; Love *et al*., 2011). This results from the processes involved in project delivery that is at variance with the monotonous system attributed to other sectors, such as manufacturing (Ballard, 2012). Also, this is influenced by the use of outdated methods and techniques in delivering construction projects (Aghimien *et al*., 2021; Ikuabe *et al*., 2023). Consequently, it is believed that innovations and adaptations to new technologies can help attain a better delivery mode for construction projects. Kamara (2010) asserted that due to perennial problems like cost overrun, delay in completion, and poor quality delivery, the construction industry is an ideal candidate for a step change to abate the inefficiencies emanating from outdated methods. Other sectors have encountered improved delivery mandates resulting from implementing digital technologies. This is evident in the health, manufacturing, banking, and insurance sectors (Ikuabe *et al*., 2020). Hence, the call for using innovative technologies in the construction industry is highly encouraged. In construction processes,

adopting technological innovations would immensely compensate for the deficiencies in human intelligence (Liu *et al.,* 2018).

The fourth industrial revolution (4IR) has served as a vehicle for applying emerging innovative technologies, aiding the promotion of digitalisation and overhauling the delivery processes in sectors such as manufacturing (Lu, 2017). This concept is applied to the construction industry and is termed *Construction 4.0* (BDC, 2016; Oesterreich and Teuteberg, 2016). The *Construction 4.0* idea is underpinned by the implementation of new technologies and the creation of smart construction sites and making work more efficient by doing construction work to be more accurately, reducing waste, cutting down on cost, timely completion of projects and creating safer construction sites (Edirisinghe, 2017). Other benefits of digitalising the processes involved in construction project delivery include accurate construction methods; better quality delivery; less physical work; better cost control and predictability; and easy clash detection and avoiding rework (Akinradewo *et al*., 2022; Adekunle *et al*., 2022; Akinshipe *et al*, 2022). However, Castagnino *et al*. (2016) stated that the construction industry is known for the slow adoption of innovations, hence, continuously subjected to the conventional challenges plaguing the industry due to the use of outdated techniques. These challenges are exacerbated due to factors such as the cost of implementation, maintenance cost, cyber security issues, the expense of employing requisite professionals, and resistance to adopting new technologies, amongst others (Oke *et al*., 2018; Dimick, 2014; El-Masaleh, 2007; Oladapo, 2007). Aside from these highlighted challenges, stakeholders' low level of awareness of various technological innovations still poses a great drawback to the adoption of digital technology in construction processes. Furthermore, Goodrum *et al*., (2010) noted that the awareness of a specific technological innovation does not guarantee its adoption; as a result, interrelated circumstantial events are needed to achieve a successful implementation. Therefore, it becomes imperative to have an assessment of construction stakeholders' current perception of the potential impact of the implementation of the use of innovative technologies in South Africa. Hence, this study is focused on unravelling professionals' viewpoints on imbibing construction 4.0 for the South African construction industry. The study will contribute significantly to the growing conversation of digital transformation within the construction industry with the specific mandate of focusing on South Africa.

2. Methodology

The study deployed a quantitative method of research using Gauteng province, South Africa, as the study area. The study's target population was construction professionals comprising of construction project managers, architects, quantity surveyors, and engineers. A quantitative survey approach to data collection was adopted using convenience sampling as a result of the peculiarity of the study and time constraints. Data was collected with the aid of a well-structured questionnaire which entailed two sections. The first section elicited the background information of respondents. In contrast, the second part dwelt on respondents' views on the impacts of the adoption of construction 4.0 in the delivery of construction projects. A 5-Likert scale was provided to ascertain the respondents' perception of the level of significance of the identified impacts of construction 4.0 in project delivery. A total of eighty-four questionnaires were distributed, while seventy-four were returned and deemed appropriate for analysis. Data analysis methods adopted for the study include mean item score, standard deviation, and one-sample *t*-test. The reliability of the questionnaire was ascertained using Cronbach's alpha which gave a value of 0.719, affirming the research instrument's reliability and validity (Tavakol and Dennick, 2011).

3. Findings and Discussion

3. 1 Background Information

The findings from the analysis conducted on the demographic information of the respondents for the study show that 46% of the total respondents are affiliated with contracting establishments. In comparison, 34% are associated with consulting firms and 20% work in government entities. Also, based on the years of working experience of the respondents, 70% have worked for 1-5 years, those having 6-10 years of working experience make up 20% of the total respondents, while 8% have a working experience of 11-15 years. Furthermore, based on the highest academic qualification of the respondents, 54% possess an honour's degree, 18% have a bachelor's degree, and 12% have a master's degree.

3.2 Impacts of Construction 4.0 Implementation

The study aims to evaluate the construction professionals' perception of the impact of construction 4.0 on the delivery of projects in South Africa. The review of extant literature yielded the identification of sixteen variables. These were presented to the target respondents of the study for rating based on their significance. The data retrieved from the survey were subjected to statistical analysis, including mean item score, standard deviation, and one-sample *t*-test. The study employed a one-sample *t*-test to ascertain the significance of the identified impacts of implementing construction 4.0 in South Africa. Consequently, a hypothesis was set for the study, which is: Null hypothesis states that an impact is insignificant if the mean value is less than or equal to the population mean (H_0: $U \leq U_0$); While the alternate hypothesis states that an impact is significant if the mean value is greater than the population mean (H_a: $U > U_0$). The study fixed the population mean (U_0) at 3.5 while the significance level was set at a 95% confidence level. The result from Table 1 indicates a two-tailed *p*-value indicating the significance of the identified impacts. All the identified impacts were proven to be significant, with all having a *p*-value of 0.000.

Table 1. One-Sample t-test

	Test Value = 3.0					
					95% Confidence Interval of the Difference	
Impacts	t	df	Sig. (2-tailed)	MD	Lower	Upper
Improved delivery time of projects	9.211	49	.000	1.08000	.8444	1.3156
Improved cost delivery of projects	4.911	49	.000	.74000	.4372	1.0428
Better quality delivery	8.791	49	.000	1.02000	.7868	1.2532
Less physical work	7.339	49	.000	.96000	.6971	1.2229
More accurate results	8.486	49	.000	1.08000	.8243	1.3357
Workers are more productive	6.416	49	.000	.86000	.5906	1.1294
Improved efficiency of the industry	7.012	49	.000	.96000	.6849	1.2351
Increased customer satisfaction	7.768	49	.000	1.04000	.7709	1.3091
Better waste management	7.000	49	.000	.90000	.6416	1.1584
Damage can be detected to infrastructure easily	5.505	49	.000	.66000	.4191	.9009
Can conduct safety inspection on site	7.399	49	.000	.98000	.7138	1.2462
Capturing data during claims management	5.308	49	.000	.74000	.4598	1.0202
Easy clash detection and avoiding rework	5.261	49	.000	.76000	.4697	1.0503
Reduces conflicts on projects	6.424	49	.000	.80000	.5497	1.0503
Improved collaboration owner/design firms during construction	5.261	49	.000	.76000	.4697	1.0503
Better cost control and predictability	7.054	49	.000	.92000	.6579	1.1821

Note: MD=Mean Difference

The findings presented in Table 2 show the ranking of the impacts of the implementation of construction 4.0 as perceived by construction professionals in South Africa. It is revealed that all the identified impacts have a mean value greater than 3.50, which is the threshold set for the study. Therefore, this affirms the postulation of the alternate hypothesis set for the study, which states that an impact is significant if the mean value is greater than the population mean (H_a: $U > U_0$). Also, it is shown that the outcome of the *p*-values of the impacts at a 95% confidence level is significant. The ranking of the impacts shows that improved time delivery and more accurate construction methods were ranked first with (*MIS=4.08, Sig.=0.000, R=1*) and (*MIS=4.08, Sig.=0.000, R1*) respectively, followed by increased customer satisfaction (*MIS=4.04, Sig.=0.000, R=3*), better quality delivery (*MIS=4.02, Sig.=0.000, R=4*), can conduct safety inspection at large site (*MIS=3.98, Sig.=0.000, R=5*), less physical work and improved efficiency of the industry were ranked sixth (*MIS=3.96, Sig.=0.000, R=6*) and (*MIS=3.96, Sig.=0.000, R=6*) respectively, better cost control and predictability (*MIS=3.92, Sig.=0.000, R=8*), better waste management (*MIS=3.90, Sig.=0.000, R=9*), workers are more productive (*MIS=3.86, Sig.=0.000, R=10*), reduces conflicts on projects (*MIS=3.80, Sig.=0.000, R=11*), easy clash detection and avoiding rework (*MIS=3.76, Sig.=0.000, R=12*), improved collaboration owner/design firms during construction (*MIS=3.76, Sig.=0.000, R=12*), improved cost delivery of projects (*MIS=3.74, Sig.=0.000, R=14*), capturing data during claims management (*MIS=3.74, Sig.=0.000, R=14*), and damage can be detected to infrastructure easily (*MIS=3.66, Sig.=0.000, R=16*).

Table 2. Impacts of the implementation of construction 4.0 on project delivery

Impacts	MIS	Std. Deviation	Sig. (2-tailed	Rank
Improved delivery time of projects	4.08	0.829	0.000	1
More accurate construction methods	4.08	0.899	0.000	1
Increased customer satisfaction	4.04	0.947	0.000	3
Better quality delivery	4.02	0.820	0.000	4
Can conduct safety inspection at large sites	3.98	0.937	0.000	5
Less physical work	3.96	0.925	0.000	6
Improved efficiency of the industry	3.96	0.968	0.000	6
Better cost control and predictability	3.92	0.922	0.000	8
Better waste management	3.90	0.909	0.000	9
Workers are more productive	3.86	0.948	0.000	10
Reduces conflicts on projects	3.80	0.880	0.000	11
Easy clash detection and avoiding rework	3.76	1.021	0.000	12
Improved collaboration owner/design firms during construction	3.76	1.021	0.000	12
Improved cost delivery of projects	3.74	1.065	0.000	14
Capturing data during claims management	3.74	0.986	0.000	14
Damage can be detected to infrastructure easily	3.66	0.848	0.000	16

3.3 Discussion of Findings

Findings show that implementing innovative technologies can improve delivery time and produce more accurate results for construction projects. Consequently, it is imperative that emerging technologies' diffusion is propagated to harness the glaring benefits from their espousal. This is corroborated by Oesterreich and Teuteberg (2016) by affirming that the significant strides presented by the uptake of digital technologies for construction project execution bring a shift from the conventional systems that are attributed to several bottlenecks. Also, Aghimien *et al*., (2018) noted that the emerging technologies presented by the 4IR have the potential to help reduce cost and time overrun as a result of more accurate construction methods. This is a pointer that time wasted on site unduly would be drastically cut down with the right and accurate methods deployed with the aid of digital technologies in construction processes facilitated by construction 4.0. Moreover, clients' needs are increasingly demanding and more complex; hence utilising digital technology in construction processes would aid in delivering clients' needs with minimal hitches. Castagnino *et al*. (2016) opined that the needs of construction project clients are significantly attained with the fusion of innovative technologies in construction processes. This results from improved process delivery and quality of work, cost optimisation, and timely completion of projects. Also, improvement in the working conditions on site is significantly guaranteed with the uptake of innovative technologies propelled by the 4IR (Hashim *et al*., 2013).

4. Conclusion

The study assessed construction professionals' viewpoints on the impact of the uptake of construction 4.0 within the South African construction industry. A review of the literature unravelled sixteen impacts and subsequently presented them to the target respondents of the study using a questionnaire for rating. Based on the study's findings, it is concluded that the significant impacts of the espousal of construction 4.0 are timely delivery of projects, improvement in the methods deployed for construction, customer satisfaction is met and better-quality delivery of construction projects. The construction industry is one of the cardinal sectors of the economy of any nation; hence, deploying digital technologies would result in an aggregate improvement of the industry, consequently, have a positive effect on the economy of any nation. The study proposes that digital technologies should be rapidly adopted and integrated into construction projects' delivery methods and processes. As evident from this study, the impact of its adoption is

enormous. The propelling measures, such as its inclusion in the academic curriculum of higher institutions of learning and training of professionals of its usage, should be set in place to enable its embracement in the industry. Equally, stakeholders in the industry should imbibe the culture of changing from outdated conventional methods to accommodate recent innovations in technological participation in the construction industry. It is pertinent to state that the study was limited to Guateng Province, South Africa. It is proposed that future studies can be carried out in other Provinces in the country, as a more robust result would be achieved given that a larger study area would be covered.

References

Adekunle, S., Aigbavboa, C.O., Akinradewo, O., Ikuabe, M.O**.,** and Adeniyi, A. (2022). A principal component analysis of Organisational BIM implementation. *Modular and Offsite Construction (MOC) Summit Proceedings*, Edmonton, Canada, July 27-29, 161-168 https://doi.org/10.29173/mocs278

Aghimien D., Aigbavboa C and Oke A, (2018). Digitalisation for effective construction project delivery in South Africa. *Proceedings of the contemporary construction conference: Innovative and dynamic built environment. Coventry*, United Kingdom, 5 – 6 July 2018.

Aghimien, D.O., Aigbavboa, C.O., Meno, T., Ikuabe, M.O. (2021). Unravelling the risks of construction digitalisation in developing countries. *Construction Innovation*, 21(3), 456-475 https://doi.org/10.1108/CI-02-2020-0026

Akinradewo, O., Aigbavboa, C.O., Ikuabe, M.O., Adekunle, S., and Adeniyi, A. (2022). Unmanned aerial vehicle usage on South African construction projects: Perceived benefits. *Modular and Offsite Construction (MOC) Summit Proceedings*, Edmonton, Canada, July 27-29 146-153 https://doi.org/10.29173/mocs276

Akinshipe, O., Ikuabe, M.O, and Aigbavboa, C. (2022). Digital Transformation in Quantity Surveying: Where Lies the Issues?. In: Waldemar Karwowski, Henrijs Kalkis and Zenija Roja (eds*) Social and Occupational Ergonomics. AHFE (2022) International Conference*, 65, AHFE International, USA. http://doi.org/10.54941/ahfe1002658

Ballard, G. (2012). Should Project Budgets be Based on Worth or Cost?. *Proceedings, 20th annual conference of the International Group for Lean Construction*, San Diego, CA, 761-770.

BDC (2016). Industry 4.0 the new industrial revolution are Canadian manufacturers ready, https://bridgr.co/wp-content/uploads/2017/06/bdc-etude-manufacturingen.pdf [Accessed 13 September 2022].

Castagnino, S., Rothballer, C., and Gerbert, P. (2016). What's the Future of the Construction Industry? World Economic Forum, Retrieved from https://www.weforum.org/agenda/2016/04/building-in-thefourth-industrial-revolution/ [Accessed 18 September 2022].

CIDB (2017), SME business conditions survey Q3 report. | *Infrastructure news. 2018.* Construction industry has moderate outlook until 2021 | [ONLINE] Available at*: http://www.infrastructurene.ws/2017/06/20/construction-industry-has-moderate outlook-until-2021/.* [Accessed 06 May 2022].

Dimick, S. (2014). Adopting digital technologies: the path for SMEs*. The conference board of Canada*, Ottawa.

Edirisinghe, R., (2017). Digital Skin of the Construction Site: Smart Sensor Technologies Towards the Future Smart Construction Site. *Engineering, Construction and Architectural Management*, 26(2), 184-223.

El-Mashaleh, M.S. (2007). Benchmarking information technology utilization in the construction industry in Jordan*. Journal of information and technology in construction*, 12(19), 279-291.

Goodrum, P., Haas, T., Caldas, C., Zhai, D., Yeiser, J., and Homm, D. (2010). Model to Predict the Impact of a Technology on Construction Productivity. *Journal of Construction, Engineering and Management*, 137, 678–688.

Hashim, N., Said, I., and Idris, N. H. (2013). Exploring E-Procurement Value for Construction Companies in Malaysia. *Procedia Technology*, 9, 836–845.

Ikuabe, M.O., Aigbavboa, C., Anumba, C., Oke, A. and Adekunle, S. (2023). Business Environment as a Determinant in the Uptake of Cyber-Physical Systems for Facilities Management. *Facilities* [Ahead of Print] https://doi.org/10.1108/F-02-2022-0022

Ikuabe, M.O., Aigbavboa, C.O., and Oke, A.E. (2020). Cyber-Physical Systems: Matching Up its Application in the Construction Industry and other Selected Industries. *International Conference on Industrial Engineering and Operations Management*, Dubai, UAE, March 10-12, 1543-1542.

Ikuabe, M.O., Aigbavboa, C.O., Anumba, C. and Oke, A.E. (2022). Confirmatory Factor Analysis of Performance Measurement Indicators Determining the Uptake of CPS for Facilities Management. Buildings, 12(4), 466. https://doi.org/10.3390/buildings12040466

Liu, D., Lu, W., and Niu, Y. (2018). Extended Technology-Acceptance Model to Make Smart Construction Systems Successful. *Journal of Construction, Engineering and Management*, 144(6), 04018035.

Love, P., Edwards, D., and Wood, E., (2011). Loosening the Gordian knot: the role of emotional intelligence in construction. *Engineering, Construction and Architectural Management*, 18(1), 50 – 65.

Lu, Y. (2017). Industry 4.0 a survey on technologies, applications and open research issues. *Journal of industrial information integration*, 6(1), 1-10.

Oesterreich., T.D and Teuteberg, F., (2016). Understanding the implications of digitisation and automation in the context of industry 4.0.A triangulation approach and elements of a research agenda for the construction industry. *Computer in Industry*, 83(10), 121-139.

Oke, A., Aghimien, D., Aigbavboa, C and Koloko, N. (2018). Challenges of digital collaboration in the South African construction industry. *Proceedings of the International Conference of Industrial Engineering and Operations Management*, Bandung, Indonesia. 6 – 8 March, 2442-2482.

Oladapo, A. (2007). An investigation into the use of ICT in the Nigerian construction industry, *Journal of Information Technology in construction*, Vol. 12, 109-123.

Tavakol, M., Dennick, R. (2011). Making sense of Cronbach's Alpha. International Journal of Medical Education, 2, 53-55.