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# Construction 4.0: The Future of the Construction Industry in South Africa

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***Abstract*****—**The construction industry is a renowned latecomer to the efficiency offered by the adoption of information technology. Whereas, the banking, manufacturing, retailing industries have keyed into the future by using digitization and information technology as a new approach for ensuring competitive gain and efficiency. The construction industry has yet to fully realize similar benefits because the adoption of ICT is still at the infancy stage with a major concentration on the use of software. Thus, this study evaluates the awareness and readiness of construction professionals towards embracing a full digitalization of the construction industry using construction 4.0. The term 'construction 4.0' was coined from the industry 4.0 concept which is regarded as the fourth industrial revolution that originated from Germany. A questionnaire was utilized for sourcing data distributed to practicing construction professionals through a convenience sampling method. Using SPSS v24, the hypotheses posed were tested with the Mann Whitney test. The result revealed that there are no differences between the consulting and contracting organizations on the readiness for adopting construction 4.0 concepts in the construction industry. Using factor analysis, the study discovers that adopting construction 4.0 will improve the performance of the construction industry regarding cost and time savings and also create sustainable buildings. In conclusion, the study determined that construction professionals have a low awareness towards construction 4.0 concepts. The study recommends an increase in awareness of construction 4.0 concepts through seminars, workshops and training, while construction professionals should take hold of the benefits of adopting construction 4.0 concepts. The study contributes to the roadmap for the implementation of construction industry 4.0 concepts in the South African construction industry.

***Keywords*****—**Building information technology, Construction 4.0, Industry 4.0, Smart Site.

## I. Introduction

THE manufacturing, automobile, and the banking sector have already tapped into the future by adopting a full digital approach to their everyday business; thereby, contributing to their productivity, accuracy, efficiency and improved customer satisfaction [1]. However, the construction industry, which contributes a significant quota to the country's GDP, is still dominated by a paper form of communication for passing information [2], [3]. Reference [4] submitted that the segmented nature and site-based activity of the construction industry, coupled with the resistance to change of construction professionals have made the evolution of the industry into a fully digital process difficult, as most of the contracts are still documented in paper form.

Reference [5] reported that the performance level of a construction professional is related to the quality of information available to the professional. In a bid to increase the performance of the construction professional, the use of BIM has been introduced into the construction industry for easy means of passing information, especially at the design stage. Reference [6] avowed that BIM is expected to eliminate the requirement of passing construction designs in paper format through different construction professionals that are predisposed to making errors. Authors such as [6]-[8] opined that the use of only BIM as a form of ICT for construction work is coming of age due to its interoperability and disjointed method of application. These shortcomings give rise to the adoption of industry 4.0 concepts as the future direction for the construction industry. Reference [9] suggested that industry 4.0 has its origin in Germany manufacturing sector and used as a synonym for the scheduled 4$^{th}$ industrial revolution which represents the increase in the digitization of the manufacturing sector towards enabling communication between the products, business, and customers.

Reference [10] asserted that applying industry 4.0 concepts to construction industry is a new concept using the Internet of Things (IoT) for the integration of information among different platforms and adopting new gadgets like laser scanning, drones, 3D printing with the expectation of enhancing the ability to monitor construction projects at the design, construction and in use stages towards delivering sustainable and smart buildings. Similarly, [11] opined that the construction industry 4.0 involves the digitalization of the industry towards producing a smart and intelligent way of assembling data by using sophisticated and new gadgets; thereby, facilitating easy analysis of data towards making prompt decisions that enable the establishment of a smarter, efficient and responsive built environment.

Reference [1] posited that construction industry 4.0 strives on the principle of creating a smart construction site, simulation and virtual storage of data allowing construction companies to arrange and evaluate data from different stages of the construction project and from end users after completion of the construction project towards delivering a faster, more flexible construction project at a higher-quality and reduced costs. However, despite the advantage and benefit of applying industry 4.0 concepts for construction projects, few studies have been conducted in South Africa towards examining the awareness of construction professionals for the application of the industry 4.0 concept in the construction

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industry. With most of the studies relating to construction with industry 4.0 concept such as; [10]-[12] carried out in countries like the United Kingdom, America, and Germany pointing towards the use of the concept in such countries and highlighting the challenges of adopting construction industry 4.0. Against this background, this study will examine the awareness and readiness of construction professionals towards adopting construction industry 4.0 in South Africa with the intention of creating a roadmap for the implementation of construction industry 4.0 concepts in the South Africa construction industry.

## II. Review of the Construction Industry and Construction 4.0

### *A. Construction Industry in South Africa*

All over the world, including South Africa, the construction industry is a significant sector of the economy that creates job prospects for many citizens and contributes to the country GDP [13], [2], [14]. Reference [15] described the construction industry as the driver of economic development, providing an atmosphere where resources such as equipment, materials, labor, and capital, are traded to create an infrastructure within an economy. Likewise, [16] asserted that the construction industry is a vital sector for South Africa's economic growth and performance, as it is responsible for employing about 1.4 million people; thereby, reducing the unemployment rate.

Reference [17] affirmed that the South African construction industry has its origin and roots in the British construction though, the industry has experienced significant changes from the apartheid period that was previously restricted by racial policies affecting its growth. Authors such as [15], [18], [19], avowed that after the apartheid period towards developing the construction industry the government formed new construction policies and bodies such as the construction industry development board (CIDB) aimed at ensuring the standardization of the construction industry. Reference [20] suggested that the government were also the biggest client of the construction industry in the development of RDP houses and other infrastructures.

Reference [17] asserted that the industry has experienced significant growth since, but was then confronted with a downturn after the completion of the 2010 World Cup soccer projects and the crash of the Rand. Reference [21] examined top construction industry firms in South Africa and discovered that eight out nine have experienced a decrease in market capitalization in 2015, with the likelihood of a further reduction of their market capitalization in the coming months. Reference [18] opined that the reduction in market capitalization of the construction firms can be attributed to the strikes of the construction laborers and workers that have a negative effect on the construction industry; thereby, leading to delay of the important construction project.

Construction project delays, in the form of cost and time overruns, have been a major challenge for the sector in South Africa [22], [13]. Reference [15] described delays as the failure to complete the project, at the assigned or proposed cost and time. Reference [23] asserted that finalizing construction projects on time and within the proposed budget has remained a major challenge for the South Africa construction industry. Reference [24] attributed the delays to the advancement and intricacy of construction projects; thereby, putting pressure on construction workers to deliver on time at the stipulated cost and at the right quality. Likewise, [14] affirmed that the construction industry is presently characterized by the low performance of construction professionals thereby leading to low quality of work and reduced productivity.

Studies done by [25], [3], [26] revealed that poor communication among construction sector members is one of the major factors responsible for the poor performance of construction projects in Africa, with nearly two-thirds of project problems caused by the inadequate exchange of information, and inefficient communication. Likewise, [27] affirmed that lack of information integration among construction professionals is a main barrier to effective construction project performance. The authors believe that poor means of sharing information results to every member of the construction project struggling to collect various information generated by different partners, which is time-consuming. Many researchers have made some contribution in this area, such as [5], [28], with the aim of developing an integrated information system to store, transfer and share various information. However, most of the research mainly focused on the transfer of the fragmented information rather than providing or encouraging the digitalization of the construction industry.

### *B. Construction 4.0*

Construction 4.0 was coined from industry 4.0 concepts, which refer to the 4$^{th}$ industrial revolution that was created by the German Federal Government in respect of its manufacturing sector. Reference [29] acknowledged that industry 4.0 enables the connection of people and objects towards creating the factory of the future that ensures the full digitalization of the manufacturing sector. The industry 4.0 is an innovation in the manufacturing sector that allows the merging of the physical and virtual world using the IoT, simulation and virtualization [30], [31]. The South African manufacturing sector has also embraced the benefits of the industry 4.0 concepts. Recently, [32] developed a model for system optimization in the manufacturing sector, as:

Industry 4.0 + Advanced manufacturing = system optimization [32]

The authors recognized the significance of industry 4.0 in manufacturing towards increasing the performance of the sector within the country. Reference [33] opined that in spite of the potential advantage of the innovative technologies offered by industry 4.0, the construction industry has not been able to totally reap the benefits and compete with the manufacturing sector. Reference [4] reported that peculiar characteristics of the construction industry such as the site-based nature of construction projects, and a large number of

small and medium-sized firm with low capabilities for investments in new technologies, make it difficult for the applying industry 4.0. Reference [1] submitted that the low investment in research and development of the construction industry is responsible for the lack of innovation and technological progress. Despite this hindrance to the adoption of innovation in the construction industry, it has evolved through various stages as shown in Fig. 1.

From Fig. 1, the first stage involves the use of crude tools for construction such as shovels, diggers, and hoes; the second stage is driven by mechanization and the use of machinery like backhoes, loaders, and cranes; while, the third stage is driven by information technology that has given birth to the rise of software such as BIM, and Revit, among others. This study proposed the fourth stage referred to as construction 4.0 that involves the digitalization of the construction industry, where the internet, wireless sensors, software and other advanced technology such as lasers and drones work together towards enhancing construction project performance and improve client satisfaction.

The main idea of construction 4.0 is directed at creating a digital construction site assisted by attaching internet-connected sensors on the equipment and each stage of the construction project to monitor progress coupled with the use of drones and virtual simulation [1]. This opinion recognizes construction 4.0 as the process of implementing modern technology to encourage the digitization of the construction industry as well as the supply chain; thereby, leading to an increased performance of the sector.

Fig. 2, which shows the conceptual framework, recognizes construction 4.0 as the creation of the smart construction site, simulation, and virtualization that will in return lead to improved construction project performance. The smart factory is further breaking down to the use of IoT, RFID (radio frequency identification) cyber-physical systems and many others. The creation of the smart construction site is borne out of the innovative thinking of using internet sensors to monitor construction work on site. Reference [16] opined that the use of RFID in construction promotes the automation of the construction process by allowing effective tracking of equipment and tools, theft prevention and inventory management, as the attached sensors can act as a tracker to locate stolen items. Reference [34] suggested that the use of RFID could assist the construction industry in moving away from reactive maintenance, as it will provide an opportunity for equipment and machines to automatically send performance data to engineers.

The second stage of the conceptual framework is the simulation of construction projects due to the complex nature of construction works. This stage involves the use of BIM, virtual reality, 3D printing and many others. Reference [35] proclaimed that BIM is often used on construction sites due to its ability to provide a simulation about the technical information of the building regarding its cost estimate, material inventories and time for completion. This suggests that BIM can be regarded as one of the first innovations providing the background for construction 4.0. Authors such as [7], [8], [23] reported the shortcomings of BIM and that to enjoy its full benefits, the use of BIM needs to be merged with other technologies like cloud computing that facilitate the free-flow of information within the industry, as it is expected to deliver fast information for construction professionals using cloud data storage.

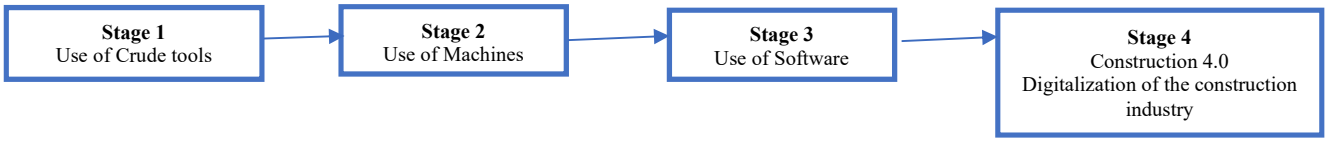


Fig. 1 Evolution of the construction industry [10]

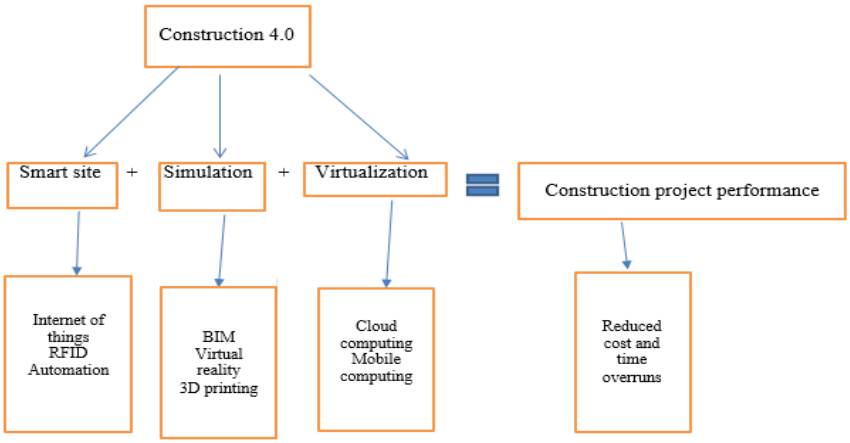


Fig. 2 Conceptual framework Source; Adapted from [32], [1]

## III. Methodology

The success of a construction project is dependent on the communication and interaction among project theme members, so this study is based on the perspective of construction sector professionals. Towards meeting the objectives of the study, which entails determining the awareness and readiness of construction sector professionals in South Africa with the construction 4.0 concept, a quantitative research approach was adopted. This approach was used due to the ability to effectively study the relationship between facts and relate them in accordance with findings or theories from existing or past studies.

The study adopted a convenience sampling technique, the non-probabilistic sampling method. The instrument of data collection was a close-ended questionnaire addressed to practicing construction professionals within Gauteng province in Johannesburg, South Africa. The questions posed by the questionnaire were acquired from reviewing different articles and journals related to construction 4.0, industry 4.0 and the South African construction industry. The questionnaire contains three sections, with the first section examining the personal information of the respondents, the second section appraises the construction professional's awareness and readiness of construction 4.0, and the last section examines the importance of adopting construction 4.0 concepts to the construction industry in South Africa.

Seventy questionnaires were distributed to construction professionals, while ensuring that they are registered with their respective professional bodies and are also currently working on a construction project that will allow an adoption of a form of ICT. A total of 50 questionnaires were returned representing a response rate of 71%, which is adequate for this research. The questionnaire was analyzed using SPSS version 24, while adopting the Mann Whitney test to ascertain the significant difference between the consulting and contracting organizations on the readiness for adopting construction 4.0, and factor analysis was used to examine the importance of construction 4.0.

## IV. Discussion of Findings

This section presents the results and discussion of the findings from the returned questionnaires that were distributed to the construction professionals in South Africa.

### *A. Background Information*

The background information of the respondents is summarized in Table I.

Table I shows that an equal proportion of response was acquired from respondents working with consulting and contracting organizations. Regarding the academic qualification of the respondents, the table shows that all the respondents are educated; thereby, confirming their eligibility to answer the questions posed by the research instrument. However, 38% of construction professionals have B.Sc/ B.Tech as their highest academic qualification, followed by 30% of the respondents that hold ND/Diploma certificates, while 24% have obtained MSc/MBA/MPM degree and a few (8%) have studied to the PhD level. The table shows that half (50%) of the respondents have work experience in the construction industry in the range of 11-20 years, 30% have about 1-10 years, 14% have about 31-40 years, while 6% have work experience in the range of 41-50 years.

TABLE I
SUMMARY OF BACKGROUND INFORMATION

| Category of Respondents | Frequency | Percent (%) | Cumulative Percent |
|---|---|---|---|
| Consulting base | 25 | 50 | 50 |
| Contracting organization | 25 | 50 | 100 |
| Total | 50 | 100 | |
| Highest Academic Qualification | | | |
| ND/Diploma | 15 | 30.0 | 30.0 |
| B.Sc/ B.Tech | 19 | 38.0 | 68.0 |
| M.sc/ MBA/ MPM | 12 | 24.0 | 92.0 |
| PhD | 4 | 8.0 | 100 |
| Total | 50 | 100 | |
| Working Experience | | | |
| 1-10 years | 15 | 30.0 | 30.0 |
| 11-20 years | 25 | 50.0 | 70.0 |
| 31-40 years | 7 | 14.0 | 84.0 |
| 41-50 years | 3 | 6.0 | 100 |
| Total | 50 | 100 | |

### *B. Awareness with Construction 4.0*

The term construction 4.0 was coined from the industry 4.0 concept; this study recognizes that construction 4.0 is driven by the need to create a smart construction site, adopt simulation tools and virtualization for construction works. The smart construction site, simulation, and virtualization tools are further broken down into various components and presented to the construction professionals to rate their level of awareness with construction 4.0 concepts and their response is presented in Table II. A look at the table shows that construction professionals are not aware of construction 4.0 concepts, judging from the low mean score attributed to all the components. These findings coincide with the studies conducted by [4], [33], when they discovered that construction professionals are not aware of some modern technologies and the advantages it offers to increasing performance. Reference [1] also discovered that most construction professionals have low awareness concerning modern technologies, but the authors related this to the low investment in research and development of the construction industry.

However, under the creation of a smart construction site, Table II shows that the respondents are aware of the use of prefabrication/modularization. Their level of awareness may be related to the already established benefit of adopting prefabrication in other developed countries, as shown by authors such as [36], [37]. Other factors that construction professionals are aware of, in order of hierarchy are: IoT, automation, internet of services, product lifecycle management, human-computer interaction, addictive manufacturing, radio frequency identification, and robotics and cyber-physical systems (CPS) embedded systems.

Table II shows that construction professionals are aware of

Building information modeling (BIM) as a form of simulation tool, followed by virtual reality. Regarding the use of virtualization, the table shows that the respondents are aware of mobile computing, social media, big data and cloud computing. From the study, it can be implied that construction professionals are becoming newly aware of the modern innovations and technologies that have been extensively applied in foreign countries such as BIM and prefabrication, and have low awareness of the technologies that are beginning to gain ground such as the use of radiofrequency for construction works which has been adopted by [16], [34]. These studies demonstrated that the use of radiofrequency promotes automation of the construction process by allowing effective tracking of equipment and tools, theft prevention and inventory management.

TABLE II
AWARENESS OF CONSTRUCTION 4.0

| | Mean | Rank |
|---|---|---|
| **Smart Construction Site** | | |
| Prefabrication/ Modularization | 3.82 | 1 |
| Internet of things | 3.55 | 2 |
| Automation | 3.45 | 3 |
| Internet of services | 3.27 | 4 |
| Product-lifecycle management (PLM) | 3.18 | 5 |
| Human-computer interaction (HCI | 2.64 | 6 |
| Addictive manufacturing | 2.64 | 7 |
| Radio-frequency identification (RFID) | 2.45 | 8 |
| Robotics | 2.36 | 9 |
| Cyber-physical systems (CPS) embedded systems | 2.00 | 10 |
| **Simulation tools** | | |
| Building information modeling (BIM) | 3.55 | 1 |
| Augmented /virtual/mixed reality | 2.82 | 2 |
| **Virtualization** | | |
| Mobile computing | 3.64 | 1 |
| Social media | 3.45 | 2 |
| Big data | 2.91 | 3 |
| Cloud computing | 2.36 | 4 |

### *C. Readiness to Adopt and Importance of Construction 4.0*

Having explained the different concepts of construction 4.0 to construction industry professionals, they were asked to indicate their readiness to adopt the concept and the assumed importance they will derive when it is fully embraced within the industry.

1) Readiness to Adopt Construction 4.0

Table III presents the response of respondents regarding their readiness to adopt construction 4.0. The table shows that more than half of the respondents are ready to fully embrace the concept of construction 4.0 in their day-to-day construction work. This finding also corroborates the findings of the study done by [11], [3], when they discovered that construction professionals are ready to adopt the use of modern technologies for their day-to-day activities, but are inhibited by their level of understanding of the technologies. It can be implied from these findings that low research into modern technologies is the main factor hindering the adoption of construction 4.0 within the South African construction industry.

TABLE III
READINESS TO ADOPT CONSTRUCTION 4.0

| | Frequency | Percentage |
|---|---|---|
| Very ready | 32 | 64 |
| Ready | 16 | 32 |
| Slightly ready | 2 | 4 |
| **Total** | **50** | **100** |

2) Importance of Adopting Construction 4.0

Factor analysis was used to explore the importance of adopting construction 4.0 in the South African construction industry. In the analysis, KMO and Bartlett's test of sphericity show good factorability features, as shown in Table IV. The Bartlett's test of sphericity gave a chi-square value of 1007.007 at 120 degrees of freedom, significant at the 5% confidence level. This, therefore, suggests correlation among the chosen factors (importance of adopting construction 4.0) and supportive criterion for factorability.

TABLE IV
KMO AND BARTLETT'S TEST

| | |
|---|---|
| Kaiser-Meyer-Olkin Measure of Sampling Adequacy | 0.642 |
| Bartlett's Test of Sphericity: | |
| Approx. Chi-square | 1007.007 |
| Degree of freedom | 120 |
| Significant level | 0.000 |

The study adopted the varimax rotation method, which shows the 16 factors loaded differently on three components which form the importance of adopting construction 4.0, as reported in Table V.

Items that have the highest coefficient in all the three components are usually considered. On the first component, 'creating sustainable buildings' and 'waste minimization' are the items with the highest component. Regarding the second component, 'ensuring adequate construction planning' and 'encouraging seamless communication' are the highest loading factors; while in the third component, 'time savings' and 'cost savings' were highly loaded.

The name given to the components is usually adopted from the highest item within each component; therefore, the three components obtained in the analysis are named thus; 1) developing sustainable buildings, 2) increased communication among construction professionals, and 3) better performance (cost and time savings) of construction projects. These are recognized as the three benefits of adopting construction 4.0 for construction projects the sector in South Africa.

Although construction 4.0 is a new concept within the construction industry, some studies such as [27], [5], [28] also discovered that digitalizing the industry through using various internet-based communication systems (part of the construction 4.0 concept), will enhance communication among construction professionals, and in return, enhance sustainability of buildings and increase the performance of the construction industry. The advantages of applying industry 4.0 in the construction industry is similar to the same benefits of

using it in the manufacturing sector, as indicated by authors such as [29]-[32], when they discovered that the application of the industry 4.0 concept has the capability of increasing the performance of the manufacturing industry.

It can be implied from the findings of this study that to increase the sustainability of infrastructures provided by the construction industry and increase the overall performance of the sector in South Africa, there is a need to apply construction 4.0 concepts to the industry.

TABLE V
ROTATED COMPONENT MATRIX

| | Component | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| Creating sustainable buildings | 0.894 | | |
| Waste minimization | 0.823 | | |
| Enhancing safety | 0.795 | | |
| Facilitating harmonious relationships with other professionals | 0.736 | | |
| Improving the image of the construction industry | 0.643 | | |
| Improving the quality of construction project | 0.595 | | |
| Ensuring adequate construction planning, monitoring, and control | | 0.839 | |
| Encouraging seamless communication throughout the organization | | 0.810 | |
| Automation of site production activities | | 0.725 | |
| It encourages employee's participation in the decision-making process | | 0.668 | |
| Enhancing client satisfaction | | 0.661 | |
| Reducing errors | | 0.571 | |
| Improving communication among construction professionals | | 0.560 | |
| Time savings | | | 0.879 |
| Cost savings | | | 0.821 |
| On-time and on budget delivery | | | 0.636 |

### *D. Difference between Contracting and Consulting Organization on the Readiness to Adopt Construction 4.0 Concepts*

The analysis deploys Mann-Whitney U test, a non-parametric alternative of the Independent t-test, to carry out an inferential investigation on the difference between the contracting and consulting organization on the readiness to adopt construction 4.0 concepts. The results of the analysis are presented in Table VI.

TABLE VI
MANN-WHITNEY U TEST FOR SIGNIFICANT DIFFERENCE IN READINESS TO ADOPT CONSTRUCTION 4.0 BETWEEN CONTRACTING AND CONSULTING CONSTRUCTION FIRMS

| | Readiness to adopt construction 4.0 |
|---|---|
| Mann-Whitney U | 12.500 |
| Wilcoxon W | 33.500 |
| Z | -0.457 |
| Asymp. Sig. (2-tailed) | 0.647 |
| Remark | Not Sig. |

As depicted in Table VII, since $p<0.05$ (i.e. 0.03), at a 5% level of significance, a statistically significant difference was not found between contracting and consulting firms in the readiness to adopt. This means that all stakeholders within the construction industry are on par in the willingness to adoption of construction 4.0 for the construction industry.

## V. CONCLUSION AND RECOMMENDATIONS

The construction industry is one of the most dynamic and responsive industrial sectors of any economy. This is because it is vital for the social and economic development of all nations as a driver of the economic development providing an atmosphere where resources such as equipment, materials, labor, and capital are traded to create an infrastructure within an economy. Despite the industry importance to the country, activities within the construction industry are characterized with traditional approaches and little implementation of ICT that results in production of low quality infrastructure, thereby, affecting the overall performance of the construction industry.

This study proposes the adoption of construction 4.0 by construction industry professionals in order to improve the overall performance of the sector in South Africa. The concept of construction 4.0 was developed from industry 4.0, which represents the 4th industrial revolution, and which has thrived successfully in the manufacturing sector and entails the merging of the physical and virtual world using the Internet of Things, simulation and virtualization. This study recognizes that construction 4.0 will be driven by the need to create a smart construction site, as well as adopt simulation tools and virtualization for construction works. The study concludes that construction professionals in South Africa have a low awareness towards construction 4.0 principles but are ready to adopt it due to its benefits which include the development of sustainable buildings, better communication among construction professionals and elimination of construction project delays in the form of cost and time overrun.

The study recommends that stakeholders in the construction industry should take advantage of the construction 4.0 concept, and therefore, create more awareness. Also, investment should be made into research on the adoption of modern technologies and innovative ideas for the construction industry in South Africa. Finally, construction sector professionals should adopt a proactive thinking approach to their daily construction activities.

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## REFERENCES

[1] T. D. Oesterreich and F. Teuteberg, "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* Vol.83, No.10, 2016, pp. 121-139.

[2] CIDB, "Construction quality in South Africa, a client perspective," Retrieved on 13th September 2017 from https://bizconnect.standardbank.co.za/sector-news/construction/swotanalysis-of-the-construction-sector-in-south-africa.aspx, 2016.

[3] L. G. Tipili, P. O. Ojeba and M. S. Ilyasu, "Evaluating the effects of communication in construction project delivery in Nigeria" *Journal of environmental science and technology,* Vol.2, No.5,2014, pp.48-54.

[4] G. B. Shrestha and M. M Kumaraswamy, "Problems in Technology Transfer vs. Potential for Technology Exchange," *A Hong Kong construction perspective,* Vol. 2, No.3, 2011, pp. 23-34.

[5] S. Mak, "A model of information management for construction using information technology," *Automation in Construction*, Vol. 21 No.10, 2011, pp. 257–263.

[6] O. A. Olatunji, "Modelling the costs of corporate implementation of building information modelling," *Journal of Financial Management of Property and Construction,* Vol.16, No.1, 2011, pp. 211-23.

[7] P. L. Fernandes, "Advantages and disadvantages of BIM platforms on construction site," Retrieved on the 29th August 2017 from https://repositorio-aberto.up.pt/bitstream/10216/68980/2/26948.pdf, 2013.

[8] N. Thurairajah and D. Goucher, "Advantages and challenges of using BIM," Retrieved on the 1st September 2017 from consultant perspective. http://ascpro.ascweb.org/chair/paper/CPRT114002013.pdf, 2016.

[9] Y. Lu, "Industry 4.0 a survey on technologies, applications and open research issues. *Journal of industrial information integration Vol. 6, No.1, 2017, pp. 1-10.*

[10] M. Buss and M. White, "The rise of construction 4.0," Retrieved on the 1st September 2017 from https://www.youtube.com/watch?v=BBNbpq24m9o&t=2702s, 2016.

[11] D. Montgomery, "The future for construction product manufacturing. Digitalisation, industry and the circular economy," Retrieved on the 1st September 2017 from http://www.thefis.org/wp-content/uploads/2016/10/cpa-future-of-construction-product-manufacturing-report-2016.pdf, 2016.

[12] R. Antunes and V. Gonzalez, "A production model for construction: a theoretical framewok, "*Buildings, MDPI journals*, Vol.5, No.1, 2015, pp. 209-228.

[13] M. D. Mathonsi and W. D. Thwala, "Factors influencing the selection of procurement systems in the south African construction industry" *African journal of business management* Vol.6, No.10, 2012, pp. 3583-3594.

[14] R. Fischer, "Productivity in the construction industry," Unpublished BSc thesis submitted at the faculty of engineering, built environment and information technology at the University of Pretoria 2009.

[15] N. T. Adugna, "A study of causes of delay and cost overrun in office construction projects in the ethekwini municipal area, South Africa," Unpublished master thesis submitted to the faculty of Engineering and built environment at Durban university of technology South Africa, 2009.

[16] A. M. Costin and J. Telzer, "Fusing passive RFID and BIM for increased accuracy in indoor localization," *Visualization in Engineering,* Vol.3, No.17, 2015, pp 1-20.

[17] A. S. Fitchett, "Skills development and employment creation through small public buildings in south Africa," Retrieved on 12st September 2017 http://wiredspace.wits.ac.za/bitstream/handle/10539/7217/A%20Fitchett.PDF, 2009.

[18] S. Mbeki, "Causes, effects and impacts of shortage of skilled artisans on contractor productivity," Unpublished master thesis submitted to the department of construction management and quantity surveying Cape Peninsula University of Technology South Africa, 2009.

[19] N. Crampton, "Swot analysis of the construction sector in south Africa," Retrieved on 13th September 2017 from https://bizconnect.standardbank.co.za/sector-news/construction/swot-analysis-of-the-construction-sector-in-south-africa.aspx, 2016.

[20] M. G. Dzunisani, "Implementation of government housing delivery programme in the gravellote area of ba-phalaborwa municipality, "Unpublished master thesis submitted at the school of leadership University of Limpopo, 2011.

[21] PWC, "Highlighting trends in the South African construction industry. Retrieved on 12th September 2017 from https://www.pwc.co.za/en/assets/pdf/sa-construction-2015.pdf, 2015.

[22] B. Flyvbjerg, M. K. Holm and S. L. Buhl, "How common and how large are cost overruns in Transport infrastructure projects," *Transport Reviews*, Vol. 23, No. 2, 2003, pp 71-88.

[23] A. A. Olatunji, "Influence on Construction Project Delivery Time," University of Nelson Mandela Metropolitan University, and unpublished PhD thesis, 2009.

[24] A. Enshassi, S. Mohammed and J. Mosa, "Risk management in building projects: contractors' perspective," *Emirates Journal for Engineering Research,* Vol. 13 No.1, 2008 pp 29-44.

[25] A. Enshassi, S. Mohammed and S. Abushaban, "Factors affecting the performance of construction projects in the Gaza Strip," *Journal of Civil Engineering and Management,* Vol. 15, No. 3, pp 269-280.

[26] N. S. Priyadharshini and K. S. Satheesh, "Project communication is key to productive construction and its research needs in the future of construction engineering and management," *International journal of science, technology and management,* Vol.4, No.1,2015, pp 1493-1499.

[27] X. Li, Q. Li, W. Wu, and W. Wang, "Application of supply chain management in construction project," *proceedings of the national doctor research forum*, 21-23 Shanghai, China, 2007, pp 34-46.

[28] P. Nitithamyong and M. J. Skibniewski, "Web-based construction project management systems: how to make them successful," *Automation in Construction*, Vol.4, No.13, 2004 491– 506.

[29] K. Daniel and R. Muller, "Industry 4.0 and its impact on internationalization," Retrieved on 14th September 2017 from https://www.s ge.com/sites/default/files/cserver/static/downloads/S-GE_Whitepaper_Industry40_2016_final.pdf , 2016.

[30] V. H. Heynitz and M. Bremicker, "Industry 4.0 The factory of the future its challenges," Retrieved on 13th September 2017 from https://assets.kpmg.com/content/dam/kpmg/es/pdf/2017/06/the-factory-of-the-future.pdf, 2016.

[31] F. Zezluka, P. Marcon, I. Vesley and O. Sajid, "Industry 4.0 an introduction in the phenomenon," *IFAC-papers online* Vol.49, No.25,2016, pp. 008-012.

[32] R. M. Mahamood and E. T Akinlabi, E. T, "*Functionality graded materials mining, metallurgy and materials engineering*," Springers eleven edition, 2017.

[33] BDC, "Industry 4.0 the new industrial revolution are Canadian manufacturers ready," Retrieved on 13th September 2017 from https://bridgr.co/wp-content/uploads/2017/06/bdc-etude-manufacturing-en.pdf, 2016.

[34] J. M Sardroud, "Influence of RFID technology on automated management of construction materials and components," *Science Iran,* Vol. 19, No.3, 2012, pp.381-392.

[35] J. Morrissy and Mansfield, "BIM best thing since sliced bread," Retrieved on the 1st September 2017 from https://www.dlapiper.com/~/media/Files/Insights/Publications/2012/01/BIM%20%20Best%20thing%20since%20sliced%20bread/Files/Engineering_Construction_Legal_Upate_BIM_31_Janu__/FileAttachment/Engineering_Construction_Legal_Upate_BIM_31_Janu__.pdf, 2012.

[36] W. Shahzad, J. Mbachu and N. Domingo, "Marginal productivity gained through prefabrication building projects in Auckland," Buildings, Vol. 5, No. 1, 2015, pp.196-208.

[37] F. E. Boafo and J. Kim, "Performance of modular prefabricated architecture case study based review and future pathways," Sustainability, Vol. 8, No. 1, 2016, pp.1-16.