Exploring the Adoption of Digital Technology at the Different Phases of Construction Projects in South Africa

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Abstract

The study aimed at having a review of the adoption of digital technologies in the South African construction industry with particular emphasis on the awareness of the various digital technological innovations, their applicability at the different stages of construction processes and the extent of usage at the different stages was equally considered. The research area for the study is Gauteng Province, South Africa, while quantitative approach was deployed with the aid of questionnaire survey. Respondents for the study are construction professionals comprising of Architects, Quantity Surveyors, Builders and Engineers. Analysis was carried out with appropriate statistical tools. Findings from the study revealed that Internet of Things (IoT) and Sensors are the digital technologies mostly deployed in construction processes, while generally there is a low adoption of digital technologies for construction projects. Equally revealed is that the design/engineering phase has the highest level of awareness and usage of digital technologies among the different phases of construction projects. Conclusively, the study emphasized the need for the adoption of digital technology at all the phases of construction projects as the potential benefits to be accrued are immense.

Keywords
Digital Technologies, Construction Industry, Construction Phases, South Africa

1.0 Introduction
There have been calls for the improvement on the delivery processes in construction activities. Perennial issues like cost overrun, delays, poor quality delivery, health and safety issues, underperforming projects have continued to plague the construction industry (Sultan and Kajewski, 2013; Fischer, 2009; Flyvbjerg *et al*., 2003; Mustapha *et al*, 2013). The construction industry is an ideal candidate for a step change due to its reoccurring problems like lack of certainty (in terms of quality, delivery date or cost), relatively poor productivity in comparison with other sectors, inadequate client satisfaction and inefficiencies as a result of out of date processes (Kamara *et al*., 2010). There have been spirited efforts to abate these problems posed to the construction industry over the years, yet the issues still persist. Taking into cognizance the need to improve on construction processes and delivery as well as the importance of the industry to the economy of any nation, there is an urgent need to adopt a redirection of the methods and ways of carrying out activities in the industry. One of such steps is the incorporation of digital technology in the processes of construction activities.

There has been an upsurge in the adoption and application of digital technology to processes like industrial systems and basic human activities in recent times. Industries such as manufacturing, banking, health and medicals have all embraced multidimensional approaches to the adoption of digital technology while the construction industry is still on the back foot (McKinsey, 2016). Some of the challenges posed to the construction industry are a resultant of its inflexible nature in embracing new methods and technological innovations. The construction industry can attain efficiency, effectiveness and creating a window of opportunities through the adoption of digital technologies (Building Radar, 2015). Digital transformation such as adopting new digital technologies can make the global construction industry save approximately $1.7 billion yearly (Sutton, 2018). According to a report on digitization by McKinsey (2016), the construction industry is ranked 21st out of 22 industries regarding digital technologies adoption. Simu (2016) asserted that the reputation of the construction industry about cost and time overrun can be improved if digital technologies are adopted. Hampson *et a*l. (2014) opined that the construction industry compared to other industries has only reached half of the efficiency improvement and this has been done in 50 years. This clearly depicts the slow adoption of new digital technologies in the industry.

The South African construction industry is not exempted from the inherent challenges facing the industry globally. Developing countries have a lot to deal with in terms of ensuring that most of these challenges are tackled wholly. In the category of developing countries in the world, the construction industry in South Africa is not among the least performers even though it is still posed with the hurdles which inhibit its service delivery processes (Emuze and Smallwood, 2011). Adopting digital technology in the processes of construction can go a long way in aiding the industry overcome these shortcomings. As outlined by CIDB (2011), the adoption of new digital technologies in the Construction Industry in South Africa can help the construction industry by increasing the employment rate; hence contributing strongly to the country's Gross Domestic Product (GDP). Since digitization in South Africa is on a maturity level (Dall'omo, 2017), the task of successfully incorporating it into the processes of construction should be highly encouraged. It is on this premise this study intends to ascertain the awareness of the various digital technological innovations deployed in construction processes, its applicability at the different stages of construction processes and the extent of its usage at the different stages.

2.0 Literature Review

2.1 Digital Technologies in Construction

One important technological tool deployed for construction projects is Building Information Modeling (BIM). Jensson (2017) defines BIM as a digital representation of functional and physical characteristics of a facility in two different aspects. The first aspect of BIM being a tool to help in minimizing information gap by developing and using a digital model, the second aspect of BIM is to store the model information throughout its life cycle. According to Succar (2009), BIM is a set of different technologies, policies and processes that helps managing design and project data on a digital format during its life cycle. Moreover, physical characteristic of a building refers to the design of the model that you can see i.e. the components of the model as a whole whilst functional characteristics are the functions that can be performed by the building such as cooling system, plumbing system, electrical system, etc. Models created with BIM have different dimensions of information. BSI (2018) categorizes BIM into 4 levels of maturity. BIM level 0: includes 2D CAD drafting but no collaboration; BIM level 1: involves a 3D concept work and 2D for drafting of statutory approval documentation, electronic sharing of data but no collaboration between parties; BIM level 2: collaboration is allowed, and data is exchanged between parties; BIM level 3: full collaboration between all the disciplines. Lee *et al*., (2016) stated that the practicability of 5D BIM, categorized time as the 4^{th} dimension of BIM (4D BIM) and cost as 5^{th} dimension of BIM (5D BIM). BIM has more advantages over using traditional 2D approaches to design and construct such as increased utility and speed, increased collaboration, improved fault finding, overall increased productivity, a better visualisation of data, minimizing disputes, facilitating collaboration, increasing efficiency all together which result in increased productivity for the construction sector. Ganah and John (2014) portrayed BIM benefits in a comparative form with the traditional system, 3D simulation against 2D design, accuracy of quantities against estimation of quantities, efficiency of construction against redundancy construction.

The adoption of Internet of Things (IoT) in construction projects has been of immense benefit. Ernst and Young (2016) described IoT as a tool that enables the connection of any device to the internet using embedded software and sensors to communicate, collect and exchange data. The Internet Telecommunication Union (2012) defines IoT as "a global infrastructure for the information society, enabling advanced services by interconnecting (virtual and physical) things based on, existing and evolving, interoperable information and communication technologies". Regarding its benefits, Saxena (2015) stated that the key benefits of IoT are data collection, tracking, time and money. Gromov (2015) noted that the adoption of IoT by construction companies is highly hindered due to the gap in knowledge on its applicability in construction processes and as well construction companies did not have a vision on how IoT could be valuable for the construction industry. In recent times Augmented Reality has gained recognition in construction processes. Rajaana *et al*., (2012) stated that Augmented Reality entails the process of combining real world objects with virtual components with the aim of the user being unable to distinguish the change in the real world. As for its usage, Azuma (2010) listed potential classes of AR application and amongst them construction industry disciplines can be found such as repair and maintenance. Zollmann *et al*., (2014) suggested the use of AR in combination with aerial 3D reconstruction to help monitoring site more effectively. Wang *et al*., (2007) encouraged the adoption of Augmented Reality in the construction industry to improve on construction projects delivery.

Robotics and automation have received wide spread focus with respect to its application in construction processes. Ruggiero *et al*. (2016) in trying to outline the implementation of robotics defined robotics as a synchronous combination of mechanical, electrical and software engineering. Further stating that the benefits of the adoption of robotics in construction are the microscopic precision and delivering of high quality results. Equally, the study listed the available robots in the construction industry as follows: demolition robots, 3D printing robots, drones, bricklaying robots, welding robots, forklifts robots, and many more. The input of robotics in the construction industry will have an impact on different methods and processes involved in the construction of different types of buildings (Kim *et al*., 2015). Sköld and Vidarsson (2015) analysed the potential of 3D printing in the construction industry stating that 3D printing is a technology that can be used in different industries such as manufacturing, automobile and medical industry but the case is different for the construction industry due to the technology being relatively young and the small amount of studies that have been conducted for the use of 3D printing in the construction industry. Foy and Shahbodaghlou (2015) asserted that even though the 3D printing industry is growing it is still difficult to confirm when the construction industry will implement it. However, the study stated that at the present time the use of 3D printing technology in the construction industry is effective with some contractors and it is used with BIM to print models. Oberti *et al*., (2015) declared that if 3D technology (Additive Manufacturing) is implemented in the construction industry it will revolutionize the construction process. Waste can be decreased, faster delivery can be achieved, and accurate construction can be possible.

Kardasz *et al*., (2016) studied drones and possibilities of using them in the construction industry and defines drones as a remotely controlled aircraft having the ability to fly without a pilot and passenger on board and without specifications in size. The use of drones in the construction industry to help manage construction sites, roads and railways as drones collect data more accurately (PWC, 2018). The benefits of the use of drones in the construction processes during different stages of construction are evident as PWC (2018) affirmed that construction sites monitored by drones have successfully reduced life-threatening accidents by 91%. Big data is currently being championed in the construction industry for its overwhelming importance considering its adoption in other industries. Ismail (2018) defined big data as a combination of velocity, volume and variety of data. Volume representing the size of the data generated from the human interactions, network and advanced technologies (Chen and Zhang, 2014). While velocity epitomizes the high speed at which data is produced as against the conventional systems (Zikopoulous *et al*., 2012). And lastly, variety refers to the diversity and complex nature of data categories and sources (Ozkose *et al*., 2015). Regarding its impacts and benefits, Zakir et al. (2015) stated that even though the use of big data technologies is still at an embryonic, its impact cannot be neglected. Sørensen *et al*., (2016) listed the benefits of using big data in construction management. Bilal et al. (2016) stated that construction data is relatively big due to large volumes of design data, schedules, financial data, etc. The study also explained how big data can bring many benefits in the construction industry and how it can be combined with different digital technologies such as Building Information Modelling (BIM), Augmented Reality (AR), Internet of Things (IoT), etc.

2.2 Adoption of Digital Technologies at Different Construction Phases

The adoption of digital technologies in the life cycle of construction projects can be viewed from three broad views which are Design/engineering phase, Construction phase, Operation and maintenance phase (Aghimien et al, 2018, Gerbert *et al*., 2016).

The design/engineering phase of a construction project consists in assisting the client in selecting material to be used, type of building and for the design team to ensure that the building meets the regulations of the proposed site by creating descriptions and specifications of a new facility represented in a form of plans (Ilveskoski, 2015). During the design/engineering phase, BIM and Computer Aided Design software are highly encouraged as it fosters a compact working unit among the professionals making up the design team. BIM has an early impact on the project design and construction teams as it enhances collaboration. This makes the construction process to become faster, less costly, more reliable and less prone to errors and risks (Eastman, 2011). The use of BIM during the design and engineering stage helps identifying potential design clashes and constructability issues, then helping reduce costly corrective rework, also helps improving the tendering stage by making information readily available and accessible to participants of the design and engineering stage. This means that by adopting digitalisation in the design and engineering stage of a construction project, efficiency can be increased on the design stage and tackle the cost and time overrun that is generally linked to design errors (Castagnino et al., 2016).

Castagnino et al. (2016) illustrated the use of digital technologies during the construction phase of a Crossrail project, which is one of the most complex infrastructure projects. Drones were used during the actual construction phase for inspection and surveying the construction site. Some materials were prefabricated using 3D printers while material and inventory checks were done using radio frequency identification (RFID) and GPS tracking. Robots and autonomous vehicles were used during the project. This project itself shows the involvement and importance of implementing digital technologies at the construction phase. Castagino *et al*., (2016) encouraged the use of digital technologies during the operation phase of construction projects, sensors can be placed in strategic places when building to check deterioration, ease predictive maintenance and updating a database. Trevik and Nilsson (2017) in a study on digitalisation on facilities management stated that there is a low adoption of digital technologies during the operation and maintenance phase of construction projects. Embracing digital technologies during operation and maintenance phases of construction projects will enhance good management of facilities and increase health and safety during maintenance phase.

3.0 Research Methodology

The study explored the adoption of digital technologies and also the awareness of its applicability at the various construction phases. Quantitative method of research was deployed for the study while the study area was, Johannesburg in Guateng Province, South Africa. Construction professionals made up the targeted population, and this comprised of Construction Project Managers (CPM), Architects, Quantity Surveyors (QS), Engineers and Construction Managers (CM) in the construction industry or academics that have previously done research on digital technology in the South African construction industry. Questionnaire was the instrument deployed for the collection of data. This was divided into two sections. The first section aimed at the information background of the respondents, while in the second section respondents were asked to rank the digital technologies deployed in construction processes based on their level of awareness of its deployment. This section equally gave the respondents the avenue to rank these digital technologies based on the extent of usage in construction processes. A 5-point Likert scale was employed, with 5 being very high, 4 being high, 3 being average, 2 being low and 1 being very low. A total of eighty-four (84) questionnaires were distributed while fifty (50) were returned and deemed fit for analysis. Methods of data analysis adopted for the study includes percentages, frequency, mean item score and standard deviation.

4.0 Findings and Discussion

4.1 Background Information

The demographic information of the respondents indicates that 20% of the respondents are attached to government establishments while 46% affiliated with contracting outfits and lastly 34% with consulting firms. Also, 70% of the respondents have worked for a period of 0-5years while 20% have 6-10years working experience and lastly 8% and 2% have worked between 11- 15years and more than 15years respectively. 81% of respondents have been privy to use digital technology in construction while 19% admitted not have used digital technology in the course of executing construction projects.

4.2 Digital Technologies Adopted for Construction Projects

Table 1 indicates the digital technologies that are adopted in the construction industry. With a 5-point Likert scale of very low to very high, the respondents were requested to which level of involvement some digital technologies are in the construction industry. The results were ranked from 1 – 8 from the strongest to the weakest respectively. Internet of Things was ranked first with (MIS=3.00, SD=1.325, R=1) followed by sensors (MIS=2.76, SD=1.238, R=2), drones (MIS=2.74, SD=1.192, R=3), augmented reality (MIS=2.64, SD=1.102, R=4), 3D printing (MIS=2.58, SD=1.108, R=5), big data (MIS=2.56, SD=1.163, R=6), automation and robotics (MIS=2.52, SD=1.111, R=7) and building information modelling was ranked last (MIS=2.46, SD=1.110, R=8).

Table 1. Digital Technologies Adopted in the Construction Industry

	Mean	Standard Deviation	Rank
Internet of things	3.00	1.325	1
Sensors	2.76	1.238	2
Drones	2.74	1.192	3
Augmented reality	2.64	1.102	4
3D printing	2.58	1.108	5
Big data	2.56	1.163	6
Automation and robotics	2.52	1.111	7
Building Information Modelling	2.46	1.110	8

4.3 Awareness of the Adoption of Digital Technologies at Various Stages of Construction Projects

Table 2 shows the level of awareness of adoption of digital technologies at various stages of construction projects. A 5-point Likert scale of very low to very high, the respondents were requested to which extent they are aware of the adoption of digital technologies at various stages in project delivery. The results were ranked from 1 – 4 from the strongest to the weakest respectively. Design/Engineering phase was ranked first with (MIS=3.38, SD=0.967, R=1) followed by construction phase (MIS=3.12, SD=0.961, R=2), operation and maintenance phase (MIS=3.02, SD=0.915, R=3), pre-design phase was ranked last (MIS=3.00, SD=0.881, R=4).

Table 2. Awareness on Level of Digital Technology Adoption

	Mean	Standard Deviation	Rank
Design/Engineering phase	3.38	0.967	1
Construction phase	3.12	0.961	2
Operation and maintenance	3.02	0.915	3
Pre-design phase	3.00	0.881	4

4.4 Extent of Usage of Digital Technologies at Various Stages of Construction Projects

Table 3 shows the extent of usage of digital technologies at various stages of construction projects. A 5-point Likert scale of very low to very high, the respondents were requested to which extent they make use of digital technologies at various stages in project delivery. The results were ranked from 1 – 4 from the strongest to the weakest respectively. Design and engineering phase was ranked first with (MIS=3.12, SD=0.824, R=1) followed by construction phase (MIS=3.06, SD=0.935, R=2), pre-design phase (MIS=3.04, SD=0.880, R=3), operation and maintenance phase was ranked last (MIS=2.84, SD=1.076, R=4).

Table 3. Extent of Usage of Digital Technology

	Mean	Standard Deviation	Rank
Design/Engineering phase	3.12	0.824	1
Construction phase	3.06	0.935	2
Pre-design phase	3.04	0.880	3
Operation and maintenance	2.84	1.076	4

4.5 Discussion

Findings from the study revealed that the digital technology mostly adopted during construction processes are Internet of things (IoT) followed by deployment of sensors in construction processes. Building Information Modeling (BIM), Automation and Robotics and Big Data are the least deployed. Equally revealed is the low adoption of the highlighted digital technologies for construction processes, with most of them having a mean score below 3.00. This corroborates the assertion of Hampson *et al*., (2014) which states that the construction industry compared to other industries has only reached half of the efficiency improvement as result of non-involvement of technological innovations in its processes. Findings also showed that there is low awareness of the deployment of technological innovations at the various stages of construction projects. This is in consonance with the study of Fengi (2006) asserting that the low awareness of Information Technology in the construction industry is a major hindrance to optimizing processes.

Result from the study equally indicates that with respect to the level of awareness of the adoption of digital technologies to the different phases of construction, the Design/Engineering phase comes tops. This is closely followed by the Construction phase. While the phases lagging behind are Pre-design and Operational/Maintenance phases. This stance is in affirmation of Trevik and Nilsson (2017) stating that there is a low adoption of digital technologies during the operation and maintenance phase of construction projects. The extent of usage of digital technologies at the different stages of construction as shown by the study reveals that it is mostly deployed at the Design/Engineering phase followed by the Construction phase, while the stages with the least deployment are Operation/Maintenance and Pre-design phases. The study of Aghimien *et al*., (2018) corroborates this view outlining that digital technologies are only adopted at the early phase of construction in the South African construction industry. Likewise, Jung and Lee (2015) affirmed that there is a low adoption of digit innovations in maintenance of construction facilities in most African countries.

5.0 Conclusion

The study explored the adoption of digital technology in the South African construction industry with emphasis on the level of awareness and extent of usage at the different phases of construction projects. Based on the findings, the study concludes that the awareness level of digital technology in the construction industry is low, it is imperative to note the importance of adopting new digital technologies in the construction industry as it bears tremendous benefits. The awareness of the various digital technological innovations available for use in construction processes is quite low which has in turn brought about a low patronage of such innovations. Efforts need to be made by various stakeholders ranging from government agencies to professional bodies to always sensitize construction professionals with recent technological innovations. Equally, the manufacturers and patent custodians should adopt revolutionary marketing strategies to aid construction stakeholders in getting acquainted with these technological innovations. The study has revealed that digital technologies are adopted more during the design and engineering phase by the aid of designing software, it is important to note that adopting digital technologies throughout the lifecycle of a project is necessary as the benefits accrued are not limited to the design stage alone but all stages. Adopting digital technologies during the lifecycle of a project has proven to be beneficial not only for the building itself but for all the stakeholders and occupants of the facility during use.

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