

Benefits of the adoption of digital technologies on South African construction projects

Micayla Prozesky¹, Shweeta Arquissandas Bagoandas¹, Amanda Mtya¹
and Abimbola Windapo¹

Department of Construction Economics and Management, Faculty of Engineering and the
Built Environment University of Cape Town

PRZMIC001@myuct.ac.za; ARQSHW001@myuct.ac.za; amanda.mtya@uct.ac.za;
abimbola.windapo@uct.ac.za

Abstract:

The construction industry has been noted to be the only industry with the least technological advancements, while other sectors are reaping the benefits. The construction industry is facing a lag in productivity on construction projects which could be solved through the implementation of digital technologies. The research focusses on the current adoption of digital technologies on South African construction projects and their effect on productivity. A case study research design was employed, where construction projects that met the criterion were reviewed through interviews with the responsible construction professionals. The digital technologies that were adopted on the projects were identified. The effect on cost, time and quality due to the adoption of the digital technologies was noted and the data obtained was analysed using a thematic data analysis technique. A cross-case analysis, as well as existing literature, were used in validating the information collected from each case study. The results revealed that digital technologies are used on construction projects in South Africa. Although the adoption varies from project to project, it emerged that more benefits are realised on construction projects with a higher level of adoption of digital technologies. The study found that the adoption of digital technologies on South African construction projects leads to an increase in project productivity, time and cost-savings. Based on these findings, the study concludes that construction projects which use digital technology will have higher productivity and lower cost and time overruns.

Keywords: Cost, digital technology, level of adoption, productivity, quality, time

1 Introduction

Digitisation is an advancement in technology that is accelerating the pace of change. This is seen through companies in different industries that are benefiting from digitisation (Laczkowski *et al.*, 2018). Despite the availability of these technologies, the construction sector is experiencing a 30% productivity gap which can be traced back to gains from the implementation of digital technology (Laczkowski *et al.*, 2018).

Furthermore, researchers have found that there is low productivity in the construction industry and construction projects, and view that the levels of productivity will be improved on construction projects and the industry with the adoption of digital technologies (Enshassi *et al.*, 2007; Pan *et al.*, 2016; Barbosa, Woetzel, *et al.*, 2017; Seadon and Tookey, 2019). However, there is limited research into understanding the level of adoption of digital technologies in the

South African construction industry. Previous studies mainly examined the barriers to adoption and benefits of digitalisation (Chan & Kumaraswamy, 1997; Peansupap & Walker, 2006; Emmanuel *et al.*, 2018). Therefore, this research examines the level of adoption of digital technologies in the South African construction sector towards determining whether the application of these technologies increases productivity on construction projects. The research objectives are to establish the current level of adoption of digital technologies by construction companies, in South Africa, including their level of productivity on construction projects. Lastly, the study establishes how the use of digital technologies affects time, cost and quality on construction projects.

2 Literature Review

Many articles and studies conducted on digital technology adoption in construction projects, both locally and internationally, have been reviewed. Firstly, the low productivity performance in the construction industry was highlighted by Changali *et al.* (2015); Blanco *et al.* (2016); Marks (2017). Reasons for the low productivity within the construction industry is due to many factors such as lack of coordination, undefined roles and responsibilities, reliance on hard copy documentation and lack of digital adoption (Chan & Kumaraswamy, 1997; Changali *et al.*, 2015; Agarwal *et al.*, 2016; Blanco *et al.*, 2016). Both Laczkowski *et al.* (2018) and Marks (2017) similarly believe the foremost reason for the stagnation within the construction industry is due to insufficient investment in technology by firms.

2.1 Types of digital technologies in use in the construction industry

Digital technologies identified throughout the studies conducted globally were summarised into ten technologies. These were Building Information Modelling (BIM), 3D and 4D Simulations, Virtual Reality (VR), AutoCAD/Revit, WinQS, GIS/GPS, Radio Frequency Identification Technology (RFID), Navisworks, Information Communication Technology (ICT) and E-Procurement (Peansupap & Walker, 2006; Ahuja *et al.*, 2009; Lu *et al.*, 2011; Costin *et al.*, 2012; Kekana *et al.*, 2015; Merschbrock & Munkvold, 2015; Barbosa, Woetzel, *et al.*, 2017). A total of 12 research papers and studies were found specifically on the adoption of BIM (Froise, 2014; Changali *et al.*, 2015; Kekana *et al.*, 2015; Merschbrock & Munkvold, 2015; Agarwal *et al.*, 2016; Blanco *et al.*, 2016; Ezeokoli, Okoye, *et al.*, 2016; Fang *et al.*, 2016; Barbosa, Mischke, *et al.*, 2017; Barbosa, Woetzel, *et al.*, 2017; Ayinla & Adamu, 2018; Wolf, 2018). These were conducted both globally by Merschbrock & Munkvold (2015) and Agarwal *et al.* (2016) as well as locally by Kekana *et al.* (2015). The adoption of AutoCAD and Revit was studied by Ibem & Laryea (2014); Kekana *et al.* (2015) in the context of both the Nigerian and South African construction industry respectively.

2.2 Level of adoption of digital technologies

Analysing various measures of the level of adoption was conducted through literature review. The measure of the level of adoption of BIM is noted through a study conducted by Ayinla & Adamu (2018) was by creating a composite model of the Bew -Richard BIM maturity model and the Singh and Holmstrom technology adoption model. The Bew – Richard BIM model divides the levels of adoption into four levels; level 0 can be described as the pre-BIM stage while level

3 stage is where a fully integrated system is in use and is interoperable without any data loss (Ayinla & Adamu 2018). Furthermore, the Singh -Holmstrom technology adoption model analyses the time of adoption and classifies it into five groups. The groups can be categorised into laggards, late majority, early majority, early adopters and innovators (Singh & Holmström, 2015). Similarly, Bin Zakaria *et al.* (2013) conducted a study on the adoption of BIM within the construction industry. A qualitative analysis method was chosen to determine the level of adoption and conducted through semi-structured interviews. Bin Zakaria *et al.* (2013) noted the difficulty involved in analysing qualitative data and therefore used a coding system to organise and categorise quotes and data. Lastly, Bin Zakaria *et al.* (2013) used a mapping analysis approach to find out the relationships between the various categories of BIM adoption. Furthermore, the level of adoption of ICT in the Indian construction industry was established in a study conducted by Ahuja *et al.* (2009).

2.3 Drivers of digital technology adoption on construction projects

Team adoption was observed to be one of the main drivers to digitalisation in the construction industry. Blanco *et al.* (2019) stated that the strategy to adopt new technology is from the top-down. The support of top management plays a key role as the support is essential for the development of infrastructure and the people in regards to the adoption of ICT within the organisation (Peansupap & Walker, 2006). Moreover, adequate training of employees was also noted to drive the adoption of digital technology. Ezeokoli, Okolie, *et al.* (2016) pointed out within the South African context that training on digital technology tools is one of the leading influencers of the adoption of digital technology. Similarly, Peansupap & Walker, (2006) state that a critical motivator in the use and adoption of digital technology is where people's knowledge is developed of how to successfully apply ICT and how it would support their work practices.

Small-scale pilot strategies, according to Peansupap & Walker, (2006) is said to drastically overcome the barriers to investment in IT technology, therefore also becoming a primary driver of adoption. The acceleration of adoption is done through governments by implementing five simple measures suggested by Blanco *et al.* (2019). The first would be to set bold aspirations. Secondly, create meaningful incentives such as providing additional financial support for first adopters. In addition to incentives, the third suggestion would be for governments to help reduce the risks and barriers that develop due to the emerging technology. Blanco *et al.* (2019)'s fourth suggestion is to ensure transparency – in both cost and progression. The progress of large projects relies on real- time information through digital technology which requires transparency. The fifth and final suggestion would be to build capabilities. Low skilled labourers are prominent within the construction industry, and according to Blanco *et al.* (2019) government investment in training programs will overcome these issues.

2.4 Barriers to digital technology adoption on construction projects

Underinvestment in IT and technology more broadly was observed by Blanco *et al.* (2016) and Marks (2017) as key barriers to digital technology adoption on construction projects. The studies conducted recognised that the failure to adopt new technology was one of the main internal challenges to improving productivity. The lack of confidence in the benefits within the innovations results in the absence of senior management support. This leads to underinvestment

in IT and technology more broadly (Blanco *et al.*, 2016). According to Marks (2017), the fragmentation of the digital technology offerings will continue to be a area and is another significant hurdle the construction industry is faced with. Blanco *et al.* (2016) submit that the immature development of technology is the cause of fragmentation as many programs perform a particular task and provide a specific solution, but lack integration problematic area and is another significant hurdle the construction industry is faced with. Companies are found to engage in technological solutions that only address one specific problem instead of an integrated solution across the three main areas of construction (Blanco *et al.*, 2018).

Another barrier noted within literature is technology adoption gaps. The first gap is the lack of technological awareness which influences investment decisions. Many senior managers are unaware of the potential innovation benefits that lie behind the adoption of IT (Peansupap & Walker, 2006). This lack of technology awareness will also obliterate their outlook upon an investment opportunity. The knowledge of digital systems and lack of training is a global barrier as revealed by Chan & Kumaraswamy (1997); Peansupap & Walker (2006); Emmanuel *et al.* (2018).

2.5 Impact of digital technology on productivity

Through a study by Hartmann *et al.* (2008), an analysis of five case studies and the impact of 3D and 4D models on aspects such as design, costing and construction was conducted. The conclusions of the study revealed a 60% decrease in design requests, 80% of respondents reported time-saving when the 3D models were used for cost. This is noted to have a significant impact on productivity with regards to the adoption of digital technology.

A moderate impact of digital technology adoption was noted by Costin *et al.* (2012) through a case study conducted on the impact of RFID technology. Costin *et al.* (2012) compared the expenses to implementing this technology to the savings made by identifying poor productivity in the workforce. A deduction of a 2.2 minimum Return on Investment (ROI) from the study was made and stated that the return would be higher if used in future projects (Costin *et al.*, 2012). Implementations of GIS/GPS was studied by Li *et al.* (2005) on the construction of a waste plant in New Zealand. The conclusion reached was that the investment in the GIS/GPS increased costs in comparison to the non- integrated system, but further utilisation in the future may decrease the costs thereof (Li *et al.*, 2005). This resembles a negative impact on the implementation of digital technology. Within South African literature, challenges of digital collaboration and ICT were conducted by Ezeokoli, Okolie, *et al.* (2016); Ozumba and Shakantu (2018).

Further, the general understanding of BIM (Kekana *et al.*, 2015) and Catalyst of BIM (Froise, 2014) was also conducted in the South African construction industry context. However, there was no study of the impact of the implementation of digital technology on productivity was found in literature, within the South African context. This has led to an interest in researching further and determining the impact of digital technology on construction productivity.

3 Research Methodology

The aim and objectives of the research were achieved by adopting a qualitative research approach using interviews as the method of data collection. A qualitative research approach was

adopted due to the nature of data required to be collected and the importance of the participants' perspective in the data. A multi-case study research design was followed using semi-structured in-depth interview of professionals that were targeted based on their knowledge on the implementation of digital technologies on the construction projects that were studied. A multi-case study research design was best suited for this research study because the researchers focused on each project to get an understanding of how these technologies brought about changes in productivity. Also, because one source of data may not reflect the range of digital technologies adopted on construction projects. The projects studied were identified using a purposive sampling technique. Although the reliability of primary sources of data may be called into question due to the subjective nature of the data, the criteria for selection of the case studies were that the project should be based in Cape Town with a contract value of R4 million or more. Also, digital technology must have been implemented on the project.

Interviews with construction professionals on the construction projects that met the criteria set for the selection of case studies were used in obtaining primary data. An inductive approach was used in data analysis; the framework for the research was developed through the data that was collected. Thematic data analysis which is a commonly used inductive approach to data analysis was employed. To do this, the textual data collected from interviews were first transcribed, various themes and categories were developed, like terms found in the data were grouped to reduce unnecessary information by crossing out repetitions and similar data (Burnard, 1996). The phases described by Braun and Clarke (2006) were followed in the study to analyse the reduced data.

To analyse and determine the level of adoption, interviews were conducted on various project managers where questions were directed to their use of ICT, benefits, barriers and industry drivers. Following this, a Likert scale was used to aid the analysis of the qualitative perceptions obtained from the interviews following an earlier study conducted on the adoption of ICT undertaken by Peansupap & Walker (2005) who determined the adoption level of ICT, using a mixed-method research approach. The data obtained was analysed using a cross-case analysis. The projects under study were compared by uncovering the digital technologies adopted and examining how their adoption affected time, cost and quality, thereby understanding their effect on the productivity of construction projects. The level of adoption of the digital technologies in the cases studies determined using a seven point Likert Scale is shown in Table 1 where 1 represents no adoption and seven represents excellent adoption following a previous study done by Ahuja *et al.* (2009).

Table 1. Likert Scale of the level of adoption

Likert Scale of the level of adoption		
No. of stages		Rating:
1		No adoption
2	x	Poor adoption
3	xx	Below Average adoption
4	xxx	Average adoption
5	xxxx	Above Average adoption
6	xxxxx	Good Adoption
7	xxxxxx	Excellent Adoption

4 Findings and Discussion

The study is specific to the South African construction industry, which is known to have low levels of productivity and a sluggish approach to the adoption of digitalisation. An interview-conducted with AEC professionals was used to establish what digital technologies are used in South Africa and how their level of adoption affects productivity (time, cost and quality) within the industry.

The projects under study are Case Study 1, Case Study 2 and Case Study 3. Case Study 1 (CS1) is a 36 storey mixed-use development and is going to be Cape Town's tallest residential tower, with street-level retail space and elevated apartments on floors 12 to 36. Case Study 2 (CS2) is located just off the R43 between Worcester and Ceres and consists of two phases. The first phase was the construction of a chapel which was completed in March 2017, and the second phase is the construction of a school, creche and aftercare facilities. Case Study 3 (CS3) is a two-storey residential development located in Higgovale Cape Town, with an estimated contract value of R9 Million.

The three case studies as seen in Table 2 have only one digital technology that all the projects have implemented, and that is Revit. The other digital technologies are either found in two case studies or only one case study. Digital Technologies found in two case studies are Navisworks, Synergy, Lumion, CCS, Drones and HD Cameras. Those found in only one case study are BIM, Snag R, AutoCAD, Sketch-Up, Photoshop, Enscape, and VR. Also noted in Table 2 is that CS1 and CS2 have more similar digital technologies in common than they do with CS3. CS1 and CS2 have Revit, Navisworks, Synergy, CCS, Drones and HD Cameras in common.

Table 2. Common Occurrences found in the Case Studies

Common Occurrences			
Themes	Case Study 1 (CS1)	Case Study 2 (CS2)	Case Study 3 (CS3)
Digital technology adopted	Revit	Revit	Revit
	BIM	-	-
	Navisworks	Navisworks	-
	Synergy	Synergy	-
	-	-	Google Drive
	-	AutoCAD	-
	Lumion	-	Lumion
	CCS	CCS	-
	-	Sketch Up	-
	-	-	Enscape
	-	Photoshop	-
	Snag R	-	-
	-	-	VR
	Drones	Drones	-
	HD Camera	HD Camera	-
Level of adoption	Design	Design	Design
	Construction	Construction	-
Performance	Time-Saving	Time-Saving	Time-Saving
	Cost Saving	-	-

Table 2 also shows that the level of adoption of digital technology is limited to the design and construction phase, although in CS3, the adoption was limited to the design phase. And regarding performance, time-saving was the main benefit noted from the implementation of digital technology, although in CS1 cost-saving was also noted. The results also revealed that a total of 14 digital technologies are used in the industry among the participants interviewed. From these technologies, Revit, Navisworks, and Synergy were the three highest adopted technologies respectively. Further, the analysis of their effects on productivity was deduced from the responses of the participants interviewed, which further revealed Revit and Navisworks having the greatest effect.

Using the Likert Scale developed for the research the data collected from each case study were analysed, the results are shown in Table 3. The analysis shows that the Revit software was used across all six stages of project development for both CS1 and CS2 and is described as an "excellent" level of adoption. In comparison to CS3, which only adopted Revit over four stages of the project development, classified as an "above average" level of adoption. Similarly, for the use of AutoCAD by CS2, an "excellent" level of adoption is recognised. Furthermore, the analysis of the level of adoption of Navisworks between CS1 and CS2 is noted to obtain two different levels. For CS1, Navisworks was adopted only in the Design Development and therefore obtains a rating of "poor adoption". While CS2 chose the use of Navisworks in both the Design and Development stage and the Documentation and Procurement stage resulting in an "average" level of adoption. The cloud-based storage tool, Synergy, was similarly adopted by both CS1 and CS3. Each project only used Synergy in the Construction stage and consequently obtaining a "poor" adoption level. The level of adoption of CCS, the programme for contractors is "averagely" adopted amongst CS1 and CS3, both using it across the last three stages of the project development. Similarly, Lumion is also employed by CS1 and CS3 and equally adopted over two phases. This leads to a rating of "poor" level of adoption.

Table 3. Level of adoption of digital technologies and their effect on performance

Technology	Case Study 1	Case Study 2	Case Study 3
Revit	"excellent"	"average"	"excellent"
AutoCAD	"no adoption."	"excellent"	"no adoption."
Navisworks	"poor"	"below average."	"no adoption."
Synergy	"poor"	"no adoption."	"poor"
CCS	"average"	"average"	"no adoption."
Lumion	"below average."	"no adoption."	"below average"
Drones	"no adoption"	"no adoption"	"no adoption"
HD Camera	"poor"	"poor"	"no adoption"
Snag R	"poor"	"no adoption"	"no adoption"
Sketch Up	"no adoption"	"below average"	"no adoption"
VR	"no adoption"	"no adoption"	"average"
BIM	"no adoption"	"no adoption"	"no adoption"
Photoshop	"no adoption"	"poor"	"no adoption"
Enscape	"no adoption"	"no adoption"	"above average"
Performance	Time saving Cost Saving	Time saving	Time-saving

From the analysis of the level of performance of the digital technologies in the three case studies, time-saving was noted to be the most significant aspect of productivity affected. Both cost and quality aspects were affected by Navisworks while all other technologies showed no effect on the cost and quality aspects of productivity. The results reveal that “excellent” levels of adoption of digital technologies translate into higher levels of productivity time wise.

The findings confirm the observations of Aghimien *et al.* (2018), where Revit has yet to be adopted by contractors during the construction phase. Contractors prefer to use 2D plans rather than 3D models as noted by C1. Furthermore, Cao & Miyamoto (2003) define AutoCAD as one of the most powerful platforms for 2D and 3D designs. CS1 and CS3 both state that AutoCAD was their previous digital tool implemented on projects although they have recently moved over to Revit and find that they have more benefits than AutoCAD. Through further review of literature, any mention of Synergy specifically has not been noted, yet Ibem & Laryea (2015) have mentioned the use of cloud-based systems being used in South Africa for use in e-Procurement. Similarly, there has been no mention of Snag R app being used globally or within South Africa. Other technologies found through the interviews conducted have not been found in literature.

5 Conclusion and Further Research

The South African construction industry is faced with low productivity in the construction industry. The research examines the level of adoption of digital technologies in the South African construction industry and their effect on productivity towards providing an insight into the effects of digital technology on productivity. Firstly, literature was reviewed, and the types of digital technologies used and their level of adoption on construction projects was uncovered. After that, a case study research design that employs interviews was used in collecting information on the extent to which digital technologies was being adopted on construction projects. The gaps in the technology market and where digitalisation is lacking throughout the construction industry was observed in literature. It emerged from the study that digital technology is widely adopted amongst professionals in the South African construction industry while contractors are the worst adopters of the digital technologies. The barriers to adoption of digital technologies in both a global and South African context was substantiated by the study. The findings also show that the benefits of using digital technology outweigh the initial costs, while it reduces costs in the long run. Based on these findings, the research concludes that digital technology adoption on construction projects will affect the time and cost aspects of productivity.

Further research can examine the barriers to the adoption of digital technology on construction projects using a quantitative research approach and how these can be combated. Quality is an aspect of productivity that is not significantly affected by the adoption of digital technologies. Further research can look at technologies that target project quality and why they are not being adopted on construction projects.

6 Acknowledgement

This work is supported by NRF (Grant Number-120843). Opinions and conclusions are those of the authors and are not necessarily attributable to the NRF.

7 References

- Agarwal, R., Chandrasekaran, S. and Sridhar, M. (2016) Imagining construction's digital future. *McKinsey Productivity Sciences Center*.
- Ahuja, V., Yang, J. and Shankar, R. (2009) Study of ICT adoption for building project management in the Indian construction industry. *Automation in Construction*, 18(4), 415-423.
- Ayinla, K.O. and Adamu, Z. (2018) Bridging the digital divide gap in BIM technology adoption. *Engineering, Construction and Architectural Management*, 25(10), 1398-1416.
- Barbosa, F., Mischke, J. and Parsons, M. (2017) Improving Construction Productivity. *McKinsey & Company, Houston*.
- Barbosa, F., Woetzel, J., Mischke, J., Ribeirinho, M.J., Sridhar, M., Parsons, M., Bertram, N. and Brown, S. (2017) Reinventing construction: A route to higher productivity. *McKinsey Global Institute*.
- Bin Zakaria, Z., Mohamed Ali, N., Tarmizi Haron, A., Marshall-Ponting, A. and Abd Hamid, Z. (2013) Exploring the adoption of Building Information Modelling (BIM) in the Malaysian construction industry: A qualitative approach. *International Journal of Research in Engineering Technology*, 2(8), 384-395.
- Blanco, J., Janauskas, M. and Ribeirinho, M. (2016) Beating the low-productivity trap: How to transform construction operations. *Capital Projects Infrastructure*. Blanco, J.L., Mullin, A., Pandya, K., Parsons, M. and Joao Ribeirinho, M. (2018) Seizing opportunity in today's construction technology ecosystem.
- Blanco, J.L., Dohrmann, T., Julien, J., Law, J. and Palter, R. (2019) Governments can lead construction into the digital era. *McKinsey & Company*.
- Braun, V. and Clarke, V. (2006) Using thematic analysis in psychology. *Qualitative research in psychology*, 3(2), 77-101.
- Burnard, P. (1996) Teaching the analysis of textual data: an experiential approach. *Nurse Education Today*, 16(4), 278-281.
- Chan, D.W. and Kumaraswamy, M.M. (1997) A comparative study of causes of time overruns in Hong Kong construction projects. *International journal of project Management*, 15(1), 55-63.
- Changali, S., Mohammad, A. and van Nieuwland, M. (2015) The construction productivity imperative. *McKinsey Quarterly*.
- Costin, A., Pradhananga, N. and Teizer, J. (2012) Leveraging passive RFID technology for construction resource field mobility and status monitoring in a high-rise renovation project. *Automation in Construction*, 24, 1-15.
- Emmanuel, O.A., Omoregie, A.D. and Koloko, A.C.O. (2018) Challenges of Digital Collaboration in The South African Construction Industry.
- Enshassi, A., Mohamed, S., Mustafa, Z.A. and Mayer, P.E. (2007) Factors affecting labour

- productivity in building projects in the Gaza Strip. *Journal of Civil Engineering and Management*, 13(4), 245-254.
- Ezeokoli, F., Okoye, P. and Nkeleme, E. (2016) Factors affecting the adaptability of building information modelling (BIM) for construction projects in Anambra State Nigeria. *Journal of Scientific Research and Reports*, 11(5), 1-10.
- Ezeokoli, F.O., Okolie, K.C., Okoye, P.U. and Belonwu, C.C. (2016) Digital transformation in the Nigeria construction industry: The professionals' view. *World Journal of Computer Application Technology*, 4(3), 23-30.
- Fang, Y., Cho, Y.K., Zhang, S. and Perez, E. (2016) Case study of BIM and cloud-enabled real-time RFID indoor localization for construction management applications. *Journal of Construction Engineering Management*, 142(7), 05016003.
- Froise, T. (2014) *Building Information Modelling as a Catalyst for an Integrated Construction Project Delivery Culture in South Africa*. Nelson Mandela Metropolitan University.
- Hartmann, T., Gao, J. and Fischer, M. (2008) Areas of application for 3D and 4D models on construction projects. *Journal of Construction Engineering Management*, 134(10), 776-785.
- Ibem, E.O. and Laryea, S. (2014) Survey of digital technologies in procurement of construction projects. *Automation in Construction*, 46, 11-21.
- Kekana, G., Aigbavboa, C. and Thwala, W.D. (2015) Understanding Building Information Modelling in the South Africa construction industry.
- Laczkowski, K., Padhi, A., Rajagopal, N. and Sandrone, P. (2018) How OEMs can seize the high-tech future in agriculture and construction. *McKinsey & Company*.
- Li, H., Chen, Z., Yong, L. and Kong, S.C. (2005) Application of integrated GPS and GIS technology for reducing construction waste and improving construction efficiency. *Automation in Construction*, 14(3), 323-331.
- Lu, W., Huang, G.Q. and Li, H. (2011) Scenarios for applying RFID technology in construction project management. *Automation in Construction*, 20(2), 101-106.
- Marks, M. (2017) Construction: The next great tech transformation. *McKinsey & Company*.
- Merschbrock, C. and Munkvold, B.E. (2015) Effective digital collaboration in the construction industry—A case study of BIM deployment in a hospital construction project. *Computers in Industry*, 73, 1-7.
- Ozumba, A.O.U. and Shakantu, W. (2018) Exploring challenges to ICT utilisation in construction site management. *Construction innovation*, 18(3), 321-349.
- Pan, W., Zhan, W., Zhao, X., Wang, J. and Lam, J. (2016) Cost paradigms of future building. In, *Symposium on Cost Management for Mega Projects*. The Institution of Engineering and Technology, Hong Kong.
- Peansupap, V. and Walker, D. (2005) Exploratory factors influencing information and communication technology diffusion and adoption within Australian construction organizations: a micro analysis. *Construction innovation*, 5(3), 135- 157.
- Peansupap, V. and Walker, D.H. (2006) Information communication technology (ICT) implementation constraints: A construction industry perspective. *Engineering, Construction Architectural Management*, 13(4), 364-379.
- Seadon, J. and Tookey, J.E. (2019) Drivers for construction productivity. *Engineering, Construction and Architectural Management*.
- Singh, V. and Holmström, J. (2015) Needs and technology adoption: observation from BIM

experience. *Engineering, Construction Architectural Management*, 22(2), 128-150.

Wolf, T. (2018) Construction in the cloud: An interview with Thomas Wolf, CEO of RIB Software. *McKinsey & Company*.