THE USE OF BUILDING INFORMATION MODELLING AND RELATED TECHNOLOGY IN THE CAPE TOWN URBAN CENTRE

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Abstract
The significant improvement of technology in recent times has provided an opportunity for construction firms to invest in innovative technology. In South Africa the construction industry seems reluctant to deviate from their traditional ways of delivering construction projects. It is believed that building information modelling (BIM) and related technology can be a catalyst for change, with information replacing documents and knowledge becoming an asset. Hence, this research investigates to what extent construction personnel feel innovative technology can stimulate building production to ensure that building projects are completed within timeframes and budgets and what issues influence a construction firm's decision to invest in these technologies. Both qualitative and quantitative survey methods are employed in data collection. Content analysis and descriptive statistics techniques are used in analysing the data. This research gives a clear indication that construction personnel feel BIM and related technology can have a positive impact on building production processes and that cost, risk and logistics are factors to consider when implementing new technology. It is concluded that construction firms utilising these technologies will have a competitive advantage over others that ignore it.

Keywords: Building Information Modelling (BIM), Building production processes, Construction management, Innovative technology, Project management

1 Introduction

Urbanisation and globalisation are the foremost trends propelling the growth and development of cities and towns in the world today (Tah, 2012:348). The Cape Town central business district is an example of an urban centre that is required to deal with rapid urbanisation. The increasing numbers of inner-city developments suggest congested construction sites are rapidly becoming the norm within the industry (Biddy, 2009 cited in Spillane *et al*., 2011). Therefor innovative building production management is crucial in driving productivity which includes reducing cost at all stages, from planning to completion. According to Hardie (2010) construction firms are not significantly proactive towards using innovative technology that could enhance the efficient delivery of building production. Venkatachalam (2014) adds that improved building production management is advancing at a slow pace both in South Africa and internationally. This becomes problematic as the success of building construction in urban centres hinges upon the ability of the construction firm to be strategic, which is to know what resources are available, and what capabilities to develop in order to fulfil some planned goal.

Hence, this research investigates to what extent construction personnel feel innovative technology can stimulate building production to ensure that building projects are completed within timeframes and budgets and what issues influence a construction firm's decision to invest in innovative technologies.

Innovative technologies considered in this article are building information modelling (BIM), location awareness technology (LAT) and laser-scanners (point cloud data). In South Africa the construction industry seems reluctant to deviate from their traditional ways of delivering construction projects, consequently the tendency is for construction managers to continue with traditional 2D and 3D drawings (Venkatachalam, 2014). It is believed that BIM technology can be a catalyst for change, with information replacing documents and knowledge becoming an asset. BIM is seen as an emerging technology that is globally accepted in the construction industry with its application gaining momentum. In order for BIM technology to be effective in the South African construction industry BIM standards need to be introduced in various policy frameworks of statutory councils and government agencies.

2 Literature Review

Tah (2012:354) acknowledged that knowledge-based decision support in project management has been slow to make an impact in the construction industry. According to Hardie (2010:387) the international construction industry has not adapted quickly enough to both new technologies and new management practices. The lack of responsiveness to more broad-minded management methods has led to many construction firms lagging behind in new management techniques and the use of technology. Hardie believes there is a desire by governments to support management strategies that inspire to continuous improvement and innovation. Lim and Peltner (2011:283) state that the significant improvement of technology in recent times has encouraged construction firms to invest in these innovative ways to improve their competitiveness. Isikdag (2012:385) clarified that BIM momentum is now changing the architecture, engineering and construction (AEC) industries in a way which is likely to cause a change in the general construction process, toward intelligent construction and intelligent buildings.

2.1 Building Information Modelling

Visual representation of a construction site is becoming useful using technologies such as BIM with 3D modelling capability that supports a wide range of construction management tasks such as construction planning, constructability review and site layout planning. Furthermore real-time position measurements during construction can assist in facilitating a variety of construction tasks at an operational level. Kim *et al*. (2005) suggests that using laser-scanning technology to produce point cloud information can also be useful for rapid on-site spatial-modelling. Whyte *et al*. (2007) describes virtual reality as an emerging design support tool that can manipulate in real-time and be used collaboratively to explore different stages of the construction process. Eastman *et al*. (2008) believes BIM is the most promising development in the construction industry today.

The main advantage of using BIM is efficient team work, better collaboration and better co-ordination and automated information management processes. Woudhuysen and Abley (2004:3) believe that construction has approached critical mass as far as the understanding of building modelling by senior technical and managerial staff. However, there are many difficulties being encountered by pioneering teams. Isikdag *et al*. (2008) goes on to describe BIM as a major innovation in technology that can assist with problems related to interoperability and information integration. However Isikdag *et al*. reminds us that an alteration in existing building processes inevitably incurs risk. Risk management is important when considering new technology including factors such as cost, who will be affected and who will be accountable. Furthermore Zawdie (2012:20) believes that innovation does not take place in a vacuum and that the culture within institutions requires a shift which introduces the necessary flexibility for a generation of new ideas. One aspect identified as important for progress in BIM is the need for standardisation.

Venkatachalam (2014:144) stated that the adoption of BIM in South Africa and other developing nations is slow because of socio-economic factors. Venkatachalam believes that despite the numerous benefits of using BIM, challenges still remain in its implementation. Kiprotich (2014:43) revealed that construction firms in South Africa have shown significant interest in BIM since the turn of the new millennium. Kiprotich (2014:15) stated however, that contractors are concerned that BIM blurs the distinction between design and build. Kiprotich indicated that intellectual property also becomes an issue considering that BIM is a collaborative tool. Bengtson (2010) (cited in Kiprotich, 2014:35) indicated that the perception in the construction industry in South Africa is that BIM capability is overrated and this poses the greatest challenge. Although BIM can hold vast amounts of information, it requires additional expertise to manage large data sets. Kiprotich (2014:35) pointed out that regardless of the fact that computer hardware and software are developing quickly, big BIM projects become overloaded and slow down the model.

Porwal and Hewage (2013) (cited in Venkatachalam, 2014:146) indicated that BIM is now being widely used in countries such as the United States of America, United Kingdom, Australia, Hong Kong and Canada. Venkatachalam believes that it depends on the readiness of the industries as to whether they adopt this technology. Venkatachalam went on to say that government and regulatory bodies need to exert a greater influence towards the use of BIM. Venkatachalam believes that the South African construction industry is reluctant to deviate from their traditional ways of delivering construction projects. Thus the tendency is for construction managers to continue with traditional 2D and 3D drawings. Venkatachalam's study revealed that affordability and lack of knowledge are a hindrance in the adoption of BIM. Furthermore, people-related readiness is generally inadequate. Barlish and Sullivan (2012) (cited in Mutale, 2014:136) believe that the challenges in the implantation of BIM are; that benefits may be vague; the cost of introducing a new system; possible conflict between stakeholders; fear of the new system; and its effect on jobs.

2.2 Laser-scanners and point clout data

According to Gleason (2013:2) laser-scanning in the construction industry has mostly been used to model existing structures from point clouds, nevertheless point clouds are now being used for many different applications relating to construction work. Point clouds can be applied in building process monitoring, used within BIM (Tuttas *et al*., 2014:341). Gleason clarified that once the fieldwork has been done the entire individual scans are adjusted and orientated together so that the object model creation process can be done. Gleason goes on to say that the 3D model created from the new data provides enormous opportunities. However there are constraints when using point cloud data which must be considered. The processing of 3D laser scans requires a lot of computer power that will halter the processing of huge data volumes. Gleason noted that scanning can be a time consuming endeavour, resulting in very large and complex datasets. Gleason cautioned that scanning technology projects must be well planned. Attempting to recreate every single element in a single area can lead to loss of focus and failure to meet the broader objectives. Attempting to capture smaller elements is often impractical and unnecessary. Gleason acknowledged that these tolerances can be set in the scanning hardware, to regulate the laser beams; such settings are known as the resolution and quality setting.

2.3 Location Awareness Technology

It has been ascertained that, considering all the activities on a congested construction site, space management becomes the most important task (Tommelein & Zouein, 1993; Spillane *et al*., 2011:143). Yun-Yi Su (2010:1) explained that innovation using LAT technologies assists in all stages of building production and supports important decision-making tasks in the field. Razavi *et al*. (2012:239) explained that location awareness is needed for decision-making and for tracking progress. Health and safety can also be improved using LAT. The challenge is that LAT has been less than satisfactory for inside measurement but rather outdoor environments. The obstruction of signals by buildings and tree canopies places limitations on the outdoor tracking ability of a global positioning system (GPS). Satellite technology cannot receive radio signal inside a building. Recent developments in indoor location sensing systems have overcome this limitation by using radio frequency identification. This offers significant potential on construction sites. However a wide range of protocols need to be followed for indoor location systems to be sufficiently accurate.

3 Research Methodology

The research method is both quantitative and qualitative using surveys for data collection. This type of research aims to record an accurate and adequate description of the problem statement and the sub-question. Data for the study are collected through observations, semi-structured and unstructured qualitative interviews and quantitative close-ended questionnaires administered to construction stakeholders working in the Western Cape Province, South Africa. This research focuses on the City of Cape Town to gain an understanding of the dynamics of innovation in building production processes within the building industry. The population of this research include building project managers, registered contractors as well as consultants. Quantitative data obtained from the structured questionnaire design was analysed with descriptive statistics, Statistical Package for Social Science (SPSS) software 21 and content analysis are used to analyse the qualitative data obtained through interviewees.

The scope of the study is limited to the personnel working on construction sites in the City of Cape Town's urban centres. This study was conducted over three distinct phases. The first phase involved a pilot study which employed qualitative data-gathering techniques to orientate the researcher with regard to the study, and to modify and debug the process, with the expected result being a smooth run for the main enquiry. The second phase of the study establishes to what degree building construction personnel currently involved with building construction projects believe BIM, LAT and laser-scanners are useful during building construction and what issues influence a construction firm's decision to invest in innovative technologies. The third phase entailed the interpretation and validation of data.

The population included personnel in the building construction industry that are currently involved in managing building projects in the central business district of Cape Town. These personnel include: Architect (2), Contracts Manager (10), Engineer (28), Facilities Manager (2), Forman (7), Laboratory Technician (1), Project Manager (12), Consultant (6), Quantity Surveyor (33), Site Agent (7), Junior Contracts Manager (1), Junior Engineer (2), Junior Quantity Surveyor (16), Site Supervisor (1), Surveyor (7) and Technician (4), the total sample being 139.

The majority of respondents (69%) were below the age of twenty six years with the balance (31%) above twenty six years. Respondents with a matric certificate represented 17% of the total sample while respondents with a National Diploma in construction management or equivalent represented 52% of the total sample. Respondents with a Bachelor Degree in construction management or equivalent represented 31% of the total sample. Respondents were employed by a variety of construction business companies/enterprises. These included architectural firms (3%), construction companies (60%), facility management firms (1%), government departments (2%), project management firms (7%), quantity surveying practices (22%), real estate companies (1%) and sub-contracting companies (4%). The majority of respondents were employed by construction companies.

4 Findings and Discussion

The pilot study revealed that respondents felt BIM, LAT and laser-scanning can have a big impact on improving current building production processes and is extremely useful technologies. Respondents believed that BIM is effective from the design stage, into construction and beyond. The respondents agreed that a database-driven model, such as BIM, would be beneficial on site, where project managers and quantity surveyors can count, cost and order material, based on updated real-time information. Furthermore, respondents felt that BIM would be useful for programming, construction sequencing and would reduce mistakes on site. Although some of the respondents described BIM as a just another documenting system, others felt that its use integrates engineering and facilitates collaboration between professionals.

Respondents agreed that laser-scanners are becoming more practical on construction sites. Respondents felt digital engineering should be encouraged at universities so as to produce industry leaders in this regard. Respondents felt that the production of point cloud information through laser-scanning technology provides a vast pool of information about as-built structures. Laser scanners provide point cloud information that can be used to interpolate information between designs and help structural engineers, architects and construction engineers to process, visualise and synthesise design and construction more clearly.

Respondents explained that LAT uses several radio technologies that supply wireless connectivity. This technology is being explored in shopping malls where retailers are experimenting with achieving deeper customer engagement by helping them find the precise location of products and staff. Respondents felt the construction industry can actively deploy these solutions to address factors that affect construction in urban centres such as the management of congested space, locating materials, managing restricted access for delivery of materials, safe movement of materials, health and safety issues, communicating, coordination management and increased resource and personnel management. This survey suggests that the use of LAT is generally used during the executing and monitoring stages in the building production process, however, the true success of implementing LAT on construction sites will only materialise with innovation and the discovery of new applications, which will be either stand-alone applications or in combination with other technologies.

With regard to the issues potentially influencing a construction firm’s decision to invest in new technology on building construction projects the pilot study revealed that cost, leadership, risk, logistics, training of personnel, lack of knowledge regarding technology, experimental time, sharing information and technology development were issues to be considered.

The second phase of this research consisted of two objectives, the first objective was to investigate to what extent construction personnel feel innovative technology such as BIM, LAT and laser scanners can stimulate building production. The second objective establishes what issues most influences a construction firm’s decision to invest in innovative technologies. Respondents were asked to indicate their response using a five-point scale, 1 = ‘not at all’, 2 = ‘sometimes’, 3 = ‘often’, 4 = ‘generally’ and 5 = ‘almost always’. Some respondents failed to answerer all the questions on the questionnaire. This was because some were unfamiliar with the technology and did not know its usefulness during that stage of a building construction project.

Table 1. The usefulness of innovative technology during a construction project

	Number of responses	Not at all (%)	Sometimes (%)	Often (%)	Generally (%)	Almost always (%)	No response (%)	Mean	Std. Deviation	Rank
Initiating stage of a construction project										
BIM	120	8.6	8.6	18.0	18.7	32.4	13.7	3.7	1.34	1
Point Cloud	121	23.0	17.3	17.3	13.7	15.8	12.9	2.8	1.45	2
LAT	122	28.1	19.4	18.7	11.5	10.1	12.2	2.5	1.36	3
Planning stage of a construction project										
BIM	125	5.8	5.8	10.8	21.6	46.0	10	4.1	1.21	1
Point Cloud	118	22.3	14.4	13.7	20.1	14.4	15.1	2.9	1.46	2
LAT	120	29.5	14.4	14.4	15.1	12.9	13.7	2.6	1.48	3
Executing stage of a construction project										
BIM	118	8.6	7.9	20.1	27.3	20.9	15.2	3.5	1.25	1
LAT	120	16.5	14.4	15.1	23.7	16.5	13.8	3.1	1.41	2
Point Cloud	121	17.3	12.9	24.5	18.7	13.7	12.9	3.0	1.34	3
Monitoring stage of a construction project										
BIM	120	5.0	12.2	18.7	27.3	23.0	13.8	3.6	1.19	1
LAT	121	19.4	12.2	18.0	18.0	19.4	13	3.1	1.46	2
Point Cloud	120	18.0	15.1	23.0	15.8	14.4	13.7	2.9	1.37	3
Closing stage of a construction project										
BIM	118	8.6	10.8	19.4	23.0	23.0	15.2	3.5	1.29	1
LAT	117	25.2	16.5	19.4	10.1	12.9	15.9	2.6	1.42	2
Point Cloud	120	25.2	23.0	15.8	8.6	13.7	13.7	2.6	1.41	3

The results presented in Table 1 show that participants felt BIM technology ‘almost always’ enhance building production process during the initiating and planning stages of a construction project, furthermore BIM technology was considered as ‘generally’ beneficial during the execution, monitoring and closing stages of a building project. Laser-scanners and point cloud data was considered not useful during the initiating, planning and the closing stages of a project but considered useful during the executing and monitoring stages. LAT technology was only considered useful during the executing and monitoring stages.

The second objective of this study was to investigate why construction firms are reluctant to invest in innovative technologies such as BIM, LAT and laser-scanning technologies. The study showed that the cost of implementing new innovative construction methods is almost always a factor (Table 2). Risk, logistics, personnel training and a lack of knowledge significantly influenced a firm's decision to invest in new innovative construction methods, whereas experimental time, sharing information and technology development is more often than not a factor. The study also revealed that strong leadership is often needed to adopt innovative methodologies for new strategic management methods on construction sites.

Table 2. Issues that influence a construction firm's decision to invest in innovative technology

	Number of responses	Not at all (%)	Sometimes (%)	Often (%)	Generally (%)	Almost always (%)	No response (%)	Mean	Std. Deviation	Rank
Cost	138	3.6	5.0	18.0	22.3	50.4	0.7	4.1	1.10	1
Strong leadership	138	5.8	12.2	26.6	23.0	31.7	0.7	3.6	1.21	2
Risk	138	3.6	18.0	23.7	30.9	23.0	0.8	3.5	1.14	3
Logistics	138	3.6	15.8	30.2	33.1	16.5	0.8	3.4	1.06	4
Training personnel	138	6.5	17.3	24.5	29.5	21.6	0.6	3.4	1.20	5
Lack of knowledge	138	10.8	14.4	23.7	29.5	20.9	0.7	3.4	1.27	6
Experimental time	138	4.3	13.7	45.3	22.3	13.7	0.7	3.3	1.01	7
Sharing information	138	11.5	16.5	33.1	23.0	15.1	0.8	3.1	1.21	8
Technology development	138	8.6	23.0	39.6	18.0	10.1	0.7	3.0	1.08	9

5 Conclusion and Further Research

Innovative technology is an effective management tool for building production in urban centres to improve building production workflows. The construction industry in South Africa seems to be reluctant to invest in innovative technology for building construction projects. The biggest obstacle a firm faces when making a decision to invest in innovative technology is cost of equipment and training. Furthermore, weak leadership was found to influence a firm's decision to modernise. Risk, logistics and training of personnel are all issues that a firm needs to consider. The lack of technological knowledge, experimental time, sharing of information and technological development are also influential. The use of technology is proving to be useful during all stages of building construction. BIM is an emerging technology that is globally accepted in the construction industry and is gaining momentum. The BIM trend in African is progressive with building construction personnel in Cape Town believing BIM should be used extensively during the initiating and planning stages of a project. BIM needs to be utilised to its full potential and be supported through various policy frameworks by different stakeholders of the AEC sectors such as the statutory councils and the government agencies. The staged adoption of BIM and a new policy framework in the South African AEC sector need to be put in place. BIM technology is applicable throughout all process in building construction management. BIM technology allows the project to be seen within the context of the system it will operate in. The convergence of building production methodologies and technology is allowing better management of information.

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