Understanding Building Information Modelling in the South Africa construction industry

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Abstract

Building Information Modelling (BIM) is a concept that has been defined as a technology that digitally constructs an accurate virtual model of a building. BIM can be defined as an IT enabled approach that involves the application and maintenance of a fundamental digital representation of a building and all its information throughout the different stages of the project. The model of the building, which will be in 3D, will depict the exact dimensions of the building. The study assesses the barriers to the adoption and implementation of BIM within the South African construction industry, and suggests ways of overcoming the identified barriers to the full adoption and implementation of BIM in the South African construction industry. The data used in this paper was derived from primary and secondary sources. The primary data being questionnaires, was designed based on the related literature that was reviewed. The questionnaire was distributed to construction professionals such as Construction Project Managers, Architects, Quantity Surveyors, Construction Managers, Facility Managers, or academics who have previously done research on BIM in the South African construction industry. The questionnaires were analysed using descriptive statistical procedures. The findings revealed that a lack of skills, education, and knowledge on BIM are the biggest barriers to the full implementation of BIM in South Africa. Furthermore, the results also show that educational and skill development initiatives are widely considered to being the answer to the existing barriers to BIM adoption. As well as, establishing feasible ways of moving away from the common practice into using BIM on all construction projects.

Keywords: Building Information Modelling, BIM adoption, BIM barriers, South Africa construction industry

1. Introduction

BIM produces a model known as the building information model, which according to Ahazar (2011) and Bryde et al., (2012), can be used throughout all the project stages to, and including the operation and maintenance of the facility. According to Riddel (n.d.), BIM represents the design of the building as objects that carry their geometry and full attributes. This is achieved because the model will depict how the building will look once all the components have been inserted or built into the data. According to Ashraf and Esquire (2008), some of the other possible uses for BIM in construction industry include it being used solely for design purposes, for coordination and clash detection, estimating material prices, construction simulation, and the creation of shop drawing and for review of submittals, amongst others. Although BIM is perceived to being able to eradicate almost all the inadequacies that arise in the process of construction, it is not the solution to all the problems in construction (Davidson, 2009). Eastman et al., (2008) further states that BIM is a modeling technology, which has an associated set of process that produce, communicate and analyze

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building models. The authors further identify the characteristics of these models by the building components that are digitally represented, the different components of the data, and the data, which produces the different views of the model. Therefore, this study assesses the barriers to the adoption and implementation of BIM within the South African construction industry, and suggests ways of overcoming the identified barriers to the full adoption and implementation of BIM in the South African construction industry.

2. Advantages of Using BIM

The initial feeling towards BIM and its usage was not one that was easily welcomed into the construction industries. Though it had been used extensively in the United States of America (USA) by 2010, it has taken a lot of time, research and persuasion on the part of the pioneers of this phenomenon in the construction industries of other countries. A good example of this is how Hobbs (2008) explained that after much research and initiating, BIM was finally gaining momentum and acceptance amongst construction stakeholders in the United Kingdom (UK).

Davidson (2009), listed some of the driving forces behind the adoption and implementation of BIM in the UK. He mentions accuracy and consistency of data. This is in regard to all the information that will be used will be derived from the model, thus guaranteeing the accuracy and consistency of the data. This may include, amongst other things, drawings and dimensions that will be accessible to all interested parties due to the 3D model that BIM provides. This is in agreement with what Tse et al. (2005) and Azhar (2011) said in their respective definitions of BIM. A second advantage was Design visualization. Due to this advantage, 3D representations of different parts of the project can be generated from the building model at any given stage. These representations can range from basic structure drawings to complex photorealistic renders of how the proposed building will look like; and all this will be consistent with the 2D drawings that will already be in existence.

Furthermore, the Ease of quantity take-off for the quantity surveyor was one of the driving forces to adoption and implementation of the BIM technology in the UK. As a result of BIM’s ability to extract quantities for elements such as floor areas, material volumes, amongst others., it makes it very easy and quick for cost estimates, material scheduling and procurement to be carried out as all data is readily available from the model at all times. These sentiments are shared by Riddell (n.d.) who also speaks about the ease of which the cost of the building can be attained, while also adding BIM’s contribution to the overall energy usage and organizational performance of the entire project team. The multi-user collaboration attributed to BIM is also one of the motivating factors to BIM adoption. The usage of BIM makes it possible for all project team members to be able to use different spheres of the same model in order to effectively share and distribute information amongst each other. This is a big bonus as manual/physical information sharing has previously had its own disadvantages.

For a more fluid and sufficient system of working, the project team may agree to bring someone on board who will oversee the operation of the model as a whole. This may forge new BIM-specific job opportunities such as a BIM-modeller or a BIM model manager as identified by Brewer et al. (2012). Davidson (2009) goes on to further conclude and reiterate that the usage of BIM in the construction industry contribute immensely in reducing cost directly and indirectly through better designs, reduced usage of building materials and efficiency gains. It should also therefore be pointed out that the usage of BIM will not automatically constitute a cheaper project for the interested parties

BIM tools are elements which form part of the BIM database, which will help the project team in achieving their BIM objectives of the project. These are the elements that make it possible for the model to function in its full capacity and produce its deliverables. According to (The Associated General Contractors of America, n.d.), these tools are advantageous towards the project. The characteristics of these BIM tools should include the following:

- Simplicity: The software that will be used needs to be easy to learn and understand. It should also be easily teachable and accessible to all stakeholders.
- Functionality: The tool should be able to meet the requirements of the model.

- Collaborative: The tool should be able to intertwine with other software to make it possible for them to share information in a model.
- Longevity: The tool should be technologically advanced enough to withstand incoming technologies over the project period or even beyond.
- Support: The tool should provide tutorials and support systems to ensure that the software adequately understood and utilized.

Advantages of using BIM in the South African construction industry throughout all the project stages are discussed by Kaber (2010). In the early design and planning stages, the planners and designers are afforded the opportunity of using BIM tools such as ArchiCAD and Revit in conjunction to aid their objectives of producing the best possible design which is in line with the relevant statutes of its intended location. For the QS, the relative ease of taking off the combining tools such as Innovaya and Autodesk QTO from the data extracted from the tools that were used by the designers of the structure.

Moreover, Kaber (2010) has identified the main advantages as improved visualization, improved productivity due to accessibility of data, and increased coordination of documents. This is mainly due to the multi-user collaboration abilities as discussed by Davidson (2009). When each of the professionals have done work on their preferred programs (BIM tools), they then add it to the database of the project. And because all of this is done electronically, it then makes it readily available at all times for the other professionals. Another benefit as identified by Kaber (2010) is BIM’s ability of embedding and linking of vital data such as specified materials, location of details, and all the quantities required for tendering and estimating purposes. The general reduction of costs has also been identified as a benefit. All this is in the form of time spent on the designing and co-ordination of the documentation, as well as on the duplication of hard copies, and the printing and copying of documentation as it will be electronically accessible. From the above it can clearly be concluded that the use of BIM offers numerous benefits and advantages to the different users. The benefits of BIM range throughout the various stages of a project, from the planning through to maintenance of the completed project.

3. Methodology

The data used for this paper was derived from both primary, and secondary sources. The primary data was obtained through a structured close-ended questionnaire, and the secondary data was obtained from the relevant literature that was reviewed by the researcher. A total number of 65 structured questionnaires were sent to individuals in the municipalities of Tshwane, City of Johannesburg, and Ekhuruleni (all in Gauteng, South Africa) who are practicing as Quantity Surveyors, Construction Managers, Architects, Facility Managers, Project Managers, or Academics.

The questionnaire was designed based on the information that was gathered during the literature review. A 5-point likert type scale was used for the questionnaires. This scale measured the extent to which the respondents agreed or disagreed with the factors presented to them. A random sampling method was adopted for the purposes of this research. This method was preferred due to the fact that it gave all the targeted respondents an equal chance and opportunity of being selected.

From all the questionnaires that were sent out; 50 usable questionnaires were returned. This meant that the response rate was at 77%. The data were then analyzed using the Statistical Package for the Social Sciences (SPSS); with the frequencies and mean item scores (MIS), and the standard deviations (SD) of the rated factors being considered. This research was conducted between the months of May and September 2014; with the data collection being carried out between June and August 2014.

The Likert scales were transformed to an MIS for each of the research objectives as applicable. The indices were then further used to determine the rank of each item according the results obtained from the respondents. These rankings made it possible to cross compare the importance of each item to the respondents. The MIS was based on previous studies as conducted by Mukuka et al., (2013) where the 'MIS' rating was used. This method was also used for this study to analyze the data collected through the distributed questionnaire. The MIS was calculated from the total of all weighted responses and then it was related to the total responses on a particular option/item on the questionnaire. This was based on the principle that respondents' scores on all the selected options, considered together, are indices of the relative importance of each of the options. The index of MIS of a particular factor is the sum of the scores that were received from the respondents (on the particular Likert scale of that question) as just a proportion the overall score that all respondents could give to that factor (one to five), which, for the two main questions for this study, mean "Not a barrier (NB)-Extreme barrier (EB)" and "Strongly Disagree (SD)-Strongly Agree (SA)". The relative index for each item was calculated for each item as follows, after Aigbavboa et al (2013).

Following the mathematical computations, the criteria are then ranked in descending order of their relative importance index (from the highest to the lowest). The next section of the article presents the findings of the survey and some discussions.

4. Findings and discussions

4.1. Biographical data results

Findings from the respondents revealed that 64% of the 50 respondents were male; while 36% were female. Furthermore, 36% were between 20 and 25 years of age, 28% were between 26 and 30 years of age, 18% were between 31 and 35 years of age, 10% were between 36 and 40 years of age, 4% were between 41 and 45 years of age, and 4% were between 46 and 50 years old. Results also showed that none of the respondents above the age of 55 years old. The results further showed that 42% of the respondents had obtained a Bachelor's Degree, 38% had a Diploma, 14% had a Master's Degree, and only 6% had a Matric certificate as their highest educational qualification, 32% were working as Quantity Surveyors, 32% were Architects, 18% were Construction Managers, 12% were Project Managers, 4% were Construction Project Managers, and only 2% were working as Facility Managers. When asked about their years of experience in their field of work, 52% had between 1 and 5 years, 30% had between 6 and 7 years, 12% had between 11 and 15 years, 4% had between 16 and 20 years, and only 2% had above 20 years of experience; while 32.7% worked for contractors, 28.6% worked for/as consultants, 20.4% represented a client in the private sector, 12.2% represented the government as a client, 2% worked for higher learning institutes, and 4.1% worked for organisations that weren't listed as one of the available options. All these biographical information were obtained within the three main municipalities of Gauteng known as Ekurhuleni, Tshwane, and the City of Johannesburg.

4.2. Awareness, Usage, and Benefits of BIM

The researchers asked the respondents to compare their organisation's ICT levels relative to their competitors. The results showed that 62% of the respondents said that their companies ICT levels were either somewhat better or much better than their completion, and only 24% said theirs were either somewhat worse or much worse than their competition (Fig. 1). Of these companies, most of them used AutoCAD (27%) and Revit (16.6%). Furthermore, when researching the respondents' knowledge of BIM, findings showed that 70% of them had an average-to-excellent knowledge of what BIM is.

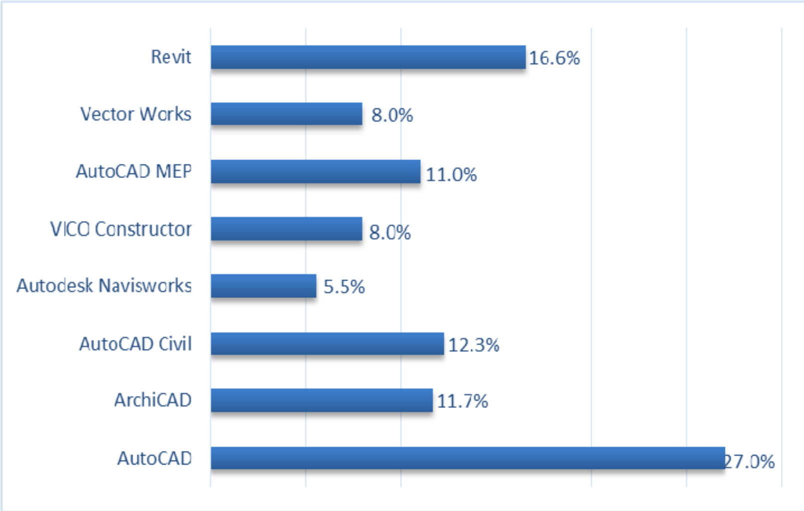

Fig. 1. BIM-related tools mostly used in the respondents' organisations

However, when it came to their actual experience and interest in BIM as a tool that they use/can use in their projects; 34% of them had no BIM experience, while 30% of them had between 1-3 years of experience. Furthermore, of the 34% with no experience, 72% of them were either interested or highly interested in BIM, while only 38% of the 66% that had some experience with BIM use it often or always. From these set of results, the researchers found that although the South African construction industry was technologically aware, the usage of BIM was very low, and this can be attributed to the unwillingness to change the traditional ways of practice (MIS=3.00, SD=0.904, R=9). This is in agreement with what Ahmad et al (2010) about companies resisting change due to a lack of flexibility and versatility. Furthermore, the researcher found that this could be as a result of the fact that 78% (Figure 3.2.2) of the respondents said the people who use BIM in their organisations are either in management positions, or are employedas designers. This is negative as it limits the exposure of the rest of the employees in the organisations who aren't in top management positions or employed as designers.

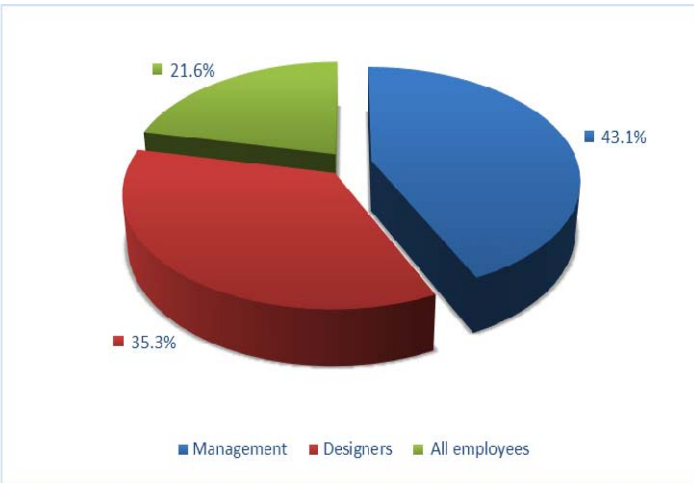

Fig. 2. BIM usage in the respondents' organisations

From the 80% of the respondents that said BIM is used in their organisations, 25% of them indicated that BIM was used for cost management purposes, while 22.8% used it for construction management, 20.7% used it for project management (Fig. 2). This showed that although BIM is scarcely used in the South African construction industry, it was mainly used for management purposes on the project which it is used on, thus validating why it was mostly used by the management (43%) in the organisations that employed the respondents'.

Table 1: Shows the motivating factors/benefits of using BIM

Motivating factors/benefits of using BIM	MIS	SD	RANK
Improves the project management process	4.35	0.855	1
Improves the design visualization	4.27	0.811	2
Provides better visualization of projects	4.26	0.828	3
Ease of taking-off quantities	4.14	0.842	4
Enhances the accuracy of data	4.12	0.918	5
Improves the cost modelling	4.06	0. 876	6
Enhances the consistency of data	4.06	0. 966	6
It is an interactive tool (Collaborative tool)	4.02	0.958	7
Improves the time management	4.02	0.979	7
Helps with the value Engineering	4.02	1.020	7
It's more efficient than normal practice	3.98	0.946	8
To increase capacity of design reviews	3.96	0. 880	9
Reduction in project variations	3.96	0. 947	9
Helps in the updating of details	3.94	1.038	10
Provides a competitive edge	3.92	0.853	11
Improves the cost management	3.88	1.062	12
Improves the management of data	3.82	0. 962	13
It minimizes collisions in the construction phase	3.82	0. 983	13
Helps with the Life Cycle Costing analysis	3.76	1.061	14
Competitors use it	3.76	1.135	14
It minimizes conflicts	3.50	0.995	15
Creates more job opportunities	3.49	1.227	16
It is a requirement of most clients	3.16	1.299	17

The respondents were further asked to rank what they thought the major benefits of using BIM were, they ranked the fact that it improves the project management process in first place (MIS=4.35, SD=0.855), secondly, the fact that BIM improves the design visualization was ranked second (MIS=4.27, SD=0.811), thirdly, BIM's ability to provide better visualisation of projects (MIS=4.26, SD=0.828), and the fact that BIM provides ease of taking-off quantities (MIS=4.14, SD=0.842) was ranked fourth (Table 4.1). These major benefits, except the fact that it improves project management, are in agreement with what Hergunsel (2011) said about them being the simplest, and most obvious benefits of using BIM. And the four least factors were the fact that competitors use it (MIS=3.76, SD=1.135, R=14), that it minimizes conflicts (MIS=3.50, SD=0.995, R=15), that it creates more job opportunities (MIS=3.49, SD=1.227, R=16), and the fact that it is a requirement of most clients (MIS=3.16, SD=1.299, R=17). The next question set out to find out what BIM was used for in the South African construction industry, the results revealed that project management (MIS=4.38, SD=0.945, R=1), constructability analysis (MIS=4.36, SD=0.776, R=2), cost scheduling (MIS=4.20, SD=0.926, R=3), and virtual mock-ups for design evaluations (MIS=4.18, SD=0.869, R=4). The importance of BIM for the fluency of project management has also been highlighted by Aranda-Mena et al (2009) in their investigation carried out in Australia and China, and He (2012) in the Hong Kong construction industry.

5. Conclusions

The study has assessed the levels of awareness, usage, and advocated benefits of using BIM by stakeholders in the South African construction industry. This objective was met as the research findings revealed the ICT levels of the respondents' organisations, their knowledge of BIM, their experience and interest in BIM, their frequency of use of the BIM technology, as well as the benefits of using BIM in the South African construction industry. The findings have shown that although most of the respondents had minimal BIM exposure (64%), their general exposure to ICT was good. Research has also found that although the ICT levels were satisfactory, and the usage of BIM is at 80%; the main reason for the low BIM experience of respondents was due to the fact that it was mostly used by management and designers in construction organisations (78%).

Furthermore, the researcher found that the respondents indicated that their organisations used BIM mostly for cost, construction, and project management purposes. Moreover, the results also revealed that respondents thought the major benefits of using BIM in the South African construction industry were because it improves the project management purposes, the design visualization, it provides better visualization of projects, and it makes provision for easier taking-off for the QS.

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References

Azhar, S. (2011). 'Building Information Modelling (BIM): Trends, benefits, risks, and challenges for AEC industry'. Leadership and Management in Engineering. 241-252

Azhar, S., Carlton, W., Olsen, D., Ahmad, I. (2010). 'Building information modelling for sustainable design and LEED rating analysis'. Automation in Construction. 20 (2011), 217-224

Ashraf, H. W. (2008). 'Implementing BIM: A report from the field on the issues and strategies'. Proceedings of the 47th annual meeting of invited attorneys. June 2008. Seattle, WA. 53-84

Bank, L. C., McCarthy, M., Thompson, B. P., and Menassa, C. C. (2010). 'Integrating BIM with system dynamics as a decision making framework for sustainable building design and operation'. Proceeding of the first international conference for sustainable urbanization (ICSU). December 2010. Hong Kong.

Bryde, D., Broquetas, M., Volm, J. M. (2012). 'The project benefits of building information modelling (BIM)'. International Journal of Project Management. 31 (2013), 971-980

Cidik, M. S., Boyd, D., Thurairajah, N. (2014). 'BIM and conceptual design sustainability analysis: An information categorisation framework'. Proceedings of the 50th ASC annual international conference. March 2014. Washington, DC.

Davidson, A. R. (2009). 'A study of the development and impact of building information modelling software in the construction industry'.

Ding, G. K. C. (2008). 'Sustainable construction-The role of assessment tools'. Journal of Environment Management. 86, 451-464

Eastman, C. M., Teicholz, P., Sachs, R., and Liston, K. (2008) BIM handbook: A guide to building information modelling for owners, managers, designers, engineers, and contractors. Hoboken, N. J: Wiley Publishing

Gu, N., London, K. (2010). 'Understanding and facilitating BIM adoption in the AEC industry'. Automation in Construction. 19 (2010), 988-999

Hobbs, C. (2008). 'BIM by the back door'. The Structural Engineer. 86 (13), 18

Ku, K., Taiebat, M. (2011). 'BIM experiences and expectation: The contractors' perspective'. International Journal of Construction Education and Research. 7 (3), 175-197

Riddell, C. (n.d). 'Building information modelling. Who is liable?'

Schlueter, A. and Thessling, F. (2009). 'Building information model based energy/exergy performance assessment in early design stages'. Automation in Construction. 18 (2), 153-163

Takim, R., Harris, M., Nawawi, A. H. (2013). 'Building information modelling (BIM): A new paradigm for quality of life within architectural, engineering and construction (AEC) industry'. Procedia-Social and Behavioral Sciences. 101 (2013), 23-32.