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The Strategic Application of Building Information Modelling (BIM) to the Role of Construction Project Management

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Abstract

The iron triangle which contains time, cost and quality plays a very important role in the construction industry. Building Information Modelling (BIM) has triggered the way the construction industry operates and in particular 5D BIM. This dimension within the BIM model is more associated with the cost aspect of the iron triangle and the potential to be used by the constructional project manager or built environment professional to streamline workflows and increase the quality of services they provide to clients. 5D BIM encompasses the traditional 3D (three dimensional) model added to the 4D BIM time and then the costing as the fifth dimension. 5D BIM provides the contractor with the ultimate opportunity to produce accurate costs of projects, the expected timeline when the actual costs of the projects will occur, at the same time allowing the schedule to be optimised by taking into account the quantities of material produced from the 5D BIM model and the productivity rate of the project team. The 5D BIM model provides a great platform for the construction project manager to connect the processes of design, construction methods and costs; this on the other side calls for the construction project manager to embrace the digital transformation in the way quantity take off (QTO's) are produced. this research focuses primarily on the role of the construction project manager in south africa whereby bim is been perceived as merely being a software. the research method adopted a quantitative approach and qualitative approach were semi-structured interviews were conducted to get a clear picture of the digital transformation of the construction project manager professional. The findings show that in south africa and in particular the construction project manager still use the old method of using Computer Aided Design (CAD) and 2D models to produce the costs. The research will be important for the construction industry and in particular for the QS practitioner to produce more accurate costs and thus productivity rate.

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Keywords: 5D BIM; Building Information Modelling; Computer Aided Design; construction project management

1. Introduction

Building Information Modelling (BIM) with its momentum and capabilities is gaining attention in the Architecture, Engineering and Construction (AEC) industry. The new methodology has made it possible for construction problems to be resolved in association to issues of management of information in comparison to the old processes [31]. [3] states that BIM has the ability to produce quick estimations of cost schedules such as Quantity Take Offs (QTO's). According to [10] cost analysis can be produced at any point, which is defined as five-dimensional BIM (5D BIM) technology. [31] believes that 5D BIM, plays an important role in the integrated project delivery approach. Several

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efforts have been undertaken to investigate the 5D BIM application [37;7; 11] and the role of the Quantity Surveyor's (QS's) [31] within the process of using 5D BIM. However few have researched the challenges of 5D [38; 17] and the role of the QS.

Quantity Take off (QTO) is extremely important in a construction project mainly because of the management application which is applied to infrastructure has to be accurate and consistent. QTO is normally completed manually or even using necessary software's from 2 dimensional (2D) and 3 dimensional (3D) Computer Aided Design (CAD) drawings. The construction industry has accepted the adoption and implementation of BIM and the utilisation of the collaboration tool makes it possible to automate the QTOs process by using 5D BIM QTO tools via model based quantity extraction techniques. However QS's have fears and concerns that the 5D BIM process will eliminate the profession completely. Therefore, this paper wants to explore the approach of 5D BIM among QS's perspective in the South African context, taking in consideration those from both academia and industry.

2. Literature Review

The main problem and the relatively high confusion in the construction industry is related to what BIM is and this is because of the many definitions the methodology has [12, 5, 28, 23] Building Smart continue to be the leaders of BIM implementation and developers over the past several years and they have also investigated the terminology of BIM. Building Smart have defined BIM as;

"A Building Information Model is a 3D object database that can be easily visualised, has rich data and structured information. Building Information Modelling is a process of representing building and infrastructure over its whole life cycle from planning, design, construction, operations, maintenance and recycling. BIM importantly provides a framework for collaboration, a multi-disciplinary environment that brings together all the parties that design, construct and operate a facility, suggesting a new model of procurement Integrated Project Delivery (IPD)" [5].

[28] believe that BIM does not only involve the use of software's however it requires a different manner of thinking and a completely new way of project delivery and procurement. Therefore it becomes a very important for industry professionals to move away from the old ways of delivering projects amongst the different industry role players who are working on separate information typically with the incompatible and different technologies to a totally integrated common platform where professionals can come together to work and share the same information.

BIM is more than 3D modelling and it has other dimensions such as the 4D BIM (time), 5D BIM (Cost) and 6D BIM (Facilities management). The 4D bring the information and data from the 3D model with facilities, scheduling data and project programming and ultimately interprets and does an analysis of the construction activities. 5D brings together all the relevant information with the cost data such as prices, quantities and scheduling. The 6D represent the as-built model which can be utilised during the full operation stages of the building. [19] states that *"the role of the Quantity Surveyor should embrace the 5th dimension and become the key players in the BIM environment - the 5D Quantity Surveyor"*.

[21] supports [19] and states that the value of the QS is for the professionals being able to explore and simulate the different construction and design scenarios in real time through having their quantities and cost data linked in the live model.

The concept of Integrated Project Delivery (IPD) is regarded as playing a huge role to a successful adoption and implementation of BIM. According to the American Institute of Architects IPD is defined as *"a project delivery approach that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to optimize project results, increase value to the owner, reduce waste, and maximize efficiency through all phases of design, fabrication, and construction"* [1]

The study by [2] discovered that the implementation and adoption of BIM in collaboration with IPD, the strategies can improve productivity by 6-9%. The [9] study investigated 32 construction firms in the USA which had adopted and

implemented BIM and discovered that *"Cost Estimating accuracy fell within 3% range, up to 40% elimination of unbudgeted change, savings of up to 10% of the contract value through clash detections, up to 80% reduction in time to generate cost estimates and up to 7% reduction project time"*.

2.1 The Implementation of BIM

[27] conducted a study of BIM adoption and implementation by the project managers or quantity surveyors in the United States of America and United Kingdom which is almost to be the most comprehensive study of this type to invest the adoption and implementation of BIM across the world into construction thus far. The study provides a picture of the level of BIM adoption and implementation by the built environment profession and the problems which they came across which may be applicable to other countries.

The study was distributed to 8500 RICS members in the year 2011. The study discovered the following;

Only 10% of QS firms used BIM regularly with a further 29% having limited engagement with BIM. Accordingly 61% of QS firms had no engagement with BIM. For the QSs that were using BIM the most frequent use was for construction scheduling (14%) followed by the extraction of quantities and facilities/asset management (both 8%). Only 4% of QS firms regularly invest in BIM training and only 10% actively assessing BIM tools for potential adoption [27].

This indicates that the QS profession in this region is not embracing BIM to the level that is needed. However, given that the UK government mandate for BIM usage was introduced at the time of this survey it would be interesting to see what effect this has had on QS firms since then. The biggest barriers for QS firms adopting BIM were cited as the lack of client demand, training, application interfaces and standards.

2.3 BIM for the QS: 5D BIM application

BIM provides the Information Technology (IT) platform where all AEC disciplines can come together to collaboratively share and ultimately work effectively [6; 25]. This allows for an approach which enables for the easy trickle of data right through the phase of the project, equivalently the better cooperation amongst collaborators allows for easy and quick data move by bringing together the different types of industry professionals within a single model [13]. [32] believes that 5D BIM allows for the project manager to focus their efforts in bestowing their expertise and knowledge to the project team, because through the 5D BIM process is significantly reduced. According to [21]5D BIM increases the usefulness of the QS service by providing the capabilities to envisage, explore and initiate the tremble of different construction scenarios and designs through the blending of quantities, data, project programmes and cost within the model.

Within the BIM model, the integration of the cost aspect is provided by the 5D dimension, which by several consulting organisations, can be seen as an advantage towards cost management [31]. The model gives the project manager the capabilities to measure, take-offs and count straight from a regular updated BIM model through 5D BIM application by connecting the estimating software and the model [14]. According to [4], with the dragging process of qualification in some instances being effortless and automated, this provides more time to the project manager to give for more focus and give the knowledge on other project specification e.g. for instances pricing and factorising risk. Furthermore they has been research conducted which look into 5D BIM and how this dimension helps the role of the project manager [37; 7; 11] the main benefits of 5D BIM is more towards cost estimating and scheduling [30; 34] the potential benefits can be more than schedule and cost estimation. For example "[15] *suggested a way to analyse cash flows through the use of automated processes, which includes QTO scheduling and cost estimating. Additionally, operational and lifecycle costs could also be analysed and appreciated before the building is built using collaborative procedures, which in turn, can lead to cost savings* [17]'.

2.4 BIM for the QS: Challenges of 5D BIM

Design detail:

The accuracy and quality of the model will depend to what extend the construction project has been explained to the QS [18]. Among the concerns experienced by the project manager in the BIM model is the shortage of available data presented within the model. This will arise from the representation (2D or 3D models) which are created by the designer. The Royal Institute of Chartered Surveyors (RICS), has stated that the one of many tasks of project manager is to analyse BIM models for information richness and accuracy, furthermore on several instances it has been stated that the BIM model would not have the needed data to assist with the QTO's and model based measurement [32]. [33] agree with [32] state that the missing information and inadequate details within the BIM model results in inaccurate information and design errors. According to [37] makes the argument that the BIM model that do not have all the information which is required by the project manager to perform precise estimations can lead to problems in searching and managing for the needed data within the model.

Standardisation

Quantities which are generated from the model are in line with the parameters which are positioned by the software vendors who do not go according to the conventional procedure of measurement. According to [29] consistency and accuracy of the information may be at danger because of datasets are transmitted using the different format. According [32], the lack of consistent modeling standards, can lead to the QS having to obey to several approaches, which has a pessimistic impact, resulting in inaccuracies and inconsistencies.

Training and Skills

The full adoption of BIM has been endorsed and mandated by the United Kingdom (UK) government since the year of 2016, whereby all government funded projects must implement level 2 using BIM (2016), however on the upside of this mandate, a survey which was undertaken in the UK made arguments, that this task is unachievable. The findings of the survey revealed that some firms or organisations are not able to fund this process of introducing and incorporating BIM in their organisations because this would require training and educating their workers, which ultimately require cost and time dedication within the organisation. [32] believes that the education of BIM can be helped by universities offering the under-graduates the basic knowledge needed before going to the industry to practice as a professional.

3. Research Methodology

From the available literature it was shown that there has not been any current study which has been conducted on the strategic implementation and adoption of BIM by QSs as part of project manager in South Africa. The Republic of South Africa has six professional bodies in the built environment which fall under the Council for the Built Environment (CBE) mandated by The Department of Public Works, one of the professionals where data was gather from was The South African Council for Quantity Surveyor's Professionals (SACQSP). This research utilised quantitative data collection methods from which rich data was gathered to reveal significant findings. The questions adopted a 5 point likert scale because this is the most popular method amongst researchers and the method is easy to commute with the respondents [16;8]. The questionnaire was comprised of 12 questions which were designed to explore the following aspects; 1) the current adoption of BIM levels amongst the QS's, 2) awareness of 5D BIM and 3) the readiness of 5D BIM adoption. The respondents were categorised to identify whether they are employed by Government, contractors, institutions of higher learning or by quantity surveyor's consultancy firms. The second aspect of the questions related to what BIM was used for clash detections, costing, design or management etc. This was followed up with questions of who requested BIM to be used for the project the contractors, client, management etc. The final aspect of the questions related to software's which are used and the importance of BIM.

4. Findings

This section shows a detailed exploration accomplished through statistical contrast of responses obtained from the questionnaires distributed to the members of the South African Council for Quantity Surveyor's Professionals, who predominantly work as construction project managers.

4.1 *Please indicate your level of experience in the construction industry.*

Figure 2 profiles the respondents in terms of the years they have been active in the construction industry and their experience. The majority of the respondents have only been in the construction industry for less than 5 years at 41% of respondents, followed by those who have been in the construction industry for more than 10 years at 38% and followed up by respondents who have been in the construction industry between 6-10 years at 21%.

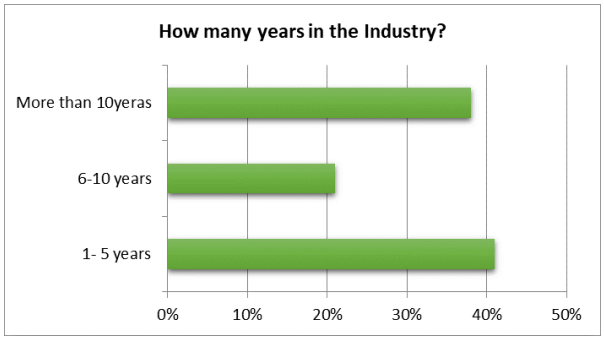


Figure 2: Number of years in the construction industry.

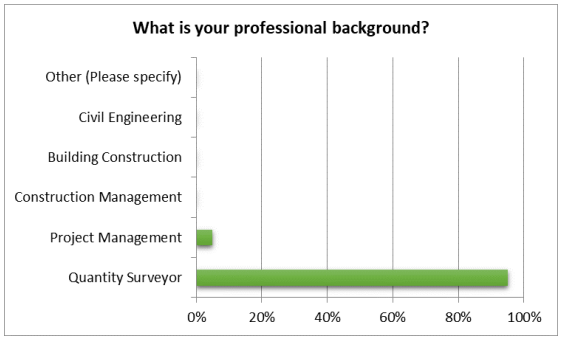


Figure 3: Professional Background

4.2 *What is your professional background?*

Figure 3 depicts the professional background of the respondents from the questionnaire. The majority of the respondents from the questionnaire are Quantity Surveyors at 95% of them which is then followed by some of the Project Managers at 5%. It is not surprising that the majority of the respondents are Quantity Surveyors, because the majority of the respondents came from the Council of Quantity Surveyors, who are already practicing in the industry.

4.3 *What type of organisation do you work for?*

The majority of the respondents were working for the Quantity Surveyors consultancy firms at 49%, which was followed by 27% of respondents working for Contracting firms who are employed as Quantity Surveyors for their employers which was then followed by 12% of respondents employed by Government Departments, followed by State owned entities at 7% and lastly followed by others at 5% which were (1) Institutions of Higher Learning and Professional Organisations.

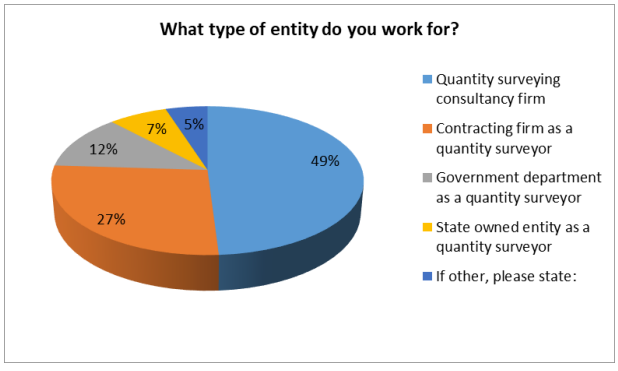


Figure 4: Type of entity

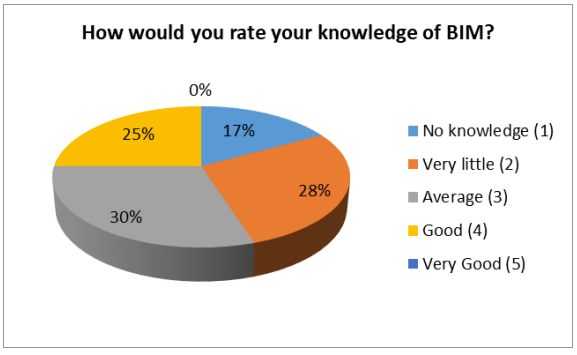


Figure 5: Knowledge of BIM.

4.4 *How would you rate your knowledge of BIM?*

Figure 5 was looking to understand the level of BIM knowledge amongst the Quantity Surveyors. The respondents were asked to rate their level of knowledge about BIM using a 5 point likert scale. The majority of the respondents at 30% rated their level of knowledge of BIM at 30%, which was followed by 28% having very little knowledge of BIM, followed by good knowledge at 25%, then those who had little knowledge were at 17%. It was very interesting that from the respondents that neither of them had very good knowledge of BIM.

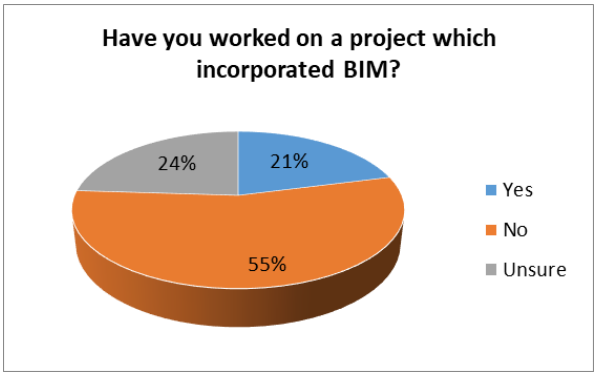


Figure 6: Project which incorporated BIM in the past 3 years.

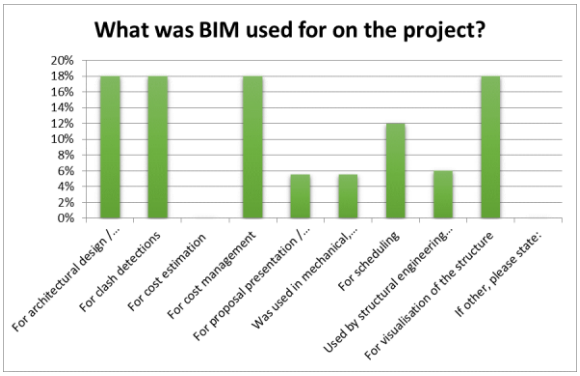


Figure 7: What was BIM used for?

4.5 *Have you ever worked on a project which incorporated BIM in the past 3 years?*

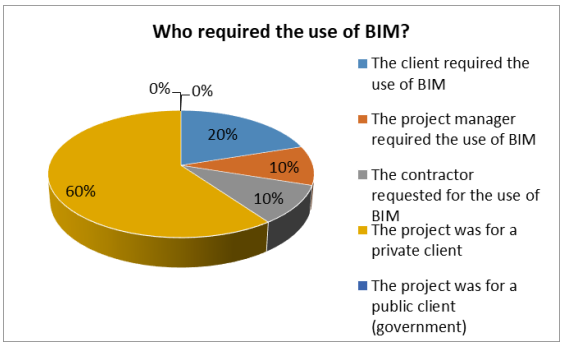
The authors had to probe the project which had incorporated BIM in the past 3 years. The results show that 55% of the respondents had not worked on a BIM project in the past 3years, while 24% of the respondents were unsure if they had worked on a project which had incorporated BIM in the past 3 years and 21% of the respondents had worked on project which incorporated BIM in the past 3 years.

4.5.1 If the answer to above is "yes", what was BIM used for?

When the respondents were quizzed about what BIM was used for on the, the responses were interesting. Architectural design/ modelling were ranked at 18% from the respondents, followed by it was used for clash detections at 18% also, interestingly enough neither of the respondents indicated that BIM was used for cost estimating. Cost management came in at also 18%, while 6% used BIM for proposal presentation and marketing, while 6% used BIM for mechanical, electrical and plumbing (MEP) design, 12% used BIM in their projects for structural engineering design and 18% used BIM for visualisation of the structure.

4.6 *Who required the use of BIM on the project?*

This was a critical question which the authors had to interrogate, being fully aware that when looking at available literature that some North America, Europe, Scandinavian region and Asia BIM is entirely endorsed by Government. 60% of the respondents stated that the use of BIM was required by private clients, while 20% was required by a client, while also some project managers also required BIM to be used at 10% and the contractor also requiring the use of BIM at 10%. What was interesting was that Government and States owned entities did not require any BIM to be used on public funded projects. This is clear shows that the South African Government is still far behind in the implementation and adoption of BIM on publicly funded projects. One of the project value of the project which was required to use BIM was valued at R11 500 000.



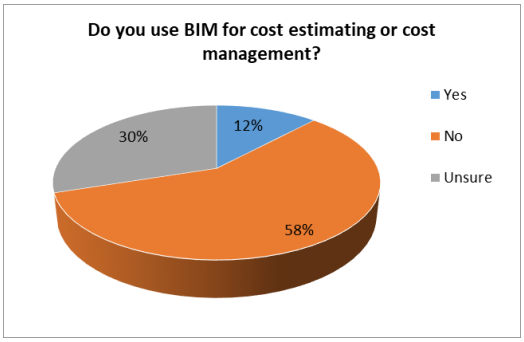


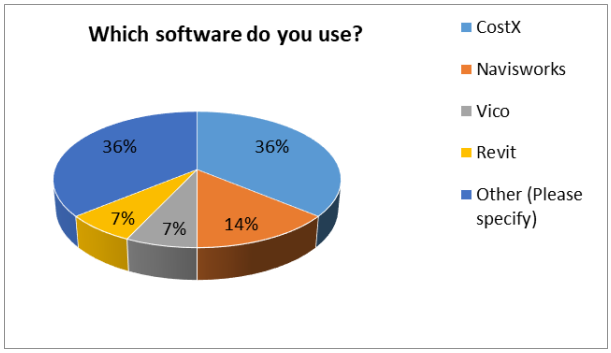
Figure 8: Who required the use of BIM on the project. Figure 9: Do you use BIM for Costing?

4.7 *In your organisation do you use BIM either for quantification, cost estimating, cash flow or cost management?*

For the authors to fully understand the level of adoption and implementation amongst the Quantity surveyors, they had to probe this question rigorously. A large majority at 58% have not used BIM either quantification, cost estimating, cash flows or for even cost management. While 30% of the respondents were not sure if BIM was used for cost estimating, quantification, cash flows or cost management. Only a small margin of 12% have used BIM for either quantification, cost estimating, cash flow or cost management.

4.7.1 *If the answer to above is "Yes" Which software was used?*

It was critical for the authors to find out which software's were used in their organisations. The most popular software at 36% was CostX used in respondents organisations, which was then followed by Navisworks at 14% then also Vico at 7%. The Revit software was at 7% used by respondents which was followed by other at 36%. The "other" software in this instance being WinQS. What the authors also wanted to find out was how long were these software's were used in their respective organisations. The number of years ranged from 1 year and 6 years of using these software's.



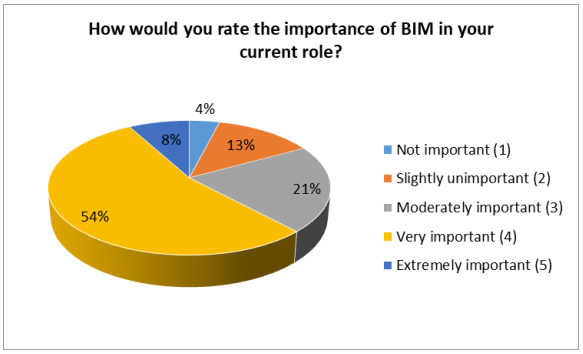


Figure 10: Software used

Figure 11: The importance of BIM

4.8 *How would you rate the importance of BIM in your current role?*

Figure 11 was looking to understand the level of importance amongst the Quantity Surveyors. The respondents were asked to rate their level of knowledge about BIM using a 5 point likert scale. The majority of the respondents at 54% believed that BIM was very important, 21% stated that BIM was moderately important, while 13% believed that slightly important, 4% of the respondents believed that BIM was not important and 8% stated that BIM was very important for them. One of the comments by a respondent was that *"Unknown as I have not used it"*.

4.9 *How would you describe your organisations future use of BIM?*

What was evidently clear was that the level of BIM implementation and adoption amongst the Quantity Surveyors was not strong enough. In future looks like the implementation and development of BIM will be on rise in South Africa among the QS's. The majority at 50% of the respondents replied that they will be fully using BIM in their Projects in the next coming 3 years. While a significant 30% state that they will be incorporating BIM in their respective organisations in the next 1 year and 20% of the respondents say that they will only begin to use BIM in their organisations in the next 5 years. One comments from a responded was that *"I don't think we will use BIM as currently there is no understanding what it is and its benefits for State Owned Entities (SOE's) and Government"*.

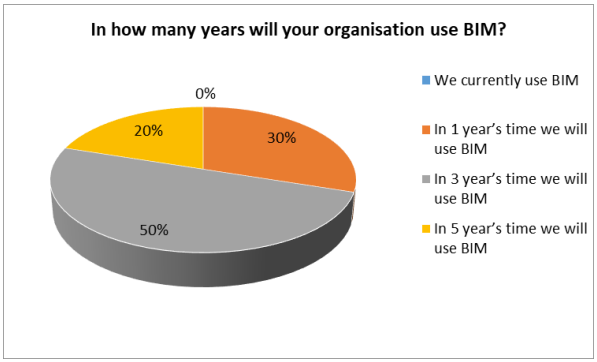


Figure 12: Years organisation will use BIM.

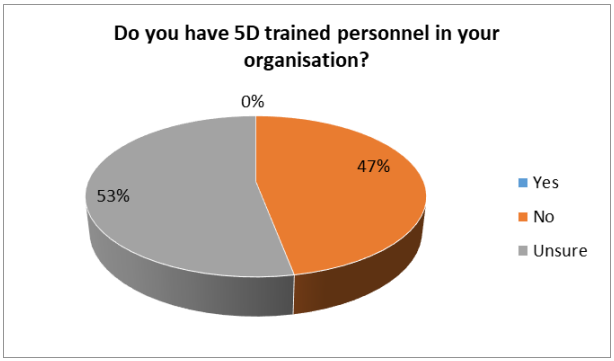


Figure 13: Trained personnel on 5D BIM

4.10 *Do you have 5D trained personnel in your organisation?*

With this question the authors wanted to find out if in the respondents organisations they had any sort of training in 5D BIM. It was clear that this has not been done in either of the respondents. 53% of the respondents were not sure if they had any personnel who was trained in 5D BIM and while 47% of the respondents stated that they had not personnel within their organisation who had training on 5D BIM.

5. Discussions of findings

This study in particular explored the application of and adoption of Building Information Modelling by the South African Quantity Surveyors operating in the construction industry. A study of this kind has not been undertaken in the South African context, however when looking at available literature similar studies have been conducted in other countries. The study by Mohammad, Michael, and Sharon, [20] which conducted in the United Kingdom investigated the integration of a QS's role and practice within the BIM process to enable better implementation of 5D BIM. Furthermore the study by Patil and Manish [24] focused on BIM application for Project Scheduling and Costing of Construction projects including barriers in implementing BIM. Also the study by Olatunji, Sher and Gu [22] explored the relationship between BIM systems and the roles of quantity surveyors in the construction industry. This study focused on BIM as it relates to the built environment in South Africa.

BIM is implemented in the South African built environment Profession. However it's still not extensively adopted. There are several challenges for implementing BIM as well as using BIM based QTO. Shifting from CAD based current South African construction industry to BIM based system need a lot of requirements like hardware, software and livewire alterations. Hardware includes system requirements to implement BIM and software includes the BIM platforms and other BIM tools and livewire includes construction industry professionals who need to have knowledge on BIM tools in their respective practices. Still after implementing, interoperability and IFC supported BIM platform and BIM tools selection will only lead to successful quantity extraction. Except the challenges in implementing BIM, with in BIM based QTO, competency of professionals is an ultimate requirement for success.

6. Conclusions and Recommendations

This final section the author will provide the conclusions and recommendations based on the data gathered from the different respondents by way of questionnaires. It becomes very important and critical that the conclusions be taken to heart and consideration by the project manager if they are to be able to participate in the 4IR and not get left behind.

Recommendation 1:

What was critical and clear was that there was not enough level of knowledge about what exactly BIM is among the Quantity Surveyors particularly 5D BIM. It is recommended that the professional council of Quantity Surveyors have seminars which are compulsory to attend, most importantly BIM should be taught in undergraduate studies in the universities as this is where the foundation is build before going to become a professional. That way when an individual enters the professional world or industry they are already knowledgeable about BIM.

Recommendation 2:

Quantity Surveyors need to start using 5D BIM for quantification, cost estimating and cash flows or cost management and how this can be done is individuals should be provided training sessions whereby Continuous Professional Development (CPD) points are awarded to individuals. Training can be provided by Universities who have capabilities or training facilities and trained staff in BIM specifically on 5D BIM.

Recommendation 3:

What was clear was that respondents acknowledged that BIM is very important, how what will drive the implementation and adoption of BIM amongst these Quantity Surveyors is cultural change for than anything else, Especially the mindset need to change and start thing about how 5D BIM will help them out in doing their job and not be afraid of change and technology.

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