# Implementing Building Information Modeling in Tanzania

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**FOREWORD**

I would like to express my utmost gratitude to my supervisor Univ.-Prof. Dr.-Ing. Mike Gralla at TU Dortmund, for his tireless guidance and encouragement all along to the accomplishment of this thesis. I could have not known him if it was not Prof Joseph Msambichaka, currently the Vice Chancellor of Mbeya University of Science and Technology (MUST).Working as Assistant Lecturer in the Architecture Department by then, with Quantity Surveying background, the chance to undertake this study was far of lucky out of many staffs deserving it.

The knowledge I acquire today results from the very useful financial support of Ministry of Education and Vocational Training (MOEVT) through Tanzania Commission for Universities (TCU) and the German Academic Exchange Programme (Deutscher Akademischer Austauschdienst) or DAAD.

It is hard to comprehend all the construction project delivery challenges, but through additional skills of Building Information Modelling, which is the talk of the Architecture, Engineering and Construction (AEC) industry worldwide I am hoping to make a significant contribution to the development of the construction industry in Tanzania. I feel so privileged to be among the Tanzanians who acquired this level of knowledge in such a conducive environment.

I am respectfully indebted to all those who spared their precious time to help me. The same respect goes to Frau Iris Rüters and all the Staffs of Civil Engineering and Construction Management department at TU Dortmund, for their selfless cooperation, which facilitated me in obtaining this knowledge. At this point, I am equally thanking my wife Rukia Ephraim Konga, all my family and clan members, relatives and friends for the excellent support, guidance and relationship that gave me an excellent mentality to achieve this.

I once again return my deepest thanks to my supervisor Univ.-Prof. Dr.-Ing. Mike Gralla, an experienced professional in Construction Engineering and Management, I believe that his generous guidance will persistently enlighten my future success.

Dortmund, 2016

Juma Ahmed Mpangule, M.Sc.

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## ILLUSTRATIONS

## ABBREVIATIONS

| | |
|---|---|
| 5DBIMBOQ | Fifth Dimension Building Information Modeling Bills of Quantities |
| AAAS | American Association for the Advancement of Science |
| AAT | Architects Association of Tanzania |
| ACET | Association of Consulting Engineers Tanzania |
| AEC | Architecture, Engineering and Construction |
| AIA | American Institute of Architects |
| ALAF | Aluminum Africa |
| AQRB | Architects and Quantity Surveyors Registration Board |
| Arch | Architects |
| ARU | Ardhi University |
| BGB | Buergerliches Gesetzbuch (BGB |
| BIM | Building Information Modelling |
| BOQ | Bills of Quantities |
| CAD | Computer Aided Design |
| CI | Construction Industry |
| CIP | Construction Industry Policy |
| COBei | Construction Operations Building Information Exchange |
| CoST | Construction Sector Transparency Initiatives |
| CPD | Continuous Professional Development |
| CRB | Contractors Registration Board |
| CRC | Cooperation Research Centre |
| DIN | Deutsche Industrie Norm |
| ECO | Ecological |
| ECOTEC | Emissions Control Optimization TEChnology |
| ERB | Engineering Registration Board |
| ERB | Engineering Registration Board |
| GDP | Gross Domestic Production |
| GWB | Gesetz gegen Wettbewerbschränkungen |
| HOAI | Honorarordnung für Architekten und Ingenieure- |
| Ibid/ Ibidem | meaning "The immediate previously citation" |
| ICT | Information and Communication Technology (ICT) at UDSM |
| IT | Information Technology |
| IDT | Innovation Diffusion Theory |

| | |
|---|---|
| IPD | Integrated Project Delivery |
| ISO | International Standards Organization |
| LCC | Life Cycle Costing |
| LCCA | Life Cycle Costing Assessment |
| LOD | Level of Details |
| LOI | Level of Information |
| LV | Leistungsverzeichnis/Leistungsbeschreibung |
| MEP | Mechanical, Electrical and Plumbing |
| MoEVT | Ministry of Education and Vocational Training |
| MoID | Ministry of Infrastructure Development |
| NBS | National Bureau of Statistics |
| NCC | National Construction Council |
| NHC | National Housing Corporation |
| NRW | North Rhine Westphalia |
| NSSF | National Social Security Fund |
| Nth D | n Number Dimension |
| PC | Prime Cost |
| PPP | Public Private Partnership |
| PPP | Public Private Partnership |
| QA | Quality Assurance |
| QASS | Quality Assessment |
| QC | Quality Control |
| QS | Quantity Surveyor |
| QS/BE | Quantity Surveyor /Building Economist |
| QTO | Quantity Takeoff |
| R&D | Research and Development |
| SMM | Standard Method of Measurement |
| SPSS | Statistical Package for the Social Sciences |
| TACECA | Tanzania Civil Engineering Contractors Association |
| TANROADS | Tanzania National Roads Agency |
| TBS | Tanzania Bureau of Standards |
| TCM | Total Costs Management |
| TCU | Tanzania Commission for Universities |
| TQD | Total Quality Delivery |

| | |
|---|---|
| TQM | Total Quality Management |
| TTM | Total Time Management |
| TU | Technische Universität |
| UDSM | University of Dar Es Salaam |
| UNESCO | United Nations Educational, Scientific and Cultural Organization |
| VgV | Verordnung über die Vergabe Oeffentlicher Aufträge |
| VOB | Verdingungsordnung für Bauleistungen |
| WC | Water Closet |
| WLCCA | Whole Life Cycle Costing Assessment |
| WSSD | World Summit on Sustainable Development |

# I. Introduction (Einleitung)

## 1. Problem Statement (Problemstellung)

Construction industry forms an important part of the Tanzanian economic growth and development. It contributes more than 50% of capital formation (Tanzania Bureau of statistics report, 2007). Nevertheless, the construction projects in Tanzania are not free from the inefficient deliverances. Cost overruns, time overruns and weakened quality of completed projects are among the common challenges. Efforts to eliminate these challenges has been the never-ending work in Architectural, Engineering and Construction (AEC) industry scholars and professionals. Scholars are changing methods, techniques and management from inspection to total quality management (Hellard, 1993) and procurement methods from traditional, integrated delivery and partnering ((Latham, 1994), (Egan, 1998), (McGeorge & Palmer, 2002) and (Greenhalgh & Squires, 2011))

However, the effort is inadequate. There is a need to increase effort towards the information integration, which is an important ingredient for the better decisions in attaining objectives during construction projects deliveries. Information integration is at the centre of contract documentation, which is the reflection of the intention of the project participants. Contract documents holds the material and ideal value of the purpose and endavour devoted by the team members. Lack of collaborative and comprehensive contract documents hinders a notable realisation of the desired outputs in terms of time, cost, quality or safety at large.

To address the problem, Building information modelling (BIM) is suggested in order to improve the performance of the contract documents during the whole delivery process. The strength of BIM is on the ability to facilitate collaboration and communication among participants, and so enhancing the information integration in the whole construction project delivery process. BIM is capable of giving better visualisation, exactness, transparency, details, specification and simulation of the design options. This ensures efficiency in documentation and effective communication between participants. It also reduces the fragmentations problems of the construction, which affects the information flow needed to ensure efficient delivery of the projects. Information is the ghost that when well understood, brings into light the whole reality.

In summary, there are construction projects delivery challenges related to time, cost and quality in construction industry in Tanzania. The solutions posed to address the problems are inadequate without a significant improvement in contract documents performance. Although the efforts works better to fight inefficiencies, yet a failure in the transfer of the valuable inputs between stages and among participants hinders desired satisfaction. At every stage in the construction, information is needed in a different format (Arayici Y.,2015), hence organization are now using Information Technology (IT) systems to facilitate the process.This can be achieved using BIM. BIM facilitates information integration and hence preventing the inefficiencies resulting from the incomplete information and communication flow during delivery process. The world is increasingly requiring collaborative effort in any endavour, which in construction project undertaking BIM is the way forward.

## 2. Study Objective (Zielsetzung der Arbeit)

This study generally aimed at appraising Building Information Modelling (BIM) to the Tanzanian construction industry. The construction industry with low technology and low economic capacities. To be viable, BIM need to be economically and technologically affordable. Building Information Modelling consists of key information to all participants and covers the whole life of the facility. It is a database representing graphical and non-graphical documents and communication.

Implementing BIM in fully, involves industrial change technologically and procedurally. It may involve a significant amount of investing in training, technology and bureaucracy. Therefore, government commitment is crucial for the success of BIM in Tanzania. Unless the government is evidently convinced with BIM, the implementation efforts are not worthwhile. Therefore, this thesis, proposed the use public related construction projects as the way forward adopting BIM to Tanzanian construction Industry.

It is suggested that, many of the time, cost and quality related problems in the public construction projects stem from the inadequate performance of the Bills of Quantities (BOQ) during the project delivery. Lack of enough BOQ productivity in the total cost management (TCM) of public related construction projects lead to inefficient decision making on the desired objectives of the project. The bills of Quantities, despite of being central information and contractual documents in Tanzania, they are not informing the members of projects sufficiently to allow for optimal decisions in budgeting, tendering, life cycle costing or in variation control. If well appraised and utilized, BIM can improve the productivity of BOQ in total project delivery.

Therefore, main objective of this thesis was to appraise the use of BIM in improving Construction contracts documentation in Total Performance Delivery of Public Construction projects in Tanzania. Specifically concentrating on the description of the relation between BIM and BOQ productivity during construction projects delivery and suggestion of the BIM model for Tanzania.

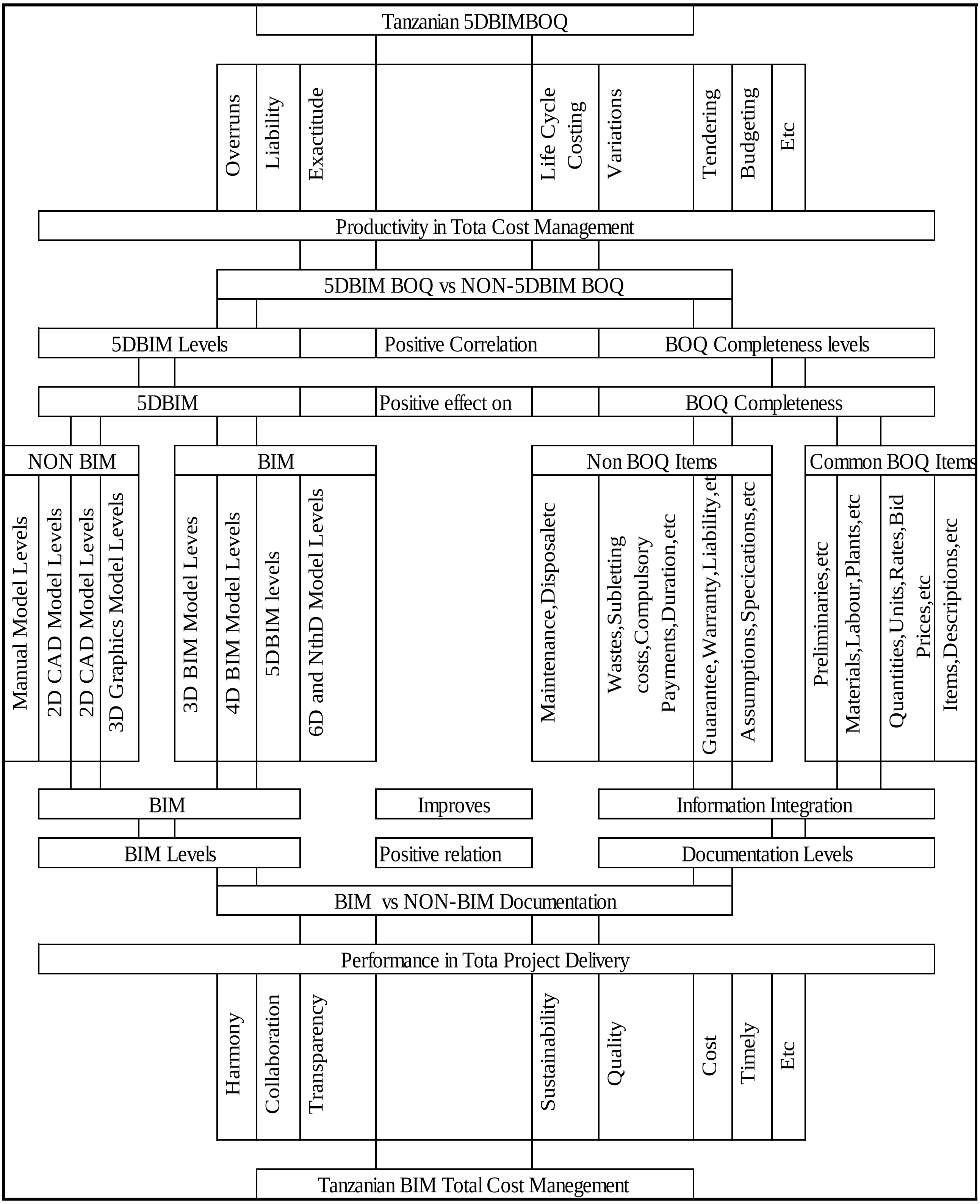



**Figure 1: Study Objective Concept[1]**

[1] Source : Own Construct

## 3. Study Approach (Vorgehensweise der Untersuchung)

To attain the objective of this study, the concentration was on what BIM does in the project delivery. To find few universally unique outputs that BIM provides to the construction project anywhere and at any time. Through that, the hypothesis that *"If 5D BIM has positive effect in Bills of Quantities (BOQ) Completeness, then the use of BIM can improve BOQ Productivity in the Total Cost Management of construction projects in Tanzania"* was developed. The intention was to objectively deduce BIM from the best practice elsewhere in this world. To Tanzania, this BIM is to act as a starting point towards more technological or best practice world BIM.

Out of many models, cost models are relatively central and richer source of information during the construction project. Costs models consists of the components of the contract documents. That said, it is in the view of this study that for a BIM to be of value in Tanzanian, at least there should be a positive relationship between BIM usage and the cost models efficiencies in total construction projects delivery. In Tanzania, like anywhere else, Bills of quantities form the basic and central contract document that itemises key activities and works components with costs estimates. In short, this study expects that in Tanzania construction project, the higher use of BIM relates positively to the higher level of completeness in the BOQ.

BIM benefits goes beyond handing over of the project to the client. It facilitates simulation and visualisation of the project undertakings to the operation and demolition levels. In BIM, the Total Costs Management (TCM) is of concerned at large. An efficient cost model will be more productive in TCM, and enhance total time, total safety, and total quality and total project delivery at large. In this thesis, technological disadvantages is no longer a problem. The assumption is that, it is a constant influencing criterion. The hypothesis is that in total costs management (TCM), the level of BIM usage has positive relationship to BOQ completeness level. A BIM BOQ is expected to have relatively adequate information that can facilitate higher productivity in the total costs management compared to non-BIM BOQ.

In this thesis, first chapter of the study introduced the subject in brief. It gives the statement of the problem, thesis objective and the approach used. Then followed the background in the second chapter. This substantiated the importance of quickly embracing BIM. It placed the study in perspective on how much the country is losing by not using BIM in public building projects. This part deduced the overall general idea to the researchable question. It gave how the objectives and hypothesis were preliminarily conceptualised and theorised.

Literature were reviewed in order to acquire the understanding of BIM in relation to the project delivery performance. Literature was covered in the chapter three, four, five and six. In the chapter three, the performance of BIM in delivery and contractual arrangement was reviewed. The intention being to understand the perspectives of scholars on the efficiency of BIM when used in different construction projects strategies. In addition, the overall fundamentals and challenges with regard to BIM implementation are reviewed. The fourth chapter describes Cost management efficiency of BIM.The chapter explains why BIM efforts should be directed towards cost objectives. It justifies on the need for participants to focus on total cost management models like BOQ. On top, the importance and uniqueness of BOQ in contract documentation and in ensuring information integration is set forward to justify the knowledge gap. Chapter five includes the review of construction industry in Germany. The key issues being the industry contractual documentation set up and BIM status. This intended to strengthen the research tools, refine the problem and add implementation vision. It was equally necessary to get an overview of the Bills of Quantities (BOQ) specifically in Germany, before rethinking on the BOQ of Tanzania. The sixth chapter gives a special attention to the 5DBIM importance as related to the study and the cost management models. It explains why the 5DBIM forms a central them in the study and in knowledge gap filling.
To acquire scientific skills necessary to solve research problem, it was necessary to review and establish the philosophical stance of the thesis, methodology and methods. Chapter seven covers a thesis setting philosophically and the research inquiry stance. It actually explains why the post-positivism paradigm was chosen to guide the thinking and activities in this research work. On the other hand, the terminologies like epistemology, theories, research design, hypothesis, and variables relative to the research were explained. Nevertheless, the measurement of the constructs and operationalisation of the research design to show how the study ensured validity, reliability and replicability are presented. The next chapter is about Methods. This eighth chapter include the data collection and data analysis considerations that were necessary for ensuring validity and reliability of data. The data analysis involved mainly questionnaires from the quantity surveying and architectural firms. The BIM and BOQ levels were clearly categorised and analysed in both ways descriptively and inferentially. The hypothesis testing using Gamma (G) non-parametric test was applied.

In the ninth chapter, there are findings and conclusion. The findings are categorised following the BIM and BOQ levels. Hypothesis testing and interpretation has been stated. The findings of the levels of BIM are presented from architectural firms and then quantity-surveying firms. The response on the levels of bills of quantities completeness followed the quantity surveying and architectural firms. All of these are supported by the structured interviewees’ responses. Graphs, Tables and Quotations has been added to display and facilitate grasping of perception of the respondents. The findings displays the contents of Bills of Quantities relative to the probable usage of BIM. The conclusion is fused with the model development. The section gives detailed contents derived to be used as foundations in the developed BIM model. Although, the parameters are currently temporary, they have been clearly explained and linked with the existing literature review and empirical evidences found in the study to justify their potential in the model. Items necessary in 5DBIM like communication, collaboration, visualisation and transparency has been explained relative to the Tanzanian developed BIM or 5DBIMBOQ.

The study is closed with the figures, attachments and references in the tenth chapter. The word figure has been used to represent both tabled items, drawings and pictures. There is also illustration boxes that contains remarking contents from sources to stress a given explanation. Attachments of the examples of questionnaires and related documents used during the research work are attached to display the closer picture of the effort in different undertakings. References are following the American Psychological Association (APA) style.

| STUDY APPROACH | | |
|---|---|---|
| Chapters | Key Headings | Brief explanation |
| I<br><br>Introduction | Problem Statement<br>Study Objective<br>Study Approach | This section gives the executive summary of the thesis. It shows why this study is worth, what is the key objective of the study and how this objective has been addressed |
| II<br><br>Background | BIM in Construction Industry<br>Why Tanzania need BIM?<br>BIM in Thesis Context<br>Research Methodology and Strategy | This section gives the foundation of the thesis. It explains the urgency for the study and briefly states the guiding conceptual and theoretical thinking proposed to approaching the study |
| III<br><br>BIM in Construction Project Delivery Methods | BIM and Performance Improvement<br>Construction Projects and Procurement Methods<br>Fundamentals of BIM | This Chapter substantiates the strength of BIM over other methods and techniques in the improvement of performance in the construction Projects delivery efforts. It equally explains the fundamentals of BIM as a technology and process in the delivery efficiency. The chapter has also explained the strength of BIM in different delivery method or contractual arrangements |
| IV<br><br>BIM in Construction Cost Management | BIM in Total Cost Management<br>Life Cycle Costing | This chapter gives the need of BIM focus into central contract documentation or information integration efficiency. It explains the importance of Bills of Quantities in achieving construction projects objectives. It equally justifies the need to relate BIM efforts with the total Cost Management Models like Bills Of Quantities. Additionally, the need to include life cycle thinking in the BIM environment has been displayed |

**Figure 2: Study Approach (1/3)[2]**

[2] Source: Own Construct.

| | | |
|---|---|---|
| V | Construction Contract Overview | This chapter reviews the thesis key focus from the Germany perspective and practice. It explains the fundamental contractual relationship of participants and the importance of BOQ in practice. Differences and similarities of BOQ contents between countries has also been reviewed. The status of BIM and the implementation strategy has been touched. |
| Germany Construction Industry in Brief | Bills Of Quantities in Germany | |
| | BIM in Germany | |
| VI | 5DBIM Efficiency | This section gives a special attention to BIM dimensions. It explains why the focus of BIM should be directed into the Fifth Dimension, which is Cost dimension. It shows the importance of 5D BIM in construction performance. 5DBIM has shown to be the secret of filling the knowledge gap in this study because it contains the strength of BIM. The chapter shows how 5DBIM can facilitate development of BIM in Tanzania through Bills of Quantities, which justifies the hypothesis of the study. |
| **5D Building Information Modeling** | 5DBIM Rationale in knowledge gap | |
| **VII** | Philosophical Stance | This section articulates the mental worldview that guided the researcher during the whole undertaking. The chapter explains why the focus on BIM were mostly on tangible output than otherwise. It explains the post positivism and critical realism stance followed. It shows the grounds that lead to the choice of cross-section research design and snow ball sampling instead of other methods like simple random. Also this part gives the bases for measurement and operationalization of the variables, including showing the effort to ensuring validity and reliability in the study. |
| **Thesis Philosophy, Methodology and Methods** | Scientific Inquiry | |
| | Research Strategy and Design | |
| | Sampling | |

**Figure 3: Study Approach (2/3)**[3]

[3] Source: Own Construct.

| | | |
|---|---|---|
| **VIII** | Data Collection | This chapter has shown the way variable were developed, measured and analysed. The BIM levels and BOQ completeness levels were clearly shown in Likert scaled questions. The choice and reasons for using questionnaires and structured interview were explained, indicating the source of data and relevance to the problem statement, hypothesis testing and objective. The analysis were both descriptive and inferential, which included only the data from quantity surveyors and architects questionnaires. The use of Gamma test was necessary because of the ordinal measurement level. |
| **Data Methods** | Data Analysis | |
| | Response on Predictors | |
| | Response on Responses (dependent Variable) | |
| | Distribution Data Interpretation | |
| | Inferential Analysis | |
| **IX** | Findings | This chapter summarizes the findings in category of presence of BIM, BOQ completeness and existence of the association of BIM usage and BOQ completeness. It explains the contents level of BOQ completeness relative to the level of BIM usage. The chapter comprehensively discusses the parameters necessary to form the developed model for Tanzania, which is 5DBIMBOQ. It finally gives the concluded remark and show the further areas of study that can be suggested from this thesis. |
| **Results and Conclusion** | Presence of BIM and BOQ Completeness | |
| | Proposed Model Development Contents | |
| | Conclusion | |
| **X** | Study Schedule from March 2013 TO 2016 | This chapter outlines the list of supporting documents. Questionnaires samples and Interviews coding were also attached. Figures, which include tables and photos or diagrams to be found in the thesis are also outlined. Illustration boxes outlined separately as they form specific remarks in the thesis. Equally the declaration to be signed is at the end of the work after references. |
| **Appendices** | Questionnaires and Interviews Sample | |
| | Reports | |
| | Figures and Illustration Boxes | |
| | References | |
| | Declaration and Copyright | |

**Figure 4: Study Approach (3/3)**[4]

[4] Source: Own Construct.

# II. Thesis Background

## 1. BIM in Construction Industry

This thesis dream is to contribute to the development of Tanzania through an improvement of performance in the Construction Industry (CI). The performance of sectors like Agriculture, Health and Manufacturing largely depend on the prosperity of Construction Industry because the CI is catalytic in nature (Hellard, 1993). In (Lopes, 1998) the study suggested that, there is a positive interdependence between construction sectors and a national economies of sub-Sahara African countries. The prosperity of Construction Industry usually reflects the economic development of the country. Lack of quick response to challenges of Construction Industry, will affect key activities including the development of infrastructural in the country (Alarcon, 2007). It was suggested that construction sector is one of the key economic indicators and wealth creators in Tanzania as well as in Kenya (Njuguna, 2008) **.** In (National Bureau of Statistics, 2013) the statistics showed that 24.0% of GDP comes from Construction Sector *(See the Figure 5: Percentage Share of GDP at Current Prices*, (2012*).* Infrastructures play a big role in saving time and cost, and in improving productivity through enhancing peoples mobility and maintanining a healthier working environment. A loss incurred by traffic jams (Weisbrod & Reno, 2009) or unhealthy physical work environment ((Burton, 2008) and ((Smith & Tardif, 2009) Pg 23)), may real be horrible when converted into monetary values.

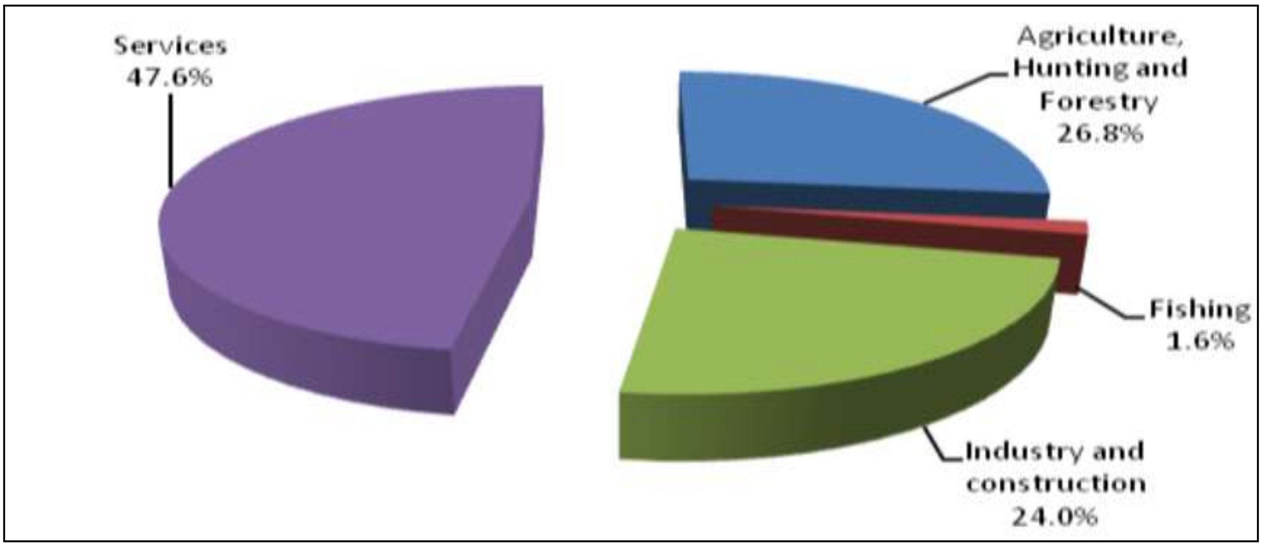



**Figure 5: Percentage Share of GDP at Current Prices, (2012)[5]**

[55] Source: National Bureau of Statistics. ( 2013), Page 38

The person living in Dar Es Salaam, knows what it means to cover the 2 Km distance when one is travelling to and fro City Centre between 7.00 AM and 9.00 AM or 3 PM and 8 PM in working days during 2000s years.Uncomfort zones of walking or cycling adds to increased accidents effects, resulting to significant loss of labour force and capital waste. Katala,(2015) estimated the loss to be 655 Billions Tanzanian shillings per year only due to congestion in Dar es salaam, and hence calling upon efficiency in Dar Rapid Bus Transit (DART) project.
On top of that, hot and cold weather conditions in Dar Es Salaam and Mbeya regions respectivelly may give a good example on the effect of facility environment. Lack of air conditions or inefficient design of ventilation systems may lead Students, Doctors and Clerks to perform lowly without noticing. Such a situation may lead to “idleness”, stress and the like. Nevertheless, choice of materials may also cause healthy problems and interruption of daily activities unknowingly. Think of internet and phones connectivity. Sometimes to reduce noisy one may need the lesser noisy materials or the materials that automatically disconnects the connectivity, say in classrooms. Likewise, polutants effects, like that of noise resulting from errors in design may equally disturb a genuine connection and communication as well.To achieve such a multidimension coverage of design and execution it is important to have a total teamwork effort and well informed collaboration.In BIM environment, such extensive information reaserch is possible (Hardin, 2009). Definitely, any participant in the procurement process of a facility is worth something to its performance.

The construction industry is blamed due to insufficiency in productivity and infrastructural value for money. This is so, not only in Tanzania but also in the United Kingdom ((UK (Nour, 2007) and (Sommerville, 2004)). The buildings, roads and plants handed over to clients satisfy less than what they are expected. Projects being timely delivered, within budget, is prerequsite to their purposes. Operational needs of the users are achievable necessary standards for defining the success of those projects. An individual effort, is no longer desirable in covering such a delivery milestone.

According to (Forbes & Ahmed, 2010), the relationships among participants can influence the delivery of the project. Today, collaboration is more challenging efforts than finding the right resources for the construction projects. The advanced civilization world wide has made the boundaries open and so facilitating availability of materials, plants and labour necessary for any kind of project anywhere in this world. This leaves managerial challenges among the suspects of unsatisfactory performance of Construction Industry. Poor management, lack of effectiveness in communication and inefficient flow of information are among the mentioned sources and reasons for the noted low productivity in the construction industry *(ibid).*In Tanzania, (Ntiyakunze, 2011), noted that among others an opportunistic behaviour of project participants frequently results in conflicts in construction projects.

Efforts has been done to eliminate inefficiencies in Construction industry.Much of the effort has been managerial rather than technical. Arditi, (1985) suggested to concentrate on improving planning and scheduling. Hellard, (1993), suggested that a change of culture through Total Quality Management (TQM) can reduce the in-built inefficiency in the Construction sector. In TQM, it is expected that by involving everyone in the construction process and activities, the contractual and production barriers may be eliminated. Such an effort is also witnessed in the Integrated Project Delivery and Lean Project Delivery System. The focus is to bring all participants in play as earlier as possible to ensure successful collaboative project delivery.The aim is to deliver a facility with lesser wastes in the whole delivery chain. According to (The American Institute of Architects National (AIA) and AIA California Council, 2007), Integrated Project Delivery (IPD) refers to

> *" a project delivery approach that integrates people,systems, business structure and practices into a process that collaboratively harness 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*."

Generally, IPD seeks to achieve the necessary performance through the maximum use of the potentials of all participants toward the project. It seeks to achieve optimal project success through cohesive project teamwork (Eastman, Teicholz, Sacks, & Liston, 2011). However, bringing closer the participants, does not guarantee complete flow of the information in the delivery process. It requires the *right technology and model* to convey the image from participants to among and between them in a more refined way, so that it can easily serve as a base for the right decision making. Participants internally are professionals with differing languages. A foundation element line drawn in a Floor Plan view, is viewed differently by a Quantity Surveyor who intends to *take off* the quantities by making some allowance of excavation.

As mentioned in (AutoDesk, 2010), that BIM can significantly reduce errors ,omissions, and reworks. It can enhance an internal value in the delivery process. Forbes & Ahmed, (2010), supported that, inadequate design and documentation quality decline the efficiency in construction projects. The difficulties encountered in streamlining the construction process in such a way that information can not flow perfectly, timely and completely may be solved by BIM. That information flows and materials should be a focal point, because they contains time, cost and value characteristics in the construction projects (Koskela, 2007).

Building Information Modelling can facilitate decision making, teamwork cooperation and process integration in Lean production philosophy (Li, Aouad, McDermott, Liu, & Abbott, 2007). In Lean Construction, key endavour into adding value include reducing waste and time cycle.To attain this it is important to ensure that what designers are intending to deliver to the client, is just and timely transferred to all other participants.If an Architect can spend one more hour in improving the same design, then it is far better than sending the drawings one hour ealier to the quantity surveyor and devoting that effort to the other activity unnecessarily. This hour belongs to this client and the improved quality would be relatively wasted by sending the drawings earlier to the QS. Accurately informed subcontractors or suppliers will provide sevices of more value than the lesser informed because of the likely reworks and clashes resulting from discrepancies between planning and actual construction. In BIM more visualisation and clash detection ability, gives participants an opportunity to avoid wastes and reworks.

Building Information Modelling (BIM) is probably the best tool to fulfil the IPD, Lean and TQM efficiency in Construction, because the key decisions made are collaborative and are resulting from the integrative nature of construction project delivery information. At its heart Building Information Modelling, consists of key information to all participants .BIM can help to reduce waste and improve project delivery internally and externally (Oskouie,*et el*, 2012). BIM facilitates the flow of necessary information during the whole life of the facility. Clients are no longer in front of drawn lines, but rather parametric components of windows, doors, columns and beams joined to perform a function. Clients or financiers can now request instant answers and justification in order to ensure they acquire the right value of the facility. The greater value to the owner is more on the purpose of the facility (Smith & Tardif, 2009). The way this facility will serve the users in the whole life cycle. With BIM, design alternatives covering life cycle milestones can be tested by participants

> *"BIM provides information infrastructure that will allow architect,engineers,contractors, and owners to assess multiple life cycle factors in the early stages of design collaboratively, including energy consumption, total life cycle cost of materials, equipment and systems, and workplace productivity"* (Smith & Tardif, 2009,Pg 24)

BIM will definitely capture the whole world at last (Hobbs, 2008).It is the choice of the future, so a professional denying it, may find it difficult to exist in the construction market. Governments are demanding a compulsory use of BIM in all public projects by 2016 ((Robson & Littlemore, 2011) and (Eastman C. P., 2008)), and the UK being one of them. Sustainable design and sustainable thinking in construction, they all rely on the way BIM is embraced. In Tanzania, for example, CAD was hardly used before 2000s. But today,some 10 years later, technical institutions hardly install Drawing Boards, and instead construction design Students are buying laptops and spend time to learn CAD softwares themselves, because it is what the market demands. The transition from manual to CAD was mainly for architects and engineers, the purely designing professionals. Not even services engineer bothered much to be competent in CAD. To Quantity Surveyors, excel competence was much important than CAD, the same to Valuers and Facility Managers. The reasons behind included among others, the fact that, CAD merely replaced the pencils and drawing tables, without influencing more on the information integration in the project. The extra CAD knowledge, influenced clients on more improved graphics and not a noticeable increased value adding information,like that resulting from collaboration. BIM gives raise to both, improved graphics and collaborative delivery,which enhances the project information value exposure to the clients.

The above CAD transition, was not without resistance. A time saved and output improved significantly, the use of CAD software to recopy and edit what has been done at the expense of creativity and concentration of the manual effort was not so justifiable. A harm to the construction industry, among others, was a *hiden weakness* in documentation, the clients could not see. Quickly delivered and highly decorated *designs graphics*[6] can easily be justified to hold the desirable project value. This will not be the case for BIM. Because, apart from the speed of delivery, BIM adds the advantage of possiblity of collaborative delivery. Transparency eliminates hiden weakness to a significant level. Clients are closer to the extenal and internal value of their available products and services. It is their concern to decide whether to choose or to take what they are being given by the designers. Clients can now question the relation of the drawings to cost and time schedule and get answer instantly.Quantity Surveyors can no longer spend time taking-off, but rather more time in contributing value adding inputs to designers, see (Sabol, 2008).On top, facility managers can easily be involved in designing stage as well to ensure satisfaction of the users is met.

[6] The human being, creature of eyes, needs the image. *Leonardo da Vinci qoutes*


**Figure 6: BIM around the World**[7]

Like any industry, competition in construction is fiercer today than yesterday, as it may be fiercer tomorrow compared to today. Simply because the advance in civilization keeps on breaking the business boundaries from village to global level. It is believed that construction spending is shifting not only to Asian countries but also towards Africa (Forbes & Ahmed, 2010). This at large means more competition to companies and professionals around the world. Globalisation effects is unstoppabe, and hence there is a need for Tanzanians to be as proactive as possible, if they are to benefit more from the global market. From (Ofori, 2013), developing countries like Singapore and Tanzania, need ***" the 3P"*** construction industry (CI), that is Professional, Productive and Progressive. Actually to benefit from globalisation developing countries may also need the "$4^{th}$, $5^{th}$ and $n^{th}$ P", that is to be ***Proactive, Persuasive*** and ***nthP***. Tanzania needs the ability to foresee, rehearse and intergrate the future construction practice within todays environment, because the world construction industry practice indicates to be far ahead of construction industry practice in Tanzania today. In 2000s, scholars like (Sun & Aouad, 2000) had already alerted the need to advance from CAD, which was hardly taught in colleges and universities in Tanzania. It was said;

> "*The use of computer aided desgn (CAD) is not enough to achieve efficiency necessary for the current construction demand.Integrated construction process requires an integrated IT system that will enable the project team members to work together and share project information seamlessly".* (Sun & Aouad, 2000)

[7] Source: WSP Group Limited, (2013)

According to (Twaakyondo, Bhalalusesa, & Ndalichako, 2002), poor literacy in ICT contributed to the low performance in different Public Private Partnership (PPP) projects. It was supported by (Materu & Diyamett, 2010), who found that, the comperatively higher cost of computers and internet services hindered the development towards fully utilization of ICT in Tanzania. Until recently, the idea of BIM is one of the newest concept among practitioners. This was obvious during the Continuous Development Development (CPD) seminar of Architects and Quantity Surveyors Registration Board (AQRB) held in Mbeya between 21st -23rd March 2014. As Kristen Broberg, an Australian Architect, practicing in Sweden mentioned BIM and confirmed that BIM is no longer a dream, but rather a reality in many European Countries. In Tanzania, on the other hand, many professionals who attended found it a new idea[8].

> *"At Liljewall Architects & Planners, our BIM development has been an organic process. Over 10 years ago, the choice was made to abandon tradition 2D CAD and begin working in a 3D object-based environment. This choice was based primarily on the need for improved quality in documentation and in the need to have a greater understanding of increasingly complicated buildings".* ( Broberg, 2014)

While Tanzanians are wondering, Kenyans are questioning the workability of the use of E-Construction Permit (E-CP) (Home African Building, 2013). It was stated that E-CP is

> "*an automated system used to electronically approve submitted plans by architects through the portal. Architects are able to submit their drawings through the system for the approvers based at the Nairobi City Council to electronically approve the building proposals."*

Such an effort gives the light on where exactly the construction industry is going in the near future. Building Information Modelling is unstoppable, the best option is to lead on adoption and implementation. By 2011, it was already rooted in the AEC industry within the United States and Western Europe (Autodesk, 2011).

Despite the fact that Construction Industry contributes to gross domestic economies, it also need attention with regard to sustainability conciousness.Struggling to consume resources carefully enough to save the ecosystem stability. On page 38, (Kibert, 2008) mentioned climate change and ozone depletion, soil erosion, desertification, deforestation, eutrophication, acidification, loss of biodiversity, pollution, dispersion of toxic substances and depletion of fisheries as some of the major

[8] RESPONDENT 4: Who attended the CPD said, "I was in CPDs, when someone presented and I asked how much does it costs. They said like 3000 Dollars. That is so challenging, with installation, and training staff and team of expert you are working together. In our country BIM would have simplified many things"

issues with respect to sustainable construction. Sustainable construction is of vital concern (Haselbach, 2010). Sustainable Design in construction is a clear trend throughout the world (Peca, 2009). It is a societal requirement facing Building Industry in Sweden (Sterner, 2000). Governments are struggling to impose the supporting laws. In Ma, (2011) a number of social and environmental laws in UK construction industry was mentioned. Sustainability is about meeting or exceeding the todays' needs without compromising the needs of the coming generation. The Task Force to assess sustainability in Africa (Tessama, Taipale, Berthge, & Schindler, 2009) financed by Germany mentioned inadequate urban planning as one of the challenges for sustainable buildings and construction in Africa. In Tanzania, it means the need to shift from local individual construction level to a standardised construction. Many of these environmental problems are well known in Tanzania, with pollution being one of the example. Polution is caused by inadequate infrastructual systems to recycling waste water in cities, Dar es Salaam being among them. Likewise, (Mafuruki, van Egmond, & Scheublin, 2007), recommended steel over timber in construction activities like scafolding and formworks, in order to minimize deforestation.

In Tanzania (National Construction Council, 2013), construction industry is defined as

> *"………… a sector of the economy that transforms various resources into constructed physical economic and social infrastructure necessary for socio-economic development. It embraces the process by which the said physical infrastructure are planned, designed, procured, constructed or produced, altered, repaired, maintained, and demolished. The constructed infrastructure include:*
>
> *Buildings Transportation systems and facilities which are airports, harbours, highways, subways, bridges, railroads, transit systems, pipelines and transmission and power lines. Structures for fluid containment, control and distribution such as water treatment and distribution, sewage collection and treatment distribution systems, sedimentation lagoons, dams, and irrigation and canal systems.*
>
> *Underground structures, such as tunnels and mines. The industry comprises of organizations and persons who include companies, firms and individuals working as consultants, main contractors and sub-contractors, material and component producers, plant and equipment suppliers, builders and merchants. The industry has a close relationship with clients and financiers. The government is involved in the industry as purchaser (client), financier, regulator and operator."*

In a nutshell, Construction Industry refers to the sector dealing with infrastructural undertakings in the economy.The definition above indicates the danger, Tanzania is heading into, if construction industry does not consider sustainability.The future of Tanzanians equally depend on how carefully the construction projects are undertaken. The Modular Building Institute, (2010) pointed out that

> *"The quality of life of every American relies in part on the products of the U.S. construction industry—houses, office buildings, factories, shopping centres, hospitals, airports, universities, refineries, roads, bridges, power plants, water and sewer lines, and other infrastructure. Construction products—buildings and infrastructure—provide shelter, water, and power, and they support commerce, education, recreation, mobility, and connectivity."*

Stepping from the above, it is clear how vital is sustainable thinking with regard to sustainability of the built environment. It is illogical to think of sustainable construction without sustainable thinking of the construction participants, because it is those participants who influences the built environment. In (Matipa, 2008), design and specification of materials are the key aspects in sustainability. Irrational design or selection of materials without multidimensional consideration, will induce the coming genaration the same characteristics. The built environment should reflect the kind of thinking the society is enjoying. To competitively enhance the sustainable thinking and sustainable construction in construction, a society needs integrated construction project delivery.Kubba, (2010), provided that intergrated design is a key aspect to achieve sustainable construction. To be societal, this phenomena should cover big projects, smaller projects and it should expressly be included in policies of the construction industry as well.

In practice, professionals of construction hardly give the same weight at every stage of project delivery. Design stage, is probably the most important to many practisioners. It is where the forecast of the works is done and justification for the existance of the project made. Nevertheless, Commissioning stage, which is very often discussed or confused with project handing over, is equally important, when it comes to real customer satisfaction (Hellard, 1993). Commissioning is delivering the project while considering utility of the facility. Designers and builders, all have to bear in mind the needs of the users, if they are to meet the value of projects.That effort is what comprises commissioning in essence. Lack of maintenance cost concept in construction projects is one of the challenges facing CI in Tanzania (UNESCO, 2009). This begins with lack of commissioning practice during projects constructions. Worse enough, not many clients are aware of what they miss by not paying attention to commissioning. Facilities consume more energy and emitting environmentally harmful energies that settle off the capital advantages (Aye, Bamford, Charters, & Robinson, 2000).

A country like Tanzania, where earnings are relatively low, a shopping mall will serve the customer a better price if unnecessary electicity and other utilities bills are vigorously value engineered.

Additionally, the construction practitioners in Tanzania were blamed for unethical and lack of technical skills related to procurement (Mlinga, 2006).Such practice weakness may be the sources of unnecessary delays and costs overruns in projects executions.The CI needs the mechanisms that can facilitate the transfer of the whole *facility life cycle* images between *executors* themselves and among *participants transparently*. That is to say, Tanzania Construction Industry (CI) needs to adopt and employ BIM, in order to overcome the current weaknesses of the industry.

Through the use of BIM the user can clearly be involved in the design, and enhance the product definition instead of waiting at the end. Chiragi, (2000), suggested that property manager inclusion during design stages of construction projects is vital to the quality project delivery. BIM improves even the use of Computer Aided Design (CAD) because it easily brings into play other participants like specifier, and contractor.It gives the facility manager the chance to percieve the whole facility before actual site works (Weygant, 2011). Many behavioural and operational aspects of the facility can accurately and confidently be detailled (Crotty, 2012).The project participants can in advance be sure of what is to be done and hence avoid the unnecessary *"as usual"* said unavoidable design changes. From (Weygant, 2011), BIM has developed from only the tool for design to digital representation of the facility before any financial decision is made. It helps to detect clashes,select products and to conceptualize and analyse the whole project earlier.

Last but never the least, CI in the country like Tanzania is blamed for curruption. Corruption is attached to recurrent failure of buildings. According to (Njuguna, 2008), corruption causes uncertanities and increases the cost of doing business. Mlinga, (2006), said that the current rules work less in combating corruption, unless they are implemented by the actors themselves. On the other hand, (Taylor & Mawenya, 2013), required proactive strategies like Construction Sector Transparency Initiatives (CoST) to fight corruption, financial mismanagement and non trasparent systems in Tanzanian CI. Not mentioned openly in ((Chiragi, 2000) and (UNESCO, 2009)), corruption can sensibly be within professional misconduct and unethical doings.Also the use of inappropriate technologies was mentioned to be among challenges to the Tanzanian CI. However hard it my be, to find the evidences of corruption, it still sound worth to rely on the opinions pointing to it and to accept as true, than otherwise. Countries with low technology like Tanzania, solution to this, depends partly to the participants attitude and transparency of the process of projects delivery. In (Tanzania Civil Engineering Contractors Association (TACECA), 2008) it was said;

> "*CoST is about increasing transparency. Enhanced transparency in the construction sector has two main benefits. First, corruption is reduced since persons intending illegality would perceive a greater risk of getting caught thus modifying their behaviour; and second, management would improve since slack practices would come to light and more care would be taken. Corruption and bad management both lead to poor quality construction and inappropriate structures that are unsafe and unsustainable*".

It is obvious that, Tanzania needs the cultural change in the construction projects undertaking. It needs the paradigm shift, the process that can positively effect change to all participatory machineries of the project, from inception to disposal (Reddy, 2012).This study concurrs in that BIM may rescue the Construction Industry from inefficiencies. Among others, BIM can be used as evolutionary tool of the CI development through information integration. The input data and experience are the key hindrance to full benefit from Life Cycle Costing (LCC) in CI.Such problems can be reduced through the use of databases compatible LCC models (Sterner, 2000).By acting as a central database, BIM will eliminate all the barriers to viewing the facilities in life cycle, and enhance a sustainable design view at large. Currently, scientist are finding ways to deal with Demolitions (Kein, Thanh, & Lu, 2013), to reuse for the sake of reducing the environmental impact as well as cost of re-construction process. Through as built BIM model, clients can easily attain this. All the information of the facility can instantly be retreived and traced from the model.

To a Tanzanian construction professional, BIM is not a challenge, but a way toward international competitiveness. In Africa, BIM is still at infant stage, as (Booyens & Bouwman, 2013) remarked, *"…… BIM is growing, but that it is still far away from realising its full potential"* .This presents Tanzanian professionals with an opportunity to be on table with other African Construction Professionals. In (Mosha H. , (2007)), quality was mentioned among the key pillar to help Architecture graduates from Ardhi University in international market competition. Most of the Architects, Quantity Surveyors,Valuers and Environmental Engineers in practice today, originate from Ardhi University, which were the only University in Tanzania until 2004 providing this level of construction education.

## 2. The need of Building Information Modeling in Tanzania

The definition of Building Information Modelling is within its name.That is the output (model) and process of modelling the information in the building (construction) process.The American Institute of Architects National (AIA) and AIA California Council, (2007) defined BIM as a *model based technology* linked with a *database* of project *information* while Demchak,et el (2008) defined it as the management of *information* throughout the entire *lifecycle* of a design process from early conceptual design, through construction administration, and even into facilities management. It was argued that, visualising the project in BIM, enables huge benefit of assessing the operational costs in the early stages of the projects (Mütze, Senff, & Möller, 2012). More than 80% of the operation costs can be dealt during design. The decision on the type of doors in the domitories or offices, are much certain because, the facility manager are now able to add their valuable user perspective experience, which an Architect or a Quantity Surveyor could have skipped.

Eastman, et el (2008) viewed BIM as a collection of tools and processes that result in a product that is greater than the sum of its parts. To them, BIM is a modeling technology and associated set of processes to produce, communicate, and analyse building models. It facilitates experts to collaboratively model the intended image of facility out of many sub-components of the facility. A foundation element model is joined to superstructure element models. Architectural models can be joined by Structural Engineering models and to these, they can be extended to the Facility Managing information models at large.

Different professionals view the same building component models differently as project information. To Quantity Surveyors, the models of the building are viewed in terms of Costs implication, Architects first priority may be aesthetics and space functions, while engineers intend primarily on stability. To come up with decision with regard to suitable design, communication alone is not enough, without understanding and simulation of the likely situation. The composed BIM adds those value that are very important in decision making. In (Morrissy,et el 2012) view, BIM is a 3D virtual representation of the building to be constructed. It provides a digital simulation of the structure to be built showing how it will be constructed and how it will allow the design to be tested before the construction phase begins. Because BIM is not fully explored, definition of it is a yet to stay debate among scholars. BIM

> *"refers to a creation, representation and management of a constructed structure information integration level necessary to facilitate efficiency in the total project delivery endavour. It is a measure in which Information Integration Performance can be ordered from the Low Level through the Highest Level, and the intervals between them. BIM is often described in terms of Dimensions, along with the spatial parametric digital Models".*

In this study, the above definition of BIM is preferred. It is about manual or digital outputs and inputs of the construction project participants. BIM is related to the project, from human resources involved, materials and as well as contractual matters related to the facility. From (Eastman, Teicholz, Sacks,

& Liston, 2011) and (Crotty, 2012), BIM facilitates integration, enhances the quality and accommodates many functions related to all the participants. BIM is not only a tool but also a process that helps in making decisions about the facility (Forbes & Ahmed, 2010). BIM will not only give the quantities but also the spatial location and interoperability of the facility components .Architect is expected to collaborate with Geomatician to set the building in the model and detect difficulties in advance and equally the Services engineers can far easily trace their installation clashes in advance.

According to (Sabol, 2008) Building Information Modelling (BIM) provides more accurate and automated quantification, and hence improving accuracy and speeding up cost estimates. This helps in dealing with instructions or changes order in the construction. In Tanzania, the changes in scope causes unneccesary cost overruns and results in conflicts (Ntiyakunze, 2011). BIM is capable of more accurately conveying the image of the facility and undertakings in construction project cycle, something that clients, users, designers, supervisors and constructors dream about. Although (MacGraw Hill-Construction, 2010) said the project value of BIM is not equally distributed, however the understanding of design intent is far better with BIM, and the critical information can highly and easily be shared among many participants. It is worth the effort.This thesis favourite demostration, used in questionnaire too, was that photo by (Dispenza, 2010) in the web page titled the daily life of Building Information modelling (BIM), as seen in the (*Figure 7: Image demonstrating the Information flow within BIM environment*)

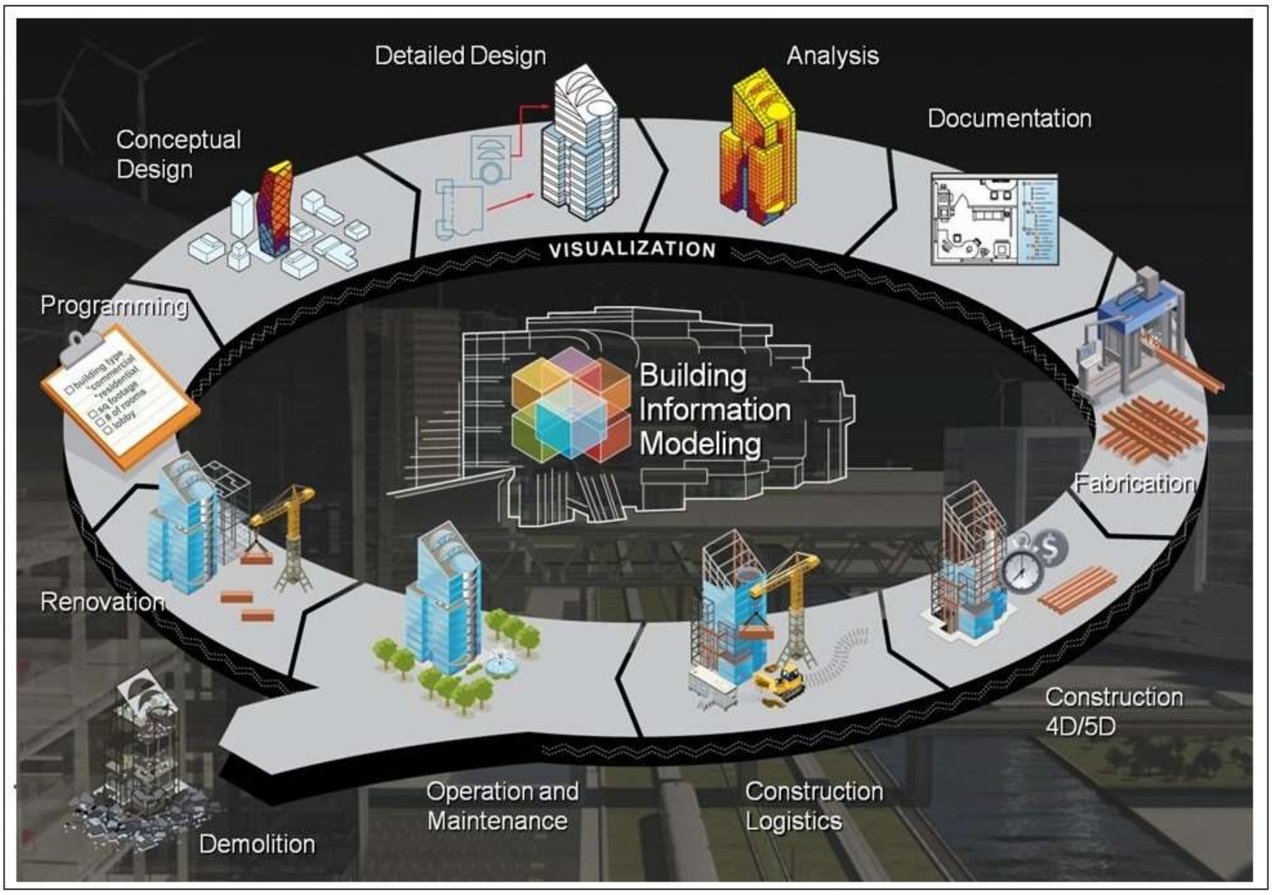



**Figure 7: Image demonstrating the Information flow within BIM environment**[9]

Contract documentation is the reflection of the intention of the project participants. It holds the material and ideal value of the purpose and endavour devoted by the team members. On the other hand, segmentation and fragmentation nature of the Construction Projects (Hellard, 1993) causes inefficiency in *documentation* and *effective communication* between participants. In short, the fragmentation nature of the construction industry ( Nawi, Baluch, & Bahauddin, 2014) affects the information flow needed to ensure efficient delivery of the projects. Information, including drawings and specifications (Li, Aouad, McDermott, Liu, & Abbott, 2007) is not only interfered but also changed to reflect unintended ends. Crotty, (2012) claimed that over 100 years the CI have been in struggle with regard to drawings deficiencies. Information is the ghost that when well understood,

9 Source: Dispenza, K. (2010)

brings into light the whole reality. A good example may be a *deoxyribonucleic acid* (DNA)[10] in animals.

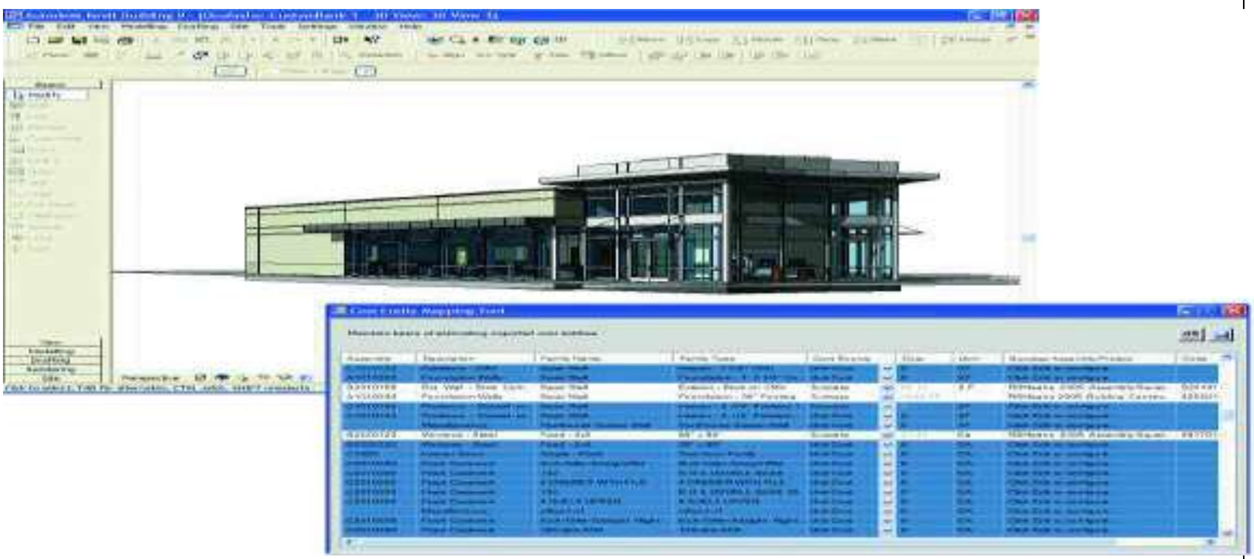
According to (Forbes & Ahmed, 2010), poor design and documentation quality are among the factors that hinder CI performance in general.Assume, an architect, who provides an 800 x 2000 mm wide as the only entrance gate in a stadium with intention of controlling entry fees. The time wastage during entry and exit, may lead to a significant loss due to reduced attendances. The nice drawings (documents) and efficient in delivery, may have ended into a poor facility performance. The same results, can be witnessed when the well designed and rightly dimensioned gate drawings are differently built. It is not enough to have complete and accurate document, without efficient management and documentation of the information in it, throughout the delivery process. Ntiyakunze, (2011), found that unnecessary conflicts in Tanzania building projects, mostly originate from documentation and communication. It was suggested collaboration approach suites best for the conflict resolution. Collaboration improves completeness of the information and accuracy of the transferred information. Most important is that, it fills the informational gap with regard to overall delivery performance. A Quantity Surveyor (QS) estimating costs in one desk with an Architect is more likely to be more informed than when the same is doing estimating self reliant. It becomes easier to perceive better what the level of finishing through discussion together with models,as compared to the use of models or drawings alone.

Additionally, from (Levy F. , 2012), complex project are time consuming, and hence architect models are more satisfactory when digitally represented than otherwise. This may imply that BIM is likely to give more collaborative efficiency than CAD or manual modelling in complex project. Likewise, (Forbes & Ahmed, 2010), gave out that, with BIM, QS can save up to 80% of normal time used in generating cost estimate and hence more time can be devoted into Contractual and Financial implications of those costs items.

Actually, if there is any benefit in BIM, then it is not without the improved information efficiency, which simply means improved documentation productivity in Construction projects. Information is vital to whatever phase of construction project. It is equally important in productivity techniques like lean and just-in-time production (Li, Aouad, McDermott, Liu, & Abbott, 2007), where minimum waste and process integration forms the key areas of effort in achieving project objectives.

[10] DNA-is a molecule that contains the instructions an organism needs to develop, live and reproduce. These instructions are found inside every cell, and are passed down from parents to their children (Rettner, 2013).

(a) Manual or Traditional Taking -Off of Quantities



(b) BIM Software oriented Taking Off of Quantities (Digital facility and Tabled results)

**Figure 8: Traditional cost estimating take-off vs. BIM-based quantification[11]**

Stepping from the above, it is worth considering what is contract documentation in construction projects. Kwakye, (1997) briefly gives construction contract documentation as the binding descriptions of works. To be precise, the construction projects may have many documents relative to the project complexity, but still the contract documents will mean the binding description at its priority. In Tanzania (Public Procument Regulatory Authority (PPRA), 2004) it is stated that

> *"the documents forming the Contract shall be interpreted in the following order of priority:Agreement, Letter of Acceptance, Contractor's Bid, Special Conditions of Contract, Conditions of Contract, Specifications, Drawings, Bill of Quantities, and Any other document listed in the Special Conditions of Contract as forming part of the Contract".*

PPRA documentation rules is the key guiding document in Tanzanian public projects.Private and international projects have more choices, depending on the will of the financiers. According to (American Institute of Architects (AIA), 2007),

> *"The Contract Documents are enumerated in the Agreement between the Owner and Contractor (hereinafter the Agreement) and consist of the Agreement, Conditions of the Contract (General, Supplementary and other Conditions), Drawings, Specifications, Addenda issued prior to execution of the Contract, other documents listed in the Agreement and Modifications issued after execution of the Contract. A Modification is (1) a written amendment to the Contract signed by both parties, (2) a Change Order, (3) a Construction Change Directive or (4) a written order for a minor change in the Work issued by the Architect. Unless specifically enumerated in the Agreement, the Contract Documents do not include the advertisement or invitation to bid, Instructions to Bidders, sample forms, other information furnished by the Owner in anticipation of receiving bids or proposals, the Contractor's bid or proposal, or portions of Addenda relating to bidding requirements."*

From the above statements, essentials of the constrution contracts includes binding descriptions between parties, contractor´s bid, specifications and drawings.The documents varies with the complexity, implying that at its ***core*** there are key documents that will always sustain level of complexity. Taking the simplest model of project to be a component of the construction, the

[11] Source: Sabol, L. (2008)

documents will consist of Specification or designers descriptions of the product and the image of the component or the works as well as the order or binding statement.In American Institute of Architects (AIA), 1911), it was given that

> *“As in almost all cases Drawings, Specifications, General Conditions and Agreement are necessary for complete expression of the obligations of Owner and Contractor, they are in fact as set forth in Article 1 of General Condition and Agreement, as Documents Forming the Contract”.*

The above statement somehow gives a safety to assume the importance of the Drawings and Specification as contract documents. They are key documents because they are used to transfer the image that designers wish to give to the clients and to instruct to the contractors. BIM promise, should be nothing short of providing improvement in Contract Documentation ever happened in the construction industry. One of BIM necessities, as a model it is facilitating the participants to collaboratively create and clearly visualise their *image* before implementating it. On the other side, BIM as a process, promises to ensure extended management, simulation and testing of the facility image or information to cover the whole life cycle. All together, with BIM, the construction contract documents *information* is improved in completeness, transparency, reliability and exactitude. Its efficiency covers not only design phase but also demolition or even beyond.

In USA some clients are insisting on three dimensional (3D) models to be part of tender documents (Succar, Sher, & Williams, 2012). It is actually not enough to insist on the model of BIM as a replacement of the drawings, because the informational efficiency of BIM, is far important than a model. BIM is a database where all graphical and non-graphical documents of the project can be handled and communicated (Li, Aouad, McDermott, Liu, & Abbott, 2007). In (MacGraw Hill-Construction, 2010), building participants were ranked and the improved accuracy of construction documents was a top benefiting driver in adopting BIM. Accuracy in contract documents is only one advantage derived from the grahical representation. The fact that details can be measured and quantities can be calculated accuartely, does not help much the facility manager to efficiently do maintenance. For example, provision for space for the person doing maintanance in the heating systems is of high value to facility manager than the dimension accuracy of wrongly installed systems. Such a contribution, comes into graphical representation in BIM, reliably if the facility manager is involved. Building participants are ranking accuracy the top, probably because the full use of BIM is not yet to be realised.

Construction Projects comprises of a variety of efforts. Classification mostly depends on the purpose. It is common to divide the construction industry into rehabilitation and maintenance of civil works and building works or sometimes specialized construction works are set separate ( Eurostat , 2013). In Tanzania the same categories are common (UNESCO, 2009) when different statistics are referred. From (Mrindoko, 2011), the government was mentioned the biggest employer with registered works; building (1.4 trillion) and civil works (884 billion) while special electrical works (amounting to 231 and 187 billion). This was more than 60 percent spent on construction sector.The distinctions somewhat seem unnecessary, depending on the purpose and type of the project. Building project can include a heavier civil work and otherwise.

In Tanzania, National Housing Corporation, constructs affordable houses massively (UNESCO, 2009). To attain affordable houses all the unnecessary costs and time wastes must be cut to minimum. On top, to be affordable, should not be reflected on buying price, but also the operational costs.When mortgage system is among the options in selling, the lesser the alternatives designs the higher the costs the houses are, and so denying the real lower income Tanzanians an opportunity to this benefit from the flats. Actually, developers are urged to rethink their costs of houses to fit the intended low income earners (Mwakyusa, 2013). The  The use of BIM is prospering faster on the building projects (Eastman C. P., 2008), not only to Architects and Engineers but also to owners and property managers at large.The earlier detection of clashes is good to plumbing and structural engineers (Azhar, Hein, & Sketo, 2008). McAuley, Hore, & West, (2012) mentioned a number of benefits that the Ireland government could leap by embarking on BIM, and it was insisted that UK is even far on the use of BIM than Ireland. The question with regard to BIM in todays builidng sector, is on how to implement BIM and not whether to adopt or not (Ibrahim, 2006). To Tanzanians, that is the available option as well.

Tanzania budget set (Hanif Habiba, 2013), to finance water infrastructure, transport and energy sector. According to (Strafaci, 2003), BIM can be helpful to civil works as well. The constructability and road safety benefits are only part of it. Pioneers of BIM in civil works (Yabuki, 2010), alerted the governments on what they are losing due to their rigidity to change toward BIM usage and especially in civil works. BIM usage is slow in civil works (WSP Group Limited, 2013). BIM promises number of advantages, as long as it is used for the built component. No wonder some governments are insisting on starting using BIM without delaying, (US Army Corps of Engineers (USAGE), 2013) shows this. In Liverpool ( Institution of Civil Engineers (ICE), 2012) reported a significant benefit in terms of costs and safety in the construction of wastewater treatment facility using BIM.

BIM is the heart of any built structure, as long as information is necessary. Tanzanians need BIM to improve construction perfomance.It is an axiomatic fact. The biggest challenge is on what BIM do we need given our technology level and construction industry context.BIM means value for money to the governmet, it is the heart of the efficiency in construction projects, it means transparency to project procurements, it means better documentation and management of facilities to property managers.As such, BIM means competence of professionals and contractors themselves and their competence toward global market. It really mean conflictless collaboration in projects and never the less, BIM means more trust among participants.

Just to support the above, it is said that Universities, Institutes and Colleges need BIM (Azhar, Hein, & Sketo, 2008) from curriculums to consultancy practice. In Tanzania universities usually do consultancy. According to (Mwakyusa, 2013) report, NHC projects are supervised by Bureau for Industrial Cooperation (BICO), from the College of Engineering and Technology (CoET) of the University of Dar es Salaam (UDSM). Technical school and vocational should not be left behind, because it is where the operators are born, people who essentially interpret the BIM models and convert into reality.Actually today, it is not uncommon to find the job requirement mentioning CAD as an adding advantage.It may not be far before BIM becomes "the compulsory skill" in construction projects.

Although BIM has existed for over 20 years, it is only over the last few years that building owners are becoming aware of BIM ***(***Coates, et el 2011), in Tanzania BIM is still lowly understood by the key stakeholders (Monko & Roider, 2014). On top, the implementation and adoptation of BIM is challenging (Arayici, et el 2009). Bernstein and Pittman, (2004) and Eastman et al, (2008) agreed that implementing BIM effectively requires significant changes in the way construction businesses work at almost every level within the building process. BIM needs both administrative and operational changes, from individual level to company level, and to govermental level at large. BIM requires learning new sofwares, training staffs, reformulating the policy of ownership rights, and it also requires changes in project procurement procedures. A complete change in work organization accompanied with technological change is definitely risky business to undertake in a construction projects. Never the less, the BIM models are argued to be project specific (Forgues,D. et el, 2012), that is depending on the competence of the experts.

The benefit that the construction participant can not afford to miss from BIM is basically the inbuilt ability to display in detail and support the construction project life cycle information. According to (Cooperative Research Centre (CRC), 2007) "*the key benefit of BIM is its accurate geometrical representation of the parts of a building in an integrated data environment"*. However, it can be noted that, BIM is just the improvement of CAD and not a shift from paper based design to computer based project management. BIM does not take away the professionalism, but rather makes it transparent and so enhance the real value. This suggests less difficulty to adoption and understanding of the technology at least within a few Tanzanian who are currently conversant with CADs, but if and only if the attitude to change is well committed.

## 3. BIM in this Thesis Context

A number of challenges has been put forward by scholars. According to (McAuley, Hore, & West, 2012), BIM adoption in public building projects in Ireland is likely to face process and operability difficulties. It is difficulty to decide who is doing what during implementation and whether the model and sofware sharing free from legal liabilities and copy-right conflicts. Other challenges include the need for new policies and costs risks. Despite of the challenges and immaturity, BIM is emerging and fiercely attacking the construction industry globally. In (Wahab, Zayed, Goh, & Wang, 2011)[12] for instance, it was suggested that BIM virtual capabilities can be helpful in maintenance of port in Singapore. On the other hand, in Tanzania the value for money in construction projects are still debatable. While traditional method is common in procurement in Tanzania, the report from (World Bank Group, 2015) suggested that there was a 10 percent chance that traditional procurement will be less costly than a Public-Private Partnership (PPP) in the Tanzania Bus Rapid Transit (BRT) Project. In order to capture the global market, BIM adoption and implementation is necessary. But the number questions need to be answered before, which include What is BIM? What BIM to adopt? How to adopt BIM? How to implement that BIM? And Where to start the whole journey?

The construction industry is too wide and complex in nature .The fact that BIM can be used in any construction, whether Civil or Building Works is posing a challenge. Additionally, construction projects have many categories from international to local, and from private to public projects. The projects usually comprise of many stages from design to disposal of the facility. All of these brings difficulties that may affect adoption process. As if not enough, BIM being on its early stages of development world wide, it endangers the trial to country like Tanzania. BIM needs the huge outlay of money at the beginning, which is a big risk. Also, BIM being pioneered as tool, as well as process for Owners, Users, Consultants and Constructors increases a challenge of focus. In construction participants are entities with their own varying differences and complexities. Nevertheless, as a revolutionary agent, BIM need to be incoporated to construction related educational and training systems as well as in government policies. In particular, Tanzania need a simplified BIM that can be adopted, demostrated and understood by the participants. Thereafter, that simplified BIM must assure a dynamic grow and competitive growth towards a global level BIM.

Meeting efficiency in cost is among the key objectives of any construction project. Actually some give it first priority in construction management as supported by (Forgues,et el 2012). Quantity Surveyors (QS) being cost information pivotal to project life (Matipa, 2008), may necessarily not

[12] Source: Wahab, Zayed, Goh, & Wang, (2011)
Note: This paper was still under discussion.

guarantee reliable BIM adoption focus point to Tanzania. It may end up working as AutoCAD, mostly saving the designers.On the other hand, because BIM primarily facilitates flow of information to all project participants, the construction project contract QS can give the fertile area for testing the BIM. But how exactly? Quantity Surveying is equally widely applied in the Construction Industry and differently in the construction projects stages.

**Illustration Box 1:Quantity Surveying and BIM**[13]

| |
|---|
| *"Looking at the concept of building product modelling, it is possible for the Quantity Surveyor to model data pertinent to building products, mainly because quantities are part of the data that a surveyor uses. However, there is also the aspect of quantifying using Standard Method of Measurement (SMM) rules that separate the data according to the way they ought to be measured, priced and in, most cases, built. Modelling of this process is vital for the work of a Quantity Surveyor. In fact modelling all aspects of Quantity Surveying may be a challenge because some of the data required is dynamic, and is dependent on economic trends as well as market forces in the property market. It is therefore important to review the implementation of building product modelling,,,,,,,,,,,,,,,,,,, so as to weight the possibility of involving the Quantity Surveyor in product model-driven work environments. Current industry research, ,,,,,,,,,,,,,,,,,,,,,,,,, indicates that there is a critical requirement for the including of cost management in order for the industry to implement sustainable construction. This is because the generic principles of sustainable construction cannot be implemented without the application of the principles of cost management that Quantity Surveyors use. Meaning, the deployment of modern technologies such as building product modelling could ease the requirements for cost management throughout the product lifecycle, hence improving the contributions that a Quantity Surveyor could make to the implementation of total cost management in construction business."* |

[13] Source: Matipa, (2008),Page 97

Actually key documents used in the construction projects intends primarily to display the image of the work (Drawings and Specification), and to ensure efficient Contractual Management (BOQ and Others). Basically, BOQ is the transformation of Drawings and Specification into document that describes the Cost implications of facility components. From the (Bandi , Abdullah, & Adnan, research into Bills of Quantitie: Where can it be focused?, 2015), it was stated that

> *"BQ should be regarded as an indispensable tool for the management of construction project and an important source of information in the process of construction".*

It is in the light of this thesis that BIM improves the efficiency in Construction Documents. In (MacGraw Hill-Construction, 2010), BIM was found helpful in reducing omissions, error in the construction documents, reducing reworks and reducing cycle time of some specific works.At large this means BIM is capable of improving cost and time management significantly. And so at its simplest form, BIM is expected to provide the BOQ with more productivity in time and cost management.The BOQ which is more complete, more exact and more efficient in delivering project life cycle information to all participants of the construction project.The BOQ that can facilitate integrated project delivery and sustainable design and thinking. The need for such a study toward BOQ, relative to sustainability has also been suggested by (Shamsulhadi & Fadhlin, 2012).

## 4. Definition Of Building Information Modeling (BIM) in this thesis

Defining BIM is not as easy as it may seem to be. Some scholars view it from the technological aspect as generation of information from digital representation of the facility, while others view it from management angle as the optimisation of the decisions making process from the information generated by the digitally represented facility. Never the less, there are many other views from vendors of softwares and professionals relative to what they consider to be the key function of BIM in their daily undertakings.Despite the huge coverage of the definitions, this study found the definitions inadequately helpful in guidng the adoption and implementation of BIM in the country with technology and economy like that of Tanzania. Lack of reliable Internet in Tanzania is a good example of the irrelevance of the many definitions with regard to BIM implementation in Tanzania. In this study the following definition of building information modelling (BIM) were proposed to be more relevant for Tanzania BIM implementation;

> *Building Information modelling (BIM) is a creation and representation of the information integration level necessary to facilitate a total construction project delivery.*

It is in the view of this study that the building information model to be developed in Tanzania need to be economically and technologically affordable. In essence, Building information modelling (BIM) has long been there, irrespective of the technological development advantages. Computer aided design (CAD) only added the time, quality and cost advantage of using computer over manual designing methods. A description of an aluminium material and a line showing a wall can all be called building information at some point during construction project delivery. This study proposes that building information modelling in a simplified state is all about a representation (model) of the purpose of those materials and lines and the process (modeling) of establishing the conveyance of that reality behind the model or representation.

Viewing building information modeling from the angle of distinctiveness output that it produces, is a one way of approximating the reality behind the BIM. It is common practice to indicate the reality of a thing from what the thing does. Time for example, can be viewed as a dimension used to measure events occurence. Then, irrespective of the technological advancement, any simbol, sign, element, event may be chosen to be a measure of event occurences and yet produce the desired impact in any environment. So this study suggest that Tanzania BIM implementation efforts should be focused to what unique output that BIM provides rather than what it is as a thing. BIM facilitates generation of information that helps to improve performance of construction project delivery. It is from this amount of generated information that the advantages and benefits of BIM are being derived. Because of the generated information the collaboration and transparency increases during construction project delivery. If the focus was only on the capital cost, the generated information gives an opportunity to think and decide on the operational cost as well during construction project delivery process.

The BIM definition in this study is different from other definitions slightly. While most of the definitions concentrate on the ***information*** generated, this study goes further by focusing on the ***information integration level***, as the most desired impactful BIM output that should be valued. It is what BIM does uniquely in construction project delivery. On top, this study measures BIM in levels of integration and not in dimensions of BIM as many other definitions do. In this study, a three dimensions building information modeling (3DBIM) construction project delivery contains the possibilities of different levels of information integration. By *information* this study refers to objective knowledgable data, objects, description, symbols and the like containing a manageable message during construction project delivery.On the other hand, by *information integration level* this study refers to the optimal parametric measurable purposeful entity or structure representing a specified desired certainty in the construction faciliy delivery.

The information and information integration level explained above are different significantly. While information only depends on the total inputs variation, the information integration level depends on the optimal inputs productivity.One way to understand the difference is by imagining the simplest form of construction element of a window. In such a work the *information* (sketch) may be enough to finalise the work, and *information integration level* (standard and price description) may be optimal structural possibility. In such a work it may also be possible to add more information possibilities (sketches + prices +alternative prices + pictures + user manuals + energy data….) or it may even be possible to work out a *higher information integration level* (digital elemental window cost analysis software) out of many other possibilities. Here, the increase in information like pictures may mean the increased chance to create better information integration level that can give more *collaboration*, *transparency* and *customer focus, but* in the expense of unnecessary increased costs and delay in execution of the work. This simply it means spending resources to produce unnecessary information integration level or BIM level, which is going beyond optimal information integration level or BIM level. The BIM level performance is dropping while the BIM dimensions, information, technology or the like, may still be increasing.

Assume that the distinctive output of BIM which is information integration only increases collaboration in the project delivery. If collaboration results from an additional stakeholders to the project participation, then adding a professional will logicaly mean adding the possibility of more information. That is information level increase but not necessarily an increase of information integration. Architects has enourmous amont of information with regard to building and so they can as well provide endless possibilities of building information models. Plan and Elevetion Sketsches,cost views,energy analysis and management aspects of the building will all form the available information for the given project. The collaboration magnitude of the Architect is added with the objective amalgamation of the optimal variables necessary to achieve the desired objectives of the project. That is modeling and the resulting structure or system once has acquired measurable parameters to provide more collaboration in any construction life cycle project delivery, it is hereby reffered to as a BIM model or BIM level. With increased complexity, Architects information become inadequate to provide optimal collaboration. Cost information for example may be better supplied by the cost experts to increase assuarance. The same trend holds on with increased stakeholders.

With involvement of Engineers,Clients,Contactors and users the information levels is increased, because of the knowledge they have and doubts on the available information they raise. On the other hand the information integration level possibilities has been increased as well, meaning relying on former BIM level, is too low to exhaust the collaboration benefits. Example, an Architect may not be enough to explain the electrical specification consequences to the users. So,there is a need to create and represent the system or mechanism that not only collects information from the electrical engineer, but also it assures that an electrical specification information contributed is the optimal, efficient and effective contribution by the electrical engineer and it is productively used to provide the collaborative benefits of the project delivery. This breakdown of the optimal information barrier and assurance acquiring includes what is hereby valued as information integration and the resulting structure, object or description is an information integration level or BIM level. This BIM level is optimal focus, meaning going beyond it becomes resource wasteful or seeking unnecessary collaboration in this exmple. Involving an engineer and engineering information requires fees, and time to assess the optimal variables including attaching relationship to other parameters. Staying behind BIM level is loosing the collaboration benefits to the construction project delivery, or not BIMing efficiently. This study suggest that irrespective of the BIM dimension the project is operating, the optimal information integration level in construction project is determined by the cost objective. So, implementing BIM in Tanzania the focus should be on the information integration level provided by 5D BIM which is cost parametric BIM dimension.

5DBIM transforms quantities into financial implication of the project. Therefore it is the closest objective to both participants intentions, methodological efficiency and financial values. The scope of the project is highly related to the quantities just like time and quality. Information integration in construction project can therefore be productively achieved, because of the huge chance of finding the significant breakthrough of the assured optimal informational variables from the participants, phases and standards. Hence reducing the fragmentation difficulties in construction project delivery, which is a collaborational benefit of BIM. On top, it is logical to assume that such an environment may give the optimal opportunity for the balanced system, structure or object capable of covering huge portion of construction industry complexity. For diagramatic explanation please refer the figures below.

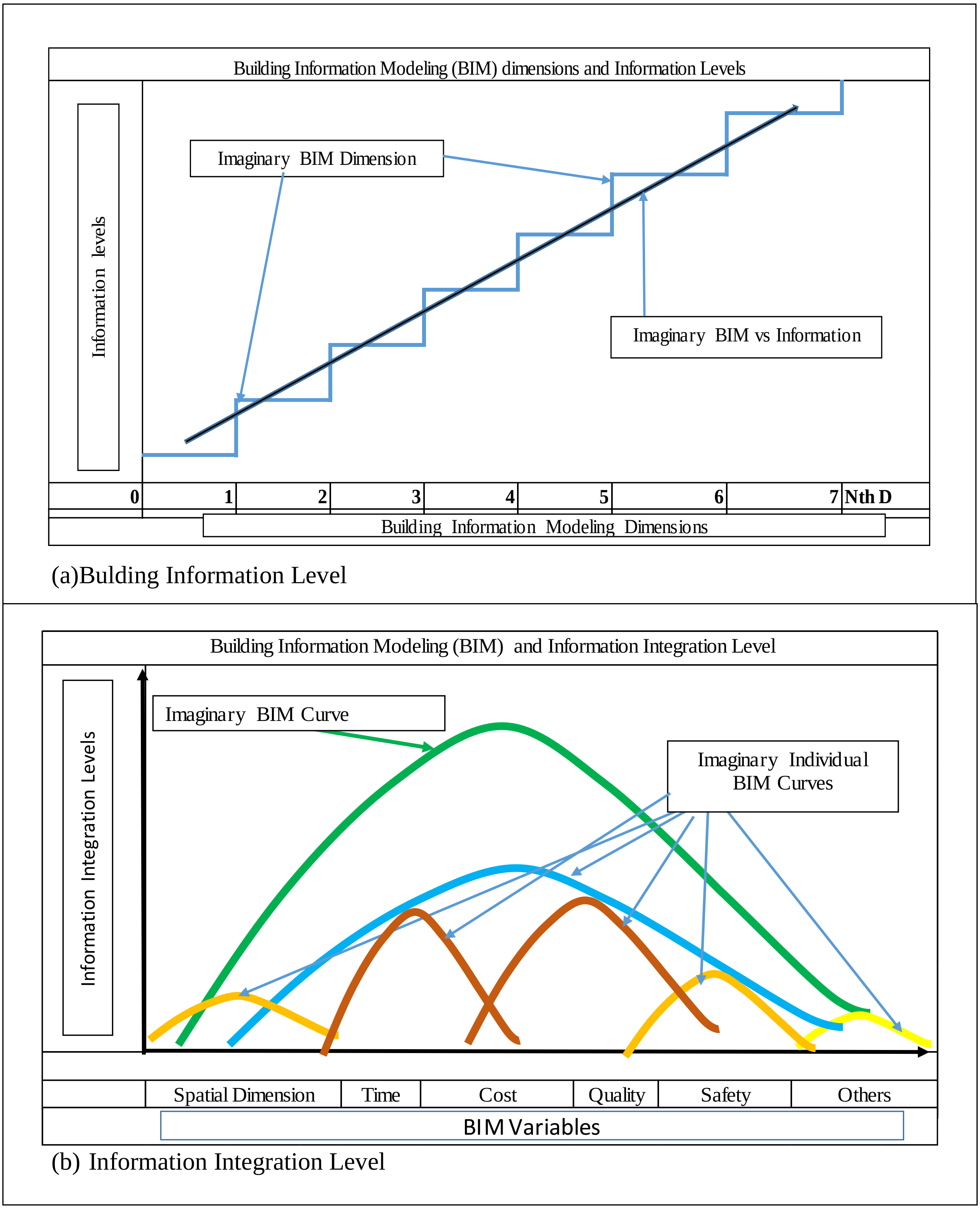



**Figure 9: Definition of Building Information Modeling in this thesis Context in diagram[14]**

[14] Source: Own Construct

# 5. Research Strategy

## 5.1. Hypothesis Formulation

In-adequate performance of Bills Of Quantities (BOQ) in Public Construction Projects forms the basic challenge of this study. Developing the right Building Information Modeling (BIM) level or model that can improve the BOQ productivity in the Total Cost Management of Public Related Construction projects is necessary. The purpose behind this is to appraise and utilize the strength of BIM in Information Integration improvement, which is arguably centered on cost and time. To Tanzania, adopting and implementing BIM should be economical and technologically affordable. The main objective of this research is to appraise the use of BIM in improving Total Performance Delivery of Public Construction Project in Tanzania. Specific objectives are

i. To describe the relationship of BIM and (BOQ) productivity in Total Cost Management in Public Project in Tanzania.

ii. Suggest *parameters of the model* for the adoption of BIM in Tanzania

## 5.2. Research Hypothesis

If <u>5D BIM</u> has positive effect in <u>Bills of Quantities (BOQ) Completeness</u>, then the <u>use of BIM</u> can improve <u>BOQ Productivity</u> in the Total Cost Management of construction projects in Tanzania. That is; *In TCM, 5D BIM has Positive Effect in BOQ Completeness.*

## 5.3. Justifcation

Construction contributes more than 50% of capital formation (Tanzania Bureau of statistics report, 2007). Insufficiency in productivity and infrastructural value for money in construction related to relatively low performance and lack of effectiveness in communication and information (Forbes & Ahmed, 2010). To timely rethink and re-assess the construction industry is now a best practice of any country. BIM can improve building information management **((Sabol, 2008) (Suermann & Issa, 2009)),** by acting as digital database to construction projects participants. In this thesis, the contribution is centred on the development of a costs centred BIM that can sustainably support Total Cost Management in Construction project in environment of Tanzania.

Efforts to fight the inefficiencies in Construction industry include improving planning and scheduling (Arditi, 1985), use of Total Quality Management (TQM) ((Rutaguza, 1997)(Hellard, 1993)) as well as the use of Integrated Project Delivery and Lean Project Delivery System ((Forbes & Ahmed, (2010), (Eastman, Teicholz, Sacks, & Liston, 2011) (The American Institute of Architects National (AIA) and AIA California Council, 2007)). All these philosophies and project procurement methods, suggest that the information integration may be the right solution. BIM comes as the way of fulfilling all these.

Assessing BIM relative to *procurement methods* as suggested by ((Eastman, Teicholz, Sacks, & Liston, 2011), (Ilozor & Kelly, 2012) and (Forbes & Ahmed, 2010)) is worth the effort, especially in Public related project. But,in this thesis, the illustration of BIM benefits into the existing system is desired because, it is important that BIM be part of change toward itself if it is to be inexpensive.

### 5.4. The Scope,limitation and expected outputs of the thesis

It is in the light of this thesis introduction that, BIM is wide and as complex as the construction industry itself. To address the related problems, especially in Tanzania, is equally challenging. A construction project, is not a building or civil work, or from design to operational but also can be private or public and usually it comprises of different documents and varying procurement procedures. Therefore, it is necessary to define the expected boundaries of the effort and the framework from which the results can reliably be assessed.

The scope of the research focused on the following

- Public related Construction Projects undertaken by the local participants. The reason, was the fact that BIM requires Governmental Support, which means, the government as the biggest employer must be assured, of the benefits and workability,before taking the big risk. Another reason for this was the fact that, BIM is intended to be injected to Tanzanians, who are expected to catalytically benefit the country direct. So, with project mainly being foreigners, the intention may not well be guaranteed. Never the less, if BIM increases transparency, it is what the government want in construction industry.

- The concentration was on the effect of BIM on the financial consequenses of construction projects. Likewise, the choice of Contract Documents was restricted to Bills Of Quantities (BOQ).

Some of the limitations to this thesis were

- The use of snowball sampling instead of random sampling limited the population generalisation of findings to all Tanzanians. However, this was necessary in order to strengthen the external validity of the study, given the situation. BIM awareness and practice in the construction projects were very much unlikely.

- Time available was very academic, while the problem, not only required practical experience but also practical testing and retesting in different projects before concluding. It was difficulty to smoothly complete the one practical side of study in order to compare the two designed parts. Relying on the Tanzania data was not enough to justify the results. However, the study has managed to establish the strong base for further data collection and retesting of the hypothesis.

The study may be useful to the following areas:

- To the Country, the study may have promoted BIM knowledge and give base for the further researches

- To the Construction Stakeholders, the study through its findings may have contributed in the promotion and support of Efficiency and Effectiveness in the construction industry. Using BIM.

    - Clients can be in a position to visualise and detect what the actually want

    - Designers can be in a position to collaboratively detect the weakness prior construction phase and enhance the designs

    - Contractors can be in position to confidently price the bid through well detailed and visualised components of the facilities

    - Property Managers, can be involved in the design team.

- To the construction professionals, increased awareness on how BIM can improve their ability in the international projects competition.

## 5.5. Research Methodology

From (Lastrucci, 1963) and (Kothari, 2004), it is clear that a researcher needs to develop the methodology and methods necessary for the the concerned problem. This will not only give the objectivity sense of research but it will also lead to saving of time and cost of the research. Research are scientific undertakings, and so they need methodology to explain logical and systematic reasoning behind the relevant methods and techniques used to undertake them.The data derived from researches are used to make key decisions, and so (Matipa, 2008) warned that as such, the infromation from reserches can be very benefiacial or very harmful.

In (Guba, 1990),it was given that, the researcher needs the basic set of ideas and assumptions (*The Worldview Paradigm*) that will guide the research. Such world pictorial can help to identify the right strategy towards solving the problem in question. Likewise, it helps to shape the thinking of the researcher towards relevant investigation. To a researcher, the philosophical assumptions will be like a steering in driving the research, said (Hakansson, 2013).

Basically, this research was in the view that BIM is unstoppable worldwide and it has knocked the door of Tanzanian Construction Industry.With this in mind, it was suggested that the right BIM model should be developed and injected in the construction industry. The model should be relative simple, economical, and technologically compatible.The BIM for Tanzania should be dynamic enough to sustainably grow to world market level. It was in the view of this study that, there may be different truth, view or understanding of what BIM is. But the one truth of what BIM does to any construction project irrespective of time and context was of greater interest to the study. That truth was the part of BIM, that this study devoted the effort to search. It is the reality that Tanzanian Construction Industry need to primarily embrace.The key aim being to appraise BIM in Tanzania. what is the relationship between the level of BIM usage and the level of information integration in construction project performance?

It was suggested that, this objective, static, contextual and time free truth of BIM can be modelled and transferred without problem to Tanzanian CI. To do this, the values of the researcher and other participants involved in the investigation need to be at a distant from the investigation. In reality, a complete separation was difficulty and not that much desirable in this study, because construction projects involves artistic values that can not be reduced to laboratory test easily.Aadditionally, the need to develop the suggested model, the values of individuals from their context were found worth noted. It was found important, to explore beyond what is experienced by the player in the construction project. To (Potamaki & Wight, 2000) , this is what is expected from doing science, unbreaking the laws, tendencies, structures or forces behind what we see, say, feel, do or appear to be. Critical realism or post positivism was preferred as an ontological stance of this study, because of this belief. That is the truth, can only be approximated not conceived as a whole, and to concur that causes to this truth may sometime transcends the experienced material things.

From **(**(Creswell, 2003), (Kothari, 2004), and (Bhattacherjee, 2012)) mult-investigations challenge needs the mixing of approaches to minimize the weakness of each other.However, this study was quantitative strategically.Not because, no need for qualitative strategy contribution, but because of the sufficiency of the choosen strategy and academic time frame of the study, as related to the objectives. The use of crossectional research design was not guaranteeing the causal impact.However,this design facilitated efficiency in time. Difficulties in involving the second strategy, qualitative, which would help to conclude on the effect found from BIM by using cases significantly limited the study inferences to problem solving view. On the other hand, the use of snow ball sampling was prefferred in order to capture BIM related firms and participants in Tanzania, while reliance on the structured questionnaires were also necessary to reduce the researcher values in the investigation.

Compared to the preliminary coding done during piloting of the tools, the interview codes were slightly different from the actual because some of the questionnaires were reviewed to substitute closer terminologies and some questions were removed to retain few relevant items. The coding facilitated the use of SPSS in descriptive and inferential analysis of the data. The use of frequency and mode were supported by the Gamma hypothesis test to draw the findings of the study. The choice of these analysis tools and statistics based on the level of measurement which was nominal and ordinal. The unit of analysis was the Bills of Quantities of ongoing Public construction projects.

### 5.6. Conceptual, Theoretical Framework Movement

Conceptual framework is an abstraction and formulation of plans and important details from specific instance (Tromp & Kombo, 2006). It explains graphically or in narrative form, the key factors, constructs or variables and the presumed relationships among them (Miles & Huberman, 1994). According to (Tromp & Kombo, 2006), researchers need theoretical frameworks to help them in research execution and findings interpretation. The key driving concept and theory of this study is based on the need to value the greater impact. Reh (2013), explained the 80/20 Rule of Italian Economists of 1900s Vilfredo Pareto and that of few (20 percent) are vital and many (80 percent) are trivial principles of one of the quality management gurus of 1930s Dr. Juran, Joseph M. While in Pareto the principle based on the finding of many resources being owned by few people, in Juran's principle it was found that many problems stem from few defects. The 80 and 20 number mostly used to signify magnitude of ratios. The two principles are insisting on the need to value the factors with greater impact in undertakings that comprise of many factors.

Conceptually this study intends to trace the suitability of BIM adoption and implementation to Tanzania through the Cost efficiency objective. This study proposes that the performance of Tanzania Construction Industry can be improved through improving efficiency on few key factors with greater total impact. This research assumes that the application and implementation benefits of BIM should first be traced through the factors suggested to have greater total impact to performance and process. That is the Government being suggested to be the main financer and biggest client of the Construction Industry in Tanzania, will have greatest total impact on the industry performance as well as adoption of BIM. Likewise, of all common objectives of the construction projects, cost being central to project information, is proposed to have the greatest impact to the success of the project information integration through BIM in Tanzania. Never the less, from (Bhattacherjee, 2012) and (Sahin, 2006), it is suggested that the Innovation Adoption Process Theory of Rogers can form the theoretical base for diffusing BIM. *(See Figures 3 and 4 below).*

### 5.7. Conceptualisation-Operationalisation Framework

In order to sail from theoretical and conceptual framework a researcher needs to convert the two to operational variables. Conceptualization helps to eliminates vagueness while operationalization brings into light the variables (Bhattacherjee, 2012). It is necessary to convert the theory and concept to a researchable language. It is in the light of this thesis that, if BIM based contract documentation can improve the information integration and help integrated project delivery in the construction industry in Tanzania, it may be more likely because of its ability to cause improved productivity in the Total Costs Management. To test this, the concept was first oriented into developing a BIM based BOQ and equating with the Non-BIM BOQ, to view the variables and then it was secondly tested against existing situation to describe the relationship between the BIM variables and BOQ completeness variables. It is through such effort that the most relevant items were chosen as the preliminary variables or components of the suggested BIM model. (See *Figure 11: Proposed Conceptualisation-Operationalisation Framework)*

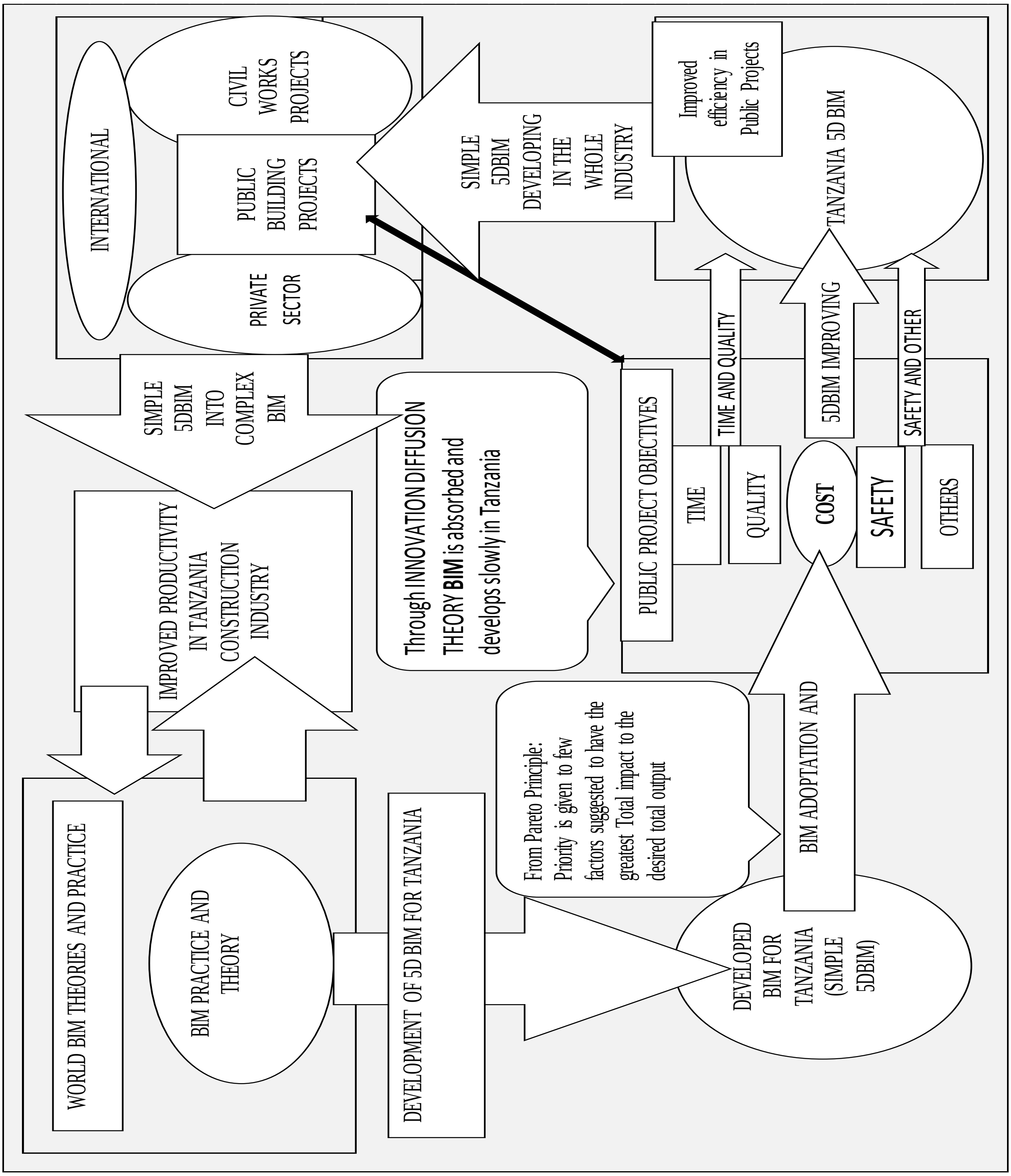



**Figure 10: Proposed Theoretical Framework for BIM Implementation to Tanzania[15]**

[15] Source: Own Construct

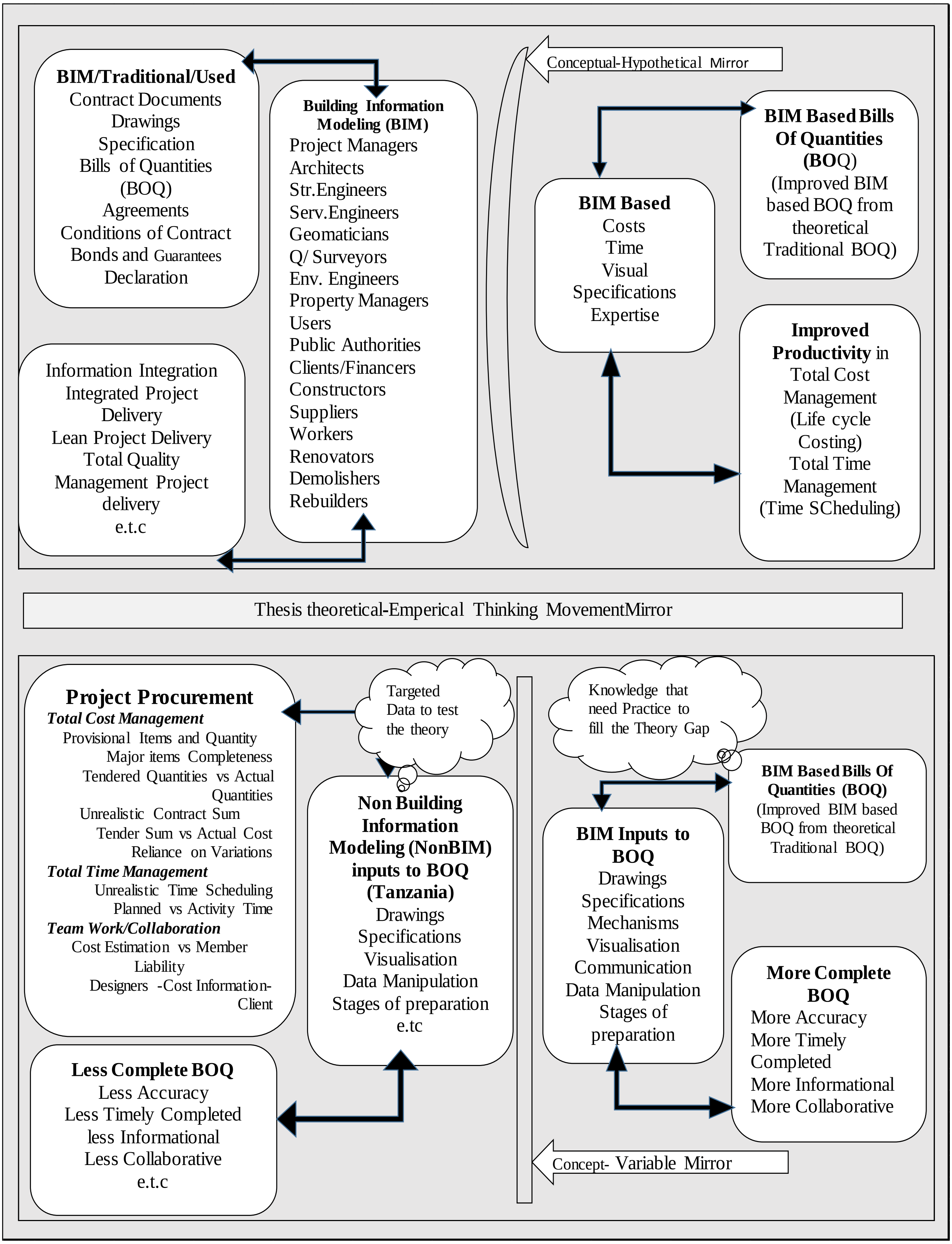



**Figure 11: Proposed Conceptualisation-Operationalisation Framework**[16]

[16] Source: Own Construct.

## 5.8. Research Design

There is a say; *not planning is a planning to fail*. Every step involved in answering the question needs a plan. In research, the design of steps from the basic question to conclusion is a mental effort necessary to avoid that failure. Yin, (2003) mentioned question, propositions, unit of analysis, link of data and proposition; and criteria for interpretation as the key components of any research design. On the other hand, (Bhattacherjee, 2012) argued that to be a good research design, four key features are important,that is internal, external,construct and statistical validity. Research design gives also the procedures for data analyis, reporting and interpretation (Creswell, 2007). In this study, research design comprised the map of the key components from developing the question to attaining the conclusion of the research work.

The design of this study based on the fact that, BIM is believed to help the construction industries world wide in improving performance. So, the common static feature that BIM installs in the differing systems, can be approximated and used to develop the model suitable for the injection of BIM in Tanzania.That means, before proposing the BIM model for further testing, constructs are tested to BIM and Non BIM environment and the results compared. Corretional Design works best in describing the relation, despite of the likely lack of causality. The design is time saving and relatively replicable when a structured tool is well designed. To acquire a hypothesis, wide literature and practice was necessary. In (Black, 1999), it was insisted that questions must be well refined to hypothesis so that the replicability and validity of the research can be attained.

Inference helps to intuitively describe the cause, but it does not completely assure the internal validity. The challenge dealt in crossectional design include response biases and subjectivity. In this study, significant time were spent to reviewing literature, piloting and repilot the structured questions to ensure they are relatively many, simple and they are tapping the constructs of the concepts reliably.This can equally assure replicability. In social research, it is important to enhance reliability,replicability and validity (Bryman, 2012). The unit of analysis, that is Bills of Quantities, has been the focal point of thinking and doing. The linkage with the hypothesis, concepts, participants and tools was the focus all along. To arrive to the conclusion, the non parametric test of hypothesis were used. This test suits better the ordinal measurement.

# III. BIM in Construction Project Delivery

## 1. BIM and Performance Improvement

### 1.1. BIM rise in productivity improvement

Construction industry is among the engines of the economy (Halpin & Senior, 2012: pg 14) because many of the other sectors largely depend on it ((Ministry of Infrastructure and Development , 2006) and (Tanzania Bureau of statistics report, 2007)). However, productivity and infrastructural value for money of the construction sector is still in question world wide ((Nour, 2007) and (Sommerville, 2004)). Out of many, poor management and lack of effectiveness in communication and information were mentined by (Forbes & Ahmed, 2010) as crucial weaknesses.In (Ofori, 2013), it was argued that inability to deal with key issues prolongates construction industries problems in developing countries, although in Tanzania, (Ntiyakunze, 2011) found that conflicts due to unprincipled behaviour of project participants is also among the key challenges in the construction delivery performance. On the ather hand, it is said that the construction spending has been shifting towards Asia and Africa (Forbes & Ahmed, 2010). Such a fierce globalisation trend leaves developing countries with no option other than to deliver projects at international standards (Ofori G. , 2000, 2013).

Arditi, (1985) suggested to concentrate on improving planning and scheduling. Hellard, (1993), suggested that Total Quality Management (TQM) can reduce the in-built inefficiency and according to (Forbes & Ahmed, 2010) , construction industries need more effort in design and documentation quality for better performance. Scholarly works mostly agree on the need for cohesive teamwork (Eastman, Teicholz, Sacks, & Liston, 2011) in the construction project delivery process. It is expected that by involving everyone inside, as well as outside the organization, it may be possible to remove the contractual and production barriers. In that Integrated Project Delivery and Lean Project Delivery System (Forbes & Ahmed, (2010)) has been well in trust currently.

Generally, IPD seeks to achieve the necessary performance through the maximum use of the potentials of all participants toward the project. BIM,which is developing in Europe and United States (Hobbs, 2008), can facilitate decision making, teamwork cooperation and process integration in Lean production philosophy (Li, Aouad, McDermott, Liu, & Abbott, 2007).BIM can help to reduce waste and improve project delivery internally and externally (Oskouie,*et el*, 2012). Actually, as (Ibrahim, 2006) mentioned, the question on BIM today is only on how to adopt it advantegously,because it is what everyone need in construction projects. BIM will definitely capture the whole world at last (Hobbs, 2008).

### 1.2. The use of Information Technology

From (Ofori, 2013), developing countries, need ***" the 3P"*** construction industry (CI), that is *Professional, Productive and Progressive*. Actually to benefit from globalisation developing countries CI like that of Tanzania may also need the "4$^{th}$ *P*", that is to be ***Proactive,*** and be able to foresee and reharse the future of its CI.Just like what (Turk, 2001) insisted, it is important to make interaction of human and computer more or less the same as human interaction in real world. This may facilitate meeting the users needs in contemporary world. Suggestions has pointed information integration to be the best route towards productivity improvement in CI globally (Forbes & Ahmed, 2010). There is nothing much out of Information and Communication Technology(ICT) because the world is moving from current drafts and building regulations technologies to model based construction information systems.

In (Harty, et al., 2007), it was alerted that, sustainable construction is as important as ICT in now and future development. This is to both, an individual and an organisation effort in the construction. In the future, the construction industry is expected to embrace more life cycle management, facility management and involvement of robots in automation. Similarly, dependence on individualism and on-site creativity is increasingly perishing, because standardisation is cutting across between nations, regulations and educational systems. In general advance in ICT tool has lead to a significant advance in design and management process of CI . ICT is about communication strategies through computer that allow the convenient global sharing of information (Forbes & Ahmed, 2010).That is a hardware and software related technologies. Common areas that ICT tools affects construction projects includes information management and services, communication and processing and computing.

Technology was not prioritised back then, as a tool for construction productivity improvement (Department of Trade and Industry, 1998). It was reported that, ***"technology on its own can not provide the answer to the need for greater efficiency and quality in construction"***. Some scholars, (Rezgui & Zarli, 2006) today argue that *adoption* (embracing) and *adaptation* (reworking) of information and communication technology may be key to the future of the construction sector. In essence, it is the end user desire that gives the ultimate decision on whether improvement made is satisfactory or not,and that satisfaction mostly depend on the individuals involved, rather than on the technological factors like automation.

| **Needs** | **Item** | **Traditional Technology (Becoming Obsolete)** | **ICT supported Technology** |
|---|---|---|---|
| Information Processing and management | Object,Company,Country and the World | Drafts,Folders,Archieve, Microfilm,Library,Building regulations, Journals and conferences | Documents management,products and process models, Global ICT networks,national construction information systems |
| Interaction facilities | Man Machine interaction | Direct contact | 3D visualization, vusual reality, Graphical user interfaces |
| Time saving | Just in Time | Books, Calls,e.t.c | Database look up, internet search Distance learning and subscription to customize |

**Figure 12: Impact of Information and Communication Technology on Construction Industry**[17]

In information management and services, almost all aspect of ICT tools are essential for internal and external integration process of the CI. Construction challenges are not without time and cost planning and controlling. Enhanced project schedulling through efficient and effective computing and processing technologies is comparatively high due to ICT tools.Contemporary computer aided design can integrate 2D and 3D modelling, graphical and non graphical design information (Forbes & Ahmed, 2010). On line bidding, building permits,project administration and management control, model based costa estimation, shared project database and integrated computer aided design, animated and visual design and many other productions formerly dreamed in CI, are all today possible concepts because of ICT tools (ibid). Accuracy and timely costing and drafting works are much assured, and hence giving time for experts to deal with more value adding matters.

[17] Source: Modified from Forbes, L. H., & Ahmed, S. M. (2010). Modern construction: Lean Project Delivery and Integrated Practices. Boca Raton, FL, CRC Press, London-New York: CRC Press (an imprint of Taylor & Francis).

| ICT tools | Design | Management |
|---|---|---|
| Information management and services | Integrated CAD Systems (Informational Database)<br><br>BIM | On line bidding/permit/administartion of project |
| Commnication | Automated 3D/4D visuaization Simulation Techniques | On line project management and control |
| Processing and computing | Integrated CAD Systems | E-commerce application,model based costs Estimation, BIM,Project schedulling |

**Figure 13: ICT Tools in Design and Management of Construction Industry (CI)[18]**

From (Twaakyondo, Bhalalusesa, & Ndalichako, 2002), the poor literacy in ICT contributed to the low performance in different Public Private Partnership (PPP) projects in Tanzania.From (Materu & Diyamett, 2010), it was found that, the comperatively higher cost of computers and internet services hinders the development towards fully utilization of ICT in Tanzania. On the other hand, from (Home African Building, 2013), the Kenyans are moving towards the use E-Construction Permit (E-CP), meaning that it will not take a minute before Tanzanians feel the temperature of E-CP,which needs ICT in order to achieve efficiency necessary for the current construction demand (Sun & Aouad, 2000).

[18] Source: Modified From Forbes, L. H., & Ahmed, S. M. (2010). Modern construction: Lean Project Delivery and Integrated Practices. Boca Raton, FL, CRC Press, London-New York: CRC Press (an imprint of Taylor & Francis)

### 1.3. Sustainability in Construction

Forbes & Ahmed, (2010) pointed out that *"A green building / A sustainable building" is a structure that is designed, built, operated ,renovated, or reused in an ecological and resource-efficient manner*.Today, nothing is without sustainability conciousness. Sustainable construction is of vital concern (Haselbach, 2010) throughout the world. Green Buildings are healthy facilities designed and built in a resource efficient manner, using ecologically based principles (Kibert, 2008). Sustainable construction requires meeting or exceeding the needs of the generation today without compromising the needs of the coming generation. Despite the fact that Construction Industry contributes significantly to gross domestic economies, it needs an attention with regard to sustainability. Ma, (2011) mentioned different social and environmental laws currently operating in the UK construction industry. In US, the Leading in Energy and Environmental Design (LEED) is a well practiced certification programme. All of these are efforts to ensure green building. LEED is done by systematically rating and awarding points for attaining some standards of green building design.

> *"….Sustainable development is the most daunting challenge that humanity has ever faced, and achieving it requires that the fundamental issues be addressed immediately at local, regional and global levels. At all scales, the role of science and technology is crucial; scientific knowledge and appropriate technologies are central to resolving the economic, social and environmental problems that make current development paths unsustainable. ……….." (World Summit on Sustainable Development (WSSD), 2006))*

According to the definition of construction industry as given by (National Construction Council, 2013), which simply is the sector dealing with construction and buidling activities in the economy, sustaibility is very important to the future Tanzanian construction industry.Actually, like citizens in any other country, Tanzanians fruitful future will equally depend on how carefully the construction projects are undertaken. (The Modular Building Institute, 2010) pointed out that

> *"The quality of life of every American relies in part on the products of the U.S. construction industry—houses, office buildings, factories, shopping centres, hospitals, airports, universities, refineries, roads, bridges, power plants, water and sewer lines, and other infrastructure. Construction products—buildings and infrastructure—provide shelter, water, and power, and they support commerce, education, recreation, mobility, and connectivity."*

The need for renewable energy, optimal energy consumption and proper use, design and specification of construction materials are vital to achieve sustainable built environment. Matipa (2008) established that design and specification of materials is key aspect to be considered when built environment is related to sustainability. In that regard, the multibilion projects requires sustainability consideration as a compulsory criteria of design.This at large, is commanding change in professionalism, practice and constructing methodologies. According to ((Kibert, 2008),Pg 9), in USA building team converge their thinking (*use systems thinking*) together to ensure high building performance.Illustration box 1 below from (Syed, 2012), the economic growth and development can not avoid construction projects. From (Kubba, 2010), integrated design is a key aspect to achieve sustainable construction, which means the development of Tanzania depends partly on the efficiency of the collaborative efforts of all participants.

**Illustration Box 2: Trends and Barriers to Sustainability**[19]

*Trends:*

1. *Rapid penetration of LEED green building rating system and growth of USBC membership*
2. *Strong Federal leadership*
3. *Public and Private incentives*
4. *Exapansion of state and local green building programs*
5. *Industry professionals taking action to educate members and integrate best practices*
6. *Corporate America capitalizing on green building benefits*
7. *Advances in green building technology*

*Barriers:*

1. *Financial disincentives*
    a. *Lack of LCC analyisis and use*
    b. *Real and perceived higher first costs*
    c. *Budget separation between capital and operating costs*
    d. *Security and sustainability perceived as trade-offs*
    e. *Inadequate funding for public school facilities*
2. *Insuficient research*
    a. *Inadequate research funding*
    b. *Insufficient research on indoor environments, productivity,and health.*
    c. *Multiple research jurisdictions*
3. *Lack of awareness*
    a. *Prevalence*
    b. *Aversion to perceived risk*
    c.

*In the NOTES Section page 14,serial number 1*

*Sustainability was first define in 1981 by Lester Brown, a well known american Environmentalist and for many years the head of the Worldwatch Institute. In "Building a Sustainable Society", he defined a sustainable society as "….one that is able to satisfy its needs without diminishing the change of future generations."*

*In 1987, the bruntland Commission,headed by then Prime Minister of Norway, Gro Bruntland, Adapted browns definition,refering to sustainable development as "….meeting the needs of the present without compromising the ability of future generations to eet their needs."*
*Sustainable development or sustainability, strongly suggests a call for intergenerational justice and the realisation that today`s population is merely borrowing resources and environmental conditions from future generations.*

[19] Source: Kibert,C.J (2008)

## 1.4. Ethical and Practice Transformation

Building Information Modelling (BIM) is quickly reshaping the Architecture-Engineering Construction (AEC) industry,generally from mid 2000s. BIM is the n-D modelling or virtual prototyping technology as well as a process (Azhar & Khalfan,2012). It does represent a new paradigm in AEC (ibid). BIM support the recently pioneered project delivery methods like Integrated Project delivery (IPD) ((Forbes & Ahmed, 2010) and (Azhar & Khalfan, 2012).Through the use of BIM the user can clearly be involved in the design, and enhance the product definition instead of waiting the output at the end. Chiragi, (2000), suggested that property manager inclusion during design stages of construction projects is vital to the quality project delivery. The foundation pillar of BIM is enhanced communication and collaboration among participants (Azhar & Khalfan, 2012). This improvement increases professional transparency during project execution. Reducing relaxed practice and corruption in the construction process (Tanzania Civil Engineering Contractors Association (TACECA), 2008) is among the challenges of construction industry in Tanzania. The increase in transparency through BIM, are likely to work positively on these two challenges.

BIM improves the use of Computer Aided Design (CAD) by involving more participant in the projects design. Example is the specifier, and contractor . BIM gives the facility manager the chance to percieve the whole facility before it is taken to the site in a far detailled view than before (Weygant, 2011). Many behavioural and operational aspects of the facility can accurately and confidently be detailled (Crotty, 2012) in advance.The project participants can in advance be sure of what is to be done and hence avoid the unnecessary design changes. From (Weygant, 2011), BIM has developed from only the tool for design to digital representation of the facility before any financial decision is made. It helps to visualise the facility to the rebuilding state,which is the desired professionalism of today. Currently, scientist are finding ways to deal with Demolitions (Kein, Thanh, & Lu, 2013). To find out how to reuse the demolished materials or reuse them otherwise in order to reduce the environmental impact as well as cost of construction process.At large, this is dealing with the future. When dealing with the future, ethics is not an underdog factor at all.

> *"Ethics addresses relationship between people by providing rules of conduct that are generally agreed to govern the good behaviour of contemporaries. Sustainable development requires a more extensive set of principles to guide behaviour because it addresses relationships between generations, calling for what is sometimes refered to as intergenerational justice."((*Kibert, 2008)*, pg 22)*

## 1.5. Performance and Productivity Techniques

In construction the terms *Performance* and *Productivity* are somehow unclearly used. From (Smith & Tardif, 2009), productivity metrics are useful measure of construction performance. Energy efficiency is an example. Actually, productivity in construction is argued to be a subset of construction performance,which comprises of qualitative measures like safety and absenteeism, and quantitative measures, which include on time completion,cost,quality control and productivity (Barlish & Sullivan, 2012). It was argued that even farming seem to do better than construction in improving productivity. According to (Allen, 1985), an observation made on the construction productivity trend between 1968 to 1978, indicated that a systematic shift of resources from potentially big scale projects undertakings to lesser projects like single family house was among the reasons for the noted productivity decline. Negative trend in construction productivity may have many other reasons as it was indicated in the (U.S Bureau of Labor Statistics, 2014).

The need for information integration to improve productivity in the construction industry can easily be traced from (Hellard, 1993), who said construction project can as well utilize Total Quality Management philosophy to reduce the difficulties in feedback and teamwork. TQM was found capable of merging the managerial and quality effort towards productivity. It is supported by many other scholars like (Forbes & Ahmed, 2010) who agree that the continuous quality improvement philosophy of management can trigger efficiency in project delivery methods. Likewise, (Arditi & Mochtar, 2000) insisted that instituting total quality management (TQM), may help productivity improvement in a construction project.TQM has the ability to impart a quality culture in an organization. Probably this is the basic advantage of the TQM. The philosophy is found on internal-external customer relationship, process focus and continuous improvement by though involvement of everyone in the chain of delivery. The barrier to TQM implementation in construction project stem at the fragmentation nature of the industry.

BIM is far the way forward. Higher visualization ability in BIM enhances the ***lean management*** in the construction process (Sacks, Radosavljevic, & Barak, 2010). BIM visualization improves design process by eliminating wastes (Arayici, et al., 2011). The primary goal of lean production is to avoid wastage of time,money,equipment and the like (Melles, 2007). In essence, lean requires that all players are liable to the results. In (Melles, 2007), it can be said

> *“ the most important goal of lean production is to change the attitude of all employees of the company.Kaizen is the most important instrument of lean production. All other instruments (multifunctional task groups, simultaneous engineering, just in time dlivery, co-makership, customer orientation and information, communication and process structure) are logical*

*implications of change in attitude.Kaizen stimulates all employees in all levels to use their brains to reduce costs. Lean focuses on reduction of cost and productivity improvement by bringing pain to those who create them.”*

With BIM, the whole construction industry is warmed, including policies governing the game. According to (Succar, 2009) the term BIM include a procedural change within the Architecture, Engineering, Construction and Operations (AECO) industry. As such Building Information Modelling, completes the transfer of the intents from designers to users in the construction process. It gives players an opportunity to fully collaborate in total project delivery.*(See the Figure* 14: BIM in Movement of information integration in Productivity Improvement*)*

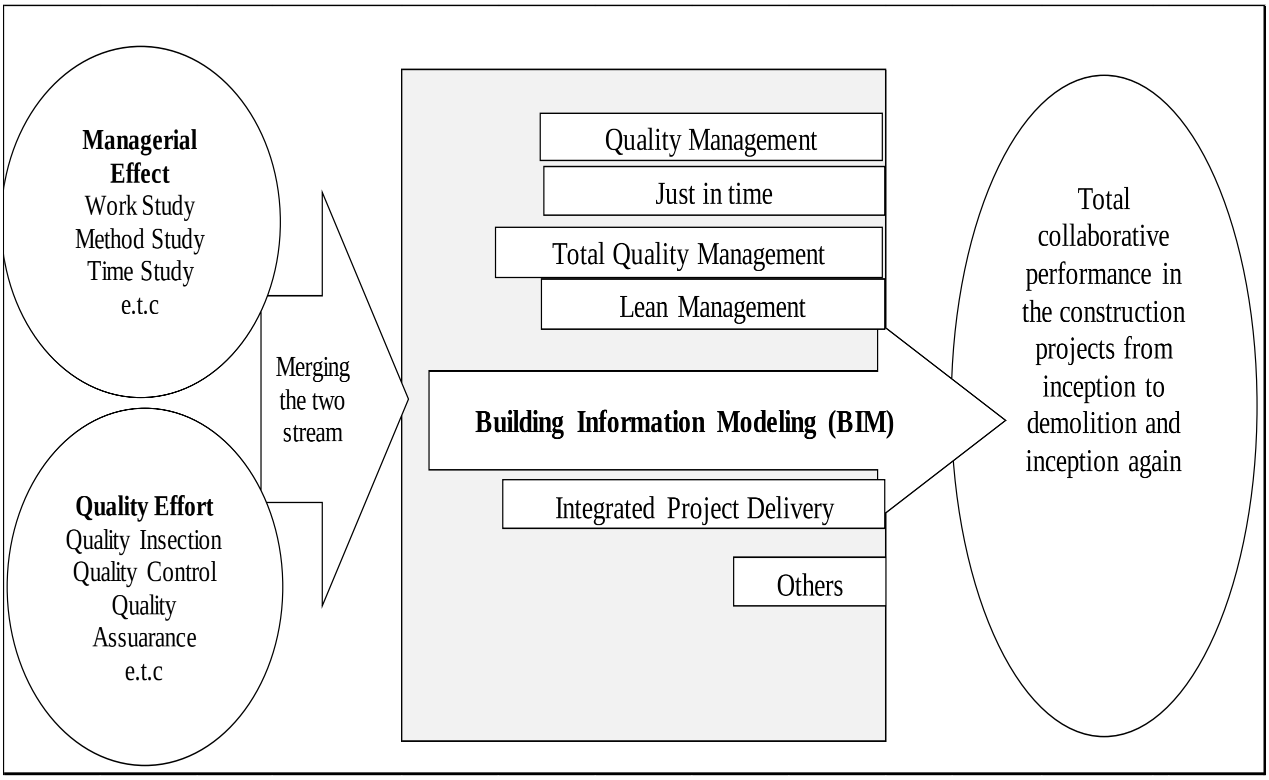



**Figure 14: BIM in Movement of information integration in Productivity Improvement[20]**

[20] Source: Own Construct

## 2. Construction Project Procurement Methods

A *project procurement or delivery method* is an arrangement to achieve the agreeable objectives of the client in construction project. *A project delivery method is a system designed to achieve the satisfactory completion of a construction project from conception to occupancy* (The Construction Management Association of America (CMAA), 2012). Two key issues stressed by the delivery methods are how many entities does the client deal with and the criteria for awarding the project to the entities (Halpin & Senior, 2012). The main consideration in project procurement usually vary with the type and nature of the project. However, time, cost and quality are considered common and crucial in construction projects (Cooke & Williams, 2009). In most cases, these three factors determine the value for money of the project to the client ((Greenhalgh & Squires, 2011), in page 7). Changes in procurement methods are inevitable.

> *"As clients became more professional, understood the construction process better and were forced to be more customer-oriented themselves, they naturally required this change of focus from their own suppliers and contractors. This move from almost total reliance on traditional procurement to a much wider variety of methods depending on clients´ requirements has been quite a long and sometimes painful transition. This move has probably been helped by three economic recessions from the early 1970s, which taken together have necessitated a much leaner industry."* (Greenhalgh & Squires, 2011)

In construction projects, time, cost and quality are only the main factors. Other factors worth consideration during procurement method selection include the complexity of the project, degree of competition and risk distribution (Cooke & Williams, 2009).A *balance* of all of these factors is important.

Building Information Modelling comes as a tool and process into the procurement effort and practice in the construction industry. To well comprehend the benefits of BIM, it is equally important to review these methods (Eastman C. , Teicholz, Sacks, & Liston, 2011).Today, Construction Industry has variety of procurement methods, probably varying from traditional method to integrated project delivery method? Relative to BIM development traditional methods like Design-Bid-Build (DBB), Design and Build (DB) and integrated methods specifically Integrated Project Delivery (IPD) can usefully be illustrated. In additional to DB and DBB, a number of construction management related methods can be formed, mostly with effort to overcome the traditional methods weaknesses as well as trying to attain IPD advantages. Construction Management at risk, Contracting Management, Project Management to mention but few.

### 2.1. Design-Bid-Build

Mostly referred as traditional method, still one of the popular method, (Cooke & Williams, 2009,pg 27) ranked second with 37% after design and build which was given 43% of popularity. Here, an Architect is the leading consultant, who establishes the whole program and design objectives from schematic design, design development and contract documents. Mostly, the final set of drawing and specification are arrived with assistance of other hired consultants, like structural engineers and service engineers and Quantity Surveyors. Lack of sufficient details usually raise disputes with contractors (Eastman C. , Teicholz, Sacks, & Liston, 2011). The winning general contractor is decided under client and Architects overviews, and the subcontractors follow the same rule of selection by the general contractor. The start of the work is characterized with *redrawing* of the details to both general and subcontractors, resulting from the *incomplete information* from the consultants that is drawings and specifications. This brings conflicts and are very time consuming weakness of the method. Common inaccuracy, inconsistence and incompleteness of drawings and specification of this method, mostly results to the necessity of on-site fabrications and later causes increased costs due to variations during construction. The method is characterized mainly by the separation of the design phase from that of construction. In (Greenhalgh & Squires, 2011), the methods has been categorized into single stage lump-sum competitive and two stage selective tendering. The two stage selective tendering traditional method, involves a contractor in detail design, which is just before the construction stage.

The fact that the winner of the bid is usually with the lowest bid, sometime contractors bids low to win and struggles to compensate the loss through *variations* by taking advantage of the *omissions* from the *contract documents*. This is common dispute source between the client and the building team (Eastman C. , Teicholz, Sacks, & Liston, 2011).Never less the need of approval of payments from the client and commissioning process at the end of the project involving preparation of as built drawings and the like are among many problems that cause the traditional method to be relatively time and cost inefficient. The competitive nature of DBB is relatively helpful, especially in public projects.

### 2.2. Design-Build

Here the owner contracts direct with the contractor. The contractor has the capability of designing or collaborating with the Architect and also of constructing the facility. It may be complete Design and Build or Partial design and build, depending on the amount of preliminary information the contractor is given. The work with regard to costs, time planning, contractual arrangement with subcontractors and modifications is done by the contractor and approved by the client before the work starts. Such arrangement results in more time saving project execution as well as cost efficiency due to less disputes and variations. Never the less, a chance is there for higher contract amount and changing the scope after approval. This may be more costly.

Variety of methods can be under design and build. According to (Greenhalgh & Squires, 2011), all those methods that integrate design and construction under the responsibility of one organization fit the category. Examples include develop and construct, design and manage and turnkey. Management contracting and Construction management are not in this category. Management contracting, the contractor is involved as a design team, and is paid fees, but the many other works subcontractors executing the works are under that contractor. On the other hand, in the construction management arrangement, the construction manager is purely a professional manager who manages the projects on behalf of the client. The contractual relation with other professional are in separate arrangements.

### 2.3. Integrated Project Delivery (IPD)

The customer focus is the core to any productivity improvement. Total Quality Management (TQM) adoption to construction industry targeted the same (Hellard, 1993), and the strength of most pioneered IPD procurement method is centered on the concept that team members dispose all their effort at best for the satisfaction of the client (Eastman C. , Teicholz, Sacks, & Liston, 2011). Integrated Project Delivery (IPD) intends to significantly reduce time and costs of the project by involving all the members from inception to project handover. According to (The American Institute of Architects National (AIA) and AIA California Council, 2007), Integrated Project Delivery (IPD) refers

> ***"to a project delivery approach that integrates people, systems, business structure and practices into a process that collaboratively harness 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."***

The client can be part or hire representative in the project, but it is necessary that client contractually states the expectations from the team members. Integrated Project Delivery principles are not specific to contractual arrangement (Integrated Project Delivery Task Force, 2007). Ideally it is suggested to cover some basic items as those explained in *Illustration box 2 below*.

Encouraging trust and collaboration is also found on the *partnering* method.Defining features of this method, given by  (Greenhalgh & Squires, 2011), are mutually agreed objectives and goals, inter-organisational trust,mechanism for problem resolution and continous improvement related to benchmarking process. When Organisations make arrangement to accomplish those four commitments are said to be in partnering. When the endavour is for infinite period, it is referred to as strategic partnering and when only few years are involved then it is project partnering (Cooke & Williams, 2009). The method of partnering is related to TQM, because it inspires integration of all participants in project in the effort to achieve excellence.The target is a win-win situation among all players, with a continous improvement effort. Originally a by product of the Total Quality movement, partnering gained popularity in both, construction projects and other types of projects. It helps to build a united team with a common goal, which in turn improves quality, reduces costs, and increases efficiency. Success in partnering requires competent partners, an understanding, and intensified commitment among players in the project (Cowan, Larson, & Gray, 1992).

> ***"Partnering is more than a set of goals and procedures; it is a state of mind and a philosophy. Partnering represents a commitment of respect,trust,co-operation, and excellence for all stakeholders in both partners´ organisations". (***(Cowan, Larson, & Gray, 1992) in (McGeorge & Palmer, 2002)).

**Illustration Box 3:Integrated Project Delivery principles (1/2)[21]**

**Mutual respect and trust:** In an integrated project, owner, designer, consultants, constructor, subcontractors and suppliers understand the value of collaboration and are committed to working as a team in the best interests of the project. To harness the collective capabilities of the integrated team, all key participants should be involved as early as possible with multiple disciplines and interests represented. Roles are not restrictively defined, but assigned on a "best person" basis.

**Mutual Benefit and Rewards**: All members will benefit from integrated project delivery. Because the integrated process assumes early involvement by more parties, the compensation structure must recognize and reward early involvement. Compensation should be based on the valued added by an organization and risk should be equitably allocated. Integrated projects will use innovative business models to support, rather than discourage, collaboration and efficiency.

**Collaborative Innovation and Decision Making.** Innovation is stimulated when ideas are freely exchanged among all participants. In an integrated project, ideas are judged on their merits, not on the author's role or status. Key decisions are evaluated by the project team and, to the greatest practical extent, made unanimously.

**Early Involvement of Key Participants.** In an integrated project, the key participants are involved from the earliest practical moment. Decision making is improved by the influx of knowledge and expertise of all key participants. Their combined knowledge and expertise is most powerful during the project's early stages where informed decisions have the greatest effect.

**Early Goal Definition**: Project goals are developed early, agreed upon and respected by all participants. Insight from each participant is valued in a culture that promotes and drives innovation and outstanding performance, holding project outcomes at the center within a framework of individual participant objectives and values. True value engineering is obtained by collaborative Focus on the project goals, including system performance throughout the facility lifecycle.

**Illustration Box 4: Integrated Project Delivery principles (2/2)**[22]

**Intensified Planning** The IPD approach recognizes that increased effort in planning results in increased efficiency and savings during execution. Thus the thrust of the integrated approach is not to reduce design effort, but rather to greatly improve the design results, streamlining and shortening the much more expensive construction effort.

**Open Communication**: Focus on team performance is based on communication among all participants that is open, straight and honest. Responsibilities are clearly defined in a no-blame culture leading to identification and resolution of problems, not determination of liability. Disputes are recognized as they occur and promptly resolved.

**Clearly Defined Open Standards**: Open and interoperable data exchanges based on a disciplined and transparent data structure is essential to support integrated project delivery. Enhanced communications between all participants is made possible with open standards. All technologies used on an integrated project should use open standards to eliminate the costly practice of integrating every application (and version) with every other application (and version). Interoperability exists on the human level through transparent business exchanges, supporting these exchanges with open standards completes the goals of integrated project delivery.

**Appropriate Technology**: Integrated projects often rely on cutting edge technologies. Technologies are specified at project initiation to maximize functionality, generality and interoperability. Open and interoperable data exchanges based on disciplined and transparent data structures are essential to support IPD. Because open standards best enable communications among all participants, technology that is compliant with open standards is used whenever available.

**High Performance**: Integrated projects will lead to optimized design solutions, higher performance buildings, and sustainable design.

**Organization and Leadership**: Although each participant is committed to achieving project goals, leadership should be taken by the person or organization most capable with regard to specific work and services. Often, the design professionals and contractors

The benefits of integrated practice are built on early collaboration between designers, contractors and fabricators. Under design-bid-build key participants cannot be identified until bids are received –far too late to meaningfully participate in developing the integrated design. For this reason, traditional design-bid-build is inconsistent with an integrated approach and cannot achieve the efficiency and performance benefits of an integrated process.

[21] Source: The American Institute of Architects (AIA), (2007)
[22] Source: The American Institute of Architects (AIA), (2007)

## 2.4. Public-Private Partnership (PPP)

Public construction projects need effective procurement method that can reduce the bureaucratic problems and enhance the value for money expected (Greenhalgh & Squires, 2011).Private Financial Initiatives (PFI), Outsourcing and Joint Venture form elements of the Public-Private-Partnership (PPP) arrangements that are emerging to facilitate efficient delivery of construction project with huge outlay of fund. The idea to these sort of arrangement was partly for the government to reduce public sector borrowing (Cooke & Williams, 2009). In (Hall, De La Motte, & Davies, 2003), PPP had no formal definition in Europe. It is a case to case terminology that originally can be traced from the UK. The intention to balance the involvement of private in the huge public capital expenditure in exchange for efficiencies from the private sector, is suggested to be the core reason behind privatization and later Public-Private Partnerships. Giving experience of UK, (Alshawi, 2009) considered Private Finance Initiative (PFI) as another form of PPP, with close relationship to DBFO (Design, Build, Finance, Operate), DCMF (Design, Construct, Manage, and Finance), BOO (Build, Own and Operate), BOT (Build, Operate and Transfer), and BOOT (Build, Own, Operate and Transfer).It is in this light of this thesis that, defining Public Private Partnership is difficulty. It is supported in (World Bank Group, 2015) that

> *"..there is no standard, internationally-accepted definition of a PPP. The term is used to describe a wide range of types of agreements between public and private sector entities, and different countries have adopted different definitions as their PPP programs evolved. Typically a PPP is a long-term contract between a private party and a government entity, for providing a public asset or service, in which the private party bears significant risk and management responsibility".*

According to (STRABAG, 2013), this PPP is another type of outsourcing like Build-Operate-Transfer (BOT), except the different financing system. In (COST Action TU1001, 2014), it was mentioned that PPP has not yet played a great role in Germany, compared to other conventional procurement methods in infrastructural projects. It was exemplified that, increasing efficiency in infrastructure projects was not the priority goal for opting PPP, but rather decreasing the budget deficit in federal states. In principle, scholars agree that the need for value for money, risk management between private and public, utilization of know-how of private sector; and the incorporation of maintenance in infrastructural projects are desired outputs of any PPP ((Al-juboori, 2014) (Alshawi, 2009) and (Hall, De La Motte, & Davies, 2003)).

However, according to (Al-juboori, 2014)[23] the PPP arrangement must include a public new capital effort that necessitates a fixed asset expenditure by the partner private (Concessionaire) entity. For the purpose of his thesis, the definition by the World Bank (2007) was adopted. Broadly PPP was defined as *“an agreement between a government and a private firm under which the private firm delivers an asset, a service, or both, in return for payments contingent to some extent on the long-term quality or other characteristics of outputs delivered”*. Like any other procurement method, PPPs have advantages and disadvantages. The key to deciding whether to adopt lies on the value for money analysis relative to other traditional methods. It is a matter of how far optimal is PPP/PFI over conventional public procurement methods. In (Alshawi, 2009), value for money refers to optimum combination of whole life cost and quality to meet the requirements of the users. Although PPPs may lack definition or legal sense of partnership, yet the fact that are being pursued in infrastructural projects makes them worth being considered. So, this thesis assumes that all PPPs are worth considered as alternative procurement methods.

### 2.5. Which procurement suits BIM

BIM is founded on communication and collaboration (Azhar & Khalfan, 2012). The strength of BIM lies on the ability to involve all participants of the project as early as possible and its capability to visualize the life cycle of the project. DBB is said to be unsuitable for BIM, as it means unnecessary wastage of time, to wait the bid process before fully using BIM. For some time these traditional approaches have caused unnecessary waste and errors (Eastman C. , Teicholz, Sacks, & Liston, 2011) due to its fragmentation nature, and so DB with the single point responsibility of design and construction is suggested to provide fertile ground for BIM.

According to (Ilozor & Kelly, 2012), many scholars agreed on BIM and IPD similarities and difference in terms of benefits *(see the figure below).*From the benefits, it is relatively clear that, IPD can be achieved without BIM (Integrated Project Delivery Task Force, 2007),but only with less productivity desired. On top,low quality and building operational benefits in IPD, may imply the lesser collaboration level among project participants.Worse enough the client being excluded. So, the procurement and teamwork advantages of IPD over BIM, are more or less commanding the employing of BIM in IPD related projects. Supporting this ((Integrated Project Delivery Task Force, 2007), (Forbes & Ahmed, 2010) (Eastman C. , Teicholz, Sacks, & Liston, 2011)) showed that BIM guaranteed the advantegeous involvement of clients and users in the construction process.It may be safe to utilize BIM in IPD than in DB, due to the need to rescue clients from contractors dominance,

[23] Un-published Ph D Dissertation Report Supervised by the Univ.-Prof. Dr.-Ing. Josef Zimmermann, Technical University of Munich.

and so the choice between the two is relative to project compexity and size.The more complex the project, the more BIM suits IPD and the lesser the more it suits DB.

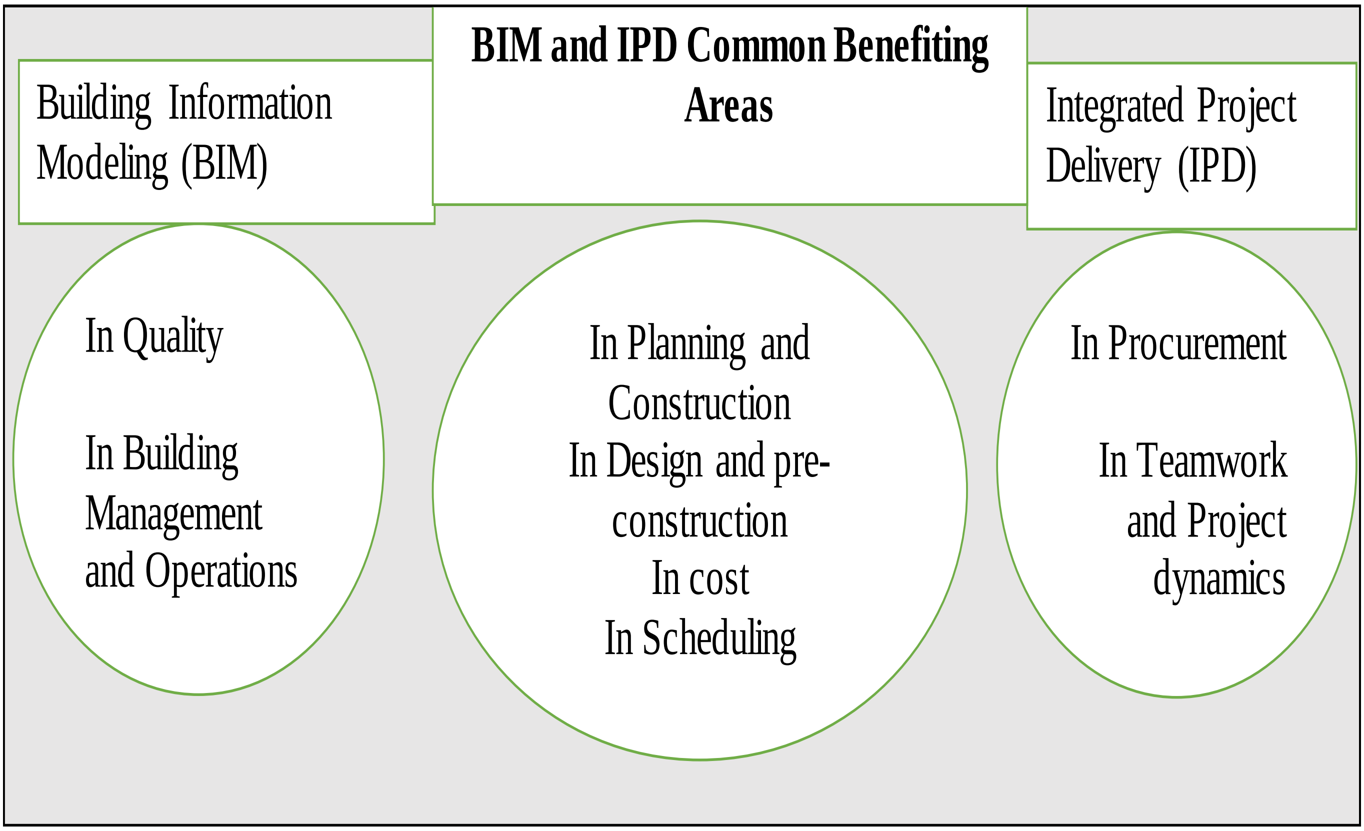



**Figure 15: Comparison of benefits between BIM and IPD[24]**

In this thesis, BIM is what BIM does. It extends from individual BIM as a manual model to environmental BIM, where multinational professionals are networked to perform a project.

> *"5D Building Information Model (BIM) is a highly sophisticated project control method which allows STRABAG to simulate and manage a project 'model' in 'real time', The BIM 5D process and techniques allow the entire turnkey construction delivery team – clients, engineers, architects, operators, main contractors, subcontractors, manufacturers and materials suppliers to share and understand a single 'real-time' view of the entire project. This BIM 5D approach is also dedicated to enabling the construction delivery team to explore options and manage solutions as never before due to the accurate interface of design, programme and engineering costs. At the Technical Head Office of the STRABAG Group, innovative tools to help realize*

[24] Source: Modified from Ilozor, B. D., & Kelly, D. J. (2012). Page 23-36.

> *effective and transparent cooperation are tested and implemented in the 5D Design department."* (Strabag, 2013)

Procurement method selection in construction project is very situational. They depend on the objectives of the projects. Sometimes these methods are intruded by the philosophies intending to foster factors like trust in order to facilitate attaining the projects desire. Partnering is among the arrangement used in construction project delivery whose definition is unclear but yet claimed to have purposes, and being more efficient in some projects than other methods. In (McGeorge & Palmer, 2002), Alliance was distinguished from Partnering. Alliance is a partnering underpinned in the economic fairness. In alliance, partners share loss and profits contractually. In partnering, partners gaining or losing from the partnership is not contractually binding. So, in alliance, the firm is formed and resource contributed, but the management service of the project may be appointed and work independently. In partnering it is the commitment and trust of the stakeholder in the project that matters towards the desired goals, whoever gains at the end is contingent. BIM does not know the methods, but the objectives of the projects. The efficiency towards Time, Cost, Quality, Safety and other project objectives usually cut across type, size and context of the project. The level of participants' commitment to the project is at large influenced by the contractual arrangement. How far stakeholder benefits from BIM may differ relative to the procurement method used, only because the contractual arrangement can facilitate better communication, information flow and collaboration among stakeholders. This does not mean there is specific procurement method suitable for BIM, but rather, it means that the effective use of BIM is relative to the type of delivery method to be used.

> *"Which problems prevail during project implementation depends on contractual arrangements (system of contracts and influence of contractual environment in every country) of the project delivery, because those arrangements forms general atmosphere of the project participants relations climate. The contractual arrangements of lump sum contracts between CM team and client and back to back between CM team and suppliers lead to environment, where each member of project team gives priority to its individual interests not to common project goals."* (Migilinskas, Popov, Juocevicius, & Ustinovichius, 2013)

## 2.6. Contractual Arrangements in BIM

*According to (*Cooke & Williams, 2009) *„A Contract is a means of formalizing the relationship between the contracting parties in which the rights and obligations of the parties are agreed and the balance of the risk between the parties established".* In construction projects, exist standard contract documents, which help parties in formulating the specific projects contracts. Although the use of standard contract is not mandatory, it is a practice that need to be encouraged (Ashworth, 2006). Example is the Joint Contract Tribunal (JCT) contracts series and Institute of Engineers (ICE) in England and Public Procurement Regulatory Authority (PPRA) in Tanzania. It is highly tedious and uneconomical, to re-write construction contracts in every project. Focuses of any Construction Contract arrangement include the provision for the performance desired on time, cost and quality. These three, together with many other project objectives must be balanced against the factors considered in the selection of contract arrangement to be used. The procurement methods and contractual arrangements are highly related. The procurement method efficiency depends on the contractual arrangement adopted. The contractual arrangement influences the collaborative and informative efficiency in the whole construction. In Traditional procurement, the common contract arrangement are fixed, measurement and cost reimbursement (Latham, 1994). Other methods of procurement utilize these arrangement and many other management contracts (The Construction Management Association of America (CMAA), 2012).

> *"A common cause of complaint by the industry is that the client does not know its own mind. An inadequate brief is presented to the consultant and/or the contractor. The client subsequently requires detailed changes in the work, with serious implications for cost and programme. Formulation of a project strategy by the client is the first building block to a successful and cost effective scheme."* (Latham, 1994)

According to (SMART Construction, 2013), individual construction projects differ relative to how individuals are responsible to prepared *documents*, how the *price* is set, *contract* administered and *risks* allocated. All these consideration are focused towards the objectives of the projects. The priorities and objectives of the employer are the principle considerations in choosing the contract arrangement (Cunningham, 2013). The choice of whether to use Traditional, Design and Build, Design and construct and Management Procurement method depend on the balance between risks, cost, payments and responsibilities among construction project participants (Cooperative Research Centre (CRC), 2008). The Lump Sum contract for instance, favours the certainty in costs and so traditional and design build (Latham, 1994) can be used because of the need to give enough time to detail design and prepare the costs.

| **Project Objectives** | **Parameters** | **A** | **B** | **D** | **Contractual Arrangement** |
|---|---|---|---|---|---|
| Timing | Early Completion | NO | YES | YES | Management Contract |
| Cost | Price certainty before construction start | YES | NO | YES | Fixe-Lump sum |
| Quality | Prestige level in design and construction | YES | Y/N | NO | Management Contract |
| Variations | Avoid prohibitive costs of change | YES | YES | NO | Fixed-Measure and Value |
| Complexity | Technically Unclear or highly complex building | NO | Y/N | NO | Fixed-Measure and Value |
| Responsibility | Single contractual link for project execution | NO | Y/N | YES | Management Contract |
| Professional Responsibility | Need for design team to report to sponsor | YES | Y/N | NO | Management Contract |
| Risk Avoidance | Desire to transfer complete risk | NO | NO | YES | Lump sum-Fixed |
| Risk/Complexity | Unclear or Emergent or Urgent works | NO | Y/N | YES | Cost reimbursement |

**Figure 16: Example in choosing procurement Methods and Contractual Arrangement**[25]

*Key: Yes-Suitable, No-Not Suitable Y/N –It depends on the arrangement. Procurement Methods: A-Traditional Method, B-Integrated Management Methods, D-Design and Build.*

[25] Source: Modified from Latham, M. (1994). Page 15-16

The two common types of contracts in *fixed contract arrangement*, are Lump Sum and Measure and Value. Lump sum contract is when the *contract sum* is determined before construction starts. The drawings and specification or contract documents are supposedly complete to details, including schedule of works and preliminaries (Cunningham, 2013). Measured or measure and value contracts or re-measurement contracts are fixed price basing on the agreed *firm price filled by the tenderer*. The thin line of distinction is the word *fixed* and *firm*. By *fixed price*, the target is the *total contract sum*, while *firm price* refers to *rate* of an item (Greenhalgh & Squires, 2011). While in fixed price the bills of quantities (BOQ) is assumed to be from a fully detailed information, in the firm price the BOQ is only approximate, meaning it is prepared from the incomplete information. The actual quantities is measured in-situ during works execution. In Cost reimbursement contracts or Cost plus arrangement, the payments base is actual cost plus percentage fees. The actual costs of labour, plant and materials, plus a predetermined fee to cover overheads and profit is calculated to as the contract sum of the project *(ibid).*When this contract sum is set earlier as the maximum cost of which above that, the client is not obliged, the arrangement is referred to as Guaranteed Maximum Price (GMP). GMP contract refers to an arrangement where the client and the contractor establish a price for a specific scope of work that cannot be exceeded (Greenhalgh & Squires, 2011).

> *"Guaranteed Maximum Price contracting is an arrangement in which an owner contracts with an entity to perform a fixed scope of work in exchange for a price that is guaranteed to not exceed a stated maximum price. The GMP will typically include a base cost along with several allowances and contingencies that, depending on their ultimate use, may result in a final cost below the stated GMP. These "savings" may fall to the owner or may be shared with the entity providing the GMP."* (The Construction Management Association of America (CMAA), 2012)

The contract arrangements are systems design for the relationship and payment in construction contract. The arrangement are situational, requiring exhaustive analysis before signing the contract irrespective of the procurement arrangement chosen. In essence the contractual arrangement may be the way towards balancing the objectives of the projects. Because it impacts on the cost of the project and commitment of the participants to the project. The efficiencies of *collaboration* and *information* highly depend on the strength of liability among the players and towards the project objectives.

Building Information Modelling is essentially facilitating keeping critical design *information* and creating *real time relationship* design information for the efficient and effective (Greenhalgh & Squires, 2011). Irrespective of the procurement method, the information integration crucial. It is important for information liability to be coordinated among players. In (Hardin, 2009) on page 14, the construction documentation phase of the design-build process often starts with 50 percent of the construction documents going to the local code authorities to secure permit. In design-bid-build similarly, the information between designers, estimators and construction team is disconnected, and hence the rise of huge unnecessary contingencies. The estimator and construction team wait for 100 percent information from designers (ibid), which may result in delay and conflicts during construction phase as a result of unclear items. With BIM, the information flow is connected and it equally gives a chance for clarifications. The estimator have a chance to digitally request and give clarification and quickly catch up with the construction process. BIM eliminates the degradation of the information value from author organization to other parties, and enhances the project focus value of information over the firm focus value (Smith & Tardif, 2009).Information is accurate at first time and migrate between authoritative points urgently enough to optimize the entire delivery process. Nevertheless, BIM gives more advantage to clients over other players, because of the chance to utilize the model information and the embedded knowledge during operation stage (Greenhalgh & Squires, 2011).

# 3. Fundamentals of BIM

## 3.1. Defining BIM

According to (Halpin & Senior, 2012, pg 92), ***BIM is fundamentally a computer based*** 3D representation of the facility delivery. Rapid growth of Building Information Modelling can be demostrated by the many definitions of the terminology (Succar, Sher, & Williams, 2012). As a model, (Associated General Contractors of America, 2005) defined BIM

> *"As a data-rich, object-oriented, intelligent and parametric digital representation of the facility, from which views and data appropriate to various users' needs can be extracted and analyzed to generate information that can be used to make decisions and to improve the process of delivering the facility"*

BIM is not only a tool but also a process that helps in making decisions about the facility (Forbes & Ahmed, 2010). *BIM is the process of generating and managing building data during its life cycle* (ibid). As a process it facilitates efficient and integrated project scope definition, designing, costing and scheduling in real time. BIM as a virtual process comprises all aspects, of a facility within a single, virtual model, allowing more participants (owners, architects, engineers, contractors, subcontractors and suppliers) to productively contribute to the process than was traditionaly possible (Azhar & Khalfan, 2012). An Architect is expected to collaborate with a Geomatician to set the building in the model and detect difficulties in advance. Equally, the Services engineers can trace difficulties in their installational and fittings very much in advance. As a model BIM consists of building *geometry,spatial relationships,geographical information as well as quantities and properties of the building* (Forbes & Ahmed, 2010). The American Institute of Architects National (AIA) and AIA California Council, (2007) defined BIM as "***a model based technology linked with a database of project information***", while Demchak,et el (2008) defined it as "***the management of information throughout the entire lifecycle of a design process from early conceptual design, through construction administration, and even into facilities management".*** On the other hand, (Eastman, et el (2008)) precautioned that BIM is a collection of tools and processes that result in a product that is greater than the sum of its parts. To them BIM is *a modeling technology and associated set of processes to produce, communicate, and analyse building models.*

Never the less, (Morrissy,et el 2012), defined BIM as a 3D virtual representation of the building to be constructed. It provides a digital simulation of the structure to be built showing how it will be constructed and how it will allow the design to be tested before the construction phase begins. From ((Eastman, Teicholz, Sacks, & Liston, 2011) and (Crotty, 2012)), BIM facilatates integration and enhances the *quality* in construction projects through computer modelling of the *whole* process. It accomodates many functions and can be together managed by all the participants.To concur with all the definitions, BIM refers to an optimal virtual and digital designation, representation and management of all physical, chemical and functional characteristics of the facility for the whole project life cycle. The model is expected to touch whatever is related to the project, from human resources involved, materials and as well as contractual matters related to the facility. The key advantage of the model stems from the fact that the facility undertakings can well be visualised earlier before starting the actual construction by all participants and so enhancing the decision making. From (Wong, Wong, & Nadeem, 2009) various BIM definitions *(see the tables below)* showed consistent with each other, although after some comparison, it was found that a more comprehensive BIM definition to present its full application may be desirable.

| BIM Definitions | Sources |
|---|---|
| Building Information Modelling (BIM) is a digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life cycle; defined as existing from earliest conception to demolition. | National Institute of Building Sciences, the USA The National Building Information Modelling Standard (NBIMS) sets forth the guidelines for the general use of BIM in the USA. |
| A building information model (BIM) is an object- oriented building development tool that utilizes 5-D modelling concepts, information technology and software interoperability to design, construct and Operate a building project, as well as communicate its details. Furthermore, 'BIM is a building development tool that is based on a 3D model of a building created in an object-oriented (intelligent) modelling software. Once the model is Created, it can be used to assist with design, construction and operational tasks; it can also be used as a communication tool. Different uses of BIM may require different software applications to utilize the model, so BIM requires software to be interoperable.' | BIM Forum, It is an open internet forum established in the USA. BIM users can deliver their opinions on this forum. It is a common platform for information sharing. It includes five sub-forums: Academic, Designers, Builders, Legal, Software and Users. |
| 'Building Information Modeling (BIM) is the creation and use of coordinated, internally consistent, computable information about a building project in design and construction. The ability to keep this information up-to-date and accessible in an integrated digital environment gives architects, engineers, builders, and owners a clear overall vision of their projects and contributes to the ability to make better decisions faster-helping raise the quality and increase the profitability of projects.' (Autodesk, 2008). | Autodesk They are the leading software developer in the AEC industry. Its product line provides many diversified solutions to the industry. Autodesk Revit Series has become the core software in BIM applications. |

**Figure 17: Various BIM definitions checked for consistent (1/3) [26]**

[26] Source: Wong, A. K., Wong, F. K., & Nadeem, A. (2009)

| | |
|---|---|
| BIM is a 'Modelling technology and associated set of processes to produce, communicate and analyse building models. Building models are characterized by:<br>• Building components that are represented with intelligent digital representations (objects) that 'know' what they are, and can be associated with computable graphic and data attributes and parametric rules.<br>• Components that include data that describe how they behave, as needed for analyses and work processes, e.g. take off, specification, and energy analysis.<br>• Consistent and non-redundant data such that changes to component data are represented in all views of the component.<br>• Coordinated data such that all views of a model are represented in a coordinated way.' | Eastman et al. (2008) They are the experts and academicians in the field of BIM from the USA. |
| BIM is an intelligent simulation of architecture. 'To enable us to achieve integrated delivery, this simulation must exhibit six key characteristics. It must be digital, spatial (3D), measurable (quantifiable, dimension-able, and query able), Comprehensive (encapsulating and communicating design intent, building performance, constructability, and include sequential and financial aspects of means and methods), Accessible (to the AEC/ Owner team through an interoperable and intuitive interface), and durable (usable through all phases of a facility's life)' (Campbell, 2006).' | Mortenson Construction Company, the USA It is a construction contracting firm in the USA. They have used BIM tools extensively within their practice. |
| A Building Information Model, is a data-rich, object-oriented, intelligent and parametric digital representation of the facility, from which views and data appropriate to various users' needs can be extracted and analysed to generate information that can be used to make decisions and to improve the process of delivering the facility.' (AGC, 2005) | Associated General Contractors (AGC) AGC is the leading construction trade association in the USA. |

**Figure 18: Various BIM definitions checked for consistent (2/3) [27]**

[27] Source: Wong, A. K., Wong, F. K., & Nadeem, A. (2009)

| | |
|---|---|
| A set of interacting policies, processes and technologies that generate a methodology to manage t5he essential building design and project data in digital format throughout the building's life cycle | (Succar, Sher, & Williams, Measuring BIM performance: Five Metrics, 2012) |
| Integrated Project Delivery (IPD) is 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 reduce waste and optimize efficiency through all phases of design, fabrication and construction. | (Integrated Project Delivery Task Force, (2007) |

**Figure 19: Various BIM definitions checked for consistent (3/3) [28]**

[28] Source: Wong, A. K., Wong, F. K., & Nadeem, A. (2009)

| | Attributes | NIBS | BIM Forum | Autodesk | Eastman | Mortenson | AGC |
|---|---|---|---|---|---|---|---|
| 1 | Modeling Scope | Physical & Functional Characteristics | 5-D modeling | | nD | | |
| 2 | Modeling Approaches | Digital | Object oriented | | Intelligent digital representation | Digital, Spatial | Object Oriented |
| 3 | Modeling Functions | Shared Knowledge Resource | | Coordinated, internally consistent, computable information | Data rich digital building components | Measureable, comprehensive, accessible & durable data | Intelligent & parametric digital representation of facility |
| 4 | BIM Aims | Reliable Decision | Better communication | Better, faster decisions, quality & profitability | Produce, communicate, analyze building models | Intelligent simulation of architecture | Facilitate decisions & improve delivery process |
| 5 | BIM Coverage | Conception to Demolition | Design, Construction, operation | Design, Construction | All phases | All phases | |
| 6 | Stakeholders Interaction | Collaboration | | Integrated digital environment | Coordination | | |
| 7 | Data Processing | Inserting, extraction, updating, modification | | Information updating, accessibility | Consistent & non-redundant data | | |
| 8 | BIM Users | Each Stakeholder | | Architect, Engineers, Builders, Owners | | AEC team, owner | |
| 9 | Compatibility Recognition | | Interoperable | | | Interoperable & Intuitive | |

**Figure 20: Comparisons of Attributes of BIM**[29]

[29] Wong, A. K., Wong, F. K., & Nadeem, A. (2009)

## 3.2. Brief BIM History

In the early 1980s PC-based CAD was used.Then the object-oriented CAD technology was introduced in the early 1990s (Autodesk, 2007). Building Information Modeling (BIM) has been universal in the construction fields over these past 20 years (Quirk, 2012).It is the paradigm shift from drawing to modelling witnessed mostly over a decade before year 2010 (Eastman C. , Teicholz, Sacks, & Liston, 2011). Likewise the shift is from traditional individually competitive to collaborative project delivery. Over these few decades players from the United States, Western Europe and the Soviet Block competed to create the perfect architectural software solution to overtake the normal 2-Dimensional CAD workflows (Quirk, 2012) (see Illustration Box 4:BIM Ideas).

Illustration Box 4:BIM Ideas[30]

*"The conceptual underpinnings of the BIM system go back to the earliest days of computing. As early as 1962, Douglas C. Englebart gives us an uncanny vision of the future architect in his paper Augmenting Human Intellect.*

*[the architect next begins to enter a series of specifications and data–a six-inch slab floor, twelve-inch concrete walls eight feet high within the excavation, and so on. When he has finished, the revised scene appears on the screen. A structure is taking shape. He examines it, adjusts it… These lists grow into an ever more-detailed, interlinked structure, which represents the maturing thought behind the actual design.]*

*Englebart suggests object based design, parametric manipulation and a relational database; dreams that would become reality several years later. There is a long list of design researchers whose influence is considerable including Herbert Simon, Nicholas Negroponte and Ian McHarg who was developing a parallel track with Geographic Information Systems (GIS). The work of Christopher Alexander would certainly have had an impact as it influenced an early school of object oriented programming computer scientists with Notes on the Synthesis of Form. As thoughtful and robust as these systems were, the conceptual frameworks could not be realized without a graphical interface through which to interact with such a Building Model."*

[30] Source: Bergin,A & Bergin,B.S, (2012)

Scholars agree that BIM development is enhanced by the building modelling software development. It was not until 1990s when *object oriented* building product model were found, giving rise to a parametric 3D modelling that many scholars dreamed and predicted more than three decades back (Eastman C. , Teicholz, Sacks, & Liston, 2008). While conventional 3D CAD will describe a building by independent 3D views such as elevations, an intelligent contextual BIM will describe the building by its element such as space, walls and columns (Azhar, Nadeem, Mok, & Leung, 2008). Having shown the potential in integrated project delivery (IPD), BIM promises more revolutionary movement in the construction industry. Among others (Forbes & Ahmed, 2010) provided the following process and technology trends as are currently noted.

***Process trend***

- *Owners are demanding BIM and changing contracts terms to enable its use*
- *New skills and roles are developing*
- *Successful implementation have led corporate wide uptake by general contractors*
- *The benefit of integration are receiving wide review and being tested intensively in the practice*
- *Green building is increasingly demanded by clients*
- *BIM and 4CAD have become common tools in large construction site offices*

***Technology trend***

- *Automated checks for code conformance and constructability using building information models is becoming available*
- *BIM tools with construction management are increasingly available*
- *Building product manufactures are beginning to provide parametric 3D catalogs*
- *BIM is encouraging prefabrication for increasingly complex subassemblies, which can be procured globally*

A lot has been said on benefits of BIM (Ilozor & Kelly, 2012),while little is available with regard to objective performance measures and guidance towards generating and enhancing BIM ((Ilozor & Kelly, 2012)& (Succar, Sher, & Williams, 2012)).It is necessary to assess BIM productivity improvement in order to consistently benefit and understand its usability, adoptability and reliability.Never the less,to achieve that, researchers need to fully be aware of the fundementals behind BIM not only as a tool,but also as technology and process at large. To be fully knowledgeable of the internal dynamics and efficiency necessities of BIM (Succar, Sher, & Williams, 2012).

### 3.3. Technological overview on BIM

The main question, technologically is to distinguish BIM from other CAD related technology. Scholars made it clear that, while to modify one part in CAD related technologies would mean, manually adjusting the other related drawings, in BIM the action is automatic self-adjusting (Azhar & Khalfan, 2012). The building elements are *parametrically* defined, containing all the *building element* and *building system* properties and specifications. *A parameter is a variable used in an equation to assign values while a parametric behaviuor is the reaction of parameters or variables by changing a parameter according to the defined relations and constraints among the parameters* (ISA Project Team , 2008). Example is when an Architect designs a door. In mind, among others, there are number of parameters of the designed door, like the size, position relative to a wall, material, and paint as well as performance coefficients. When these parameters are attached to the particular door, the door will be able to behave parametrically. That is a change in one of the parameter will be reflected on all other parameters. Such a door is an intelligent BIM object referred here. That is done to all other components of the building. As a result, an increase in the height of the door, automatically finds its related width and adjusts the wall area. It adjusts the costs of painted area, it adjusts the positions of iron mongeries and it adjusts relative to the right performance constants like transparency and thermo-insulation. The adjustments goes as far as the pre-set conditions will allow. To be a BIM digital model, is more than just being a 3D model (Eastman C. , Teicholz, Sacks, & Liston, 2011). It requires objects attributes or information, behavioural support as well as parametric ability, that is to automatically and relatively reflect changes to other parts of the model.

Traditionally designers produce drawings and then add specifications to clearly explain their works.The same is almost for the CAD and object-oriented CAD technologies and software. Only some of the abstracts of the designed part would be automated with information.There is little informational advantages compared to what BIM can provide. In 3D BIM a clear visualization of the site context is possible, 4D BIM can give a real visual respresentation of the sequence of construction activities and with 5D BIM the automated Quantity Take-Offs (QTO) and cost estimating are possible. Building information modeling (BIM), starts with *capturing information*, *storing* in a building information *digital database* and making information accessible and manageable by all participants,through the modelled view of the building (Autodesk, 2007).Designers in BIM know a three dimension component as the unit of design not a line or one dimension as it is in the traditional CAD design. The current generation of BIM Architectural design tools, including Autodesk Revit Architecture and its associated set of technological products (Eastman C. , Teicholz, Sacks, & Liston, 2011).The history goes back to1960s with 3D models related development. The technology went through some stages before being advanced to the full parametric modelling where parameters defining one shape can be linked to another shape by rules.

Architects, Engineers and other experts can smoothly design only if they can familiarize themselves with knowledge behind customizing the parametric object families and related rules and results. Never the less, today no more programming knowledge is required to attain this (Eastman C. , Teicholz, Sacks, & Liston, 2011),because standard conventions needed in the building projects are mostly captured within the BIM, given a more user friend environment compared to former 3D CAD. The challenges are only the difficulties with regard to the Real World or specific context, as it takes an imaginable effort to match with the design system. Apart from parametric shapes technological view, there are other aspects that are vital to designers in order to manage the information in the life cycle of the facility. A *relationship* for example, the definiton of what element is bound or related to what .Likewise, *attributes* and *properties* which are the inputs packed to ensure intepretability of the objects in different stage of life cycle. *Names, needed occupancy* and *material specifications* are good examples of *attributes* and *properties*.However, many of the objects properties can be found on the Building Object Models libraries (Eastman C. , Teicholz, Sacks, & Liston, 2011).

With BIM drawings generation has not been ignored.What ever is needed can be extracted from the object, that is drawings and reports necessary to the projects. Advantageously, more improvement can be made easily on detailled extraction. However BIM is still on maturity stages and still more technological improvement is needed to cover the challenges like that of linkages to external files.

As a standalone *tool*, BIM gives output like report or drawings that are far better than those from a normal CADs. It can easily develop parametric objects and model complex curved surfaces as well as give *take off quantities*.Taking example of Revit as a tool, it offers bidirectional editing from drawings and model. But as a *platform*, BIM produces higher capability tools and data that provide multiple uses from design to communication, through the primary data model. Revit as one of the leading market platforms,it can import models from google. Multiprojects can be handled simultaneously with a very accurate *scalability (ability to combine large projects scale and modelling at a high level of scale), interoperability, extensibility( ability to add more functions and building own behaviour)* and *manageability* between multiusers. *Platforms* are extra-building model tools digitally and spatially. However it takes the Multirepresantation of objects and Multiplatforms to formulate the BIM environment, as examplified by Delta Server of Arch CAD (Eastman C. , Teicholz, Sacks, & Liston, 2011).

In brief, BIM tools are task specific, BIM platforms provides data for multiple uses, that is Architect,Engineer and a contractor can use it, example is Revit compared to AutoCAD; and BIM environment goes further to even supporting policies and practices in the industry level (ibid). According to (Hardin, 2009)

> *"BIM is not just a software. BIM is a process and software. Many believe that once they have purchased a license for a particular piece of BIM software,they can sit someone infront of the computer and they are doing BIM. What many do not realize,though is that Building Information Modeling means not only using three-dimensional modeling software but also implementing a new way of thinking.It is in essence a new way of not doing the same old thing."*

It this complexity of BIM that sometimes brings confusion. Participants interprete BIM differently on how it technological BIM saves their purposes. Some feels BIM as a complex tool useful in information generation. To some BIM remains as management of building information and to some it is a complex technology based on a collaborative approach to project and facilities management intending to benefit from sharing, integrating and maintaining interaction of all participants to a single database or information model or information technology (Sabol, 2013). In essence, BIM should viewed as a collaborative technological effort that improves the informational efficiency in the total project delivery by allowing all participants to contribute in the process.

| Key Benefits | Commentary |
|---|---|
| Integrated Working | BIM commands the Project team to collaborate. It enables the whole project team to share information |
| Improved design Coordination | With BIM, the facility is built repetitively. Because the digital capabilities facilitate designers and constructors to timely model the facility, check and re-check for clashes and error in advance. |
| Health and Safety Planning | It is possible to including temporary works in construction management strategies. High Visualisation, simulation and animation of the model opens more possibilities for fruitful discussion |
| Planning and Costing Efficiencies | Automation is high. Generation of data including quantities and prices, give more valuable information in forecasting and estimating |
| Design For Manufacture and Assembly (DFMA) | 3D and 4D capabilities in BIM facilitates fabrication and hence improves delivery process through reduction of wastes and time |
| Value Adding | BIM sets a database of information for the user and facility managers, which gives the possibility of better life cycle management |

**Figure 21: Example of the Common Benefits of BIM implementation.**[31]

### 3.4. Interoperability

BIM and Interoperability are essentially inseparable (Aranda-Mena & Wakefield, 2006).Without interoperability participants incurs significant loss (ibid Pg. 128).

> *"Information interoperability needs to occur when two people using different software need to communicate effectively and efficiently.,,,,,,,,,,The interoperability challenge can therefore be described as the ability to extract the smallest, most directly relevant information required to execute a particular task, and share that information in a manner that is understandable by a wide range of users that use a wide range of software packages"* (Hecht,Louis ; Singh, Raj ,Jr., 2010)

According to (Hamil, 2012), there are three levels of interoperability. Interoperability between software from the same vendor or dealer. It may happen, a model from the Graph iSOFT ArchiCAD 17 is used between Plumbing engineer, Architect and ICT engineer. This interoperability is also important between tool to tool applications, for instance when take-off quantities transferred to costs applications. Likewise, interoperability can be between software from the different vendors, which is of more desired in construction than the former. In building projects, specification and drawings form

31 Source: Gledson, B., Henry, D., & Bleanch, P. (2012)

the intention of designers. Therefore, in order to achieve smooth communication from different software used by those designers, the rules must be agreed by the sellers of those software. To understand a Revit AutoCAD Software model in MEP software by service engineer, there must be interoperability between the two vendors. The same works for a movie between Adobe Flash and Apple Safari web browser. When open standards are used, multiple users can apply the information from a single source, that is interoperability through open data standards.

Interoperability intends to facilitate flow of information between points, commanding that the ability of exchanging data should be maximized, that is interoperability, or trying to reduce the need to copy information from point to another. Efforts are being made worldwide, to improve automation of data exchange (Eastman C. , Teicholz, Sacks, & Liston, 2011). The exchange between platform to platform (Revit to Arch CAD) are challenging than that between tools, because of the need to also transfer the editable *parametric* rules. Actually, interoperability challenge is based upon the fact that in AEC, it is difficulty to translate the meanings of participants across different field. Just like when searching in a browser, a word like BIM may mean something different from Building Information Modelling, definition of meanings of the information and language are challenging in interoperability. Architectural models cannot easily direct transferred to structural analysis model or quantities model without the input of the respective professionals (Eastman C. , Teicholz, Sacks, & Liston, 2011). To advance BIM, interoperability is necessary.

To ensure efficient interoperability, common semantic between BIM software is necessary. Standards or language that can be spoken and well understood among software packages (Aranda-Mena & Wakefield, 2006), as that of Industry Foundation Classes (IFC) and Standard for the Exchange of Product model data (STEP-ISO) in construction industry. In (Hamil, 2012) these are called open standards.IFC is an open and neutral BIM database that help to coordinate project participants in construction project by giving them an opportunity to use the same language. The "Industrial Foundation Classes" (IFC) is an ISO norm that defines all components of a building in a civil engineering project (Vanlande, Nicolle, & Cruz, 2008). In addressing the problem of incompatibility and ambiguity of information exchange within AEC/FM computer systems technologist have made various efforts including this standardisation of IFC (Owolabi, Anumba, & El-Hamalawi,, 2003). They examplified as follows

> "*use of IFCs, for example, would enable a window manufacturer to provide its product data in a format that can simply be inserted into a CAD design program with embedded properties, such as dimensions, materials, strength, energy performance, fire rating, code compliance, applicability, cost, availability, and source".*

An IFC data format can be used by a designer, quantity surveyor,contractor and subcontractors, facility managers and building owners to enhance building project performance (Matipa, 2008). It is a collection of construction virtual objects representing a world desired real projects design and management. It is the way to ensuring the building information is shared across all participants irrespective of software vendors. In (Eastman, Teicholz, Sacks, & Liston, 2011) *IFC is a schema developed to define an extensible set of consistent data representations of building information for exchange between AEC software applications*.

### 3.5. Benefits of BIM

BIM benefits everyone in construction projects. Owners and Facility Managers are not far from knowing what they have been missing all along. It is not uncommon for AEC firms to claim that the frequent changes from the owners are the main source of unavoidable increased cost or extended schedule (Eastman, Teicholz, Sacks, & Liston, 2011).Such claim, are somehow ambigous, especially in cases where the clients are not very much informed during the designing stage. And so with BIM, the owners will be in a position to participate more openly and evaluate transparently the effects of their changes orders to the projects. Through BIM, building performance, financial risks, project schedule, costs estimates, maintenance can quickly, clearly and easily be simulated and assessed. It is easier to evaluate the owners' requirements against the designs. It is equally easier for the owners and users to contribute to the design, because of the visualization and simulation efficiencies in BIM. When well utilized, BIM model can help in maintenance and development of other related facilities in the future, because it consists of the enormous amount of data digitally available and retrievable.

According to (GSA Public Buildings Service, 2005), the established definition of 'Total Building Commissioning is

> *"Systematic process of assuring by verification and documentation, from the design phase to a minimum of one year after construction, that all facility systems perform interactively in accordance with the design documentation and intent, and in accordance with the owner's operational needs, including preparation of operation personnel"*.

The above definition recognizes the need to evaluate the intent of the designers relative to the operational requirements. As such, owners need BIM, for better simulation and understanding of the design from inception to demolition. Years of relying on as built drawings is ending. The new era, the building models are there to guide judgement of the performance of the building from the inception to demolition, by giving an opportunity a facility manager to question the space allowance provided for electrical technician who will later be inspecting the main switch board. With BIM, it is a matter of click to be in a position to decide the optimal costs between two specifications of painting to be used.

| | **Specific BIM Application Areas for Owners** | **Market Driver** | **Benefits Owners** |
|---|---|---|---|
| Designers and engineers | Space Planning and programme compliance | Cost management; Marketplace Complexity | Ensure project Requirements are met |
| | Energy (Environmental Analysis | Sustainability | Improved Sustainability and Energy Efficiencies |
| | Design Configuration/ scenario Planning | Cost management; Complexity of building infrastructures | Design Quality Communication |
| | Building System Analysis | Sustainability | Building Performance and Quality |
| | Design Communication | Marketplace Complexity and Language Barriers | Communication |
| Designers, Engineers and contractors | Quantity Take-off and Estimation | Cost Management | more reliable and earlier estimates during the design process |
| | Design Coordination | Cost management; Complexity of infrastructures | Reduces field errors and reduce construction costs |
| Contractors and Fabricators | Schedule Simulation | Time to Market, labour shortages, and language barriers | communicate schedule visually |
| | Project controls | Time to Market | Track Project Activities |
| | Prefabrication | Time to Market | Reduce onsite labour and improve design quality |
| Owners | Proforma analysis | Cost Management | Improved Cost reliability |
| | Operation Simulation | Sustainability/Cost management | Building Performance and maintainability |
| | Commissioning and Asset management | Asset management | Facility and Asset Management |

**Figure 22: Summary of Benefits of BIM to Owners and Facility Managers [32]**

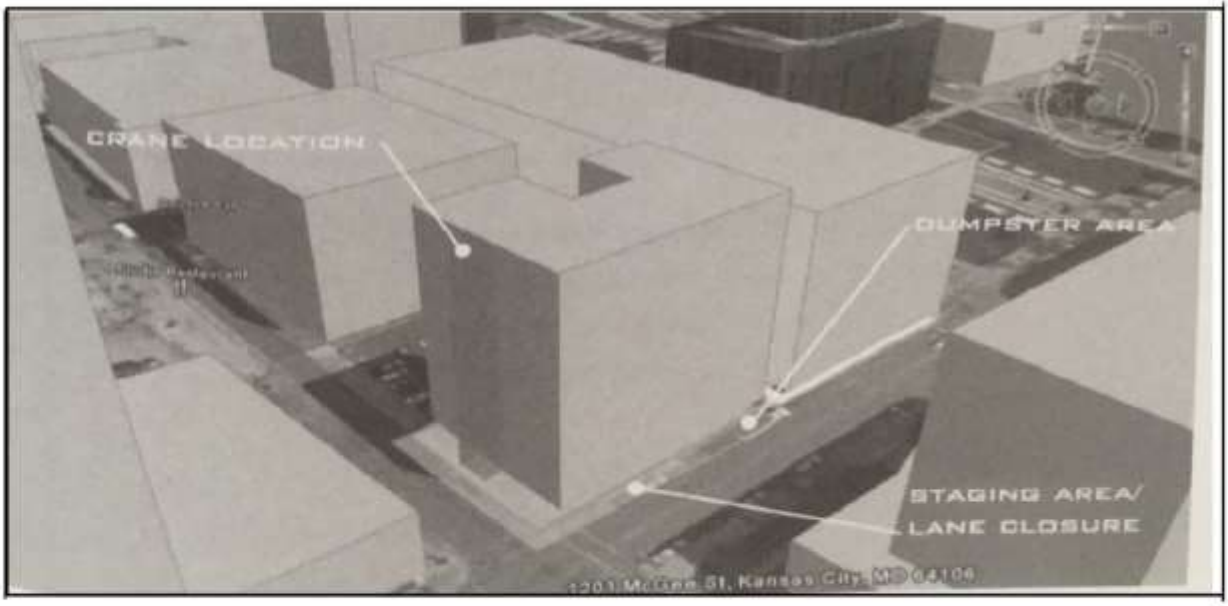
[32] Source: Modified from Eastman, C., Teicholz, P., Sacks, R., & Liston, K. (2011). BIM Handbook: A Guide To Building Information Modeling For Owners, Managers, Designers, and Contractors (Second Edition). New Jersey: John Wiley &Sons,Inc.,pg 156

Sustainability is the question of the construction industry worldwide. The World Commission on Environment and Development in 1987 raised the sensitivity of sustainability (Ortiz, Castells, & Sonnemann, 2009) and currently the need for green buildings is becoming mandatory (Hardin, 2009). Clients are forced to know how much is consumed as energy and how much their return is affected as a result of design efficiency before they approve the project. The more number of designs analysis can be done and the best sustainable option be selected with relatively lesser time at a comparatively lesser expensive fees increment. In (Motawaa & Carter, 2013), Building operation is said to account for about 40% of the global energy and carbon dioxide emission. This is making sustainable one of the key measure of building performances. Current certification and strategies like Leadership in Energy and Environmental Design (LEED is the result of the need to attain sustainable projects ((Motawaa & Carter, 2013) and (Hardin, 2009)). Increase in an amount of information and corresponding increase in the sharing of the information in the building team is what makes BIM the way to sustainable design.

> "*BIM technologies provide owners with tools needed for assessing the appropriate tradeoffs when considering the use of daylighting and the mitigation of glare and solar heat gain, as compared with project costs and overall project requirements"* (Eastman, Teicholz, Sacks, & Liston, 2011).

BIM help in Thermal analysis, provide data necessary for LEED certification and simulate the effects of system changes or renovations (Sabol, 2013). Designers are far efficient in BIM compared to Non BIM technologies or traditional CAD. Not only graphics, but also *information* can be improved and efficiently managed. Designers are in a position to involve other participants from conceptual design to detailed design. Graphics are hardly distinguishable from reality. BIM models contains 3D Objects and not 3D Data (Eastman, Teicholz, Sacks, & Liston, 2011).The objects are intelligent (they follow procedures, instructions and data injected in them) in that they contain more knowledge of design than 3D data. Apart from geometrical and visual, 3D objects are better because they can support behavioural characteristics. They allow automatic generation of drawings and schedule simulation, facilities management, and proportional adjustment. To designers, this enhances informed decisions. With parametric behaviour, the models becomes less vulnerable to human measurement errors. It is possible to work together as a team containing different disciplines, which is far a time-cost effective way of teamwork, than traditional 3D data way of teamwork. On top, BIM allows production of accurate estimates at any stage. Extracting quantities, areas, and volumes from a model is one of the most useful functions BIM technology offers (Hardin, 2009)**.**In BIM these information can quickly be shared throughout the building lifecycle, thus reducing likely errors due to manual reviews and communication.

**(a) Sketch-up site coordination plan to Google**




**(b) A model placed into Google Earth, showing a 3D view**

**Figure 23: Designers can involve user in early design stages in BIM environment projects[33]**

33 Source: Hardin, B. (2009). BIM and Construction Management: Proven Tools, Methods, and Workflows. Canada: Wiley Publishing, Inc. Indianapolis, Indiana.

BIM importance to the construction team does not need overemphasis. Partly designers and owners share the importance with contractors. Quick and accurate decisions implies lesser likely conflicts in the construction stage. However, constructors are more efficient in BIM environment, due to the *level of Detailed Information* that BIM can provide. In (The American Institues of Architects (AIA), 2008), different levels of details are provided, stipulating the design and documentation detail levels requirements. *According to (Eastman, Teicholz, Sacks, & Liston, 2011*) a detailed 3D objects can facilitate offsite fabrication and discovery of design errors or omissions before construction. As such, wastes are minimized (better lean management), and it enhances costs efficiency. More accurate quantities, facilitates construction scheduling and synchronizes procurement with design and construction gives more assured materials quantities and specifications and hence helping inquiries from vendors.

| | |
|---|---|
| LOD 100 (Conceptual Design) | Model Contents Requirements include building mass or general symbol indicative of three dimensions or represented by other data. Common uses include Cost estimation and Scheduling |
| LOD 200 (Scheme Design) | Model Contents Requirements include Modelled Elements as generalized systems or assemblies with approximate quantities, size, shape, location, and orientation. Non-geometric information may also be attached to Model Elements. Common uses include Analysis, Cost estimation and Scheduling |
| LOD 300 (Detailed Design) | Model Contents Requirements include Modelled Elements as specific assemblies accurate in terms of quantity, size, shape, location, and orientation. Non-geometric information may also be attached to Model Elements. Common uses include Traditional construction documents, Analysis, Cost estimation and Scheduling. |
| LOD 400 (Fabrication Level) | Model Contents Requirements include Modelled Elements as LOD 300 with complete *fabrication*, *assembly*, and *detailing information*. Common uses include Traditional construction documents and visual representation of proposed elements, Analysis of system performance, Actual Cost estimation and show ordered, time-scaled appearance of detailed specific elements and systems including construction means and methods used in preparing a Schedule |
| LOD 500 (Operation Level) | Model Content Requirement include Modelled Elements as constructed assemblies actual and accurate in terms of size, shape, location, quantity, and orientation. Non-geometric information may also be attached to modelled elements. General Usage include maintaining, altering, and adding to the Project, but only to the extent consistent with any licenses granted in the Agreement or in a separate licensing agreement |

**Figure 24: Level Of Details in BIM models[34]**

[34] Source: Modified from The American Institutes of Architects (AIA). (2008). AIA Document E202: Building Information Modelling Protocol Exhibit (Sample). U.S: The American Institutes of Architects (AIA).

By influencing the preliminary design and tendering and detailed design in the process, subsequently BIM influences the delivery and installation. In (Eastman, Teicholz, Sacks, & Liston, 2011), BIM facilitates prefabrication because it enhances *error free design and construction information*. In traditional drawings, interpreting bars codes from the reinforced concrete design is difficult. In BIM, color codes are detailed and reliably communicated to all participants. Likewise, the more designing team meet the schedule, the more subcontractors save time on the production of the ordered activities. Outsourcing is made more reliable by BIM, because of the enhanced coordination and collaboration in design.

### 3.6. Challenges in BIM Implementation

Challenges are inevitable in any endeavor. BIM environment requires all key players to be BIM conversant to some extent in order for the collaboration to be smooth and efficient. The use of Industry Foundation Classes (IFC) or a common server is still facing challenges (Eastman, Teicholz, Sacks, & Liston, 2011). IFCs are still insufficient of *standard enabling innovation*, which are inter-operability, trust, and compatibility (Cerovsek, 2011). That means a team with players of different modelling tools, are likely to face standardization challenges. In (UNIDO, 2006), common constraints in market participation include lack of competitiveness (removing barriers from supplier to customer side), conformity (meeting market requirements) and connectivity (integration among agencies). BIM models need to cut across these barriers as well.

> *"The key issue in this area has historically been, and remains, how to achieve inter-operability between multiple models and multiple tools that are used in the whole product lifecycle. This has led to over 30 years of standardization efforts towards a standard common product model."* (Cerovsek, 2011)

Who owns the model, the danger of involving bidders in budgeting and risks of changing the systems also do pose challenges in implementing BIM at a higher level. It is difficult to decide the owner of the Model, although contractual languages are being prepared by professional groups (Eastman, Teicholz, Sacks, & Liston, 2011). Equally are the difficulties in investing on BIM. Education means training costs and time consumption, because human resource must change in every aspect, and the existing technology be replaced by the BIM systems. In England, AEC education system is suggested be changed towards BIM (Kiviniemi, 2014)[35].it was concluded

> *We have to analyze our processes and identify the valuable core of the different professions and separate it from "old rubbish" Instead of traditional documents we must bring into our*

[35] Notes by Prof Arto Kiviniemi, in School of Architecture in the University Of Liverpool.

*education system new issues, such as lifecycle information management, enhanced communication and collaboration, and other possibilities of the modern technology.* (Kiviniemi, 2014)

Collaboration is very important in BIM, and yet it is believed difficulty to measure[36] and teach among the players (Kiviniemi, 2014). BIM introduces a new methods of collaboration accompanied with complexities in effective teamwork (Eastman, Teicholz, Sacks, & Liston, 2011). Bringing a mechanical engineer earlier in the design process is advantageous, but it requires among others cultural and technological compatibility. Managerial challenges may equally raise due to the increase in the team, and so requiring higher leadership efficiencies in the project or even employing many new personnel. Not the least, is the need for all the new players to be compatible *culturally* and *technologically*, or otherwise the effectiveness and efficiency in information or BIM may be adversely affected.

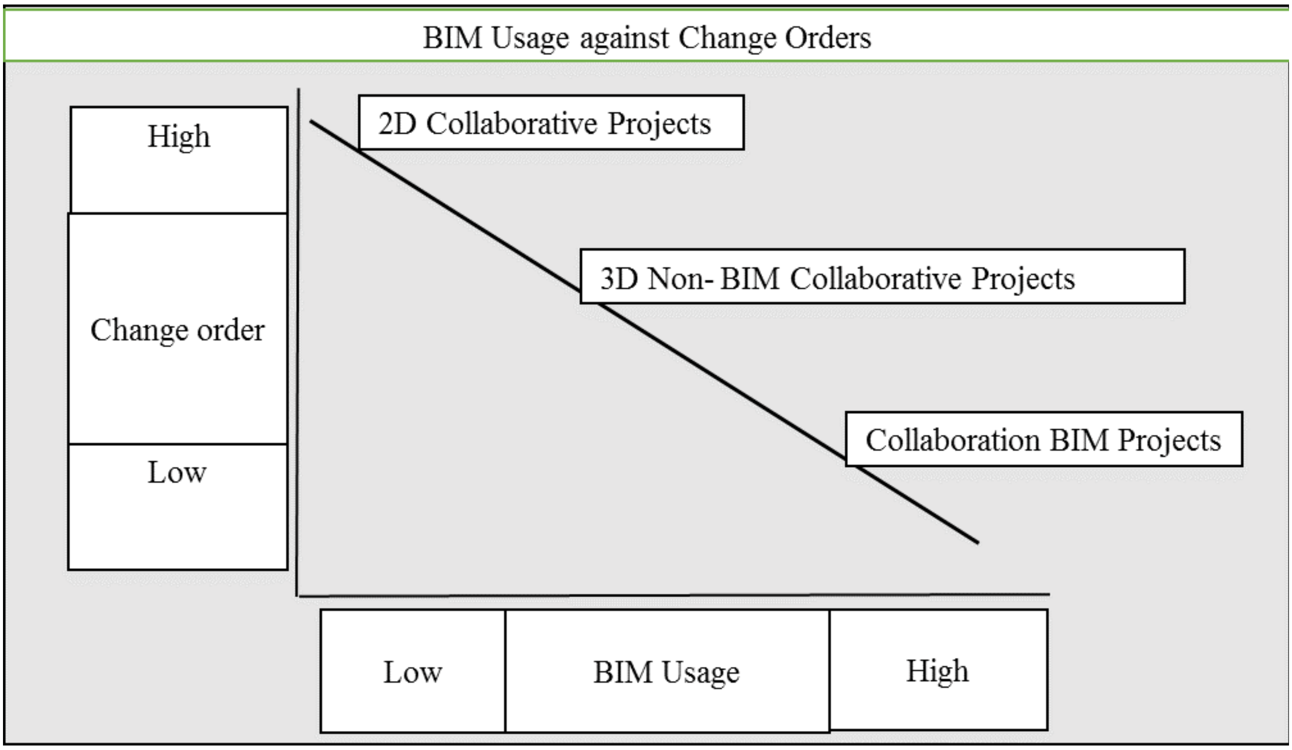



**Figure 25: Importance of Collaboration in BIM[37]**

BIM implementation strategy success, highly depend on cultural and technological transformation (Smith & Tardif, 2009).The influence of culture need not overemphasis. In (Migilinskas, Popov,

[36] Respondent 1: Said "One thing that cannot be measured but it is very important is Collaboration, it is something that you cannot quantify".

[37] Source: Modified from Autodesk Smart Market. (2012)

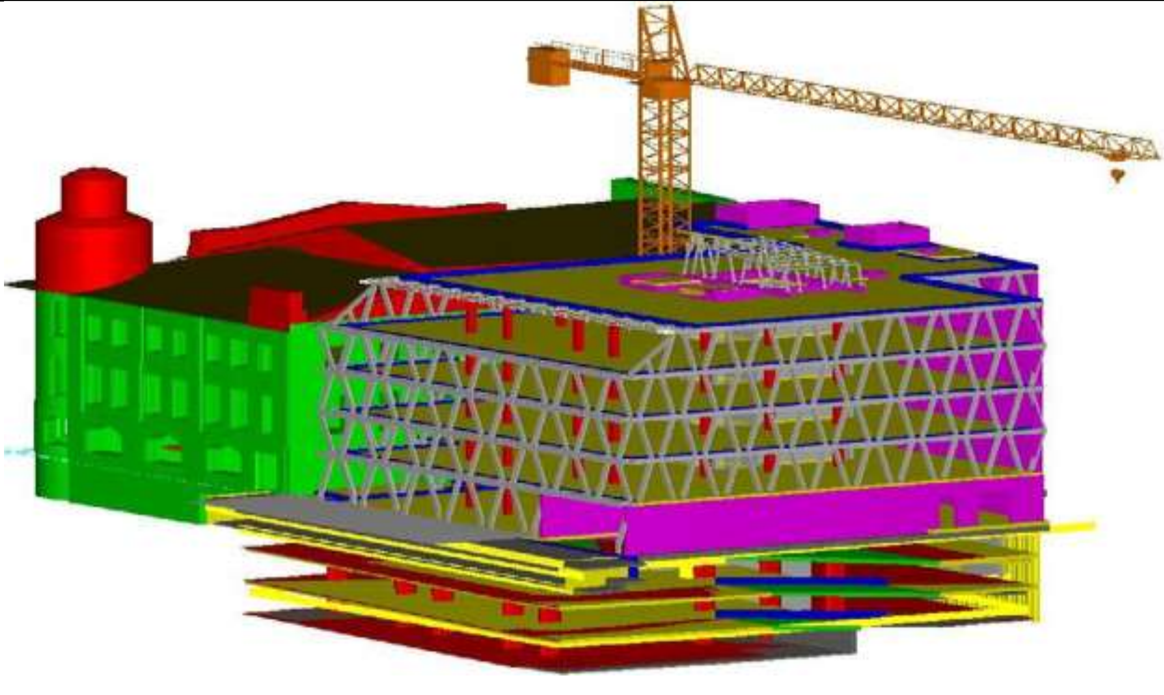
Juocevicius, & Ustinovichius, 2013), interoperability and collaboration were mentioned as the main challenges experienced in the construction project in Lithuania. Example was difficulties resulting from the distant participants. However, in (BDA, Committee of Foreign Affairs, 2011), it is given that Germany architectural practice differs from US or UK. In Germany it is an Architect who will be responsible for the Bills of Quantities, while in UK another specialist, Quantity Surveyor does the work. Such circumstances influences projects efficiency and BIM implementation if not checked. As it was insisted that *"The last but not the least obstacle in BIM implementation is the lack of information about the strict BIM implementation standards and rules for certain project participants, contract obligations in certain countries or unified documentation for regions (such as European Union, Americas, Asia and other)"(ibid).*

| Project | Office building at Gedimino ave 35 in Vilnius (2008–2012) |
|---|---|
| Information | In 2008 construction management company, started refurbishment works of administrative building in heart the Old town of Vilnius. The old building on Gediminas ave 35 was built almost 100 years ago (1913) and belong to Cultural heritage of Lithuania. The design has been made to build Office building as the complex of new office and refurbished old administrative building. Total area of office building is 10,200 sq. m., it consist of 3-storey underground parking for 2900 sq. m., 4-storey old and 5-storey new building for 6300 sq. m. of lease able area. |
| Challenges | To ensure effective collaboration between different project participants, disciplines and software. Interoperability and project participant collaboration for project implementation was main issue due distant design works: architect in Germany, design of structure and HVAC in different parts of Lithuania. |
| Works | The underground structure (half of 3-storey was underground water level) is from cast-in-situ concrete and the over ground building structure made of external load bearing steel frame interconnected with concrete structure (special Anti-thermal bridge elements were used ensure energy efficiency). |
| Software | Nemetschek Allplan Architecture – architecture and visualizations; Bentley Structural – 3D structural Modeling, Nemetschek SCIA Engineer – structural analysis and design; Nemetschek Allplan Engineering – detailing of reinforced concrete structures, drawings, BOM; TEKLA Structures – detailing of steel structures, drawings, BOM; AutoCAD & CADVENT – HVAC and pipe systems, the intents to connect all design parts were made using Bentley Triforma platform. 3D PDF in Adobe Reader was used for design improvement (clash detection) and collaboration with both participants and the client. |
| Benefits | The effective usage of BIM technology helped to check interoperability between designs disciplines save about 0.5% of project value in workshop design stage. Accurate bills of quantities enabled to minimize overpayment for suppliers at same time relations between CM team and subcontractors and suppliers were cooperative, without unnecessary disputes and with motivation to look together for better solutions. |

**Figure 26: Example of BIM benefits and Challenges from cases[38]**

[38] Source: Migilinskas, D., Popov, V., Juocevicius, V., & Ustinovichius, L. (2013

(a)



(b)

**Figure 27: The BIM models of office building in Gedimino ave 35 with 3D[39]**

[39] Migilinskas, Popov, Juocevicius, & Ustinovichius, (2013),Page 772

| Overview of the Common Barriers to Implementation of BIM | |
|---|---|
| | |
| **People barriers** | Lack of leadership and fear of Change among the people. The commitment of management by examples in all levels is proposed to be the solution |
| **Training Costs** | Training costs in new technology is merely an additional costs. The really bottleneck is the lack of appropriate staffs for BIM implementation. |
| **Process Barriers** | There is a need for information delivery manuals to ensure right information is available when needed. |
| **Technology Barriers** | More solutions to hardware and software of BIM components |
| **Commercial Barriers** | Conflicts of interest may not end, but these barriers can be reduced through a radical change of the way processes of building project are organized |
| **Legal and Contractual barriers, including copyright and ownership of the model** | Risk allocation is not well addressed. |
| **Cultural Barriers** | People are reluctant to learn a new technology, because partly they believe that what they have is working satisfactorily. As such, a Collaborative BIM may need governmental initiatives. |

**Figure 28: Example of the Common Challenges in BIM implementation[40]**

[40] Source: Modified from the work of Gledson, B., Henry, D., & Bleanch, P. (2012).

## IV. BIM in Construction Cost Management

### 1. BIM in Total Cost Management

#### 1.1. Why Total Cost Management

According to (Ostrenga, 1990), activities are the focal point of Total Cost Management (TCM) in manufacturing industry. TCM *is a business philosophy of managing all company resources and the activities that consume those resources*. It was found that, the varying needs, scope of projects and objectives of the companies change the starting point while the focal point which is activities, remained unchanged. Of the main areas, most projects both commercial and non-profit organisation have budgets as their fundamental or key objective (Nickson & Siddons, 1997). Other requirements of the clients, which is quality and time, are equally important, and their consequences result in the significant increase of project cost. In (Hu & He, 2014),it was said"*The time, quality, and cost are three important but contradictive objectives in a building construction project. It is a tough challenge for project managers to optimize them since they are different parameters".* Cost and time are quantifiable in a construction project compared to quality and hence optimal models are mostly basing on them.

Construction projects have many objectives, but preliminarily clients' wish to pay as little as possible. Apart from this, (Ashworth, Cost Studies of Buildings (3rd Edition), 1999) said, *"economics of contractual arrangements need to be measured in terms of the total cost to client,inclusive of professional fees associated with cost"*. A Simple example of this is, when a designer misuses the resources in designing process but feels less pain, because the fees paid still remains the same. Unless, the contractual arrangement is capable of including this, the designers will keep on doing errors on the expense of the client. In (Hellard, 1993), such costs were refered by popular quality gurus of 1950s (Dr.Deming, Dr.Juran and Phil Crosby) as costs of non conformance or costs of quality. These are the costs of failing to prevent defects, failing to reduce reworks, failing to satisfy the client and failing to reduce changes during construction. Likewise, in (Greenhalgh & Squires, 2011), it was stated that minimizing cost overruns form one of the major problems that the clients, project managers and contractors need to improve their skills and abilities in order to deal with it. Cost and time are *two of the most important objectives which are easily quantified in a construction project, and activities cost consist of time of resources and weight of quality* (Hu & He, 2014), and so it may be logical to prioritise cost over time. Sunde & Lichtenberg, (1995), argued that it is possible to relate costs to activity durations for both individual and shared resources and it was suggested that *under normal conditions, activities have longer durations and lower costs than those of the crash conditions*. That sugeests how difficult it is to separate cost from time in undertakings, although it gives an opportunity to assume the normal condition, for the desire of the client.However, the best way may be to view all the two in totality as *Cost-Time Model.* Space-time[41] is more absolute when considered in totality (Max Planck Institute for Gravitational Physics, 2015).

In construction projects, cost is central objective (Matipa, 2008), because it involves activities that influence financial and contractual decision making sustainably in the construction projects. Using cost as a focal point, the *designing to a cost* approach and not *costing a design* is complied. That is making *cost target*, as a key *designing* objective gives more efficiency in construction management as compared to making a *design a targeted item* of *costing*. The cost focus cut across the whole delivery process by considering the functional, aesthetical and technological design excellences (Ashworth, Cost Studies of Buildings (3rd Edition), 1999).A tender sum, for example is the cost data that includes costs breakdown of items into various levels, like insurance, supervision, labour and building elements and subdivision.

On the other hand, Building Information Modelling (BIM) is pioneered to be effective, efficient and reliable in delivering projects. It is a game changer, facilitating building participants to collaborate and communicate smoothly and enhance the delivery time, costs and performance in a sustainable way never seen before in the AEC industry. BIM is offering project participants access to design, schedule and budget information; construction quality, schedule and cost information; and operational performance, utilization and financial information (Greenhalgh & Squires, 2011). With BIM, cost-time model can be visualized by experts and non-experts. The simulation of the cost-time model can be extended from inception stage to demolition stage of the facility. The costs contents can be broken down to details never witnessed before and consequently, stored in a much more retrievable digital form. That gives helpful information flow to designers and facility managers at large. BIM is a fact that AEC industry is forced to adopt. In (NBS, 2015), it was said that by 2016, government will accept nothing short of full collaborative 3D BIM in construction projects in UK. The increase in awareness is currently significant.

With BIM, it is easier for the maintenance experts to identify the specification and suppliers available for a given item. It is equally easier for designers and facility managers to discuss in advance on the working space required during replacement of the items in the building. As such

[41] Einstein Online- In Special-Relativity Theory, simultaneity is relative, and so are time and space. It is easier to agree on what are the events rather than where or at what time those events occurred. On the other hand, Space-Time is absolute, the totality of events does not depend on the people observing the events.

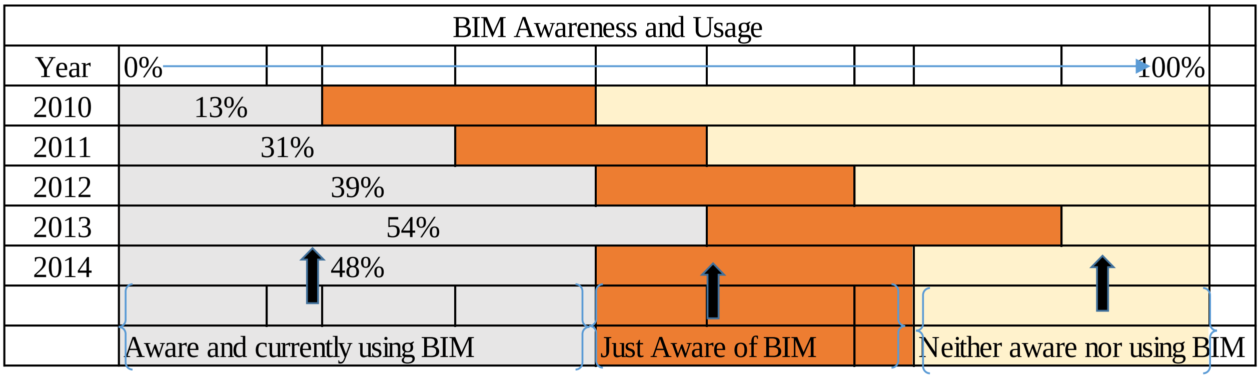



**Figure 29: BIM Awareness and Usage**[42]

BIM improves visualization of costs from the design, commissioning and operation stages of the construction facility delivery. MEP contractors and main contractors have installation materials in advance, and so enhancing the scheduling, fabrication, construction analysis and construction planning processes (Eastman, Teicholz, Sacks, & Liston, 2011). In (Ashworth, Cost Studies of Buildings (3rd Edition), 1999), it was given that evaluation of the alternative designs needs consideration of the life cycle assessment if it is to be more valuable. Usually the challenge is on the assessment of cost in use. The cost in use was not very predictable like initial construction cost. BIM is the better solution to this problem, because automation of real time construction information is possible among participants. The whole construction cost information is managed in advance through the intelligent BIM Model.

### 1.2. Cost Modeling

The terms model and modeling are easily understood when thought in dictionary language which implies image of the reality and the act of creating that image of reality. According to (The UMTP International Association (UMTP-I), 2009) web page a model may mean a three-dimensional representation of a person or thing, typically on a smaller scale, a figure made in clay or wax which is then reproduced in a more durable material, something used as an example, a simplified mathematical description of a system or process, used to assist calculations and predictions, an excellent example of a quality, a person employed to display clothes by wearing them, a person employed to pose for an artist and even a particular design or version of a product. While modeling may mean a construction of physical, conceptual or mathematical simulation of the real world. In building information modeling definition (Arayici Y. , 2015) alerted scholars not to confuse the two

[42] Modified from National Building Specification (NBS), (2015), Page 8-9.

concepts with management. The latter is of the widest view. Modeling is the process of creating the model and the model itself is the structured data describing the product in real world.

According (Ashworth, Cost Studies of Buildings (3rd Edition), 1999), *Cost modelling is a symbolic representation of some observable system which exists or is proposed, and which in terms of its significant cost, features for the purposes of display, analysis, comparison or control.* It refers to forecasting construction costs for clients and to estimating resource costs for contractors. The two activities are arguably need huge amount of data in order to be successful. Computer and mathematics has been the proposed way forward to cost modelling. Depending on the certainty of values of the variables used, the model can be deterministic or probabilistic. In construction projects, uncertainty of values makes the models mostly falling on the probabilistic type.

Whether the model is for designers, constructor or just mathematical, it has to be purposeful. *Design optimisation models* seek to suggest the best design for the client. *Tender prediction models*, forecasts the optimal tender sum and *cash flows models* are indicative of the likely expenditure on a given undertaking. *Life cycle Costing models* aim at facilitating optimal selection among available design options. *Resource based models* intends to facilitate the contractors to estimate and forecast costs.

| Method | Description |
|---|---|
| ***Traditional Models*** | |
| Conference | A consensus view of the team |
| Financial methods | Cost limits determined by client |
| Unit | For projects with standard units of Accommodation |
| Superficial | Total Floor Area of the project |
| Superficial Perimeter | A combination of Floor area and buildings Perimeter |
| Cube | The volume of the project |
| Storey-Enclosure | A combination of weighted floor, wall and roof area |
| Approximate Quantities | An analysis of the major items of work |
| Elemental Estimating | Used in conjunction with cost planning |
| Bills Of Quantities (BOQ) | Analysis prepared in accordance with detailed rules of measurement |
| ***Statistical Models*** | |
| Regression Analysis | Derived from the statistical analysis of variables |
| Causal Models | Based upon algebraic expression of physical dimensions |
| ***Risks Models*** | Monte Carlo Simulation |
| ***Knowledge Based*** | System such as Elsie (Brandon 1992) |
| ***Resource Based*** | Normally a contractor's method, using schedules of labour, plant and materials |
| ***Life-Cycle Cost Models*** | Whole-life analysis of building |

**Figure 30: Examples of Cost Models**[43]

Model serves different purposes at different levels relative to the information available. They differ in weaknesses and strengths. Knowledge based and Expert system are computer software intelligent enough to facilitate cost estimation. The efficiency yet, depends on many factors, including the human skills to input data. The ultimate goal of the models is giving the estimate that will assure the *value for money* in a given project. That is giving more value out of less resource consumption. Costs models must provide us with details and information that can address the accurately initial budget or costs, distribute design costs fairly, display life cycle and attain significant value. In developing the models, understanding the behaviour of the construction costs is vital. Nevertheless, historic data, subjective procedures and experience are equally important in improving the quality and reliability of the estimate. Computer are unavoidable technology in cost modelling because the best models need to be able to provide adequate and  accessible data, be capable of continuously updates, be able to adopt to industrial changes, be quick, be efficient, be economical, be accurate and reliable. Or else, the model my perform less.

[43] Ashworth, A. (1999), Page 386.

## 2. The Bills Of Quantities (BOQ)

Bills of Quantities describe the quantities and quality of any proposed construction works. One of the key activity in construction works relative to BOQ is measurement or quantity taking-off. As a document, BOQ facilitates decisions with regard to financial and productivity. This exercise is among the foundations in the viable construction project decisions (Monteiro & Martins, 2013). The takeoff information is organized in Bills of Quantities (BOQ).Currently, Bills of Quantities (BOQ) relevance to construction projects is debated among participants and scholars. The use of BOQ is probably over 300 years now (Davis, Baccarini, & David, 2004), especially with regard to the use of the standard method of measurement (SMM) (Davis, Love, & Baccarini, 2009).It is said,

> *"…….In deed the number of contracts based on a Bills of Quantities has declined sharply over the past 20 years or so. Never the less the "Bills Of Quantities remains un surpassed as a model on which to obtain bids in a format that allows ease of comparison between various contractors, transparency and aid to the quantity surveyor in valuing variations. What's more the ability to measure, quantify and analyse labour, materials and plant necessary to construct a new project is still a much sought after skill and many would argue the core of Quantity Surveyors"* .(Cartridge, 2012,pg 95)

From the above, changing the project approach or a method may change the form of BOQ but not the essence of BOQ. As it is explained in (Potts, 1988), the *"fast track"* project procurement method unavoidably uses BOQ to settle valuations. Bills of Quantities are said to be synonimous with the Quantity Surveyors (Rashid, Mustapa, & Wahid, 2006).

Bills of Quantities (BOQ) are usually time consuming and so whatever method that can help to improve time, without compromising the accuracy is worth considered (Smith & Skitmore, 1991). Automation is not an option in the current construction projects management. The need for cost modeling improvement has been insisted (Bowen & Edwards, 1985), expert system being pioneered with focus to paradigm shift from the current single figure based cost modeling to more *stochastic* or more risk and variability based cost modeling.

Defining BOQ, is not so easy, and there is no much of it in the literature.Lack of studies with regard to BOQ uses motivated (Bandi, Abdullah, & Amiruddin, 2014) to evaluate uses of BOQ in contracting firms. It is not uncommon to talk about construction costs without defining Bills of Quantities, as seen in ((Matipa, 2008) and (Kodikara, Thorpe, & Mccaffer, 1993)). Another example that may suggest inadequacy of definitions of BOQ is the way scholars like ((Rashid, Mustapa, & Wahid, 2006), (Razali, Tajudin, & Tajuddin, 2014) and (Davis, Love, & Baccarini, 2009)), tend to go around this single definition in their works, that is BOQ or ***a bill of quantities or BQ is a document detailing the qualitative and quantitative aspects of every constituent parts of a proposed construction project.*** In (Odeyinka, Kelly, & Perera, 2009), the definition from Seeley (1997) was used. That is BOQ is a document itemising all potential works in construction project and their estimated quantities.A distinction can be made between BOQs of civil works and building works. For instance , while in (RICS, 2011) building works BOQ is "*a list of items giving* ***detailed*** *identifying descriptions and* ***firm quantities*** *of the work comprised in a contract",*in civil works *it is a list of items giving* ***brief*** *identifying descriptions and* ***estimated quantities*** *of the work comprised in the contract* (The Institute of Civil Engineers, 1991).The differences highlighted are more of contractural effects because the words detailed and brief are very relative to the users of the document. The simple implication may be that the detailed firm quantities are more contractually binding than brief estimated quantities.

In the BOQ, there are breakdown of the construction works in an analysable and measurable costs components, derived from a common standard method measurement (SMM). The use of common standard method measurement (SMM) is important because it distuinguishes bills of quantities from simple approximate methods of costs estimates (Ashworth,1999). In (Ashworth, ,2006), BOQ was not specifically defined, but given as "***Bills of quantities were described in The Placing and Management of Building Contracts (Simon Report, 1944) as, putting into words every obligation or service which will be required in carrying out the building project".*** It was explained that, BOQ is mainly common in commonwealth countries,Tanzania inclusive, than in other countries. The advantage include giving the common base for contractors to tender for the construction work. In the countries like USA the contractors do prepare the Bills of quantities or contract bills individually.

**Illustration Box 5: Bills Of Quantities (BOQ) or Contract Bills uses in Brief[44]**

*"Some form of bill of quantities (described in JCT 98 as the contract bills) or measured schedules should be prepared for all types of building projects, other than those of only a minor nature. The bill comprises a list of items of work to be carried out, providing a brief description and the quantities of the finished work in the building. A bill of quantities allows each contractor who is tendering for a project to price the construction work on exactly the same information as other contractors using a minimum of effort. The bill may include firm or approximate quantities, depending upon the completeness of the drawings and other information from which it was prepared. The contractor's rates must not be divulged to others or used for any purpose other than the contract (clause 5.7)".*

*Apart from assisting the contractor during the process of tendering, BOQ has many other purposes, such as:*

*Preparation of payment certificates and Valuation of variations, Cost control purposes,Ordering of materials, Preparation of the final account,Production of a cost analysis for the building project,Determination of the quality and standard of work by reference to preamble clauses,Subcontracting quotations for sections of the measured work,Use as a form of cost data and in preparing contractual claims*

[44] Source: Ashworth,A. (2006)

## 2.1. The importance of Bills Of Quantities (BOQ)

Apart from being important for more than 300 years, Bills Of Quantities (BOQ) are still debated on the advantages and disadvantages (Greenhalgh & Squires, 2011). It is a document that itemise the *finished work* of the construction project (ibid). Bills of Quantities usage is said to be declining.From (Davis, Love, & Baccarini, 2009),the survey of 86 practisioners revealed that the use of BOQ prepared from the standard methos of mesurement (SMM) is on decline.The BOQ are only used in projects as tools for the post contract control activities. In works of ((Davis, Love, & Baccarini, 2009) and (Rashid, Mustapa, & Wahid, 21st June 2006)),Royal Insitute of Chartered Surveyors (RICS) was qoated that 65% of the building work by value declined to 56% from 1984 to 1989 respectively. In UK, the fall of usage of BOQ was related to the shift from the usage of traditional method of procurement. According to (Odeyinka, Kelly, & Perera, 2009), the more complex the project becomes, the lesser reliable it is to use the BOQ,especially in guaranteeing cost certainty. It was claimed that steady decline in traditional method of procurement usage from 1990 to 2004 impliedly brought a fall in traditional BOQ usage. In 2002 the shift was announced towards the use of Public Private Partnership,Prime Contracting and Design and Build as public procurement methods in UK (Cartlidge, 2006).

In contrary to above, (Bandi, Abdullah, & Amiruddin, 2014), in their analytical evaluation study, suggested that a contracting firm badly need the BOQ, especially with increase in the complexity of the project. BOQ was analysed using four categories, that is procurement, communication, control and planning.The study explained how useful BOQ is to the contracting firm. With BOQ, a contracting firm can enquire materials, and planning construction method and prepare of detail work programme. Like wise it becomes easier to manage the site through records of actual use of materials, plants and labours. As if not enough, BOQ was suggested to be a good base for the value for money (Rashid, Mustapa, & Wahid, 2006). Clients and consultants can translate the priced BOQ information into a number of valuable project management efforts. For instance the selection of the right tenderer and justification for the payments. It was further suggested that BOQ may not be necessary in fast track projects, when non-traditional procurement systems are used. Explanation that consultants may lack time to prepare BOQ is somehow contradictory, because if the contractor must later prepare more or less the same document (ibid), then it may be relevant to say BOQ is needed in all procurement systems, but with differing uses.Such view agrees with the conclusion given, *"Evidently, despite of the emergency of new ´genre´of procurements in the global construction industry,BQ is still viable to be used as an important cost document"* (Rashid, Mustapa, & Wahid, 2006).

When a BOQ is accurately prepared, it may fulfill the satisfaction of all parties such as the clients, contractors and others in the construction project (Razali, Tajudin, & Tajuddin, 2014). They also claimed that argument for and against BOQ mostly rely on the intuition.This may be one of the causes that BOQ is not fully utilised and participants fail to realise the potentials of the document. However, a number of weaknesses may be noted in the BOQ, including insuficient, inaccurate and unreliable informations (Bandi & Abdullah, 2012). Also lack of impressive format and recognition of the other experts participation in the construction process. In conclusion, (Wood & Kenley, 2004) said that, participants believed that they were not adequately consulted or represented in the developement of the Australian Standard Method of Measurement. However, the fact that document is not realised and prioritised, may be sufficient to justify logically that it has not been prepared well enough to cover the weaknesses. A standardised simple comprehensive and accurate BOQ can effectively be used in any procurement system today (Razali, Tajudin, & Tajuddin, 2014).

> *"Irrespective of what contract strategy is used, at some stage in the procurement process one party will need to quantify the extent of works to be executed; whether it be the employer's quantity surveyor/cost manager, the main contractor or the work package contractors for the purpose of obtaining a price for completing building works, valuing the extent of work complete for purposes of payment, valuing variations in the content or extent of building works, or to support applications for tax or other financial incentives"* (RICS, 2011). *(See the table Below)*

Logically,the importance of BOQ,is relative to the level of information needed for total cost management of project ((Bandi, Abdullah, & Amiruddin, 2014), (Odeyinka, Kelly, & Perera, 2009) and (Razali, Tajudin, & Tajuddin, 2014)). In theory, a *firm Bill of Quantities (BOQ),*is prepared from *sufficiently complete drawings*, and hence *no more design changes*, and so a firm BOQ price at tender stage, is expected to equal the *final cost.The opposite is an approximate BOQ*.The information is not complete enough and so only the *rates* are crucial at the beginning of the project. The quantities are to be remeasured later.It was insisted that, the descriptions should be *correct* in the approximate BOQ (RICS, 2011).

| **Contract strategy** | **Basis of 'Invitation Documents** | **Preparation by** |
|---|---|---|
| Traditional lump sum | Firm Quantities/ Approximate Quantities | Employer's quantity surveyor/ cost manager |
| Design and build | Employer's Requirements | Employer's project team (with compilation normally by the employer's Quantity surveyor/ cost manager). *Note: Either the main contractor or work package contractors; who will prepare firm or approximate BQ, or Quantified schedules of work as appropriate will carry out quantification of the Employer's Requirements.* |
| Management (design and manage) Construction management | Firm Quantities/ Approximate Quantities | Employer's quantity surveyor/cost manager (or main contractor or work package contractors if 'Invitation Documents' prepared by employer's quantity surveyor/cost manager or main contractor, respectively, are based on either 'specification and drawings' or 'un-quantified schedule of works' (i.e. unquantified information) |

**Figure 31: Types of Bills Of Quantities and Contract Strategies**[45]

To be useful, BOQ must demostrate relevance to the needs of the current status of construction industry and possibility of multi-contextual applicability. Cost management is central in the organisation and procurement of low-cost housing, and so there is a need to develop a set of criteria and database basing on the appropriate technology, labour, materials and standards (Oladapo, 2001). When well used BOQ can give a better base for information on labour,materials and local standards. Any document containing a list of construction works, complete with quantities and qualities can be referred to as a BOQ (Rashid, Mustapa, & Wahid, 2006). The management of construction ***"design***

[45] Source: RICS. (2011)

***waste"*** is suggested to be more valuable than management of ***"end of pipeline waste"*** (Firman, et al., 2012). This suggest that waste minimization is becoming an unvoidable objective of the construction project delivery process, designing stage inclusive. At large this means radically analysing the cost efficiency materials,labour,plants and other environmentally related components of construction projects. Bills Of Quantities may contribute significantly as a base in the process of construction waste related costs breakdown and analysis.

According to (Cooke & Williams, 2009) on page 406, the waste in construction can be categorised into design waste, when the design results in wasteful cutting on site. Others are take-off/ specification waste resulting when resources are overspecified for the job in hand, delivery waste (materials demaged on transit) and site waste resulting when incorrect materials are used. To improve the situation, areas emphasized where management procedures, procurement and contracts and site practices. All of which utilizes the information from the Bills of Quantities (BOQ). For instance, it was insisted to allow adequate budget in tendering for site layout, to plan for materials ordering and to take care of disposals respectively. The contents of BOQ include preliminaries where even the form of contract to be used, access to the site, any temporary works and accommodation required, health and safety requirements, financial details and insurances are described (Kodikara, Thorpe, & Mccaffer, 1993). Preambles describes workmanship and materials to be incorporated into the works and the measured items of construction works are given with descriptions, units, and quantities (ibid).

Never the less, elemental BOQ need to incorporate more operational cost or life cycle costing in order to fit better the professions involved (De Jonge, 2005). It was suggested that firm BOQ (BOQ forming contractual documents in Fixed Price Contract or Fixed Contract Sum) is only suitable in traditional method.In other methods it discourages alternative designs from contractors, as they need amendment of the quantities. Also, with BOQ in use, the tenderers may ignore the specification and rely on the bills of quantities and likewise the likley increase in costs,time and errors resulting from the preparation of BOQ in complex project (Greenhalgh & Squires, 2011). However, these weaknesses related to BOQ are due to *complexity of the document*, and so many players fail to utilise it properly due to lack of commitment or suitable facilities.Such complexity is no longer a limitation in BIM. Automation is high,collaboration is high,real time communication is possible and visualisation is more realistic.

## 2.2. Bills Of Quantities (BOQ) Contents

Bill of quantities *(BQ) means a list of items giving detailed identifying descriptions and firm quantities of the work comprised in a contract* (RICS,2011). BOQ is the contractual document containing a breakdown of construction works according to a given common standard of measurement. Among others, the key objective is to facilitate total costs management in the construction project.On the other hand, the preparation of the BOQ has different view of points, depending on the focus of the cost information and the stage of the construction process. The contractor estimate focuses on activities as specified and designed in order to facilitate pricing and management of the construction works while the consultants are intending to breakdown the cost in accordance to the requirements of the client (De Jonge, 2005).

According to (RICS, 2011):

> *"The primary purposes of a bill of quantities (BQ), which becomes a contract document, are:*
> *To provide a co-ordinated list of items, together with their identifying descriptions and quantities, that comprise the works to enable contractors to prepare tenders efficiently and accurately;*
> *When a contract has been entered into,to:*
>
> - *Provide a basis for the valuation of work executed for the purpose of making interim payments to the contractor*
> - *Provide a basis for the valuation of varied work.*
>
> *Essentially, a BQ is a list of the items, with detailed identifying descriptions and quantities, which make up the component parts of a building."*

In essence, the prepartion of Bills of Quantities from the contractors point of view is lesser contractual unless it has been approved by the client. The primary purposes of BOQ are improving effectiveness in estimating and tendering and forming a contractual base for financial undertakings during project administration.In ((Razali, Tajudin, & Tajuddin, 2014) and (Rashid, Mustapa, & Wahid, 21st June 2006)), it was argued that in *Pre-Contract* BOQ helps in breaking down contractual works in a detailed and structured manner for tendering purposes while in *Post-Contract* it assists in the valuing of progress payments,variations and it provides a financial structure for contract administration. Important, it is the fact that the items of work in the BOQ are measured in accordance with a recognised *standard method of measurement* (SMM) (Ashworth, 2006).

Basically the SMM serves as a common base upon basing the construction cost. It gives the common rules and principles that governs the quantities and qualities of the construction works components measured. According to (Packer, 1996), measurement is a starting point in establishing the cost of construction, as it provides the basis for the preparation of BOQ.In (RICS, 2011), the measurement rules are intended to facilitate understanding between all those involved in a construction project, including the employer so as to enhance communication efficiency between the project or design team and the employer. The common contents of the bills of quantities include preliminaries, measured works and provisional sums ((Kodikara, Thorpe, & Mccaffer, 1 993) and (RICS, 2011)). The other important sections include preambles, dayworks, form of tender and summary or the works, depending on the standards used and on how one views the necessity of the information. While in (RICS, 2011), form of tender was the first document, preambles was not explained separately but rather as part of annexes..Many other documents like credits,risks and summary were not mentioned in (Kodikara, Thorpe, & Mccaffer, 1 993), where the insist was made on the need to value the *individual* information over investigating information as *whole* BOQ. To them, packages common to BOQ worth considered were time,preliminaries,materials specification,work descriptions,work methods,quantities, quantity units, unit rates, provisional sums, prime costs sums and temporary works.

### 2.3. Preliminaries

The preliminaries cover the requirements of the client or employer and the obligations of the contractor carrying out the work (Ashworth, 2006). Sometimes preliminaries referred as project overheads (Chan & Pasquire, 2002), because to a contractor the preliminaries costs are inclusive of providing plants, accommodations and other site-based services. The United Kingdom New Rules of Measurement - NRM2 (2012) as cited in (Cunningham, 2015), explained contract preliminaries as

> *"….items that cannot be allocated to a specific element, sub-element or component. Main contract preliminaries include the main contractor's costs associated with management and staff, site establishment, temporary services, security, safety and environmental protection, control and protection, common user mechanical plant, common user temporary works, the maintenance of site records, completion and post-completion requirements, cleaning, fees and charges, sites services and insurances, bonds, guarantees and warranties. … ."*

In practice, (Ashworth, 2006) said only a small number of items of preliminaries, are priced by contractors. The remaining part serves as for information and contractual purposes only. Viewed otherwise, such information may be helpful in giving light on the costs impression. To a cost estimation profession, a description of the building in terms of three dimensions can be a source of cost information. The contractor may equally use such information to figure out the status of the client and consultants and decide on whether to tender or not (Cunningham, 2015).

| ITEM | DESCRIPTION | |
|---|---|---|
| | **PRELIMINARY ITEMS** | |
| **A** | **Preamble** | |
| | The Bill of Quantities shall be read in conjunction with other bidding documents | |
| | A rate or price shall be entered against each item in the priced Bills of Quantities. ***The cost of items against which the Contractor has failed to enter a rate or price shall be deemed to be covered by other rates or prices entered in the Bill of Quantities*** | |
| | The Quantities stated in the Bills of Quantities ***shall not be used for ordering of materials.*** | |
| **B** | **Drawings:** | |
| | The Contract drawings and detailed drawings used for preparation of Bills of Quantities are listed in Section VIII of this document. These drawings are bound separately. | |
| **C** | **Method of Measurement** | |
| | The Bills of Quantities have been prepared in accordance with the general principles of the ***Standard Method of Measurement of Building Works for East Africa, metric edition October 1970, published by the Project Managerial Association of Kenya, Chapter of Quantity Surveyors***. | |
| **D** | **Pricing of Preliminaries** | |
| | The Contractor shall price out individually and in detail all the items in this and any other section of the Bills of Quantities as required and under no circumstances will a ***lump sum price be allowed***. | |
| **E** | **Pricing Generally** | |
| | The Contractor should take note that the Contract shall be composed of ***[See Bid Data Sheet].*** All shall have a complete site establishment and management. The construction works shall be executed and sectional completion ***is*** acceptable | |
| | | |
| | **To collection** | |

**Figure 32: Example of Preliminaries. The underlined items may have indirect cost [46]**

The key phrase in preliminaries, include the items and cost in the construction project not related directly to the main measured works. A citation from *Chartered Institute of Building* (*CIOB*) code of Estimating Practice in (Trevor Sadd Associates Ltd, 2015) defined preliminaries as *"the costs of administering a project and providing general plant,site staff,facilities, and site based services and other items not included in the rates"*.While it is common to price preliminaries in time related, Cost related and work related categories, detailled breakdown of costs into more refined items like labour,material,plants,taxes and the like is possible and desirable (Trevor Sadd Associates Ltd, 2015).

[46] Source: Own Construct

Three steps were suggested in pricing the preliminaries. Understanding and pricing the definite costs is first, second is to consider and cost the commercial factors and the third is to consider how these costs should be allowed for into specific tender. Unrecoverable costs like those relating to lack of design information and contract admistrators are inclusive in the allowances (ibid). In  (Brook, 2008), many SMM recommends that in the preliminary costing, fixed and time related charges should be identified separately in BOQ. It was acknowledged that, some preliminary costs can be difficult to allocate, such as the use of specialised plant. From the clients point of view, usually the method to be used in payment of preliminaries is stated in advance.Common methods include the use of percentage and work progress.

| PAGE | ITEM | DESCRIPTION | INITIAL | RUNNING COSTS | FINAL COSTS | TOTAL | PAID |
|---|---|---|---|---|---|---|---|
| | | CONTRACT PARTICULARS | | | | | |
| Page 1 | C | Methods of measurements | 400,000 | | | 400,000 | 400,000 |
| Page 2 | A-B | | - | | | - | - |
| Page 3 | B | Description of the site | 400,000 | | | 400,000 | 400,000 |
| Page 4 | C | Materials excavated from the site | 300,000 | 300,000 | | 600,000 | 600,000 |
| | D | Existing services | 500,000 | | | 500,000 | 500,000 |
| Page 5 | A | Laws governing contract | - | 300,000 | | 300,000 | 300,000 |
| Page 6 | A | Progress schedule | 300,000 | | | 300,000 | 300,000 |
| | B | Records | 260,000 | | | 260,000 | 260,000 |
| | C | Inspection by the engineer | - | 500,000 | | 500,000 | 500,000 |
| Page 7 | B | Disturbance or nuisance | 200,000 | 100,000 | | 300,000 | 300,000 |
| | C | Care of works | 200,000 | 200,000 | | 400,000 | 400,000 |
| | D | Protection from weather | | 200,000 | 50,000 | 250,000 | 250,000 |
| Page 8 | A | Tools | 5,000,000 | 6,000,000 | 1,000,000 | 12,000,000 | 12,000,000 |
| | B | Site accommodation | 2,500,000 | 3,000,000 | | 5,500,000 | 5,500,000 |
| | C | Telephones | - | 1,000,000 | | 1,000,000 | 1,000,000 |
| | D | Water for the works | 500,000 | 1,200,000 | | 1,700,000 | 1,700,000 |
| | E | Lighting and power for the works | 500,000 | 700,000 | 200,000 | 1,400,000 | 1,400,000 |
| Page 9 | A | Watching and lighting | 10,000,000 | 15,000,000 | 3,000,000 | 28,000,000 | 28,000,000 |
| | E | Sign board | 500,000 | 400,000 | 100,000 | 1,000,000 | 1,000,000 |
| | F | Protection | 100,000 | 200,000 | | 300,000 | 300,000 |
| | G | Removing rubbish and cleaning | - | 200,000 | | 200,000 | 200,000 |
| | | TOTAL | 21660000 | 29300000 | 4350000 | 55310000 | 55310000 |

**Figure 33: Example of Preliminaries categories and Apportionment in payment (1/2)**[47]

[47] Source: Own Construct

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | Running Preliminaries Apportionment | | | | | |
| | | contract sum | | 600,000,000 | | | |
| | | Less: | | | | | |
| | | Contingencies | - | | | | |
| | | Preliminaries | 55,310,000 | | | | |
| | | Provisional sums | 150,000,000 | | | | |
| | | Insurance | - | 205,310,000 | | | |
| | | | | 394,690,000 | | | |
| | | Total valuation of measured work | | 242,265,200 | | | |
| | | | | | | | |
| | | Preliminaries paid in this valuation | | | | | |
| | | Initial costs | | 21,660,000 | | | |
| | | Proportionate Running costs | | 17,984,672 | | | |
| | | Final costs | | | | | |
| | | Total Preliminaries to Valuation Summary | | | 39,644,672 | | |

**Figure 34: Example of Preliminaries categories and Apportionment in payment (2/2)**[48]

[48] Source: Own Construct

### 2.4. Prime Cost and Provisional Sums

It is not uncommon to measure construction project partially. According to (Ashworth, 2006), BOQ has a lump sum section for specialist work and for defined or undefined work which cannot be entirely foreseen and detailed at design stages or when tendering documents are issued. Prime cost sums cover work undertaken by nominated or specialists and the lesser defined work is covered in provisional sums. The prime cost in UK is usually priced as part of provisional sums (Greenhalgh & Squires, 2011). This followed the modern standards not recognizing the appointment of the specialist by the Architect or client. Where applicable, the practice requires that the cost of nominated or appointed subcontractor is a prime cost (equivalency of materials, labour and plants) to the main contractor until the final account is received to replace the PC sum in the final account of the main contractor. The appointed subcontractor is entitled the additional profit and allowance for the general and special attendances to the prime costs of construction.

The provisional sums were covering only required work that has not fully designed (Greenhalgh & Squires, 2011). Example is Contingencies. It was insisted that, now works covered in PC and Day works are under the provisional sums heading. The defined provisional sums is the work that the main contractor has included in the schedule of the project. Such works are lesser entitled to claims of costs and time extension compared to those that of undefined provisional sums. There are also valuation of works that are raising and interrupting the planned schedule of the main contractor. The cost of such works (day works) is under provisional sum too. In (RICS,2011), Dayworks – *means the method of valuing work on the basis of time spent by the contractor's workpeople, the materials used and the plants employed*. The price of *dayworks* can be included within the contract sum, when it is to be treated as a provisional sum. In dealing with dayworks, the contractor is required to insert all rates for labour, materials and plants and adding the percentage for covering the disruption disturbance. In case they are *not included* in the provisional sum, it shall be clearly stated that the rates, prices and percentage adjustments tendered are included in the contract, to alert the contractor. (*See the figure Figure 35: Example of Prime Costs and Provisional Sums Separate*)

> *"Provisional sum* – means a sum of money set aside to carry out work that cannot be described and given in quantified items in accordance with the tabulated rules of Measurement. A provisional sum will be identified as either 'defined' or undefined'. Defined provisional sum means a sum provided for work which is not completely designed but for which the following information shall be provided:

- The nature and construction of the work;

- A statement of how and where the work is fixed to the building and what other work is to be fixed thereto;
- A quantity or quantities that indicate the scope and extent of the work; and
- Any specific limitations and the like identified.

*Undefined provisional sum* – means a sum provided for work that is not completely designed, but for which the information required for a defined provisional sum cannot be provided."(RICS, 2011).

| Item | Description | Qty | Unit | RATE | AMOUNT |
|---|---|---|---|---|---|
| | **BILL No. 4: PRIME COST AND PROVISIONAL SUMS** | | | | |
| | **PRIME COST SUMS** | | | | |
| | | | | | |
| | **STATUTORY AUTHORITIES** | | | | |
| A | Electricity main connection | | SUM | | 3,000,000 |
| | **ADD** : Profit | | 5% | | 150,000 |
| | **ADD** : General attendance | | ITEM | | 300,000 |
| B | Water main connection | | SUM | | 3,000,000 |
| | **ADD** : Profit | | 5% | | 150,000 |
| | **ADD** : General attendance | | ITEM | | - |
| | **LOCAL AUTHORITIES AND OTHER GOVERNMENT AGENCIES** | | | | |
| C | Project registration related costs | | SUM | | 3,600,000 |
| | - | | | | |
| | **To collection** | | | | **10,200,000** |
| | | | | | |

**Figure 35: Example of Prime Costs and Provisional Sums Separate (1/2)** [49]

[49] Source: Own Construct

| Item | Description | Qty | Unit | RATE | AMOUNT |
|---|---|---|---|---|---|
| | PROVISIONAL SUMS | | | | |
| A | Allow for Demolitions and related activities as per PM instructions | | SUM | | 100,000,000 |
| B | Allow for provisional sum for Plumbing and Mechanical Engineering Installation, Waste and Foul water Drainage including Fire Fighting Installations | | SUM | | 150,000,000 |
| C | Allow for provisional sum for Electrical Installations including Information and Communication Technology Installations | | SUM | | 100,000,000 |
| D | Allow a provisional sum for cost of construction of two Guard Huts and Fence Work of Bout 350 Linear Metres | | SUM | | 20,000,000 |
| E | Allow for the cost of construction of Car wash area: including all necessary water reticulation | | SUM | | 30,000,000 |
| | | | | | |
| F | Allow for Extra Costs of Strong Room Construction | | SUM | | 25,000,000 |
| G | Allow for Information and Communication Technology (Installations and Equipment) | | SUM | | 15,000,000 |
| H | Allow Day Works | | SUM | | 65,000,000 |
| I | Allow for the Progress Photograph | | SUM | | 5,000,000 |
| J | Allow provisional sum for contingency to be expanded or deducted by the project manager | | SUM | | 200,000,000 |
| | To collection | | | | 710,000,000 |
| | COLLECTION | | | | |
| | Page No. 1 | | | | 10,200,000 |
| | Page No. 2 | | | | 710,000,000 |
| | TOTAL; BILL No. 6: P.C AND PROVISIONAL SUMS CARRIED TO GENERAL SUMMARY | | | | 720,200,000 |

**Figure 36: Example of Prime Costs and Provisional Sums Separate (2/2)**[50]

[50] Source: Own Construct

### 2.5. Measured Works

The main body of the BOQ contains measurement of the amount of *finished* quantities of materials in project (Greenhalgh & Squires, 2011). The measured works can be presented *trade format* and *elemental format*. In (Ashworth, Contractual Procedures in the Construction Industry (5th Edition), 2006), *trade format* gives items in the bill under their respective trades groups. In this format there is a minimum of repetition, and it facilitates subcontracting the work because the main contractor can separate out the sections for distribution to specialist domestic subcontractors. On the other hand *elemental format* groups the items according to a recognized elemental subdivision of the project. Example of elements or parts of the buildings are substructure, frame, external walls, internal walls, roofs, windows, doors, wall finishes, electrical works and plumbing installation. The elemental bill, in theory, facilitates tendering by locating the work more precisely (Ashworth, 2006). The practical problem is the repetition tediousness despite of the usefulness in cost planning and analysis. It has the order suitable for quick referencing.

The bills of quantities has been evolving since then. Since the establishment of the personal computers, in the mid-1980s many of the labour involving tasks in the preparation of BOQs are easier done electronically (Greenhalgh & Squires, 2011). There is no need of teaching a student, the *cut and shuffle* or even the whole process of *abstracting* and *squaring* dimensions, unless it is for the sake of history of BOQ preparation. BOQ starts with taking off. Taking off is the procedure by which dimensions of the works are calculated or scaled off from the drawings and entered onto dimension papers or other similar computerized formats. A number of key activities can now be done quickly using computer, without interfering the expertise in it.

| 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|---|---|
| Timesing | Dimension | Squaring | | Timesing | Dimension | Squaring | |

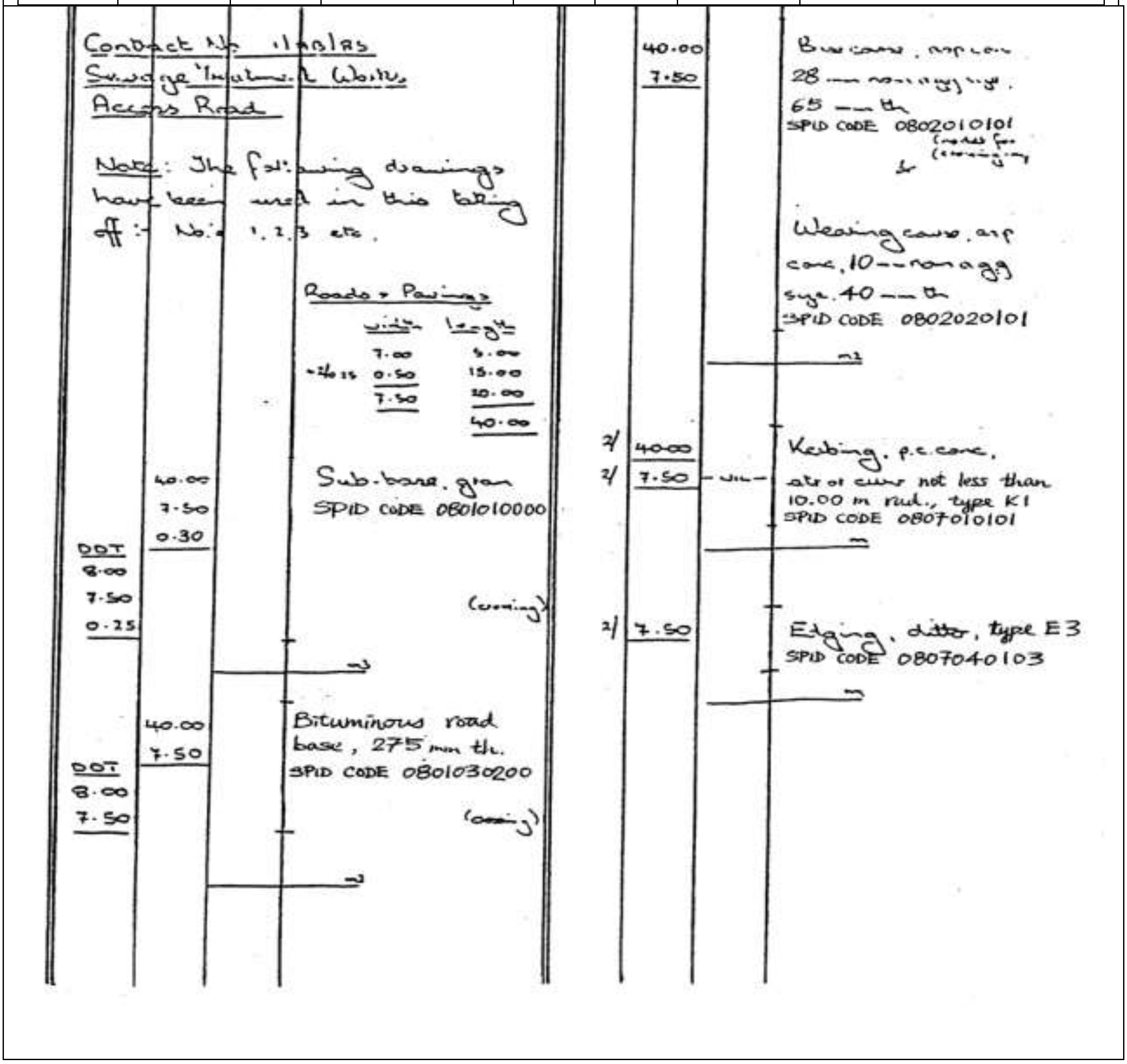



**Figure 37: Example of Take-off sheet and columns[51]**

[51] Source: Public Administration Handbook (PAH) ( 2013)

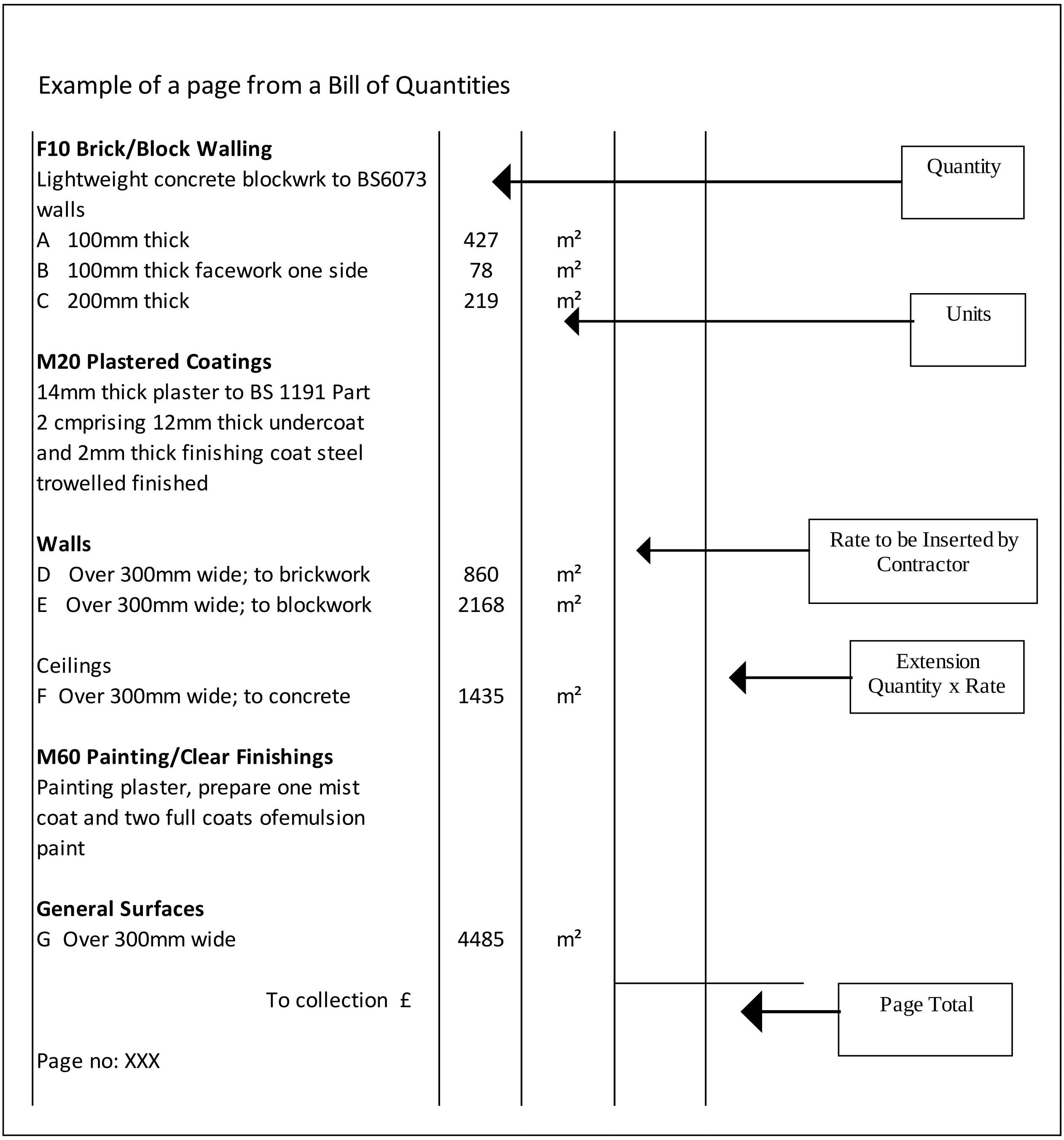



**Figure 38: BOQ Page**[52]

[52] Greenhalgh, B., & Squires, G. (2011),Page 90

**Illustration Box 6: Brief explanation of the BOQ preparation stages (1/2)[53]**

- Column 1 is the `*timesing*' column in which multiplying figures are entered when there is more than one of the particular item being measured.
- Column 2 is the `*dimension*' column in which the actual dimensions taken from the drawings are entered.
- Column 3 is the `*squaring*' column in which the product of the figures in column 1 and column 2 is recorded ready for transfer to the abstract or bill. The term `squaring the dimensions' refers to the calculation of the numbers, lengths, areas or volumes and their entry in the third or squaring column on the dimension paper. Squaring should be carried out to three decimal places, with the final squared quantities rounded off in accordance with standard. Squaring must be independently checked to eliminate errors. Any incorrect figures should be neatly crossed out in *red ink* or *ball pen* and the correct figures written above the incorrect ones. Correcting fluid shall not be used nor shall incorrect figures be erased. All squared dimensions and waste calculations should be ticked in red ink or ball pen on checking and any alterations should be made in a similar manner. Amended figures must be further checked.
- Column 4 is the `*description*' column in which the written description and codes of each item are entered. The right-hand side of this column is known as the `waste' area. It should be used for preliminary calculations, buildup of lengths, explanatory notes and related matters. All steps that have been taken in arriving at dimensions, no matter how elementary or apparently trivial, should be entered here, as this will neatly aid remeasurement, valuing the works done for interim certificates, and *answering any queries* regarding the measurements which may arise.
- A constant order of entering dimensions must be maintained throughout, that is (1) length, (2) breadth or width, and (3) depth or height, so that there can be no doubt as to the *shape* of the item being measured. If this is not possible, dimensions should be annotated to indicate length, width or breadth, height or depth, diameter, etc.
- Taking off of dimensions should be based on the tender drawings, which should be registered in a drawing record showing the date of issue and of any revisions. Taking off drawings should be clearly marked, preferably by the use of a rubber stamp, stating "Drawing used in the preparation of Bills of Quantities", as this will avoid any confusion as to what is included in the BQ. Drawings should be marked to show that the works have been measured. Should revised tender drawings be issued for tender addendum purposes, all changes should be marked in red circles and the measured quantities should be adjusted for the changes, and incorporated in the revised BQ. Queries should be raised and to be confirmed by the project engineer before making the necessary amendments.

**Illustration Box 7: Brief explanation of the BOQ preparation stages (2/2)[54]**

- Abstracting is the process whereby the squared dimensions are transferred to an abstract sheet or other similar computerized formats, where they are written in a recognized order, ready for billing, under the appropriate section headings, and are subsequently reduced to the recognized units of measurement in readiness for transfer to the bills. As each item is transferred to the abstract, the description of the appropriate dimension should be crossed through with a vertical line on the dimension sheet, with short horizontal lines at each end of the vertical line, so that there is no doubt as to what has been transferred. Each abstract sheet should be headed with the contract number, abbreviated contract title, sheet number and section of the works to which the abstracted dimensions refer. The section headings normally should follow those given in the SMM, in the same order.

- Billing is the final stage in the bill preparation process in which the items and their associated quantities are transferred from the abstract onto the standard billing sheets or other similar computerized formats that are in a format that enables the tenderer to price each item and arrive at a total tender sum.

- As each item is transferred to the bill it should be lined through on the abstract to prevent any risk of errors occurring during the transfer stage. Generally, all quantities transferred are to be billed to the nearest whole unit (see SMM). Fractional quantities are not generally necessary but, where required, should not be given to more than one place of decimals. The order of billed items should be the same as in the abstract, and they should be grouped under suitable section headings as they appear in the SMM. Items should be indexed, either by a letter or a number, in the first column of the billing sheet.

- The total sum on each page should be carried to a collection or summary for each section, and the totals from these carried to a Grand Summary, the total of which constitutes the tender sum.

- Unless for those abbreviations as defined in Part III of the SMM, abbreviations must not be used in the descriptions and the wording and layout of each description must follow the rules laid down in the SMM and its amendments in the Particular Preambles.

[54] Source: (Public Administration Handbook (PAH), (2013)

## 2.6. Valuing the Bills of Quantities

Preliminaries, Provisional Sums, and measured works are not the only items in the Bills of Quantities. In (RICS, 2011), risks, credit, overheads and profits, price adjustments and a form of tender has been mentioned to be worth included. The complexity of bills of quantities goes further than it can be thought. Through provisional or approximate quantities BOQ, the risks item is dealt between contractor and client. Credits *means a refund offered by the contractor to the employer in return for the benefit of taking ownership of materials, goods, items, mechanical and electrical plant and equipment, etc. arising from demolition or strip out works.* In case of refurbishment or any demolition, BOQ forms a base for contractor to predetermine the extent of credit. Contracts may be fixed or fluctuating in prices. Such situations are worth taken care, in order to handle the risks of the costs of construction resources. Usually clauses are in BOQ, to restrict tenderers to benefit from the situations on the expense of the client.

Pricing the bills of quantities is a mental challenging activity requiring consideration of many factors in order to derive the value of the BOQ in the contractual undertaking. BOQ columns, commonly comprises of item, description, quantity, unit, rate and amount ((Greenhalgh & Squires, 2011) on page 90). The information value of BOQ extends further than the six items mostly concentrated on. A good example is an activity schedule based contract. The method requires labour, materials and plants costs as the bases for lump sum payment, and so varying changes becomes easier and the profit mark ups and overheads are more transparent (ibid). Rates filled in the BOQ are derived from the first principles, where a huge amount of information is included. When stated, BOQ can be used in assessment of VAT (RICS, 2011).

> *"Priced bill of quantities (BQ) make available one of the best sources of real-time cost data, which can be used by quantity surveyors/cost managers to provide expert cost advice on the likely cost of future building projects. Moreover, they afford a complete cost model in a single document. The cost data provided in a BQ can be retrieved, analysed, stored and reprocessed in various ways (e.g. as distinct rates, detailed elemental cost analyses, element unit rates (EUR), cost/m² of gross internal floor area, and/or functional unit rates) for use in order of cost estimates and cost plans." (RICS, 2011)*

The Specification is said to be related to a bill of quantities (Ashworth, 2006). According to (Greenhalgh & Squires, 2011), one of the disadvantage of BOQ, is the possibility that tenderers can ignore the formal specification document and price only according to BOQ. Specification does not include a measured works section but it has detailed descriptions of the work that can assist the contractor in preparing the tender. The estimator can price the work, using specification. Prescriptive specification gives clear picture of the materials and workmanship while performance gives objective oriented requirements or criteria that the *works* must meet. Cost manager considers both in BOQ (RICS, 2011).A specification is a contractual description of the works intending to facilitate or supplement the understanding of drawings.

> *"The main purpose of a bill of quantities (BQ) is to present a co-ordinated list of components/ items, together with their identifying descriptions and quantities that encompass the building works so that the tendering contractors are able to prepare tenders efficiently and accurately. As well as assisting in ensuring parity of tendering. In addition, BQ provide a vital tool, which can be used by the quantity surveyor/cost manager to manage and control the costs of the building project. Cost management and control include Pre-tender estimates; Post tender estimates; Cost planning; Pricing variations; and Interim valuations and payment.(RICS,2011)*

When well utilised, BOQ can provide information needed for *method statements*, because description rules requires provision of the background, shapes, dimensions of the work and other workmanship standards necessary. *Insufficiency or poorly described information can mislead contractors, resulting in contract variations and potential time-related or cost related claims* ((RICS, 2011) page 28). Quantities given *net as fixed* can help to uncover the amount of basic resources required for the work and even ordering of the materials. Nevertheless, the units and serial numbers are worth categorising the works and procurement processes. Units used in BOQ are mostly related to the number of the materials. For instance floor finishing in square metres, can be matched to the number of boxes of floor tiles or the kilograms of steel bars may give an experienced engineer a good reflection of the number of tonnes needed to complete a given frame work than using linear metres.

According to (Rashid, Mustapa, & Wahid, 2006) the usefulness of BOQ in a project development depend on the magnitude of the information that is needed for project cost reporting, monitoring and controlling. BOQ is an appropriate economic tool because it facilitates detailing project accounting and financial reporting. Likewise, through a well detailed BOQ, effective project cost management at ground level is possible, and the summaries derived from the BOQ information (general summary, cost plan, budget and cash flow) are usually very crucial for the overall management of the project.

| ITEM | DESCRIPTION | QNTY | UNIT | RATE | AMOUNT |
|---|---|---|---|---|---|
| | **ELEMENT NR 2: FRAME** | | | | |
| | **CONCRETE WORK** | | | | |
| | **Reinforced concrete grade '20' including vibrating around reinforcement** | | | | |
| A | Columns | 176 | m³ | 310,000.00 | 54,560,000.00 |
| B | Horizontal beams/Ring beams | 150 | m³ | 310,000.00 | 46,500,000.00 |
| C | 150mm Horizontal suspended slab | 11236 | m² | 46,500.00 | 522,474,000.00 |
| | **High tensile steel square twisted bar reinforcement to BS 4461:1969** | | | | |
| D | 20mm Ditto | 25600 | Kg | 2,800.00 | 71,680,000.00 |
| E | 16mm Ditto | 13868 | Kg | 2,800.00 | 38,830,400.00 |
| F | 12mm Ditto | 114076 | Kg | 2,800.00 | 319,412,800.00 |
| G | 8mm Ditto Mild | 12787 | Kg | 2,800.00 | 35,803,600.00 |
| | **Sawn Formwork to:** | | | | |
| H | Horizontal soffits of suspended slab | 11236 | m² | 18,000.00 | 202,248,000.00 |
| I | Sides and soffits of horizontal beams | 566 | m² | 18,000.00 | 10,188,000.00 |
| J | Vertical sides of columns | 672 | m² | 18,000.00 | 12,096,000.00 |
| K | Vertical edges of suspended slab over 75mm but not exceeding 150mm high | 287 | m | 3,000.00 | 861,000.00 |
| | **ELEMENT NR.2 FRAME CARRIED TO SUMMARY** | | | **SHS** | **1,314,653,800.00** |

**Figure 39: Example of the Element BOQ Section and Basic information in Column form**[55]

[55] Source: Own Construct

### 2.7. Completeness Value of BOQ information.

Vital information flow is like blood in the construction project (Bin Bandi, Abdullah, & Amiruddin, 2014) because a good information facilitates a control of the quality standard of a construction project. The more information provided to cost expert, the more reliable the BOQ will be (RICS, 2011). *BOQ contain valuable information for not only the management of project cost but also the management of the project, because project cost management is an integral part of project management. The balancing of competing objectives like cost, time, quality and scope of a project is a critical activity in management. In the absence of adequate, accurate and reliable cost information, project cost management exercise would be ineffective* (Rashid, Mustapa, & Wahid, 21st June 2006). According to (RICS, 2011), it can be together said

> *“Irrespective of what contract strategy, detailed measurement in (BQ) production is beneficial. It provides data to support claims for tax benefits (e.g. capital allowances and value added tax (VAT)) and it provides one of the best sources of real-time cost data, which can be used for estimating the cost of future building projects as it provides a cost model in a single document”.*

Adequately prepared BOQ, is advantageous to every player in the construction project (Bandi & Abdullah, 2012).It contains data that are useful to the participants before actual construction, during and after construction process. From the BOQ information, insurance, taxation and maintenance schedule can facilitate asset management. However, the value of Bills of Quantities information depends on the amount of information the participants have contributed. *The accuracy of bill of quantities (BQ) is dependent on the quality of the information supplied to the quantity surveyor/cost manager by the employer, designers and other project team members (RICS, 2011).* In essence, more complete BOQ are more likely to be reliable than lesser complete BOQs. Complete BOQ contains infinite information that can serve the construction project participants indefinitely. The summary of BOQ is only helpful in summing up the tangible monetary base of the project.It is not taking the participant of the project not even closer to what the BOQ can offer tomorrow, unless more of the details are transparently and exactly displayed. In (Bandi & Abdullah,2012), it was suggested that *fostering better cooperation* between parties of the construction project may be the only way to solve problems tha prevail in the BOQ currently.

| | SUMMARY | |
|---|---|---|
| ITEM | DESCRIPTION | AMOUNT |
| <br>A<br>B<br>C<br>D | BUILDING WORKS<br>ELEMENT 1- SUBSTRUCTURE<br>ELEMENT 2 - FRAME<br>ELEMENT 3 - STAIR<br>ELEMENT n- ……….. | 1,314,653,800.00 |
| | TOTAL SUMMARY CARRIED TO GENERAL SUMMARY | 1,314,653,800.00 |
| | | |
| | GENERAL SUMMARY | |
| A | BILL 1:Preliminaries | |
| B | BILL 2:Preambles (Specifications) | |
| C | BILL 3:Measured works | 1,314,653,800 |
| D | BILL 4:PC & Provisional Sum | 720,200,000 |
| | GRAND TOTAL | 2,034,853,800 |
| E | ADD: Insurance | - |
| F | ADD: Consultancy fees | - |
| G | ADD: V.A.T (18%) | . |
| TOTAL PROJECT COSTS | | 2,034,853,800 |

**Figure 40: Example of Summary and General Summary of BOQ**

Bills of Quantities information to be advantageous in construction project, it needs completeness, exactitude, transparency and team-collaborative fostering. With completeness, the BOQ will carry critical project information of all participants, from inception to demolition of the facilities. The information of all participants can be included and analysed in integration with project objectives and individually. *One of the possible factors that contributes to the declining usage of B/Qs in the construction industry is that, it is not fully utilized by the project team and many are not able to relate B/Qs for everyday project with the development process* (Razali, Tajudin, & Tajuddin, 2014).The project participants, need to see what BOQ does to their information before embarking on using it vigorously. The user and contractors are lesser reflected in the BOQ, hence denying it a more value to them (Bandi & Abdullah, 2012) (see the figure below for more issue in BOQ). Although, not directly mentioned in ((Bandi & Abdullah, 2012) and (Rashid, Mustapa, & Wahid, 2006)), yet a very important information uncommon in BOQ is the *life cycle costs related* information. If BOQ information is to be complete, collaboration is of paramount importance. BOQ information was identified as the most important issue requiring attention. Accuracy, credibility, format, function, preparation, rates, builder´s knowledge recognition, cost estimates, environment of construction, presentation and SMM base measurement are others (ibid, page 4).

| | **Some Common issues with BOQ information** |
|---|---|
| 1 | In adequate information and for site management purpose |
| 2 | In adequate information details for contractor´s use |
| 3 | In adequate information for cash flow projection |
| 4 | In adequate information for site operation |
| 5 | In adequate information on connection between cost and time related parameters |
| 6 | In adequate information on time related parameter |
| 7 | In adequate information to address the user´s needs |
| 8 | In adequate information to convey the quality of materials |
| 9 | Inflexible information for data coordination |
| 10 | The information provided is not in final form |
| 11 | The information provided is unstandardized and require sub-processes |
| 12 | Lack of information details to explain construction processes |
| 13 | Location of information is not adequate for contractor´s utilization |
| 14 | Location of quantified items in the proposed building is inadequately indicated |
| 15 | Potential of information for other purpose is not fully explored |
| 16 | Unclear connection between BQ and construction process |

**Figure 41: Examples of Informational Issues of Bills of Quantities (BOQ)**[56]

Never the less, the value of the collaboration into information is less operational without transparency. In (Greenhalgh & Squires, 2011), it was said that the *contractor cost* is considered an open book in *partnering arrangement*, and so profit and overhead may be known to other parties. The use of activity schedule payment was claimed to expose overheads and profit of the contractors, which to them it is considered a sensitive information that should not be expose even to the client. If a BOQ information, can only be understood by cost expert, it will keep on serving less in the construction project interest. *Modern Quantity Surveyors who prepare the document should leave the shackle of their current comfort and* ***find ways*** *on how the document* ***can benefit not only them*****,** ***but also the contractor and clients who has paid for it*** (Bandi & Abdullah, 2012). BOQ information need to be transparent in both senses, easily understood by professionals and non-professionals as well as self-

[56] Source Bandi, S., & Abdullah, F. (2012)

disclosing to all participants. The selection of the contract strategy and professional service is fundamentally an endeavor targeting value for money of the project or client. The effort is toward ensuring that all activities of the construction project facilitate optimal and sustainable project performance.

> *As the representative of the owner, the consultants are expected to manage the project properly and effectively to ensure that the owner get value for money for their projects. A priced BQ, either prepared by the contractor or by the consultant QS, contains invaluable descriptive, quantitative and financial information for use by the consultants in the project cost management during pre-construction and construction phases* (Rashid, Mustapa, & Wahid, 2006).

To attain productive flow of BOQ information among participants, the BOQ as a model may need more complete, precise, open, simple, standard, participatory liable and comprehensible contents. The information that a user can refer during maintenance and demolition of the building; the information that gives chance to clients to discover, comment and contribute in finding solution to the design effort; the information where the participants can visualize the life-cycle effects of designs alternatives to the facility financial status; and at large the BOQ information that oblige the participants of full liability to the project deliverance and performance.

According to (Nagalingam, Jayasena , & Ranadewa, 2013), Building Information Modelling is the way foward. An automatic BOQ that can create reports in the needed format is possible. A number of advantages likely, include the speed and effectiveness in sharing information, higher predictability and understanding in whole life costing and environmental data, improved flexibility, automation and documentation quality and reliable accuracy in facility management data regeneration. It is through this, the construction industry may reduce the unnecessary burden clients incur over other participants. Once (Cartlidge, 2006), said *"the construction industry still persist in the rewarding of bad behavior. If the contract is delayed, all participants get their money apart from the client who has to pay"*.

| **Contractual Arrangement vs Delivery Methods** | | | | |
|---|---|---|---|---|
| | Design-Bid-Build (DBB) | Construction Management at Risk (CMAR) | Design and Build (DB) | Integrated Project Delivery (IPD) |
| Contracting Methods | | | | |
| Lumpsum | Common | Common | Common | Rare |
| Guaranteed Maximum Price | Rare | Common | Common | Rare |
| Reimbursable | Rare | Rare-Common | Rare | Common |

| **Delivery Methods vs Selection Criteria** | | | |
|---|---|---|---|
| | Low Bidder | Best Value | Best Qualifications |
| | *Selection is Based Solely on Price* | *Selection is Based on a combination of Price and Qualifications* | *Selection is Based solely on Qualifications* |
| Design-Bid-Build (DBB) | Most Common | Common; Price evaluation based on Construction Cost | Rare |
| Construction Management at Risk | Rare | Most Common; Price evaluation based on CMAR Fees and General Conditions | Common |
| Design and Build (DB) | Common | Most Common; Price evaluation based on Fees and GCs; may or may not include Construction Cost | Common |
| Integrated Project Delivery | Rare | Common | Most Common |

**Figure 42: Example on consideration in delivery methods and services procurement**[57]

[57] The Construction Management Association of America (CMAA) (2012)

## 2.8. Use of Bills of Quantities

As already mentioned, BOQ usage has shown a decline. The existence of BOQ, however has been in different form since then (Greenhalgh & Squires, 2011). The "vanishing" of BOQ from the industry is a topic on decline itself. Everyday software are created to improve the BOQ preparation and usage (*see the Illustration Box 8: Example of increase in software for BOQ preparation)*. UK is no longer the only country using BOQ. Many other countries around the world are also widely using (Rashid, Mustapa, & Wahid, 2006). The British model is almost familiar in all Europe, although Germany, France, Spain, Russia, Bulgaria, Hungary, Norway and Rumania, BOQ are prepared by the architect or engineer and they are mostly used only for evaluating bid or tenders. Some countries, like Norway, contractors price the BOQ, while in Germany Architect do so too. British has also influenced Africa, Asia, Australia and Middle East. The difference is on the rate at which the BOQ are prepared basing on the local standards and the use of Quantity Surveyors. Jordan, UAE, Qatar, Oman and Saudi Arabia for example are said to use Measurements published by the RICS. The same for Egypt from Africa. Indonesia, Australia, Singapore, India, and Malaysia BOQ are produced according to the locally produced Standard Method of Measurement (SMM). In countries like Taiwan, BOQ are sometimes prepared by the contractors so as, if errors found during construction in the quantities are not adjustable after the bid is accepted.

On contrary to the above, the United States, Canada, Central America in most islands in the Caribbean BOQ are not directly used, but they still can be found in one form or another in the project environment. This is supported in the work of (Bowen B. , 2009) who generally said

> "*So why was it that the logical process of events that occurred in Great Britain that led to the establishment of a Quantity Surveying profession there, was not repeated in the United States? In both countries today, the tedium of measurement is increasingly being taken over by digitizing and automated systems. In the UK the quantity surveying profession is in transition from measurers of quantities to cost and contract managers, even to project managers. Those employed by contractors, now act as commercial managers. In the US there is a growing body of independent cost consultants and professional construction managers emerging. Contractors in the meantime are expanding their services to the owners with a wide range of preconstruction services. Beginning in the late 1950's English Quantity Surveying firms, somewhat belatedly, began to establish themselves first in Canada and in the 1960's in the United States. Many have now grown substantially and broadened their services to include a wide range of project control and management services.*

Illustration Box 8: Example of increase in software for BOQ preparation[58]

*PriMus Free UPP for iPad is the APP that makes the PriMus Free UPP for PC features go mobile. The Bill of Quantities solution that allows you to use, update, get technical support and training for Free.*

*With PriMus Free UPP for iPad you can:*

- *Work with great simplicity and professionalism*
- *Create new documents: Price Lists, Price Books and BoQs*
- *Easily create new items: Price List, Price Book and Bill of Quantities items*
- *Easily load your reference Price Lists or Price Books*
- *Easily save your BoQ's, Price Lists and Price Books and then use them when creating new documents*
- *Acquire Price Books and Price List items even through the internet*
- *Acquire items for your BoQ from other Price Books or Price Lists*
- *Easily insert descriptions and measurements*
- *Insert images or photos as comments for measurement rows*
- *Manage all document data content in one single file*
- *Open and manage documents sent by e-mail*
- *Open and manage documents published on the internet*
- *Import and export PriMus Free UPP for PC documents*
- *Print your documents using the export to PriMus for PC features*

The Bills of Quantities information is being realized and further pioneered to take different forms and adopt different languages in order to facilitate construction costs management. In (Jadid, 2013), it was insisted that BOQ is important to all participants and it expects contributions from all of the participants. So in order to improve collaboration, the Multilanguage platforms should be developed (*See figure 37: Example of Bills of Quantities in Arabic and English*). Likewise, in (Katoula & Nshimyumuremyi, 2007), it was suggested that Bills of quantities are not necessarily detailed. It is good if the BOQ can contain items at component level, provided the system level of the facility is identifiable (*See the figure 38: Examples of development of BOQ to suit purposes of International Comparison Programs (ICP)*). This may help in the collection of the data for International Comparison Program (ICP). This is a global statistical initiative aimed at producing estimates of price levels, expenditure values, and purchasing power parities (PPPs) that allow for cross-country

[58] *Source:* ACCA software, (2014)

comparisons of price levels, and economic aggregates in real terms. Instead of using construction unit prices (*Pricing a basket of standard (hypothetical) construction projects*) or inputs (*basket of construction inputs—material, labor, and equipment*), it was suggested that the use *basket of construction components (BOCC)* is far better estimate. BOCC approaches uses tangible units like columns or beams (Construction components) of a construction project that consume inputs such as material, labor, and equipment to arrive at the projects costs from the system and components in a more simplified form. This approach then can be developed to effective weighting indices useful for ICP.

As stressed above, Bills of Quantities, as terminology is not used, but contractually the documents of construction projects consist of ***what BOQ does***. Greece for instance, (Morledge & Smith, 2013) put clear that BOQ are not used as tender documents and yet quantities of the work are measured by the contractor and used to compile a final account.

**BILL OF QUANTITIES** — **جداول الكميات**

BILL NO 1

جدول رقم (1)

Institution Name — أسم المؤسسة

Country Name — الدولة

Project name — أسم المشروع

| Item | Description | الإجمالي كتابة<br>Total in words (SR) | الإجمالي رقما<br>Total in figures | السعر<br>Rate | الوحدة<br>Unit | الكمية<br>Qty | الوصف | البند |
|---|---|---|---|---|---|---|---|---|
| | <u>Division 3 - Concrete</u> | | | | | | <u>القسم الثالث : أعمال الخرسانة</u> | |
| 03300 | CAST IN PLACE CONCRETE | | | | | | <u>خرسانة صب الموقع</u> | 03300 |
| 03300-1 | Insitu plain concrete, 20 Mpa, type I cement | | | | | | خرسانة عادية صب في الموقع قوة 20 ميجا باسكال واسمنت نوع I | 03300-1 |
| 03300-1-1 | 100mm blinding concrete, 20 MPa using Type V cement | | | | م3 | 450 | 100مم خرسانة عادية قوة 20 ميجا باسكال اسمنت نوع V | 03300-1-1 |
| 03300-2 | Reinforced concrete 35 MPa including formwork, reinforcement, curing, construction and expansion joint, filler boards, water stops and two-coats bituminous paint cold applied for concrete surfaces in contact with earth etc. complete as per drawings and specification | | | | | | خرسانة مسلحة قوة 35 ميجا باسكال شاملة القوالب والشدات، وحديد التسليح، والمعالجة، وعمل الفواصل الإنشائية وفواصل التمدد، والواح السيلوتيكس، وجيوانات توقيف المياه دهان وجهين من البيتومين البارد على أسطح الخرسانة المتصلة بالتربة وذلك حسب المواصفات والمخططات | 03300-2 |
| | TYPE V CEMENT | | | | | | أسمنت نوع V | |
| 03300-2-1 | Footings columns and walls | | | | م3 | 2150 | القواعد والاعمدة والجدران | 03300-2-1 |
| 03300-2-2 | Grade beams | | | | م3 | 190 | الميد | 03300-2-2 |
| | | | | | | | | |

**Figure 43: Example of Bills of Quantities in Arabic and English[59]**

[59]Source: Jadid, M. N. (2013)

| Item | Description | Unit | Quantity | Rate | Cost Item |
|---|---|---|---|---|---|
| 3.1 | Building concrete 150 kg cement 5 cm thick | m3 | 4 | 100 | 400 |
| 3.2 | foundations reinforced concrete for strip and independent footings 350 kg cement | m3 | 19 | 140 | 2660 |

(a) Normal BOQ

| Item | Description | Unit | Quantity | Rate | Cost Item | System |
|---|---|---|---|---|---|---|
| 3.1 | Building concrete 150 kg cement 5 cm thick | m3 | 4 | 100 | 400 | Substructure |
| 3.2 | foundations reinforced concrete for strip and independent footings 350 kg cement | m3 | 19 | 140 | 2660 | Superstructure |

(b) Systems Added to BOQ

| system | Total costs |
|---|---|
| Substructure | 400 |
| Superstructure | 2660 |

(c )Totals of the Systems in BOQ

**Figure 44: Development of BOQ to suit International Comparison Programs (ICP)[60]**

[60]Source: Katoula, M. M., & Nshimyumuremyi, A. (2007)

| Sn | Activity | Use of BOQ | Sources Supported | Rate |
|---|---|---|---|---|
| 1 | Procurement | Tendering | 16 | Highly |
| | | Subcontracting Procurement | 1 | lowly |
| | | Material Purchasing | 1 | lowly |
| 2 | Communication | Medium to Communicate design information | 3 | lowly |
| 3 | Control | Progress Payments | 12 | Highly |
| | | Variations | 11 | Highly |
| | | Financial Control and Adjustment | 5 | Medium |
| | | Final Account | 7 | Medium |
| | | Basis for Price Negotiation | 1 | Lowly |
| | | Work Supervision | 2 | Lowly |
| | | Basis for Report on work Progress and Expenditure | 4 | Lowly |
| | | Part of Contract Documentation and evidence for Dispute Resolution | 3 | Lowly |
| | | Audit Document for discrepancy between drawings and Specifications | 1 | Lowly |
| | | Reduce Tendering Risk | 4 | Lowly |
| 4 | Planning | Resource Planning | 2 | Lowly |
| | | Work Planning and Programming | 7 | Medium |
| | | Cash Flow Projection and Budgeting | 3 | Lowly |
| | | Schedule of Labour requirements | 1 | Lowly |
| | | Cost Planning | 3 | Lowly |
| | | Basis for Cost Analysis and future estimating | 6 | Medium |
| | | Costing of Alternative designs | 1 | Lowly |
| | | Provide cost of Maintenance for completed building and data for asset management | 2 | Lowly |
| | | Material schedule preparation | 4 | Lowly |
| | | Trade costing | 1 | Lowly |

**Figure 45: Example of BOQ usefulness[61]**

[61] Source: Modified from the work of Bin Bandi, S., Abdullah, F., & Amiruddin, R. (2014). Review of the Fundamental usage of Bills of Quantities (BQ) by the Contracting Organisations. Australian Journal of Construction Economics and Building 14 (1), 118-131

## 3. Life Cycle Costing (LCC)

Decisions on procurement should not totally be based on acquisition cost, but rather,it should consider the ownership costs ((Dhillon, 2010)Pg 27). A claim is that, evaluating a cost of a building without considering the cost in use is unsatisfactory because the value for money increases with life time consideration in design phase (Ashworth, 1999). Some trace LCC from 1930s, saying it was well predicted that one day maintanance and operation costs of equipment will influence the decisions on the bidding process (Wuebbenhorst, 1986). To be more valuable,the future quantity surveyors, or rather specifically the costs modeling expertise will have to answer the what if questions to the clients (Bowen & Edwards, 1985). To advise designers, contractors and clients on the selection of the best design alternative. Evaluation of that nature is the basic purpose of life cycle costing modelling.While LCC incorporates the total costs of the delivered facility from inception to demolition, cost-in-use refers to periodic recurring costs. Initial construction costs and professionals fees is not in costs in use, but included in LCC (Ashworth, 1999).

<table>
<tr><th></th><th>Life Cycle Phase</th><th>Description</th><th>Associated Costs</th></tr>
<tr><td>1</td><td>Specification</td><td rowspan="2">The formulation of the client´s requirements and translating these into an acceptable design</td><td rowspan="2">Initial Costs connected with land purchase, professional fees and construction</td></tr>
<tr><td>2</td><td>Design</td></tr>
<tr><td>3</td><td>Installation</td><td rowspan="2">The construction process up to completion and the handling -over of the project to the client</td><td rowspan="3">Recurring Costs necessary for occupational charges such as rates, insurance, repairs, improvements, fuel, cleaning and estate control</td></tr>
<tr><td>4</td><td>Commissioning</td></tr>
<tr><td>5</td><td>Maintenance</td><td>The use of the project for its intended purpose</td></tr>
<tr><td>6</td><td>Modification</td><td>Alterations necessary to keep the project in a good standard of repair or to improve to current day standard</td><td rowspan="2">Recurring Costs required for major changes to building in respect of refurbishment and redevelopment</td></tr>
<tr><td>7</td><td>Replacement</td><td>The evaluation of the project for major refurbishment, or the site for redevelopment</td></tr>
</table>

**Figure 46: Example of the Life Cycle Phases and Associated Costs**[62]

[62] Source: Ashworth, A. (1999), Page 470

### 3.1. Life Cycle Cost (LCC) and Whole Life Cycle Cost (WLCC)

Distinction is made of LCC from whole life cost. According to (Boussabaine, 2004), the difference between WLCC and LCC is debatable. They share the purpose and differ in the extent of coverage. They all aim to facilitate decision making during capital outlay, but WLCC goes on to give updates longer than LCC. Mainly LCC deals with the business focus or economical life of the project. According to (Potts, 2008) value (whole life value) forms the basis for procurement of big projects in the public and private sector. This was supported in (Davis Langdon Management Consulting, 2007),as it was said that

> "*Under a PPP project a provider contracts to provide and maintain an asset over a defined concession period (typically 25 to 30 years), for a fixed monthly fee determined prior to commencement of the project. At the end of the term the ownership and operation of the asset reverts back to the Public Sector client. The PPP contract may require the provider to deliver some or all of the operational/FM services during the concession period; maintenance and replacement works are almost always included. A robust assessment of the relevant operational costs is therefore of prime importance to the provider".*

Whole-life value (WLV) encompasses economic, social and environmental aspects associated with the design, construction, operation, decommissioning and where appropriate the reuse of the asset of its constituent materials at the end of its useful life. Whole Life Value (WLV) includes more than Whole Life Cycle (WLC) or Life Cycle Assessments (LCA). In WLV, the primary goal is perception of both costs and benefits of the value drivers, WLC is about financial costs whereas LCA is crucial for environmental impacts assessment. Life cycle assessment differs from LCC and WLC in that it is not cost-based. It combines a number of quantitative and qualitative dimensions, and it covers a wider scope.

> According to (Yorkon, 2010) *LCA "is the methodology for 'measuring and evaluating the environmental impacts associated with a product, system or activity, by describing and assessing the energy and materials used and released to the environment over the life cycle. It considers the entire life cycle of a product, from raw material extraction and acquisition, through energy and material production and manufacturing, to its use, end-of-life treatment and final disposal. Life cycle assessment differs from LCC and WLC in that it is not cost-based. It combines a number of quantitative and qualitative dimensions, and it covers a wider scope."*

To summarise, the relationship of WLV and LCA share the qualitative nature of assessment and LCA is subset. On the other hand WLC and LCC are quantititave while LCC being the subset, and the two being under LCA.

According to (SCI-Network, 2011 ), Whole Life Costing (WLC) is a tool for decision making, management, and maintenance guide because it can be used to select among alternative projects, designs, or building components.Likewise, it facilitates estimation,forecast and guidance on the likely costs during the life of the building. However, the primary use of *WLC is in the effective choice between a number of competing project alternatives and it can be applied at any stage of a construction project, including Business Justification, Procurement Strategy, Concept Approval, Design Approval, Investment Decision,Readiness for Service and Benefits/Cost Evaluation*. It was suggested that it is crucial to use WLC during early design stages where most of the options are open to consideration. In estimate, 80-90% percent of the cost of running, maintaining and repairing a building is determined at the design stage.

<table>
<tr><th colspan="4">Whole Life Value</th></tr>
<tr><td rowspan="6">Life Cycle Assessment</td><td>Raw Material Acquisition</td><td></td><td></td></tr>
<tr><td>Project</td><td></td><td rowspan="5">Whole Life Cycle</td></tr>
<tr><td>Design<br>Manufacturing<br>Construction</td><td rowspan="3">Life Cycle</td></tr>
<tr><td>Occupancy<br>Operation<br>Maintenance</td></tr>
<tr><td>End Life</td></tr>
<tr></tr>
<tr><td rowspan="2">Qualitative Non-Cost Dimensions</td><td></td><td colspan="2" rowspan="2">Quantitative Cost based Dimensions</td></tr>
<tr><td></td></tr>
</table>

**Figure 47: Illustration of the relationship between WLV, LCA, WLC and LCC[63]**

[63] Source: Modified From Yorkon (2010). A Guide to Improving the Whole Life Value of a Building. Von Portakabin Group. YK7222/6/10-http://www.yorkon.co.uk/pdf/whole_life_value.pdf abgerufen

> *"WLC should be included in the client's brief. It should be used as a decision-making tool throughout the procurement, construction and use of the project stages; for example, during initial investment appraisal, feasibility study of alternatives, outline and detailed design, tender appraisal, assessment of variations, handover and post-occupancy. WLC has the potential for adding real value to a project. However it is critical to involve the whole supply chain early in the design cycle, as 80% of the future costs of running maintenance repair is fixed in the first 20% of the design process. Experts in building services and facilities management should not be overlooked during the early design assessment if the full long-term environmental and economic advantages are to be secured. The concept of WLC was first introduced into the procurement assessment on the Ministry of Defence's Building Down Barriers projects. As part of the Defence Estates Prime Contracting Strategy, potential contractors who bid had to forecast the whole-life costs along a series of milestones. Part of the payment on the seven-year project was based on performance against the milestones."*
> (Potts, 2008)

Quantity Surveyors, in (Kehily, 2010) consider Whole Life Cycle Cost (WLCC) as an economic evaluation in which all costs arising from owning operating and maintaining a building over a certain study period or building life cycle are considered to be potentially important in option appraisal, design decisions and cash flow forecasting. To reduce the confusion, LCC was defined as the *costs arising from owning, operating and maintaining an individual building system or component throughout the components life cycle or throughout the estimated life cycle of the building itself while WLCC stood to be the accumulated sum of all the individual LCC calculations throughout the buildings life cycle or study period*. Carrying WLCC depend on client requirements and the level of detail and information available. The different purposes of WLCC and the different stages that WLCC can be carried out are outlined in Section 4 of the BSI/BCIS document *"Standardised Method of Life Cycle Costing for Construction: UK supplement to ISO 15686 Part 5 life-cycle costing for buildings and constructed assets"*.

| Item | WLCC | LCC | Source |
|---|---|---|---|
| Purpose | Society based broader view | Entity based specific view | (Norris, 2001) |
| What is included | All related to life cycle of the product | All related tom direct costs or benefits to decision maker | --ditto-- |
| Flows considered | Direct and Indirect to the decisions makers. Pollution,energy and the like | Costs and benefits dirtectly impacting decision | --ditto-- |
| Units used to calculate | Mass and Energy mostly, physical units | Monetaryunits | --ditto-- |
| Time | Is not very important | Very crucial due to discounting of the value | --ditto-- |

**Figure 48: Example of differences between LCC and WLCC**

**Illustration Box 9: Life Cycle Costing and Public Procurement[64]**

*"Understanding LCC, even at its fringes, is essential if the public procurement mind-set is to change from "best value for money" to "best value across the project/product life cycle." As discussed in Issue 1, green and more socially equitable alternatives may involve higher capital outlays at the time of purchase. These premiums can often be offset through reduced operating and maintenance cost and avoided environmental risks. However, such savings do not alter procurers' concerns that they can be perceived to be too generous or even wasteful with scarce public funds. To address this dilemma, elements of LCC need to be embedded into the main stages of the procurement process. This requires the setting of environmental, social and economic objectives at each stage of the procurement process: establishing the need to procure; setting specifications; developing pre-qualification questionnaires; developing award criteria for the evaluation tenders and making award decisions; contracting and contract monitoring."* (International Institute for Sustainable Development (IISD), 2009).

[64] Source: International Institute for Sustainable Development (IISD), (2009)

### 3.2. Definitions of LCC.

*Life cycle costing is central to the current international drive to achieve better value for money from the buildings and constructed assets we procure and use* (Davis Langdon Management Consulting, 2007). Governments are increasingly seeking better value over lowest cost alone. It has been realised that the evaluation of all the costs and impacts of facility life cycle, minimises both, the life cycle costs and the environmental effects. Definition of LCC have in common the assessment of the total cost performance of an asset over time with the primary use of evaluating design options for optimising the value for money of the project. It is a wide process covering different phases and used in different industries, with the same purpose of rescuing environment and minimalizing operational costs through earlier planning.

In (ISO 15686-5 (E), 2008), LCC stands for life cycle cost, which is defined as cost of an asset or its parts throughout its life cycle, while fulfilling the performance requirements. In the document, life cycle costing (not LCC) is a methodology for a systematic economic evaluation of life-cycle costs over a period of analysis, as defined in the agreed scope. That is Life cycle costing can address a period of analysis that covers the entire life cycle or any period of interest of the facility delivery. The provisions was stipulated as for public clients, intended to improve investment appraisals and provision of information on environmental performance. Likewise, on the Whole Life Cycle, the documents gives whole life cost (WLC) as all significant and relevant initial and future costs and benefits of an asset, throughout its life cycle, while fulfilling the performance requirements and a whole life costing as a methodology for systematic economic consideration of all whole-life costs and benefits over a period of analysis, as defined in the agreed scope (See the figure below). Moreover, the life-cycle assessment (LCA), is defined in the document as a method of measuring, evaluating the environmental impacts associated with a product, system or activity, by describing, and assessing the energy and materials used and released to the environment over the life cycle. That is doing whole life cycle costing in assessing the environmental impact of the undertakings in its totality.

| S/N | Definition | Author | Remark |
|---|---|---|---|
| 1 | The systematic consideration of all relevant costs and revenues associated with acquisition and ownership of an asset | (Bowen & Edwards, 1985) | The definition stresses on ***whole*** life cycle ***costing*** (WLC) |
| 2 | It is a tool for assessing the total cost performance of an asset over a time, including the acquisition, operating, maintenance, and disposal costs. | (Bakker, May 2007) | The definition stresses on life cycle ***costing*** (LCC) |
| 3 | Is the sum of all costs incurred during the life span of an item or system (i.e. the total of procurement and ***ownership costs***) | (Dhillon, 2010) | The definition stresses on life cycle ***cost*** (LCC) as the ***cost in use***. |
| 4 | Life cycle cost analysis (LCCA) is a process of evaluating the economic performance of a building over its entire life. Sometimes known as “whole cost accounting” or “total cost of ownership,” LCCA balances initial monetary investment with the long-term expense of owning and operating the building. | (Davis, Coony, Gould, , & Daly, 2005) | The definition stresses on life cycle cost ***analysis*** (LCCA) as the cost model. |
| 5 | Life cycle costing (LCC) is a tool for assessing the total cost performance of an asset over time, including the acquisition, operating, maintenance, and disposal costs. Its primary use is in evaluating different options for achieving the client’s objectives, where those alternatives differ not only in their initial costs, but also in their subsequent operational costs | (Davis Langdon Management Consulting, 2007) | Total cost performance is the focus. |

**Figure 49: Common definitions related to LCC from literature**

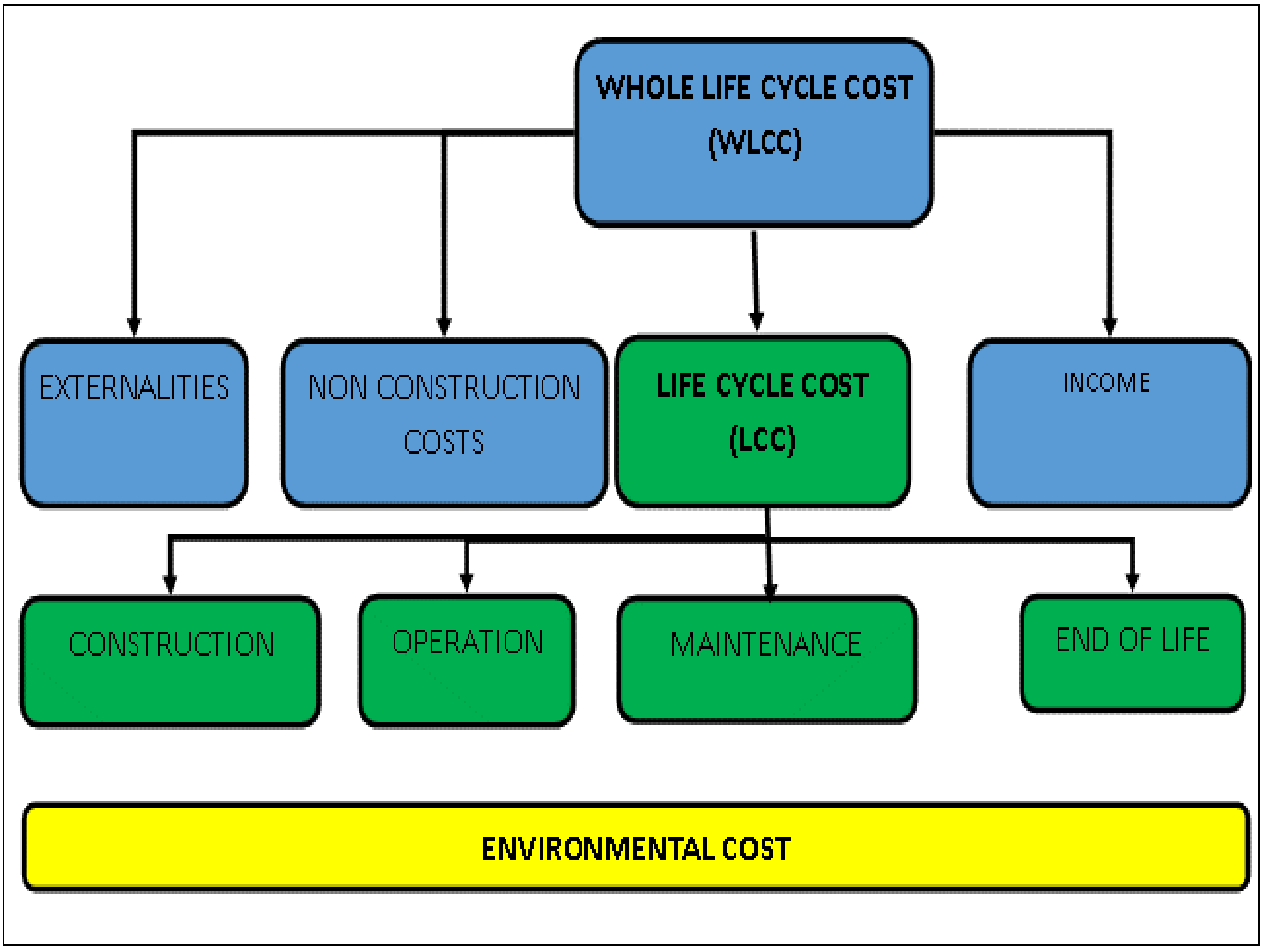



**Figure 50: Illustration of the Whole Life Cycle Cost (WLCC) and Life Cycle Cost (LCC)**

Note: This is BSI/BCIS 'Standardized Method of Life Cycle Costing for Construction Procurement.[65]

[65] 151. Kehily,D. (2011), Page 21

### 3.3. Life Cycle Costing Models

Life Cycle Costing (LCC) *incorporates all costs from inception to disposal* (Sherif & Kolarik, 1981). Generally, the concept of a LCC has been in practice since the 1960s in the United States. The LCC applied to enhance cost effectiveness in granting *competitive awards*.

> *"Value for money is the optimum combination of whole-life cost and quality to meet the user's requirement. This means that awarding contracts on the basis of lowest price tendered for construction works is rarely value for money; long-term value over the life of the asset is a much more reliable indicator. It is the relationship between long-term costs and the benefit achieved by clients that represents value for money"* (Office of Government Commerce (OGC), 2007)

To achieve competitive award criteria, a well-prepared and understandable model is crucial. Modelling the costs is a useful tool in studying system performance and cost characteristics (Sherif & Kolarik, 1981). It facilitates visualising the input side and output side of the various factors considered. Model requires information of both, those describing and categorising the resources and those explaining the purpose. Such information is crucial for quantification and estimation. As such, depending on the information, models can simple as well as very complex and their development procedures range from *educated* guesses to highly sophisticated *mathematical* techniques such as regression techniques. Model output (as well as input) is usually a function of the specific purpose of a cost study

Whether it is a general model (not tied to any system or item) or specific (item tied) model, it should involve time value for money (Dhillon, 1989,2010).

> *The purpose of Life Cycle Cost Analysis (LCCA) is to estimate the overall costs of project alternative and to select the design that ensures the facility will provide the lowest overall cost of ownership consistent with its quality and function* (Fuller, 2010)**.**

Irrespective of the project type, LCC models has common items worth considering. In (Caltrans, 2013), the LCC manual for pavement construction work was found helpful. They used a LCC software known as *RealCost,* developed by the Federal Highway Administration (FHWA) for evaluating the long-term cost effectiveness of alternative designs for new and existing pavements. Design decisions related to the energy efficiency in construction (orientation, thermal efficiency and air tightness) need LCC to evaluate whether additional *sustainable* attributes and energy efficiency measures are cost effective over a given study period. Influence on sustainability is one, yet tendering and risk management (especially in PPP) can also significantly benefit from the LCC information (Kehily, 2010).

As seen above, LCC model types are hard to pin point exactly. In (Sherif & Kolarik, 1981), three classes were suggested. Conceptual or hypothetical qualitative relationship of components in a less detailed cost estimates. In construction this corresponds to phase analysis of costs models. Analytical is the one with a well-structured, set of mathematical relationships describing a certain aspect of a system under certain assumptions. The assumptions, actual performance and complexity of the system are related. And heuristic (less-structured analytical) are the models without clear relationship between inputs and outputs information and so they need high expertise to simulate *what if questions*. Irrespective of the type of model, common items considered in the WLCC include non-construction costs (costs of acquiring land), construction costs (professional fees of design and contract sum to contractors), operational costs (rent payments and heating/cooling costs), maintenance and replacement costs (regular and specific repair costs), end of life costs(final conditions inspection of the disposed components or facility) and income (Residual value incomes and rent earned) (ISO 15686-5 (E), 2008). Specifically, LCC does not necessarily include income, because it compares the outlay altenative of designs (see the figures below),although subsidies to renewable energy effort shows how worth income flows can be to WLCC decisions (SCI-Network, 2011 ).

**Illustration Box 10:Life Cycle Costing vs Whole Life Costing definitions[66]**

> *"Practitioners, and those who advise them, are using a number of terms to describe LCC and its derivations. This inquiry found that often LCC was used interchangeably with terms such as whole life costing, full cost accounting, whole life value and total cost of ownership. We are of the view that these diverse terminologies do refer to LCC, in that they are systematic accounting approaches that seek to evaluate all costs and immediate externalities associated with a product or service. But different terms may have arisen based on how LCC is being adapted in different sectors. For example,*
> *total cost of ownership often appears to be used when LCC methodologies are being adapted to evaluate information and communication technologies;*
> *whole life costing appears to be used when LCC is being used to assess the cost-effectiveness of renewable energy technologies;*
> *full cost accounting is the preferred term across the materials management and the end of life treatment, recycling and waste management professions; and*
> *whole life value and life cycle costing are used interchangeably across the building and construction sector*."

### 3.4. Life Cycle Costing Calculation and Challenges

In (Kehily, 2010), a number of methodologies and standard method of measurements on WLCC were presented. For instance, International Standards Organization, BS ISO 15686, a multi-part series of international standards giving guidance on various aspects of planning the service life of buildings and constructed assets. In the series, Part 5 provides guidelines, definitions, principles and informative text on the application of LCC techniques in the context of service-life planning. In 2008 the British Standards Institute (BSI) and the British Cost Information Service (BCIS) in the UK published a 'Standardized Method of Life Cycle Costing for Construction Procurement, as a supplement to BS ISO 15686-5:2008 Buildings and constructed assets – Service life planning – Part 5: Life cycle costing. The document provides construction cost professionals with a standardized method of applying LCC, applicable to the Irish/UK construction industry and to the key stages of the procurement process. Above all, the document provides a *cost data structure* and a *method of measurement for LCC* which aligns with the *ISO* 15685-5.

Despite of all the benefits of LCC and availability of tools and guiding documents, a number of reasons hinder a complete use of LCC even in huge public projects. In ((Kehily, 2010) (SCI-Network, 2011 )) LCC calculation need *available quality data to precisely predicting the future* conditions of

66 Source: International Institute for Sustainable Development (IISD), (2009), Page 16

the building element and services. Such an effort is not without assumptions about intervening costs factors like inflation, which are highly vulnerable to uncertainties. *When calculating LCC it is necessary to discount all future intervention costs to a comparable time base. All future expenditure should be discounted with Net Present Value (NPV) formulae to a cumulative sum in today's monetary value.* Lack of enough available data and complexity of the process is hindering reaping of the benefits of LCC. Applications risk modelling and sensitivity analysis techniques suggested are helpful though not yet a solution, because they are themselves complex undertaking.

> *"Uncertainty can be explicitly addressed in LCCA calculations, but it makes them much more complex. To make LCCA calculations as simple and straightforward as possible, the Stanford LCCA approach makes uncertainty an external qualitative consideration rather than a quantitative analytical one. Users should consider uncertainty throughout their LCCA studies and weigh the results qualitatively. Many assumptions need to be made over the course of an LCCA study in order to generate enough data to produce results. These assumptions will strongly affect the results. All assumptions used in LCCA must be clearly stated and documented so that appropriate members of the Project Team can validate them through the design process as costs, goals, and budgets change".* (Davis, Coony, Gould, , & Daly, 2005)

Another problem in LCC calculation is due to owners or political influences. Because the building is expected to last longer, interest of owners (especially public) tend to fear that change of use, overestimation and capital-budget accounting problems may be worth foregoing LCC. A facility is built under one department and run under another department, is usually difficulty to join financial responsibilities and accountabilities especially in government projects. Fear of overestimation and the need for initial low costs for the expectation of higher return compels owner not to embark on LCC. Likewise, long-term forecast is not desirable because of the unknown change of use of the building. Joint project team, multiuse project proposals, demonstration of more options of designs and use of consistent methodology of future assessment are proposed solutions in (SCI-Network, 2011 ).

$$LCC = \sum_{t=0}^{N} \frac{C_t}{(1 + d)^t} \qquad (5.1)$$

where:

| | |
|---|---|
| **LCC** | = Total LCC in present-value dollars of a given alternative, |
| **$C_t$** | = Sum of all relevant costs, including initial and future costs, less any positive cash flows, occurring in year t, |
| **N** | = Number of years in the study period, and |
| **d** | = Discount rate used to adjust cash flows to present value. |

$$LCC = I + Repl - Res + E + W + OM\&R \qquad (5.2)$$

where:

| | |
|---|---|
| **LCC** | = Total LCC in present-value dollars of a given alternative, |
| **I** | = Present-value investment costs, |
| **Repl** | = Present-value capital replacement costs, |
| **Res** | = Present-value residual value (resale value, scrap value, salvage value) less disposal costs, |
| **E** | = Present-value energy costs, |
| **W** | = Present-value water costs, and |
| **OM&R** | = Present-value non-fuel operating, maintenance, and repair costs. |

**Figure 51: General LCC present value Model and Building energy calculation Model[67]**

The fundamental to life cycle modelling is keeping the project participants integrated enough to generate robust information for *life cycle value for money* of the project. The life cycle costing appraisal model needed is worth only if it can sustain across clients requirements while pulling the other participants commitments to the whole project delivery efficiency. To attain this, LCC model has to fit in all related components and sources of information. First to the *basic cost outlay data* (construction costs in particular) as well as other related models, like the economic, and environmental. Such a model, requires among others, the most simplified informative, comprehensive, accurate, descriptive, automated, and collaborative system capable of integrating all participants.

> *"The ability to model a building`s financial performance over its life cycle is necessary to justify measures that may require greater initial capital investment but yield significantly lower operational costs over time (Kibert, 2008)*

[67] Source: SCI-Network. (2011)

### 3.5. Life Cycle Costing within BIM

Life Cycle Costing (LCC) is always a challenge to the Architecture , Engineering and Construction (AEC) industry. In (Lai, Halvitigala, Boon, & Birchmore, 2010) it was suggested that Building Information Modelling (BIM), can assist LCC under a given conditions. One of the conditions, it requires that the entire industry is committed to BIM. Second condition mentioned was that the greenhouse gas emissions concept should be common and it should be completely computerised technology capable of reducing gas emissions is industrially. The two conditions, were necessary and possible because, BIM is unavoidably growing and without common computerised technology to demostrate the LCC before construction project starts, then it would be difficulty to standardise the assessment among participants. Government was suggested to be the leading agent on pushing for the reduction in harmful gas emissions in construction undertakings and operations.

To be efficient the IFC classes must help to facilitate life cycle management (Vanlande, Nicolle, & Cruz, 2008). The 3D-nthD research project, is one of the effort towards computer based simulation of the whole life cycle of the facility (Fu, Aouad, Lee, Marshall-Ponting, & Wu, 2005). There is a need for more efficiency in *data exchange* and *sharing*.This equally depends on how capable is BIM in facilitating the LCC. By showing the linkage between whole lif cycle costing data and BIM technologies, ((Kehily, Woods, & McDonnell, 2013), (Kehily, McAuley, & Hore, 2012) and (Redmond, Hore, & West, 2010)) have to a large extent shown the possibility of managing LCC data without affecting the existing method of estimation. Despite the likely informational inadequacy, still the fundamental of LCC, that is achieving viable alternative decisions ealier can be seen to be comparatively better. Because, there is more possibilities of accessing and retrieving informations in the documentation process. BIM gives necessary *performance requirements* data, that may trigger LCC calculations. Never the less, BIM improves data availability within the model and enhances the decision making process all along the project delivery (Krigsvoll, 2007).

According to (Nour, Hosny , & Elhakeem, 2012), with small level of operability, BIM facilited the optimization of energy performance in the facility life cycle cost With BIM, the challenges of data and uncertainities in LCC will be minimized because of the increase in collaboration,automation and availability of the various information of building participants in a digital form. Garba & Hassanain, (2004) provided that a *building information* is the critical element in AEC industry and Life Cycle Management (LCM), as it holds the connection between the design intentions and the reality. The communication breakdown of the building information can be equated to distortion of the reality. So the requirements data of the LCC process must be coordinated and communicated without distortion of the embeded reality. That is to say, the efficient *management of the building information* will influence directly the life cycle costing process.

> *"The fundamental problem of the life cycle process lies in the lack of effective frameworks for communication and the flow of information. Any initiative aimed at improving the performance of the AEC industry must therefore embody the sharing of building information. Computers and information technology offer unique opportunities for addressing the problems of the AEC industry in building LCM, and Object Oriented Computer Aided Design (OO CAD) is one of the technologies with significant potentials. Examination of the potentials of OO CAD shows that it can unify building information and provide a framework for the integration of activities, and coordination and communication across the AEC industry." (Garba & Hassanain, 2004)*

It was stressed that the *design and documentation* stages consist of structured information and team of professions brought together.This  is helpful for big decisions of the project, because of the different discipline and building information advantages available. Doing LCC decision at these stages may be more efficient and more beneficial. The *adequacy* and *sufficiency* of information from working drawings, specification, contract conditions and *bill of quantities*, depending on project compexities and delivery method are critical to the overall efficiency and effectiveness of LCM or the life cycle costing.

## V. Germany Construction Industry in Brief

### 1. Construction Contracts Overview

According to a (Welcome to Germany Portal, 2015) page, Germany Construction Industry is among the leading industries. Others are Health and Care, IT and Telecommunication, Automotive Engineering, Aerospace Engineering, Chemical and Pharmaceuticals, Medical Technology, Mechanical Engineering, Electrical Engineering and Electronics, Steel and Metal Industry, Precision Engineering and Energy and Environmental Technology. All these industries are linked to the construction industry, and as a result, the construction industry serves as an economic driver to generate prosperity. It remains to be a Germany pillar of the economy (Gornig & Michelsen, 2015). The construction volume calculations by DIW Berlin, forecasted that the value of construction in 2014 and 2015 were to grow far more rapidly than the economy as a whole, specifically by a price-adjusted 3.3 percent and 2.1 percent in 2014 and 2015, respectively. Residential construction being one of the important area. It was in plan to build at least 300,000 new residential properties every year (The German Institute for Economic Research (DIW Berlin), September 2013 - August 2014), if authorities could approve the demand.

Construction industry makes a major contribution in generating value and creating jobs in the German economy. The German construction industry is increasingly focusing on optimizing the energy efficiency of buildings and constructing. Energy-efficient and sustainable is a major focus in research and development offering new solutions of building materials and technologies in various areas like that of digital planning, construction, and integrated use of IT applications in construction. Economic policy-makers prefer existing buildings due to energy saving (ibid).

Anywhere in the world, building permit is necessary to erect a facility. In Germany, every construction project must comply with standardised specifications of zoning laws (preparatory land use and development land use), building regulations and all other public laws (Mütze, Senff, & Möller, 2012). Briefly, structures nature will determine the building permit, with some exceptions of general rule provided in the regulations to allow for fast track projects. Despite of building laws and regulations, other laws must also well be observed, inclusive of ecological or nature preservation, pollution control and protection of historical sites (ibid). So, it is a foremost important step to obtain a building permit before project implementation. Other related standardize procedures includes:

1. Competent authority to grant Building Permits

   The districts or cities are responsible for the enforcement and issuing of building permit. They are considered the lowest in the structure under respective federal building control authorities.

2. The Stages of the Building Permit-Issuing Process

   Depending on the state, filed and signed applications may include the general plan, site plan, building drawings, building descriptions, technical verifications (Stability, fire, heat and sound protection) and calculation of the cubic volume. The documents are signed by the developer, not necessarily a client or owner of the land. Another key person is the concept author, mostly experts like Architects or Engineers, but also technicians experienced personnel or trade masters can together sign the documents with the developer before taking them to the authority for further scrutiny.

3. Building Permit, Conditions and Collateral Obligations

   To ensure reliable wards of building permit, there are some collateral clauses provided in the regulations to guide the building permits from the changes of laws after release of the permit. Such additional provisions, ensure and allow the authority to issue permit subject to these conditions or collaterals and avoid rejecting permit for the sake of avoiding conflicting with public laws which can be technically and legally incorporated in the issued permit.

4. Enforcement of Law (Demolition Orders e.t.c)

   The authorities have also the power to take preventive action. If the building is being erected without new laws, lack of collateral incorporation or if the building project permit is violated and when the building is built without observing building regulations considerably, the authority may order demolition. Otherwise, prohibition and discontinuation of the works are also common intervention to prevent illegality and informality in the building project execution.

5. Challenging Decisions of Authority

   The developers have possibilities to challenge the authorities through preliminary procedures, administrative court procedures as well as challenging permits granted to third parties depending on intentions.

## 1.1. Construction Project Management

In German, the fundamental structural change that gave rise to unification construction boom in the first half of 1990s, resulted in drastic declines in building demand in the following ten years. It is said that out of ten largest construction firms in 1990 only two German companies (Hochtief AG and Bilfinger Berger AG) were in the list of the top 50 construction firms in Europe published by 2010 (Schultz, 2010). It was however accompanied by increase in a number of small companies. Despite the respect Germany has worldwide, it is common to find delivery problems just like any in construction sector in the world (Diekmann, Kröger, & Reimann, 2015). As such, the management of construction project is worth considered. In (Acker & Günther, 2015), the main parties involved in the construction projects mainly are Principal (developer or investor),General Contractor (main executor of the whole project),Specialist contractors and Planners (Architect, Engineers and others). Depending on the structure of the construction project, professionals are employed by a general contractor or the principal. If the works are executed by more than one contractor, the principal usually provides the design and supervision of the project. A contract between the principal and a general contractor is usually depending on *a basic planning (Entwurfsplanung)* and *a building permit*. Other arrangement are also possible.

> *“The legal relationships between parties involved in building project are normally classified as works contracts under the Germany Civil Code (Bürgerliches Gesetzbuch (BGB)), or as building contracts under the contract award procedure and contract regulations for building works (Vergabe-und Vertragsordnung für Bauleistungen (VOB)). The essence of a building contract is to produce a contractually determined result, in this case the construction of a building. In contrast to this, the subject of the service contract (BGB) is the work as such or working. (Neufert & Ernst, 2012)*

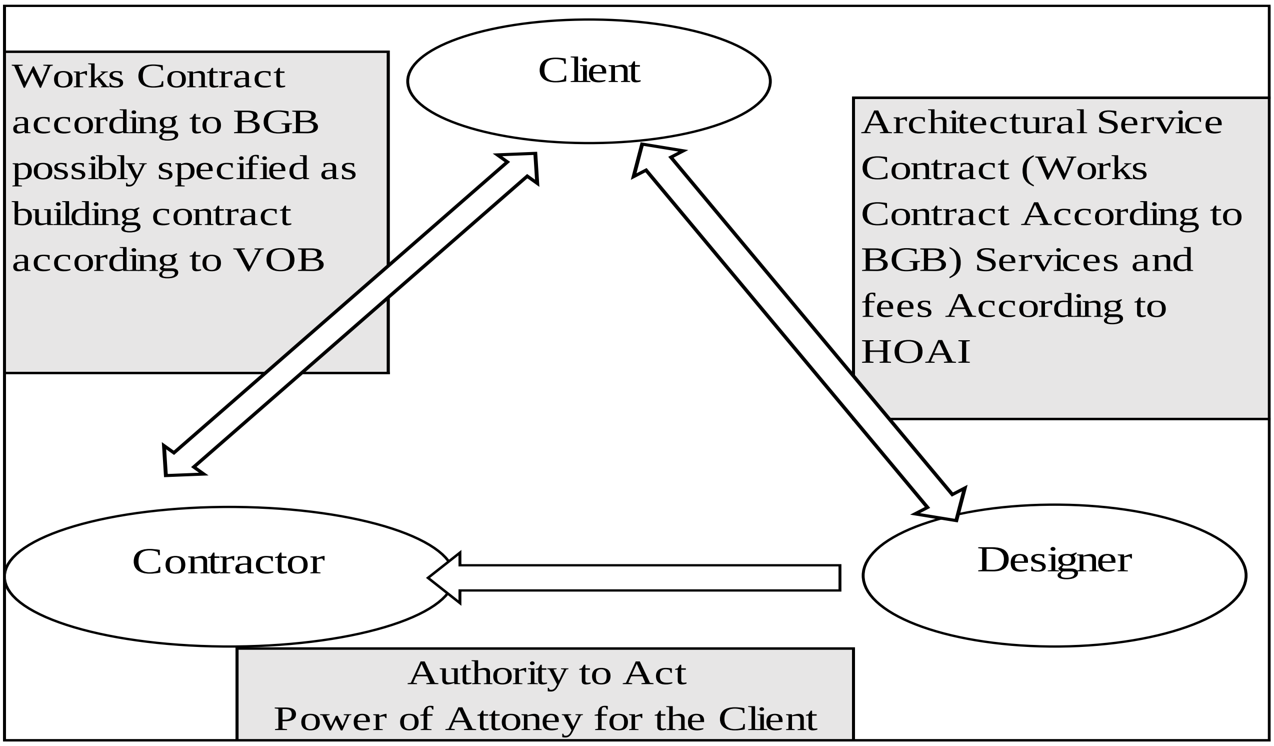



**Figure 52: Principal legal relationship between the parties in a building contract[68]**

Award of Public Works Contracts, is guided by Part A (Vergabe-und Vertragsordnung für Bauleistungen, Teil A) (VOB/A) and the Act against Restraints on Competition (Gesetz gegen Wettbewerbsbeschränkungen) contain rules on the procurement of contracts in accordance with EU competition law standards. If all parties are international, international procurement arrangements like engineering, procurement and construction (EPC), engineering, procurement and construction management (EPCM) and design-and-build contracts used. For local construction projects, the parties to a contract usually refer to VOB/B, which contains specific general terms and conditions for the execution of the construction works.In private contracts, private parties are free to choose their contractual agreements and procurement models such as guaranteed maximum price (GMP) contracts.

### 1.2. Architects and Engineers and other construction professionals

In Germany, the scope of works for Architects and Engineers is classified in HOAI. It is divided into several phases, commonly being; Planning of a Building Project which relates to planning of building works (section 15 HOAI), Planning of Engineering Structures and Traffic Systems (Section 55 HOAI),Planning of Structural Engineering (Section 64 HOAI), Planning of Technical Equipment

[68] Source: Neufert & Ernst, (2012)

(Section 73 HOAI), and Planning of Heat Insulation (section 78 HOAI) (Mütze, Senff, & Möller, 2012). In Planning of a Building Project, the Architects are expected to cover the basic services and special services. Basic services include those necessary for proper performance, while special services involves those necessarily added works to support contract performance. This section briefly covers works on new buildings, reconstruction and extension works, the addition of storey, conversion and modernization work, extensions or conversions to create rooms, maintenance and repair work as well as on outdoor facilities.

In Planning of engineering Structures and Traffic Systems, contractor's work on new buildings and new plants, as well as reconstruction, extension, conversion, modernization, maintenance and repair work are covered. While on Planning of structural engineering the work relates to proof of stability and design works, in Planning of technical equipment ensures performance with regard to the demand for heat, cold, air, electricity, water ,air conditioning systems, elevators as well as medical and laboratory systems and the like. That is only technical supply and disposal of facilities in building and engineering structures. Never the less, planning of heat insulation section has special consideration to heat losses and thermal conductivity to both building and engineering structures.

> *" HOAI (Honorarordnung für Architekten und Ingenieure-) or (Fees regulations for Architects and Engineers). This document controls the invoicing of fees for the services of Architects and Engineers. The Architect or Engineer, to each of which a percentage of the total fee is assigned (services performed in each phase, bases the fee on the zone to which a building project has assigned the chargeable costs (according to the table) and the work phases undertaken. In each of the work phases, there is a differentiation between basic services, which are performed as part of the proper performance of the service, and special services, which are separately ordered and invoiced to fulfil particular requirements (e.g. building remeasurement)" (Neufert & Ernst, 2012)*

Work phase in section 15 of planning of building project commonly contain nine (9) categories. The first is the ***Basic planning concept.*** Under this phase the basic services focuses on advising and explaining the preconditions necessary to smoothly undertake the project. To clarify the needs of the client and the ideas concerning the work. Though not necessarily done by Architects, still they may be required to do the job. Which means Architects will have to determine the prerequisite to project plan like, right financial requirement, right assistant specialists and many other advises of which, client may claim for damages if not well advised. Special services includes description of the existing situation of the building. All *information necessary for smooth taking off* with the new building project.

The Preliminary Planning involves the development of planning concept including an examination of *alternative options meeting the same requirements* which considers wishes of the clients and users. At this stage, clients should *view clearly the project image* (though roughly), should get the preliminary estimate, should also know the likely team members and it is the time to seek approval of the project from the authorities. Special service may include application for a preliminary building permit. Normally the *drawings are not so accurate*. Next is a Final Design Planning. The concept is turned into real drawings and incorporating the inputs from other specialists. Additionally, the *cost calculation is more accurately done*, although still basing mainly from experience.

The Building Approval Planning, is basically preparing and sending the complete planning documents to the authorities to assess if the meet the *public laws* requirements. Here all other *key specialists* involved are required. Special service includes to help client to get the consent of the neighbours and preparation of the documents for special examinations procedures. Sometimes architect demand more fess for this service. In the stage of Implementing Planning, preparation of drawings and all necessary information, and taking all consideration necessary during implementation is finalized. Special service may be providing specifications, which is describing design and equipment in words and not drawings.

Preparation of Contract Awarding follows, where the quantities required are to be determined and put together as a basis for the preparation of specifications and bills of quantities. The specifications for the different areas need to be *coordinated, unambiguous and clear.* The Architect must prepare the contracts and give advice on the various forms of calls for tenders but this does not constitute formulating the construction contracts, as this constitutes giving legal advice which is not part of his job. Another stage is Contract Awarding. Specifications with Bills of Quantities are now compiled to make up tender documents. The architect may sign on behalf of the client if he is contractually allowed provided the tender is economically and technically acceptable basing on the scrutiny of the documents.

The Supervision of the building project intends to ensure that the building is built without defects and according to the plans. Architects are required to directly supervise the works, something which is not easy. It is common practice to record all important information with regard to the performance of the works, from delivery of building materials to acceptance inspection of the performed works. In Supervision of final work and documentation, Architect will provide the *necessary documentation for the maintenance* and thereafter keep an eye on the building and minor rectification until the limit of the warranty of the construction company. Architects in Germany are trustees of the client from inception to completion of the project, even in documentation (BDA, Committee of Foreign Affairs, 2011)

| | % Fees | Work Phases | Number |
|---|---|---|---|
| Design | 3 | **Preliminary Information Inquiries**: Collection of the basic Information. Defining the exact project scope with the Client. Depending on size. | 1 |
| | 7 | **Preliminary Design.** Sketch design and project feasibility in a preliminary consultation with the local authorities and prepare a first cost estimate | 2 |
| | 11 | Scheme Drawings development | 3 |
| | 6 | **Building Permit Application**. Documents necessary for the building application are prepared | 4 |
| Construction | 25 | Detailed Drawings Design | 5 |
| | 10 | Preparation of Tender Documents. Bills Of Quantities and Performance Specification | 6 |
| | 4 | Collaboration in Tendering. Participating. Tender Evaluation and Award Recommendation | 7 |
| | 31 | Supervision of works. Site handover and Contract Administration | 8 |
| | 3 | Supervision of Snagging and Documentation. Project commissioning and Handover to the client | 9 |
| | 100 | | |

**Figure 53: Distribution of fees in Percentage Phases of Architects according to HOAI[69]**

[69] Source: Neufert, P., & Ernst, N. (2012)

## 1.3. Construction Contracts Documentation

The current projects, have witnessed the need for project manager due to the increased complexity of the building projects. Clients have demanded more inputs in the construction projects. In particular, with regard to control, coordination, information and commercial aspects. In Germany this has been recognized by HOAI, and the project management or client position is set with fees regulations, relative to all tasks that were formerly being done by the project clients. The construction contract requires that the contractor fulfills *individual necessities* and *contractual necessities* successfully, in order to be remunerated. Although (Buergerliches Gesetzbuch (BGB)) which is a general law on contracts for works and services is also used in minor construction works, still the construction works due to its complexity requires incorporation of specific contractual arrangement that can safeguard the interests of contractors and clients suitably.

In Germany, the award and contract for construction works follows (Verdingungsordnung fur Bauleistungen (VOB)), and it is divided into three section. *PART A* refers to General Provisions on the Awarding of Contracts for Construction Work, *PART B* is for General Contractual Conditions for the Performance of Construction Work and *PART C* deals with General Technical Contractual Conditions for Construction Works. While VOB/A deal direct with materials provisions, VOB/B and C are crucial for performance conditions technical requirements. VOB/B are claimed to balance the interest of parties especially inexperienced, so they are sensible rules to be at the outset of the contract because the absence of simple facts of it may as well mean absence of all VOB/B. Whenever this (VOB) is opted as integral part with BGB, the VOB is superior. It is believed that even other international provisions like FIDIC (International Federation of Consulting Engineers) are insignificantly prioritized over VOB.

> *"the VOB (contract award procedure and contract regulations for building works) is neither law nor legal regulation but represents freely agreed contract rights, which amend or add the provisions of the BGB (Germany Civil Code), from whose provisions it varies in essential areas (practical completion, defect claims, payment).Federal authorities and many public clients are obliged to apply the VOB in the tendering and contract award procedure of building works." (Neufert & Ernst, 2012)*

In Germany, contractors are categorized as General, Prime, Subcontractors and other variation of these. General Contractor *(Generalunternehmer)* provides all construction work and services and perform the *major* part of the construction, while a *prime* contractor is not necessarily responsible for the major or minor works. The *prime* contractor can sublet to *Subcontractors*, all of the works and remain only contractually obliged to achieve success desired. To give the principals or clients the advantages of single point responsibility, there is *General Planner and General Contractor and General Planner and Prime Contractor*, where the general/prime contractor is awarded the contract with all the planning of the construction project, sometimes with additional compensation for the coordination services and risks of liability. It is also possible for several companies to form an association or *consortium* and tender as a contractor for very complex project. For instance, PPPs arrangements are common in Germany (Acker & Günther, 2015) and usually aiming at decreasing the funding costs of the developers to the level of the public debt.

The common contract arrangement in Germany include Unit Price, Lump-sum, Partnering Contract and Guaranteed Maximum Price contract. The Unit price *(Einheitspreisvertrag)*, is where the work starts with *Approximate Quantities (BOQ)* from the drawings (more or less as assumed quantities).The *principal* use Bills of Quantities (BOQ), to select the contractor basing on the reasonable tender sum resulting from the assumed quantities and unit priced items. The works is re-measured at the end to find out the actual performance and remuneration. Lump sum contract (*Pauschalpreisvertrag*) is divided into a Detailed Lump sum (*Detailpauschalpreisvertrag*) and Global Lump sum contract (*Globalpauschalpreisvertrag*).Detail Lump-Sum Contract, is when the principal details the work and services to be provide by the contractor for each item in the same way as with unit price contract. However, the items are priced in total, **regardless of the unit prices** at tender stage. The **actual quantities is not the basic base** for the remuneration of the contractor. Tender price paid basing on the performance of the **individual items** irrespective of the unit prices. In Global Lump sum contract (Globalpauschalpreisvertrag), the descriptions of the works and services is ***lesser detailed*** compared to unit price. Tender can be called basing on the functions of the structure only. The payment is done basing on the **total tender price** and **total performance** of the works and services tendered.

In (Gralla, 2011), simple Global Lump-sum (Einfacher Global-Pauschalvertrag) is also differentiated from the complex one (Komplexer Global-Pauschalvetrag). Simple is detailed at the level of detailed lumpsum explained above and the details are describe within bills of quantities. As such the BOQ is not very accurate. *Complex Global Lump sum*, refers to an arrangement where *performance details* are produced at outset more accurately than in simple and the bills of quantities items holds contractual liability in full, as it was insisted ***"Was näher bestimmt ist,bleibt bestimmt",*** here interpreted whatever was agreed remains the same.

In North Rhine Westphalia (NRW), the association of the building Industry (Bauindustrieverband Nordrhein-Wesfalen) is practicing Partnering Contract, where the client/principal and the contractor are jointly planning the construction project at early stages. The aim is to refine and match the budget to the project objectives, and to award the work to subcontractors and handle its construction in partnership basis. If proved worthwhile, the method can be adopted countrywide. Never the less, mostly the methods are mixed to cover weaknesses of each.

### 1.4. Contractual Obligations, Performances and Remuneration

The agreed contract prices, normally covers all the works and services and the performance is with respect to conditions of works VOB in particular, and common practice in the industry. There are contractually owed works in VOB/B and also some works that are not expressly mentioned in specification, and yet the contractor must perform in accordance to common practice of the industry. Evaluation between the two works is ***mostly a matter of judgment of individuals***. Clients and contractors rights are equally stipulated with allowance of external expertise intervention in case of agreement, such as on new rates for the change orders or modifications. Despite the written and unwritten obligations, as in VOB and various code of conduct, contractual parties are expected to abide with **Duty to Co-operat**e basing on a principles of ***Good Faith***. That is respect each other, inform, collaborate and if possible opt for conflict less action. In (Jaeger & Hoek, 2010) it was said that there is no *legal definition* of the word contract, and the contract law interpretation are subject to the requirements of good faith, taking common usage into consideration.

Among other things, the performance of contracts requires observation for deadlines. Verdingungesordnung für bauleistung (VOB) recognizes binding (*Contractual Deadlines*) and *non-binding deadlines*. Binding deadlines are expressed in the contract and can be *intermediate deadlines* from the relative general schedule of works of the contractor, and they can even be subjected to *liquidate damages claim*. On the other hand non-binding deadlines are only helpful in controlling the works progress, their enforcement requires the client to first alert the contractor as stipulated in the contract. Likewise, it is the case of warranty period or defects liability period. The contractor must remedy the defects in the work, unless it is contractually agreed that the causes are out of contractor's work execution. In principle, warranty can go to *five years in building structures* or *even to ten years in case of materials likely to be affected with water.* Never the less, an important note is that under Germany law, penalties are enforceable for late completion, as (Morledge & Smith, 2013) insisted.

The installments and final payments covered in Section 16 VOB/B, provides that rough estimates can be used to *provisionally* pay the installments and the final payment requires final examination and approval of the work. Delay of payments ***may*** lead to discontinuation of the work by the contractor. On the other hand, it is provided that Performance, Prepayments and Warranty guarantees *have no statutory rights* and so must be agreed beforehand between parties, a care should be taken with regard to on *first demand* requests.

## 1.5. Facilities Procurement

Procurement in Germany starts to European Union directives. In Germany, European public procurement law is applied above certain values. Under European directives, there is Germany Act on Restraints on Competition (Gesetz gegen Wettbewerbschränkungen,GWB). This regulates who the *public contracting entity* is and stipulates the legal protection possibilities in the event of award infringements for contracts above the thresholds. Below, is Regulations on the awards of public Contracts (*Verodnung ueber die Vergabe Oeffentlicher Auftraege (VgV))* stipulating the contracts values above which the provisions of the GWB have to be observed and therefore when European call for tenders has to be issued (thresholds).IR also lays down which section of the national Contracting Rules for the Award of Public Works Contracts (*Verdingungsordnungen* [VOB/A, VOL/A and VOF]). *[VOL/A is Verdingungsordnung fur Leistungen Teil A and VOF is Verdingungsordnung für freiberufliche Leistungen]. (See Figure 54: European and National (Germany) Public Procurement Law)*.

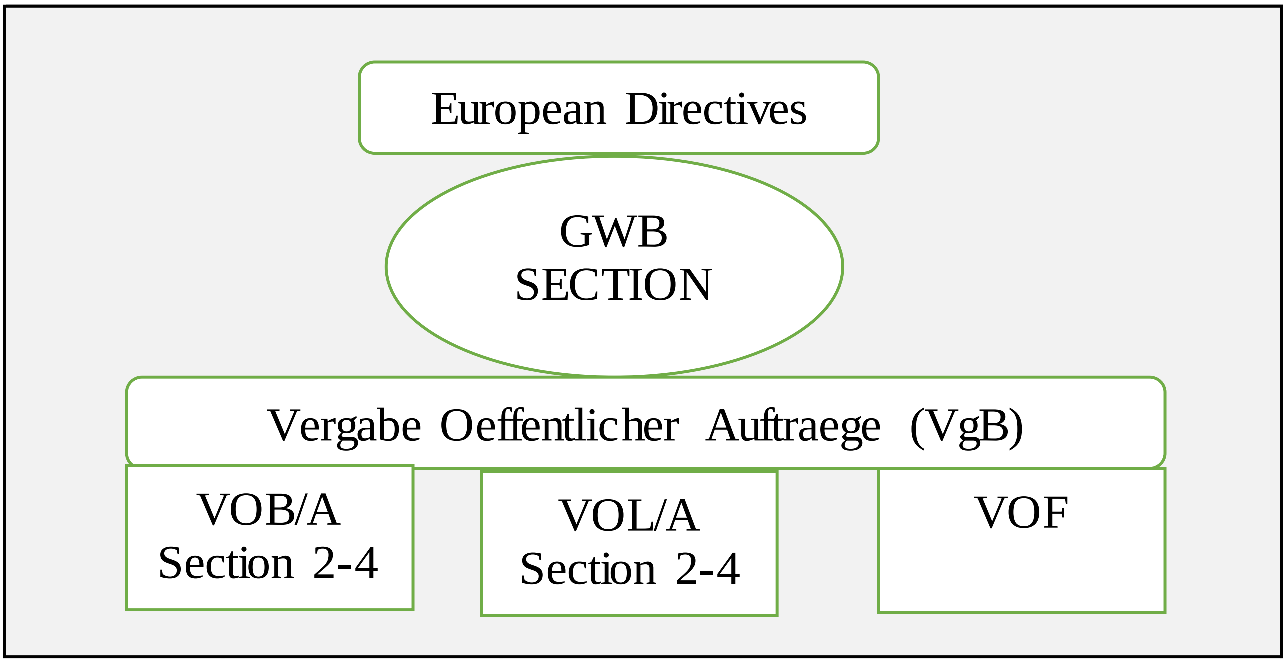



**Figure 54: European and National (Germany) Public Procurement Law**[70]

The Awards of Tender are strictly to regulation requirements inclusive of *time* limits. In complex projects 52 days may be given to tenderers to prepare the tenders, but mostly depends on the method used. Assessment of tender go through four crucial stages. Formal examination of submission conditions, suitability examination of mathematical errors, examination of price reasonability

[70] Source: Modified from Mütze, M., Senff, T., & Möller, J. C. (2012). Real Estate Investments in Germany: Transactions and Development: Transactions and Development (2nd Edition). New York: Springer-Verlag Berlin Heidelberg.

(reasonable is within 10-15% over or below of *award office* cost estimate) and determination of the most economic tender (weight of criteria used in assessment matrix, which are to be published). On the award there is legal protection to both contracts below the threshold and contracts above threshold.

Managing real estate over its life cycle has been limited to operation phase (Mütze, Senff, & Möller, 2012). By not involving the services companies in the planning phases of revitalization and new construction projects, investors are denied chance of reducing more than 25% of the annual operating costs. Examples of operating costs typically charged are fire protection,Gurding and security,garbege disposal,heating,ventilating and hot water,water and waste water systems,cleaning and lighting, building elctrics and telecommunications, property insurance, third party liability and special insurances, transportation equipment, communal facilities, staff costs, and the like.

## 2. Bills Of Quantities in Germany (Bau-Leistungsverzeichnisse)

### 2.1. Contractual Base of BOQ

VOB (*German:* “Vergabe- und Vertragsordnung für Bauleistungen”) is the standard document that governs the award procedures, execution conditions, and standard practice of construction works in Germany (Beuth Verlag GmbH, 2012). Making it clearer, (Klee, 2015) said part A(VOB/A)deals with procurement,part B(VOB/B) deals with executin of the works and part C (VOB/C) is about technical standards.

> *“According to (Neufert & Ernst, 2012), the BOQ are normally supplemented by preliminaries in the form of general and general technical contract conditions (VOB/B and VOB/C),additional and additional technical contract conditions from the clients who regularly award building works and special contract conditions, which regulate conditions for special cases.”*

VOB is an integral part of the DIN (Deutsche Industrie Norm). DIN standard that explains guidance and numerical examples. DIN is relative to Eurocode which is a result of the unification of Europe. Public clients are obliged to follow the rules and regulations of VOB, for construction procurement but Private clients are not compelled to use building materials approved by DIN.

The German DIN standards (DIN 276, 277 and 283) are the base for the initial budget on design phase. The used guideline is called *Hochbaukosten Flächen Rauminhalte*. Another handbook *Arbeits- und Kontrollhandbuch zur Bauplanung, Bauausführung und Kostenplanung nach § 15 HOAI(Honorarordnung Für Architekten und Ingenieure) und DIN 276,* which is a manual helpful in initial estimate, contains present cost data, comments on the DIN standards and guiding principles for structural design. This manual categorises the project into three quality or luxurious levels. The HOAI-manual (Honorarordnung Für Architekten und Ingenieure) is a base used by the client and architect or engineer to agree on the level of fees and payments. According to HOAI the building project complexity is in five categories. This complexity level and the budget estimate (by Hochbaukosten Flächen Rauminhalte) are bases for the fee that an Architect deserve.

HOAI, is the central document in agreements between the client and architect or engineer. In Germany, the remuneration for architects and engineers is related to the ***total costs of the project*** and is regulated according to HOAI. In essence, higher *total costs for a project* may lead to higher remuneration and it is said that this has been questioned and various alternatives have been discussed on how to model fees of consultants. Neufert & Ernst, (2012) stressed that, primarily the HAOI focus is the on the new works and rebuilding. The fees are governed by the maintenance measures, repair measures, modernization measures, rebuilding works, extensions, recreation and conversion.

> *"It should be note for all work on existing building that the HOAI is primarily intended for new building and rebuilding. HAOI is **not** adequate for production of a **resilient design** with varied uses and their effects on **cost** and listed building protection. The **appropriate** preliminary investigations (**measurement** and the surveying of defects), and the ensuing use concepts and variants with **cost breakdown**, should therefore always be agreed as **special services** or better, in order to give the client **design security** before the start of the project. The absence of such design foundations is one of the main reasons for **exploding costs in refurbishment works**". (Neufert & Ernst, 2012)*

In Germany, a client can use direct order or negotiated tender (only small or specialized project for Public), selective or limited tender (mostly private clients and commercial investors) and open tender (mostly public clients). Private clients and commercial investors (industrial or commercial companies, banks, insurance companies, and building societies) often use the form of selective tender, inviting only contractors well known for efficiency and to whom they have good, long-term relations. Bids are normally set according to a ***bill of quantity*** (BOQ).

### 2.2. Standards Used in Preparation of Bills Of Quantities (BOQ)

In Germany construction projects, is guided by the DIN standards. In (Gralla, 2011) DIN 276-1:2008-12 and DIN 18960:1999-08 standards were mentioned as guiding documents in costing effort in project delivery. DIN 276 is about initial costs from inception to handover (*Die Kosten ab Beginn der Planung über die Realisierung bis zur Abnahme sind Gegenstand der DIN 276-1*). Onthe other hand, DIN 18960 (nutzungskosten im Hochbau) is focuses on the operational costs (Die DIN 18960 umfasst die Kosten für die Betriebe eines Gebäudes).These standards include new and non new construction. The intention is to guide the projection of whole construction costs.

The cost structure and assessment of DIN 276-1 standards is categorized into three major groups (Kostengliederungen abbreviated as KG), (Gliederungsebene nach 276-1 *basisgliederung*), (Gliederungsebene nach 276-1 *Grobelemente*) and (Gliederungsebene nach 276-1 *Feinelement*). In the first group, the basic level of construction element are categorized into KG 100 Grundstück (Site Premises),KG 200 Herrischten und Erschließen (Mobilization),KG 300 Bauwerk-Baukostruktion (Building works and Building Construction), KG 400 Bauwerk-Technische Anlagen (Building Work-Technical Installations), KG 500 Außenanlagen (External Works), KG 600 Ausstattung und Kunstwerke (Furniture and Decoration) and KG 700 Baunebenkosten (Construction overheads). The second group consists of elemental breakdown and it usually take the reference from the first group, as shown in the figure below. Likewise for the third group. In the *user costs groups* of the DIN 18960, there is KGR 100 Kapitalkosten (Capital Costs), KGR 200 Verwaltungskosten (Management and Administration Costs), KGR 300 Betriebskosten (Operational Costs), and KGR 400 Instandsetzungskosten (Maintenance Costs).

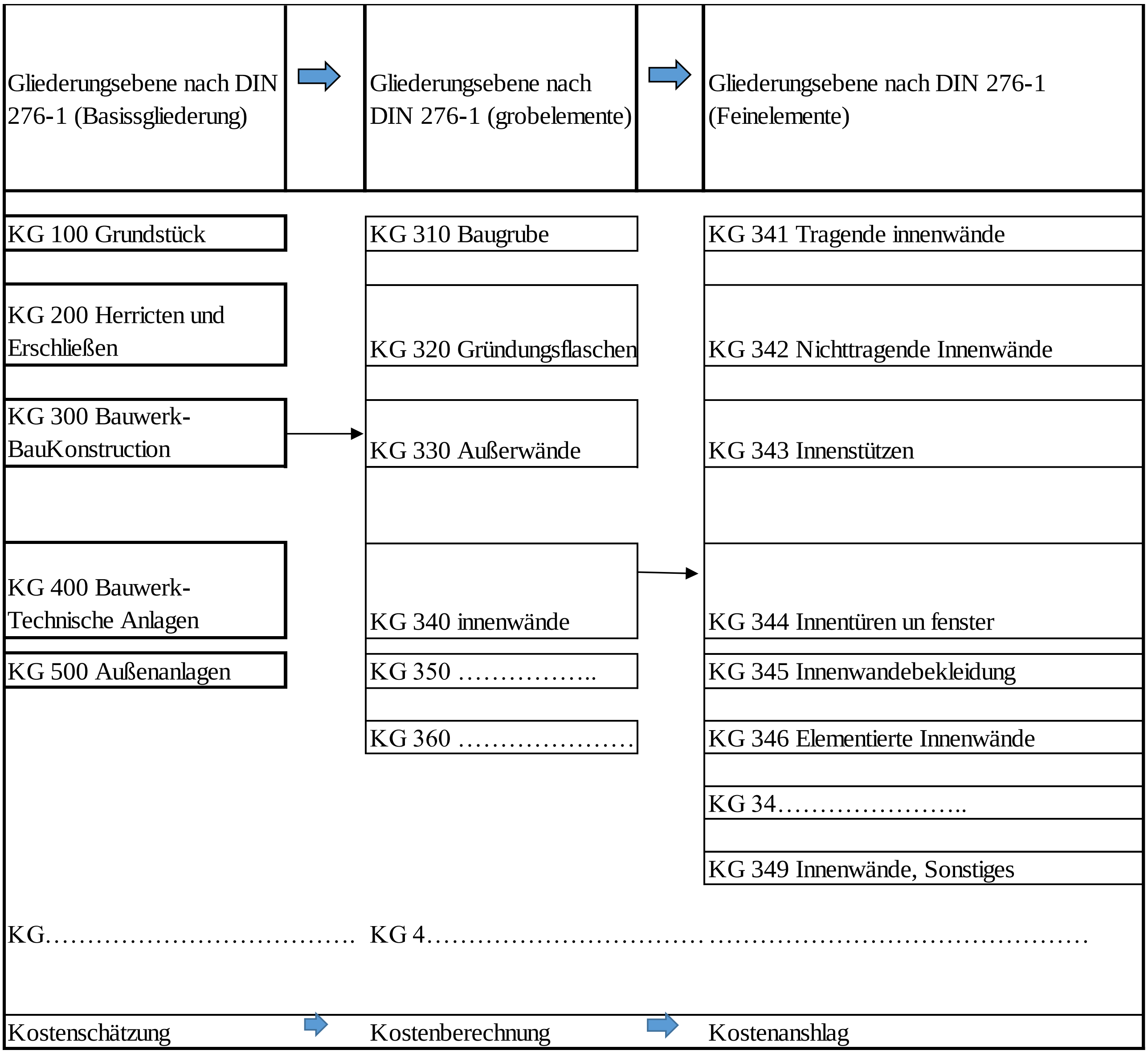



**Figure 55:Example of the grouping of the Cost Structure in Germany (DIN 276-1)[71]**

[71] Source: Gralla, M (2011), Page 59

In (Hagmann & Stoy, 2011), DIN 276-1: Building costs – building construction" [DIN 2008-12] describes cost groups and the measurement of quantities are defined in detail in the Germany standard known as "DIN 277: Areas and volumes of buildings" [DIN 2005]. In addition, there are published cost indicators for building construction costs .Example is those from Building Cost Information Center of German Architectural Associations (BKI 2011) (see the examples in the figure below). These standards are helpful in all common types of projects, that is social infrastructure (Institution and Offices) and technical infrastructure (Transportation and Communication). The documents facilitate verifying correct measurements of quantities (DIN 277) and the correct cost grouping ( DIN 276 and DIN 18960). Using DIN 277, one can arrive at the quantitative factor (say area of the floor and how to calculate it) that when multiplied by the cost factor (derived from the DIN 276 categories of facilities) the cost estimate can be found. To put it otherwise, DIN 276 will guide a professional to find the standard cost per unit of the quantity measured. The quantity intended here is the DIN 277 based or overall building area/interfacial area and volume (*die DIN 277 definiert Flächen- und Volumenbegriffe, Die normengerechte Anwendung der Berechnungsregeln ist Vorrausetzung fr eine richtige Kostenermittlung, ((Gralla, 2011),page 69)*).With regard to national standards, Germany is one of the best out of European nations (Morledge & Smith, 2013). Stressing the point, they said,

> *"in France everything is permitted; in England everything is permitted unless it is expressly forbidden; in Germany everything is forbidden unless expressly permitted"*


| Example (a) | Example (b) | Example (c.) |
|---|---|---|

**Figure 56: Building Cost Information[72]**

[72] Source: Own Collection from *Google Search*

In (Neufert & Ernst, 2012), DIN 277 contains parameters for the calculation of floor areas and room volumes of the buildings. The parameters are calculated on the basis that it is either roofed over and enclosed on all sides, roofed over but not enclosed on all sides and not roofed over. The gross floor area, is the sum of the plan area of all levels (without usable roof areas), measured between the external dimensions of the surrounding building elements at floor height. Under areas, various categories are found. The construction floor area plan area (minus building element like columns) measured between external dimensions at floor height, Net floor area is the sum of usable area serving the building purpose (without doors, windows and the like cuts) measured at floor level and technical function area (rooms for building services, such as utility connection room, accessible shafts,etc). The gross built volume refers to the net floor area multiplied by relevant clear height.

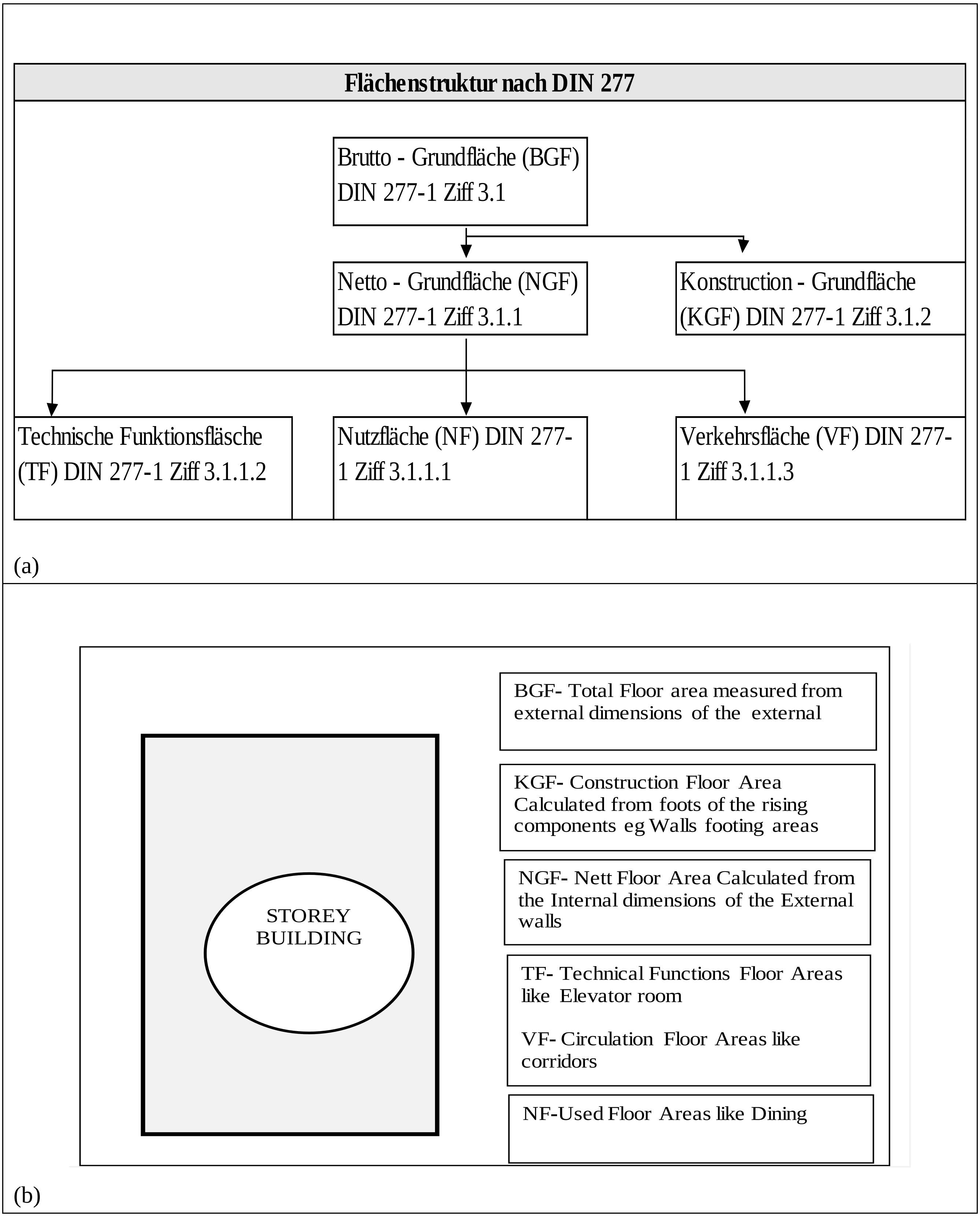



**Figure 57: Illustration of the Areas definition as per DIN 277[73]**

[73] Source: Adopted and modified from the works of Gralla, M. (2011),Page 69-72

### 2.3. Contents of Bills Of Quantities (BOQ)

According to (Morledge & Smith, 2013), Germany regulations governing constructions projects in all federal states, which include method of tendering for public works, model conditions of contract, standard specification clauses and performance standards for all major building elements, together with guidelines for measurement are published by the government. Architects traditionally carry most of the pre-contract activities including approximate cost estimate and preparation of building performance specification (Leistungsverzeichnis or Bills of Quantities (BOQ)). Architects or Engineers (Building/Civil works respectively) usually prepare BOQ in small project, while in large projects a lump sum is common option, and so performance specification is used or on rarely large projects, BOQ may be used but the quantities are contractually left at the risk of the contractor. A good point, from the practice of Bills of Quantities documentation in Germany, is that often contractors are asked to submit together with their tender sum, the detailed breakdown of the ***rates*** that is a breakdown showing materials, labour, plants and overheads. This can be done also in preliminaries.

In (Neufert & Ernst, 2012), software are facilitating production of model BOQs because the field is linking the tender data with detailed design. Presence of standard bill item, makes BOQ production easier. It was stressed that, the model BOQs contains many of the constructional solutions texts. The notes for the production of the BOQ and Specifications according to (Neufert & Ernst, 2012), include.

- *"**Scope** of the application (terms, definition of trades, differentiation from other trades)*
- ***Materials/Building elements** (definitions of the quality conditions for the materials and building elements to be used according to DIN standards*
- ***Construction** (definition of the standards for the construction with reference to current DIN standards)*
- ***Ancillary works/extra work** (differentiation of ancillary work (without extra payment) and extra work)*
- ***Invoicing** (invoicing regulations, units, re-measurement, deductions etc.)"*

According to (Halpin & Senior, 2012), an estimate depends on the quantities and prices of the project scope definition of the components. Common levels of estimating precision is categorized into conceptual, preliminary, engineering and bidding level. In Germany, the same can be seen. In (Gralla, 2011), it can be followed that, the breakdown of cost is staged from system to components of the building. The grouping of the work using VOB and DIN standards ensures that the multi-hundred items are not repeated in the BOQ and are systematically presented. The basics are not different from all over the world, except for some contents, where the BOQ (BauLeistungsverzeichnis) may contain additional items. In Germany, contractors are supposed to be familiar with cost estimates because they are required to submit the breakdown of their rates together with their Bid. The common columns are items (Position), Quantity unit (Mengen), rate (Einheitspreise) and amount (Gesamtpreise). In the preliminaries, the labour, equipment, and overheads.

| PAGE | ITEM | DESCRIPTION | LABOUR | QUIPMENT | OVERHEADS | STATUTORY COSTS (Special Order) | TOTAL |
|---|---|---|---|---|---|---|---|
| | | Time independent | | | | | |
| Page 1 | C | Methods of measurements | 100,000 | | | | 100,000 |
| Page 3 | B | Description of the site | 300,000 | | | - | 300,000 |
| Page 4 | C | Materials excavated from the site | 200,000 | 300,000 | | - | 500,000 |
| | | Time dependent | | | | - | - |
| | C | Inspection by the engineer | 500,000 | | | - | 500,000 |
| Page 7 | B | Disturbance or nuisance | 100,000 | 100,000 | | - | 200,000 |
| | D | Protection from weather | | 200,000 | 50,000 | - | 250,000 |
| | | Progress related costs | | | | - | |
| Page 8 | A | Tools | 3,000,000 | 60,000,000 | 1,000,000 | - | 64,000,000 |
| | B | Site accommodation | 1,500,000 | 3,000,000 | | - | 4,500,000 |
| | D | Water for the works | - | - | | 2,000,000 | 2,000,000 |
| | E | Lighting and power for the works | | | 200,000 | 400,000 | 600,000 |
| | | TOTAL | 7,860,000 | 67,200,000 | 5,350,000 | 2,600,000 | 83,010,000 |

**Figure 58: Example of BOQ Preliminaries Costs Breakdown**[74]

[74] Modified from Gralla, M. (2011). Baubetriebebslehre Bauprozessmanagement. Deutschland: Werner-Verlag

The specification of the construction, is either with *programme* or with *Bill of Quantities* (*Leistungsbeschreibung (LV) mit Leistungsverzeichnis (§ 7 abs.9-12 VOB/A )* ) or (*Leistungsbeschreibung mit Leistungsverzeichnis (§ 7 abs.13-15 VOB/A )* )(Gralla, 2011). The latter is what, comprises of the more accurate costs breakdown of costs during tendering. When programme used, the aim is to describe functions in such a way that technical, economical and creativity can well be acquired and observed in the project delivery. The construction programme is accompanied by the requirements in detail to allow approximate estimate of basic costs that can help contractors in deciding whether to tender on not, and probably giving alternative design advice to the client.

On the other hand, when the breakdown of costs is used, the aim is to give both the client and contractor the ability to control costs during construction. The construction t process is broke down into components measurable in quantitative and descriptive quality. The quality is described through standards (*standardleistungsbuch-STLB-Bau*) and manually. The works is categories into different levels and positions in order to standardize and facilitate the understanding and communication of information among the players in the industry. The focal point of the measurement is to the smallest component that can accurately be described and measure with utmost easiness and precision to give the most optimal unit price (see figure below).The format of the document is almost international, with items (Ordnungzahl), description (Texte), *quantity and unit* (Mengenheit), rate (Einheitspreise) and amount (Gesamtpreise) columns with the exception of the references or items. These differ with the position and detail of the measurement.

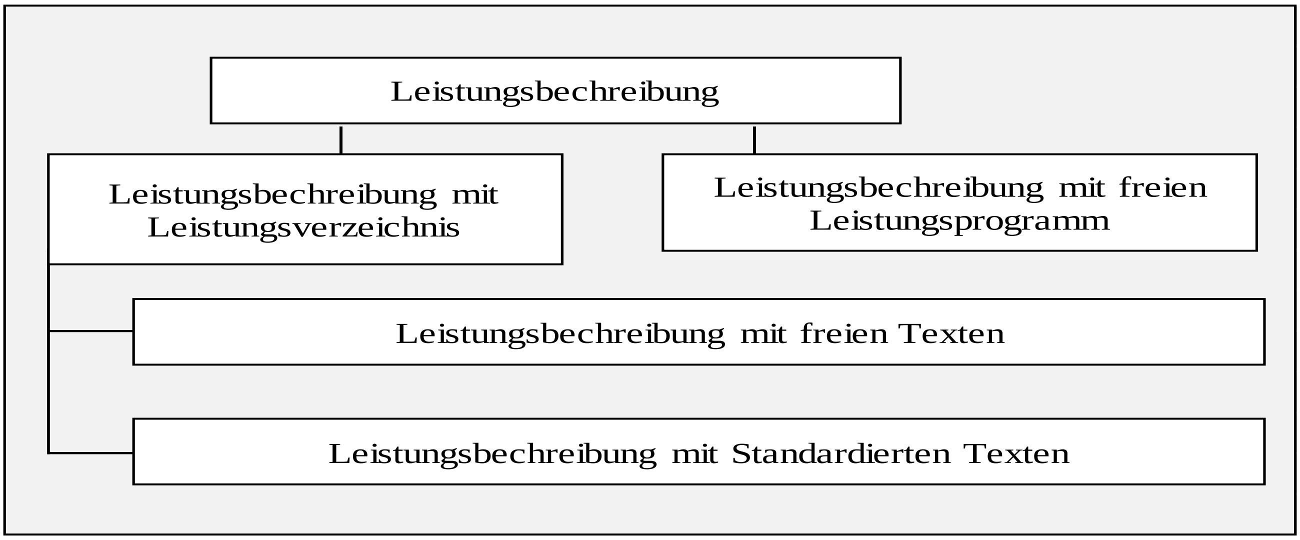



**Figure 59: Ordnung einer Leistungsbeschreibung (Order of Performance Specification)** [75]

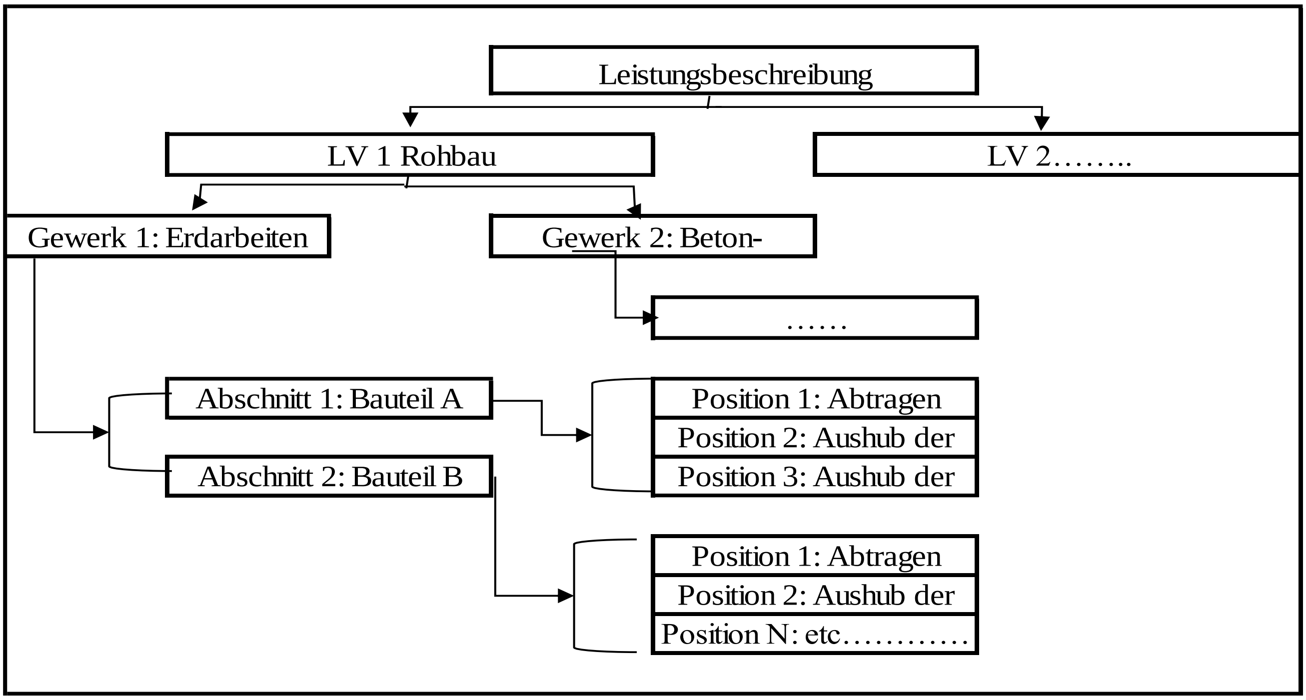



**Figure 60:Breakdown of the Construction Works Specification (example)** [76]

[75] Source: Modified Using Brandt, T., & Franssen, S. T. (2007). Basics Ausschriebung. Berlin: Birkhäuser. both versions, Germany and English.

| **OZ** | **Text** | **PA** | **Menge** | **ME** | **EP** | **GP** |
|---|---|---|---|---|---|---|
| 01.02.02.0001a | ...Randschlung Deckenplatte….(Formwork Floor Slab) | | 50 | m | *1,000* | *50,000* |
| ***NOTE:* Index a** | *Is used to categorise an alternative specification* | | | | | |
| **OZ:** | Ordnungzahl (Number) | **Los (Lot)** | **Gewert (Trade)** | **Titel (Title)** | **Position (Item)** | **Index** |
| | | 01 | 01 | 01 | 0001 | a |
| **Text** | Beschriebungstext (Kurz und Langtet) Short and Long Description | | | | | |
| **PA** | Positionsart (Item Type) | | | | | |
| **Menge** | Die aus den Plänen ermittelte Menge gemäß ME (The Quantity worked out from the plans in terms of UQ) | | | | | |
| **ME** | Mengeneinheit (Unit of Quantity | | | | | |
| **EP** | Einheitspreise Preis für eine Einheit) (Unit Price or Price for a unit) | | | | | |
| **GP** | Gesamptpreise je position (Einheitspreis x geplante Menge). Total Price per item (unit price x planned quantity) | | | | | |

**Figure 61: Example of the definition and position of the contents of the BOQ breakdown**[77]

Two challenges seem to be addressed by the construction costs system of Germany are the display of breakdown of the rates and the description of the life cycle costs in documentation. However the construction documents dealing with components are not openly displaying the inclusion of the life cycle costing. As such, life cycle costing remains to be a key talk despite the use of standards. Likewise the, the importance of time, is very clear, but only separated by the documentation systems. When detailed breakdown of costs is used, time is not of primary use, and the opposite is true. Unless the three areas are clearly and precisely joined together, the linkage and flow of the information from incept demolition of the facility and among all players, will still need significant improvement. The system is still needed that can bring together the detailed breakdown of costs, activity time and life cycle costing of the facility delivery process.BIM has already promised a lot on this.

In (Kalusche, 2008), it was argued that, using the applicable methods of cost estimation, it is possible to audit the facility delivery management in whole life cycle. This is facilitated by the approval of DIN 18960: 2008-02, which is about the utilization costs. However the professionals are reluctant to apply LCC due to the likely risks during project planning and costing. This suggests that, the difficulties in including LCC in contract documentation as a tangible item is still in question.

[76] Source: Modified Using Brandt, T., & Franssen, S. T. (2007). Basics Ausschriebung. Berlin: Birkhäuser. both versions, Germany and English.

[77] Source: Modified Using Brandt, T., & Franssen, S. T. (2007). Basics Ausschriebung. Berlin: Birkhäuser. both versions, Germany and English.

# 3. BIM in Germany

Building Information Modelling is still on its infant stage in Western Europe compared to United States of America (SmartMarket, 2010).However it was found that the adoption were growing at relative impressive.

> *"Among all Western European users, 59% use BIM on more than 30% of their projects. This is striking compared with North America, where 45% use it on 30% or more of their projects—despite the fact that North America has a higher adoption rate. This indicates that those Western Europeans who have adopted BIM have significantly integrated it into their internal processes"* (McGraw-Hill, 2010).

At the moment BIM is a talk of the professions and politician in Germany. In (Kessoudis, Steinhagen, & Lodewijks, 2014), the ministry of transportation suggested and promised the pilot study specifically for BIM, before the two projects were announced on November 2014 .

## 3.1. BIM introduction in Germany

According to (ZukunftBAU, 2013), after the Building Information Modelling has taken charge of planning, the building industry and maintenance of buildings in other countries, Germany got interest and the guide was set up to give introduction to the topic. While BIM was taking a cultural change view and was made obligatory in many countries like USA, Norway, Finland, Denmark, Singapore and Korea, in Germany BIM was used predominately in projects driven by a few private, institutional clients. The public clients and authorities had not acquired sufficient experiences and did not state their requirements ready for utilizing BIM. The BIM guide is based on numerous inquiries and analyses of completed BIM projects. In Contrast to other countries, in Germany it is mostly private clients who were using BIM standards from their own source, in other countries mostly public clients were demanding the usage of BIM. The demand for BIM goes on vigorously, as foreign investors triggered it to ensure the efficiency of their projects (Press Release BoxID 735195, 2015)[78] . It was claimed that *While Building Information Modeling is a new technology and collaboration process for German architects and engineers, foreign building owners and investors demand to drive especially planning and construction as well as Facility Management of their Germany-based buildings under BIM standards and based on Building Information Models.*

[78] Foreign investors push Building Information Modeling in Germany – BPS International establishes a Germany-based planning and project team to provide 360° BIM services for investors and to support German architects and engineers. (Press Release BoxID 735195, 2015) (München, 17.04.2015).

The first challenge identified was to synchronize the BIM based components into standards of specification used in Germany. That is to model the specification oriented standard (Standardleistungsbuch-StLB) or the master specifications for construction work (BuildingSMART, 2013) published by DIN into building element oriented BIM standards. This was intended to ensure the common language between parties is maintained. It is believed that the new specification DIN SPEC 91400, has given a further hope towards BIM (Deutsches Institut für Normung (DIN), 2015)[79].To smoothly sail, the guideline was introduced, and displayed for any one interested with BIM, to use it willingly *(See Figure 64: Recommended structure for BIM guidelines for Germany. ,Figure 62: Timeline Overview of BIM guideline publications in selected countries. and Figure 63: Master Specification towards BIM specification*.

The guideline, had among others the following basic influential points.

- The research was needed to know the BIM requirements for a BIM guide for Germany. The knowledge gaps were found on guidelines, know-how, contracts and insecurities when it comes to the usage of BIM and modern software systems. Users had their own and distinct concept and definition of what BIM is all about. The most of the stumbling blocks are not technical rather of the information, process and communication structures nature.

- With the use of guideline, first essential questions necessary for the introduction of BIM could be answered. All the *how to go about* questions are clearly explained. It shows how far the *change of thinking* is needed in BIM adoption. The big goal of BIM identified was to increase the *quality, up-to-datedness*, and *transparency* of *information in the project* in order to guarantee *cost effectiveness, sustainability and budget and schedule reliability* in achieving the main goals of the project. It was recommended and seen as essential that a *complete BIM manual* and also *obligatory BIM guidelines* be developed for Germany.
- The BIM guide provided first steps, ideas, suggestions and best practices, but no authoritative statement on how to implement BIM in Germany in general. The guide gave the explanation of the used terminology and a research on the current state of the BIM implementation at local and worldwide perspective, including showing the influence of BIM on the German planning culture. The key question raised was about the ***overall benefits of BIM*** to the project execution and the particular benefits to the various participants. The benefit for the ***client is thereby of uttermost importance***.

[79] DIN SPEC 91400 "Building Information Modelling (BIM) - Classification according to STLB-Bau", published in German and English, links a component-oriented classification and description system for BIM that is based on the German "STLB-Bau" (a database of standardized descriptions of construction work) with a model-based Industry Foundation Classes (IFC) data exchange model. In this way the new DIN SPEC provides a bridge between BIM component modelling and an STLB-based description of works. (Deutsches Institut für Normung (DIN), 2015)

- The guide provided that, BIM constitutes a cultural change fostered by integrating approach characteristics. The reliable, central and object-based way of *managing project information* generates a far productive change compared to the traditional way of working. The ability of BIM to fully consider *life cycle of the facility*, makes the key difference of all. BIM gives a universal and consistent documentation database of information in a readily readable procured and maintained ever before. This v*aluable, openly accessible, and verifiable information enables well-founded decision making*.
- It was mentioned also, that the success of a new method in the building industry depends essentially on the four parts: *people, processes, guidelines, and technology.* When introducing BIM it is also important to equally enhance the capabilities within all those parts and to foster the long term development. That's the only way for an efficient and sustainable use of the BIM method. The technology needed for BIM is far advanced in Germany, but the other three factors were assaulted by the guide as the bottlenecks. It was claimed that probable causes include lack of professional training and the absent of official BIM guidelines in Germany.
- Without fully use of BIM in contractual deliveries, 2D-documents may play an essential role. During realisation of BIM in projects, many problems were found to occur due to misunderstandings, lack of knowledge, and contract documents lacking the BIM requirements at the beginning of the project. Traditional CAD also do create complications or disallow the use of BIM.
- In BIM projects, a well-defined activities and collaboration of information between different partners is a key. As a result, new roles rise, examples are BIM manager, the BIM coordinator and the BIM author with their own requirements for knowledge, education and responsibilities. How the new role are needed and beneficial, is still in question, but the size of project is one of the determinant.

BIM is already reality of change in the way project will be executed at several levels. The BIM guide included several appendices comprising data sheets and check lists that can be used in preparing for the utilization of BIM in offices and projects. Defining the right and realistic BIM goals is a crucial part and the influencing factors are discussed. The assumption that BIM is for larger projects or costlier endeavor do not hold water all. Not only neighboring countries, are using BIM as a mandatory but also even in Germany there are more and more BIM projects, mostly initiated by private clients. On top Architectural offices and construction companies that are doing business abroad need BIM to be able to compete there. Yet, it was recommended that reliable parameters are necessary to facilitate the lasting creation of appropriate organizational structures and new collaboration processes.

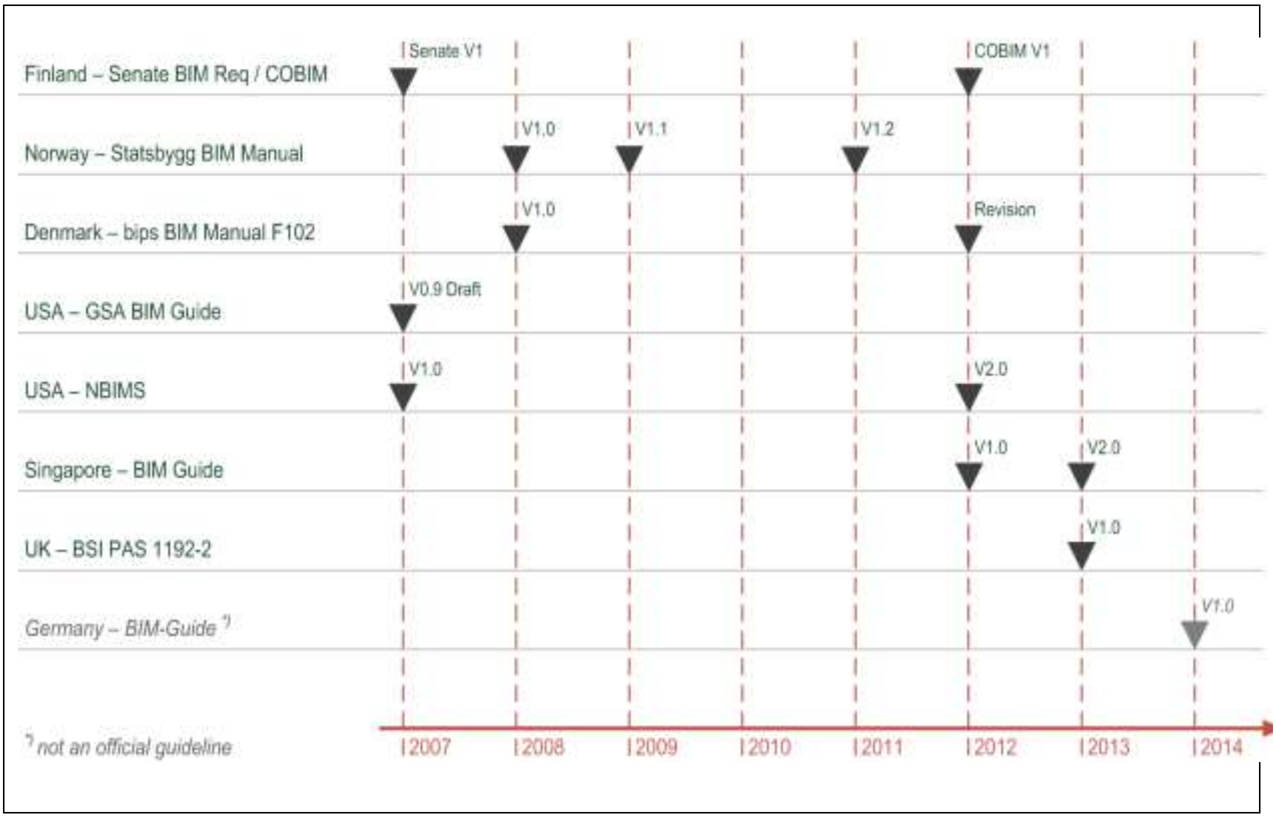



**Figure 62: Timeline Overview of BIM guideline publications in selected countries.** [80]

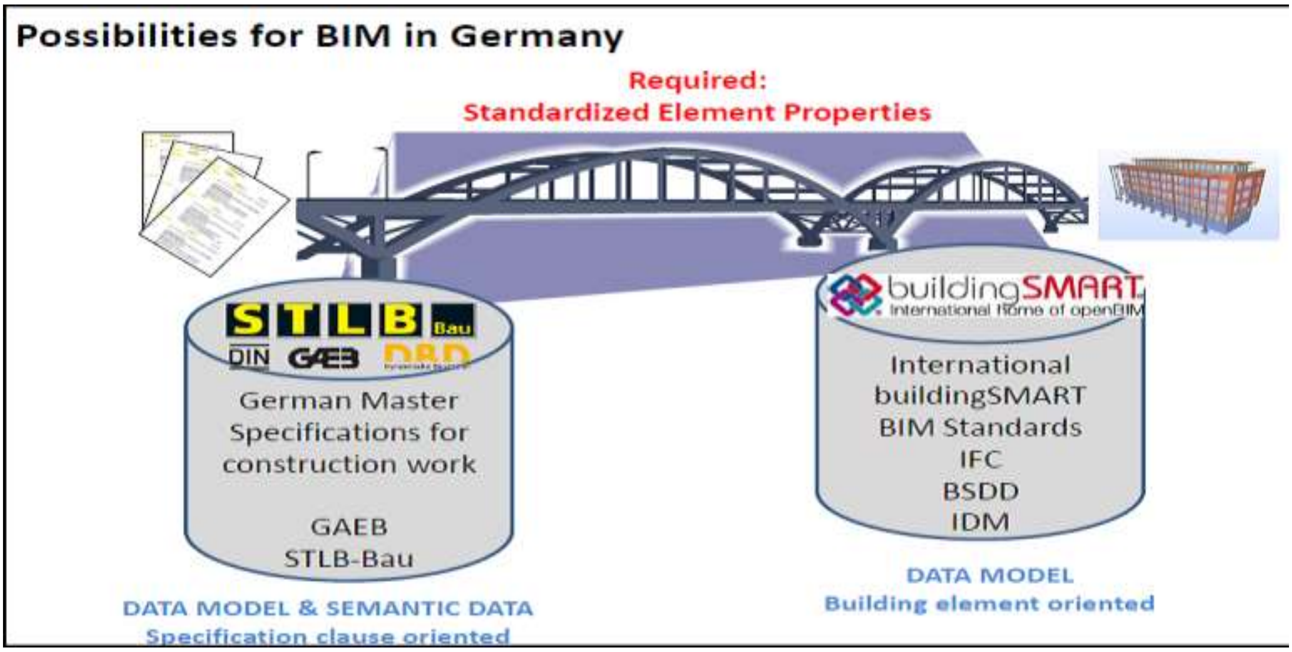



**Figure 63: Master Specification towards BIM specification**[81]

80 Source: ZukunftBAU (2013).

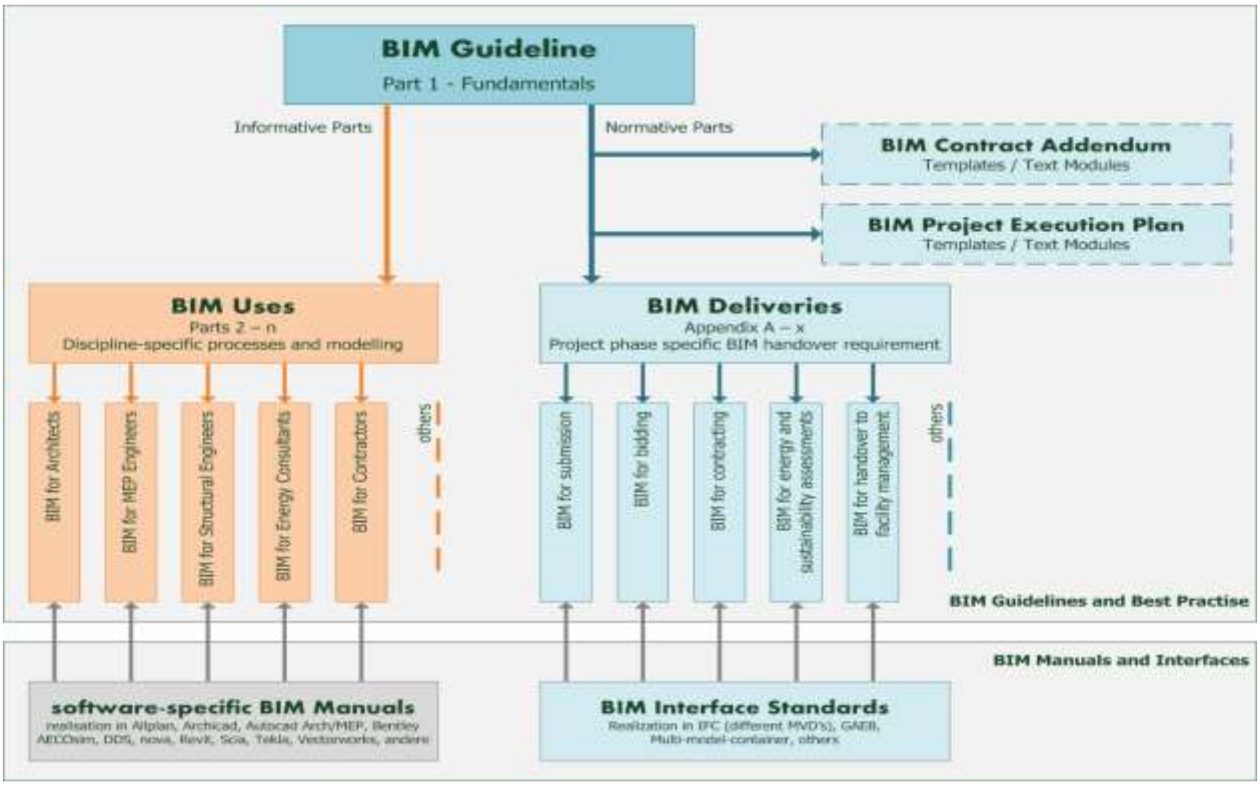



**Figure 64: Recommended structure for BIM guidelines for Germany.[82]**

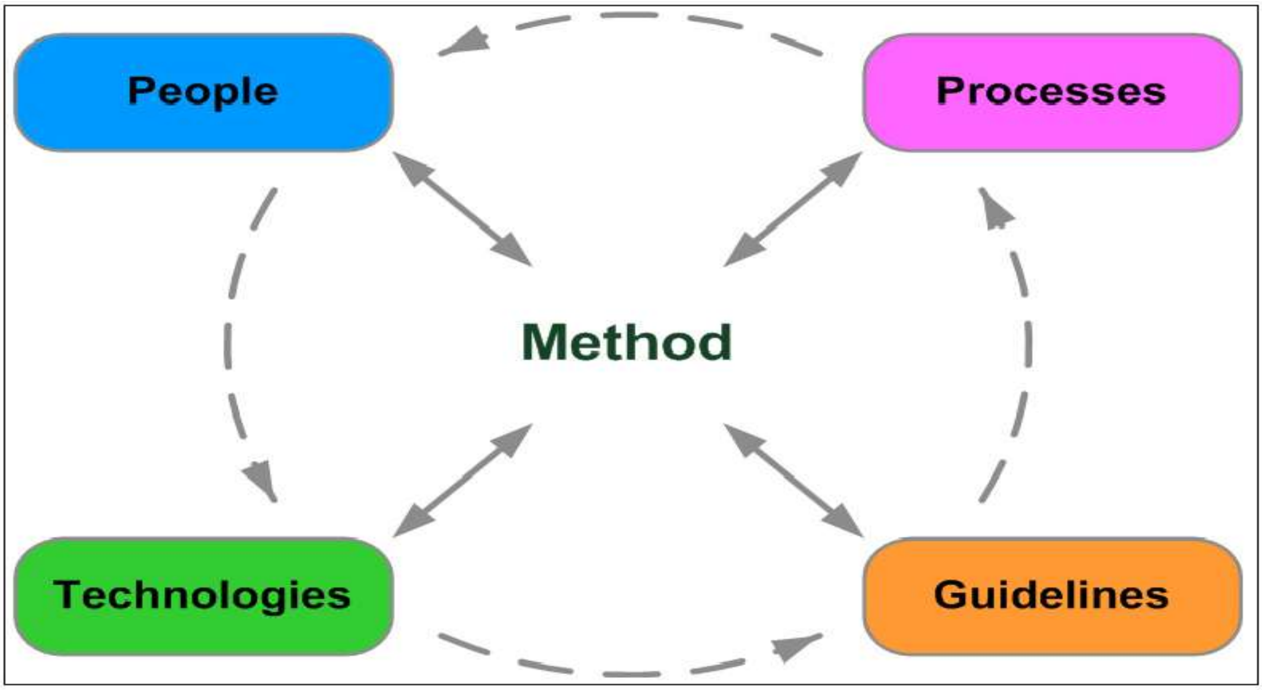



**Figure 65: Main factors of influence on the use of the BIM method[83]**

81 Source: BuildingSMART (2013).
82 Source: ZukunftBAU. (2013)
83 Source: ZukunftBAU. (2013)

### 3.2. Status of BIM in Germany

The use of BIM is not fully realized worldwide. A great part of BIM is yet to be discovered. The players are benefiting by the *model part of BIM*, while the *information and cultural part of it*, which is fundamental is left untouched (Kessoudis, Steinhagen, & Lodewijks, 2014).Worse enough, when compared to other European countries, in Germany BIM is used by the designers and construction companies. The clients and manufacturers are not even close to what they are missing from BIM. According to (Both, 2013), the German AEC (architecture, engineering and construction market) sector has yet to exhaust the potentials of the method and technology, when compared to the US and the Nordic countries. In Germany software vendors offer BIM solutions adaptable to German building processes. There are also few public-authority pilot projects and few practitioners who apply these software to calculate project-related resources, costs, revenue and overall profitability. The study found that, the term BIM is unclearly understood and used in Germany. As usual, challenges of technology, economy and standardization of documents need players to think out of box in Germany construction industry environment, yet the study rose an interesting question on *how to anchor BIM* in the industry.

> ***"****Integrated planning needs to be more than just "technical" model management and the merging of different CAD models. One key question therefore is the* ***localization of content-related quality assurance****.* ***Where such content-related synchronization and quality assurance should be anchored****? Will the architect within such a context revert to being a substantive integrator, coordinator and thus process-relevant actor? What is obvious at any rate is that the clear need for* ***additional integrating and coordinating activities is a key opportunity for the service sector****. Determining which services can be commercialized and which roles they* ***can be tied to in the extended process represents****, in people's view, an interesting challenge for applied research, although the issues of utility, affordability and payment also need to be clarified****."*** (Both, 2013)

It is easier to say BIM is present than to prove the reality of the existence of BIM. Especially when it comes to the life cycle delivery efficiency. In Germany, a number of projects are currently being pioneered as BIM projects. Porsche Ausbildungszentrum (Stuttgart), Rathaus (Leonberg), Airport Gate (Frankfurt) and Mercedes Benz Museum (Stuttgart) are among of them[84]. However, the utilization advantages of BIM is hardly exceeding the *BIM Model based* advantages of visualization and automation of the basic information. It is not very clear whether the input and outputs of facility management are in reality distinguishable from the traditional way of executing the projects. The 5D

[84] (Kessoudis, Status Quo 5D Building Design / BIM 5D-Design, 2009) and (Jacob, 2015). Based on Lecture notes too.

level BIM is mentioned more than practiced. Facility Management and many other advantages are more of the experience of the professionals and their competence in the use of the existing model capacities. As such, the use of BIM is reluctantly adopted by the professions. There is a need to develop a model that can comprehensively contain tangible time, cost and quality entities that enhances commitment of all players from inception to demolition of the facility. Germany has already on the move toward that, as suggested by the Multi-Model concept in ( Mosch & Kaiser, 2015).

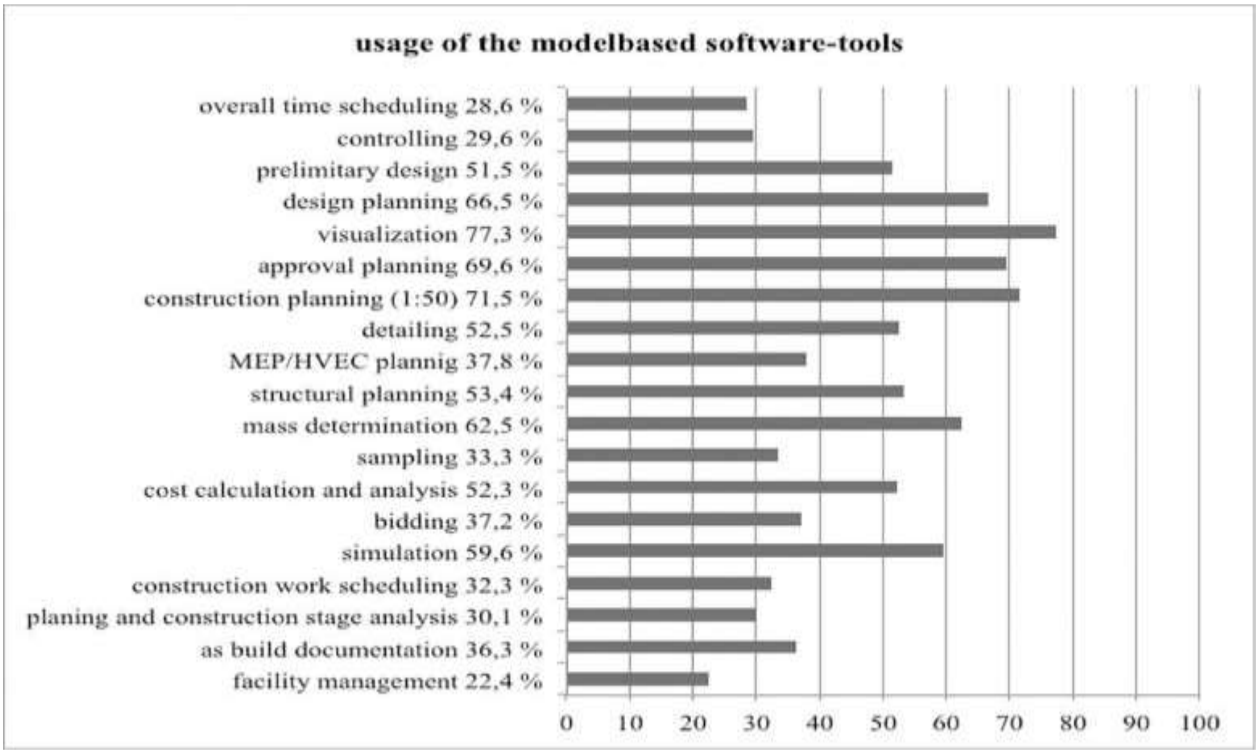
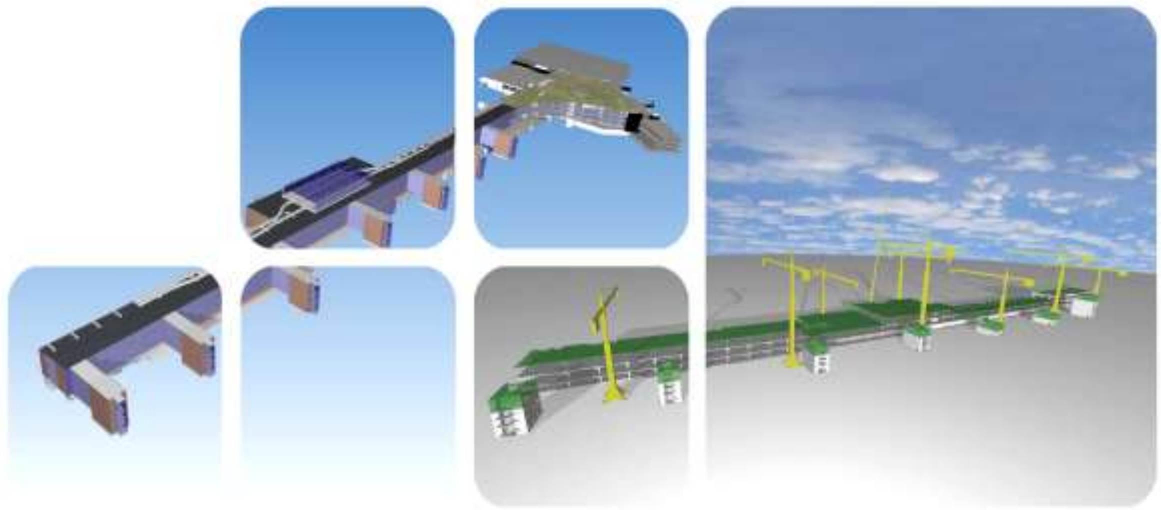


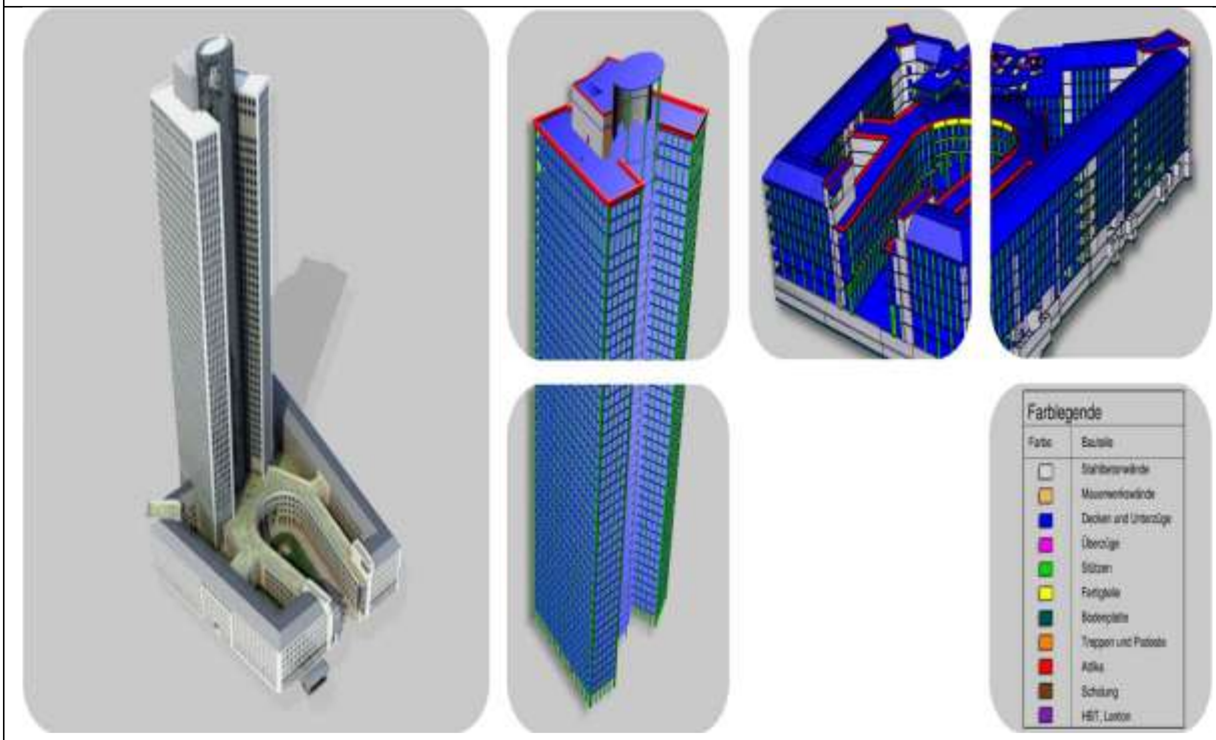

**Figure 66: Usage of model-based software in different AEC processes[85]**

According to (( Mosch & Kaiser, 2015) and (Guruz, Rodríguez, & Geißler, 2015.)) the term Multi-Model ideally is to combine both engineering and management models in a single information resource to achieve a closely linked cooperation between the different domains of the construction industry. The elementary models are interconnected in a single database to form the more intelligent and consistent Multi-Model that represents a certain status of a project. The Energy System *Information* Model (ESIM) and Building *Information* Model are synchronized to produce a more efficient BIM Multi-Model.

[85] Source: Both, P. (2013). Implementing BIM in the German Architecture, Engineering and Construction Market—A Survey about the Potentials and Barriers. Journal of Civil Engineering and Architecture, ISSN 1934-7359, USA -July, Volume 7, No. 7 (Serial No. 68), 812-820.



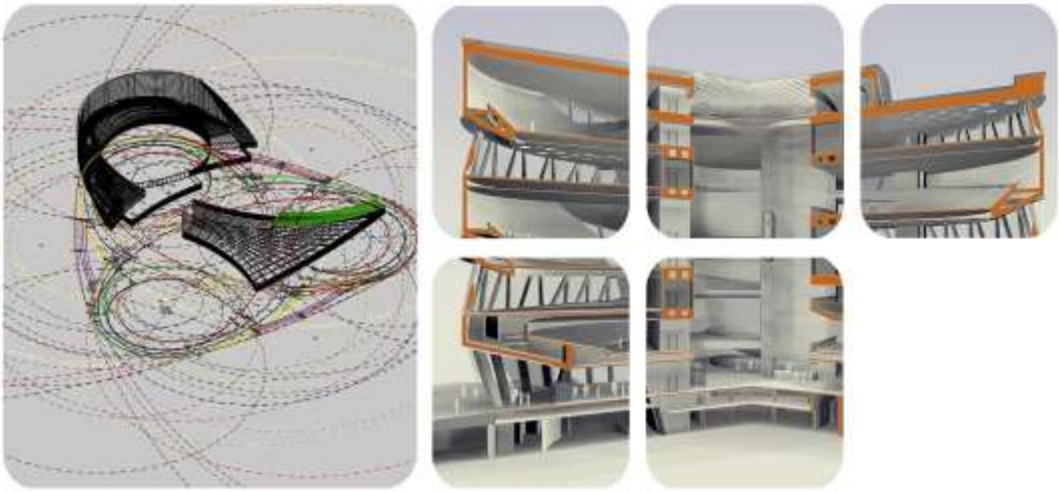
(a) Airport Gate Frankfurt, Germany. 3D-BIM, Scheduling / displaying contractual content 3D model provided by our Technical Head Office and 5D Design




(b) Tower 185 Frankfurt, Germany. Quantity take off, estimating 3D-model provided by 5D-Design department for quantity take off

**Figure 67 Examples showing BIM application in Germany Construction Projects (1/2)[86]**

[86] Source: Kessoudis, K. (2009).



(c.) Mercedes Benz Museum Stuttgart, Germany. Design to production

(d.) Mercedes Benz Museum Stuttgart, Germany. Design to production

**Figure 68 Examples showing BIM application in Germany Construction Projects (2/2)[87]**

[87] Source: Kessoudis, K. (2009)

It remains true that BIM is beneficial to the players in the construction industry. However the extent realized is still far from the expected level of BIM utilization. Whether BIM saves the client directly, it is also still unclear. The effort in Germany is promising because it is has already been declared to be the focus of the future in construction industry. Apart from DIN being digitalized, Visual Desktop Infrastructure (VDI) Building SMART and many other campaign are evolving. By 2020, Germany Railway is targeting to digitalize all its routes and activities (Jacob, 2015).All these effort, may well end on object visualisation effort rather than BIM  efficiency, unless the question of *what real BIM does* is tangibly addressed.

> *"The survey shows that in general noticeable benefits can be reached by implementing the BIM method - but not as high as communicated by the BIM lobbyists like buildingSMART or the BIM software vendors. But interestingly it became obvious that BIM does not seem to be able to increase the benefits concerning the cooperation between the different project partners in the existing German process structures considerably. Presently the BIM method is applied mostly to increase in-house efficiency – not collaborative company superordinate processes. Here seems to be an important future sphere of activity"* (Both & Kindsvater, 2012)

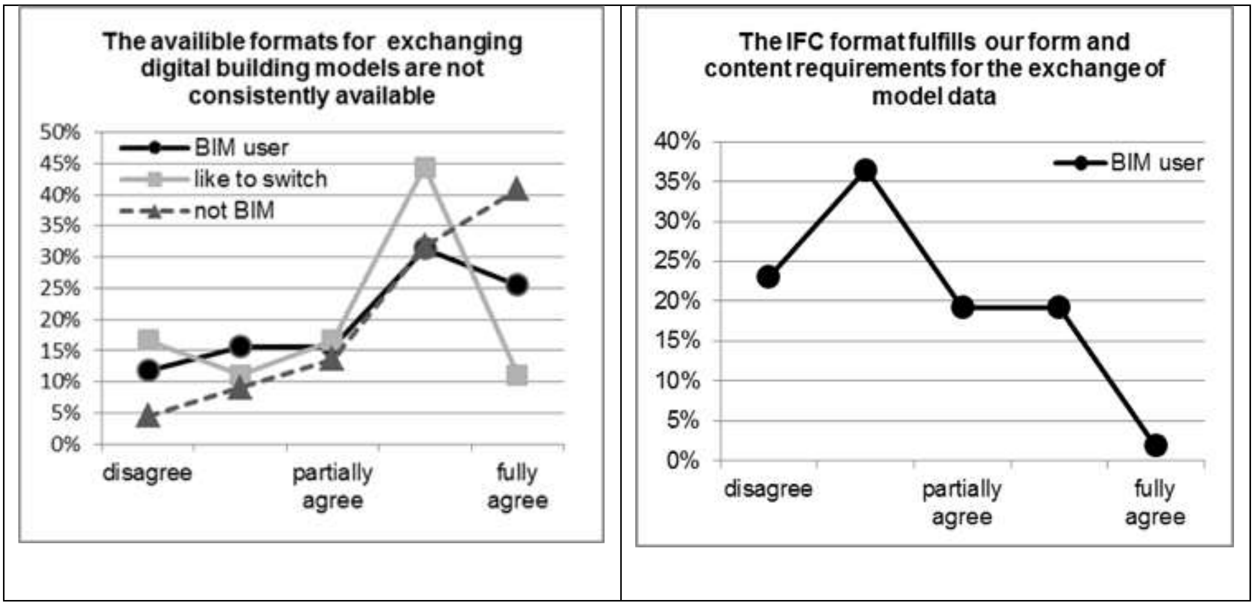



**Figure 69: Reflection on interoperability in the Germany construction projects by then[88]**

[88] Both, P., & Kindsvater, A. (2012)

### 3.3. Challenges of BIM in Germany

Some challenges of BIM are universal. Interoperability, Legal and Economical are good example. An organization will need more compatible technologies in order to smoothly collaborate with other players. The policy change and legal changes to adopt digital and collaborative contractual environment is not easy. The new venture is always accompanied by significant capital expenditure, which is another stumbling block. The same applies to the industrial adoption to BIM. In Germany the contrast can be seen in the country and individual aspect. Individual and firms have their own definition of what BIM is and it follows on what BIM does for them. The survey by (Both, 2013) showed that a number of professions using BIM is relatively high, but BIM is applied as an exclusive strategy in exceptional cases, mostly to supplement the popular 2D planning methods. At country level, Germany is faced with fragmented standards of contracts. So, unless BIM is clearly understood, incorporating within the system may be catastrophic. Architects and Engineers have standards for fees determination (HAOI) basing on the well formulated zones of responsibilities.

BIM comes with not only new duties, but also new roles requiring more participants in the project deliveries. In the lecturer, (Boldt, 2015)[89] made it clear that there are a number of issues necessary for construction contract to be addressed during BIM based project delivery . Example being the legal aspect of the new participants like BIM manager and owner of the model. It was pointed out that in England, somehow the multi-party contract (Project Partnering Contract PPC 2000) gives relief of the situation. Such a contract standard does not exist in Germany. With PPC 2000, it was given in (Association of Consultant Architects (ACA), 2010) the collaborative effort is put at the heart of the project delivery efficiency. The participants are expected to commit their effort to the project as an ultimate solution to other alternatives available to them.The contractor is procured early, and result into an opportunity to procure the required necessary specialists and skills at some any point in time during execution. Creativity, innovation and methods to resolve issues is directed towards interests of the delivery of the project.On top the PPC 2000 form of contract gives clients and consultants a chance to assess the cost and potential value of sustainability initiatives generated by the main contractor, subcontractors and manufacturers.

> *"In order to progress this initiative, the legal aspects of BIM need to be explored. Issues on ownership and intellectual property are not clear due to the lack of rules and protocols set out. The ability to use the* ***information*** *in the model as* ***evidence*** *needs to be investigated in relation to e-disclosure"* (Gibbs, Emmitt, Ruikar, & Lord, 2012).

[89] Prof.Dr. Antje Boldt ist Rechtsanwältin,Fachwältin für Bau-und Architektenrecht

## VI. Building Information Modeling (BIM) Dimensions

### 1. 5D Building Information Modelling (5D BIM) Efficiency

BIM at large may mean all information of the facility in its life (Smith & Tardif, 2009). This is probably the truth about the future of BIM, as new attributes are being added now and then. The target being to efficiently involve all Stakeholders of the constructed facility. Benefits to Owners, Designers, Builders and Facility users have been well explained ((Eastman, Teicholz, Sacks, & Liston, 2011) and (Smith & Tardif, 2009)).

Building Information Modelling advantages are infinitely understood. They depend on the modelers efficiency and environment the model is used. In (ARUP, 2014), it is believed that Building Information Modeling (BIM) technology will enhance collaboration of disciplines and in design phases in all the time. The modeling capacity of BIM in the coming few years will transform the way that design teams work across geographies and project phases into a near-realtime communication between design team members, clients and stakeholders. Future projects will be influenced by the restructured comprehensive data visualisation technologies, manageable systems and simulations of models in all stages of facility development. In such a situation, the participants are likely to be faced with a challenge of identifying the right level for the optimal use of BIM. It is unlikely that a construction firm or a project will guarantee to benefit indefinitely with indefinite BIM incorporation. This sort of challenges need among others, the reality of *what BIM does* which, will help to measure the level of BIM in undertakings.

### 1.1. Why 5D BIM?

To adopt BIM, many factors need to be considered. One of them is the maturity level of BIM (Ayyaz, Emmitt , & Ruikar, 2012). Three common levels are object based modeling,model based collaboration and network base intergration. In (Eastman, Teicholz, Sacks, & Liston, 2011), object, platform and environmental levels of BIM are mentioned. It is important to distinguish between one level and the other. However, without a clear cut of *what BIM does*, the separation may be vague, resulting into confusion between different levels. Information Integration is at the heart of BIM. BIM is recognised as a platform which can support document management systems and computerised visualisations through coordination of project information and nD modelling (Gibbs, Emmitt, Ruikar, & Lord, 2012). Exploring the experience from two BIM projects (Jeffrey, 2012), said

> *"BIM is often thought of in terms of 3D models but is a process involving Information Modelling and management in its broadest sense. The application of the BIM process during the design, construction and handover stages acts as a vehicle for better understanding and*

> *collaboration between the supply chain members. Before the BIM process obliged the articulation of requirements in a structured, disciplined, managed and collaborative way, information provided was often incomplete and/or irrelevant. This shows a lack of understanding as it is fair to argue that no-one deliberately sets out to provide the wrong information. That this situation had persisted over many years further illustrates the lack of collaboration to improve the situation."*

When information is incomplete, the players fail to derive the knowledge from the database. BIM value lies on whether the information is communicable among the players in such a way when understood it can impact on the delivery of the facility positively. Client is the ultimate player to benefit or loss from any discrepancy of information. Today, the satisfaction of client and benefits are not without life cycle costing and sustainability design. That is to say, one way to make BIM more efficient is to ensure that it exposes the information to the understanding of the client. In (Gledson, Henry, & Bleanch, 2012), the work of (Sebastian, 2011) was supported that the ultimate potential of BIM is to transfer all the virtual information to the client. One of the drivers for change in the rethinking construction report, by (Egan, 1998) is a focus to the customers.The report is claimed to have also influenced the need for collaboration in the AEC industry in UK (Leon & Laing, 2012). Wih regard to customer focus, it was reported that the industry showed no objective process to audit the satisfaction of the client. In otherwise, one can say, the construction needs a framework with tangible auditable items that reflect the desire of the client. That is among others, the costs items are important.

> *"A focus on the customer:,,,,the best companies, the customer drives everything. These companies provide precisely what the end customer needs, when the customer needs it and at a price that reflects the products value to the customer. Activities which do not add value from the customer's viewpoint are classified as waste and eliminated."* (Constructing Excellence South West, 2014).

Consequently, this means it is important to ensure that BIM gives the framework of the information that guides the clients to understand the objective planning and be able to monitor the objective accomplishment. In construction projects, this effort is centred on quality-***cost***-time management.However, it requires a new culture and thinking in order to attain sustainable solution to the old problems. *Simply using BIM to do 'business as usual' will not solve current problems. A deeper and more fundamental shift in attitude is required to genuinely engage with the complex problems of sustainability in a changing world.* (Jones & Dewberry, 2012).

In construction, *successes in facility delivery* can be demostrated using *cost management* (Daisy & Calvin, 2012).Many activities of cost management from feasibility study to final contract stage are time consuming, requiring innovation and creativity in order to dispaly the complete value of the information.The information that can help in solving the problem during and after contract stage of the project. According to (Leon & Laing, 2012), BIM as an Information Technology (IT) enabled approach, it can include both, quantitative and qualitative information necessary for the designers and engineers to be able to foresee potential design issues in the whole life-cycle before the actual construction. The importance of BIM then, it is to communicate the basic information foreseen by the designers to the clients satisfactorily. The information of construction is enormous, that clients may practically not be able to work on them. With a basic, simple,clear, collaborative and informative model clients may openly be able to productively participate in the facility delivery process advantegeously. Currently, BIM has promised the ability to give information beyond BIM model. It is possible to quantitatively incoroporate more life cycle delivery information into the costs models using BIM technologies. In (Kehily, McAuley, & Hore, 2012), it was shown that, through BIM the information columns can be added to display life cycle costing of the items in the Bills Of Quantities (BOQ). BIM gives the opportunity through automatic ability to produce,deliver and retrieve vast amount of information that an estimator need to prepare and model the costs estimate.

The difficulty in identifying the level of information in BIM related programme is not uncommon. It is even leading to misconception between CAD objects and BIM objects benefits. BIM to work better as a collaborative media, team members must be able to extract information and interpret exactly the way it was intended. In construction projects, this information inevitably involves specification details. According to ( BIM FORUM, 2013), *the Level of Development (LOD) Specification is a reference that enables practitioners in the AEC Industry to specify and articulate with a high level of clarity the content and reliability of Building Information Models (BIMs) at various stages in the design and construction process.* This was distinguished from level of detail. Level of detail, only refers to how much details are included in the model element. The level of development, on the other hand goes further to how far or to what extent or the degree of reliability on the information attached to the model element.

The LOD is sometimes related to the understanding of and usage of BIM (Latiffi, 2015). This is probably basing on the fact that LOD levels are related to the information details.However, it was insisted in ( BIM Forum, 2013) that *detail level* can be viewed as inputs of the element, which contibutes to the maximum *development level (LOD)* of information the players can derive from the element. LOD is sometimes interpreted as Level of Detail rather than Level of Development. In simple explanation, LOD refers to the non-verbal signs used to communicate information between players.

*"This Specification uses the concept of Levels of Development. There are important differences. Level of Detail is essentially how much detail is included in the model element. Level of Development is the degree to which the element's geometry and attached information has been thought through – the degree to which project team members may rely on the information when using the model. In essence, Level of Detail can be thought of as input to the element, while Level of Development is a reliable output."* ( BIM Forum, 2013)

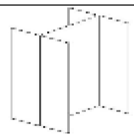
| Level | Level of Development- LOD | Model view |
|---|---|---|
| 100 | Assumptions for structural framing are included in other modelled elements such as an architectural floor element that contains a layer for assumed structural framing depth; or, schematic structural elements that are not distinguishable by type or material. Assembly depth/thickness or component size and locations still flexible. |  |
| 200 | Element modelling to include: Type of structural concrete system Approximate geometry (e.g. depth) of structural elements |  |
| 300 | Element modelling to Include specific sizes of main vertical structural members modelled per defined structural grid with correct orientation. Required non-graphic information associated with model elements includes: Structural steel materials defined. Connection details Finishes, i.e. painted, galvanized, etc. |  |
| 350 | Element modelling to include: Actual elevations and location of member connections, Large elements of typical connections applied to all structural steel connections such as base plates, gusset plates, anchor rods, etc, Any miscellaneous steel members with correct orientation, Any steel structure reinforcement such as web stiffeners, sleeve penetrations, etc. |  |
| 400 | Element modelling to include Welds Coping of members Cap pates Washers, nuts, etc. All assembly elements |  |

**Figure 70: Example of LOD: Floor Structural Frame (Steel Framing Columns)[90]**

90 Source: BIM Forum (2013)

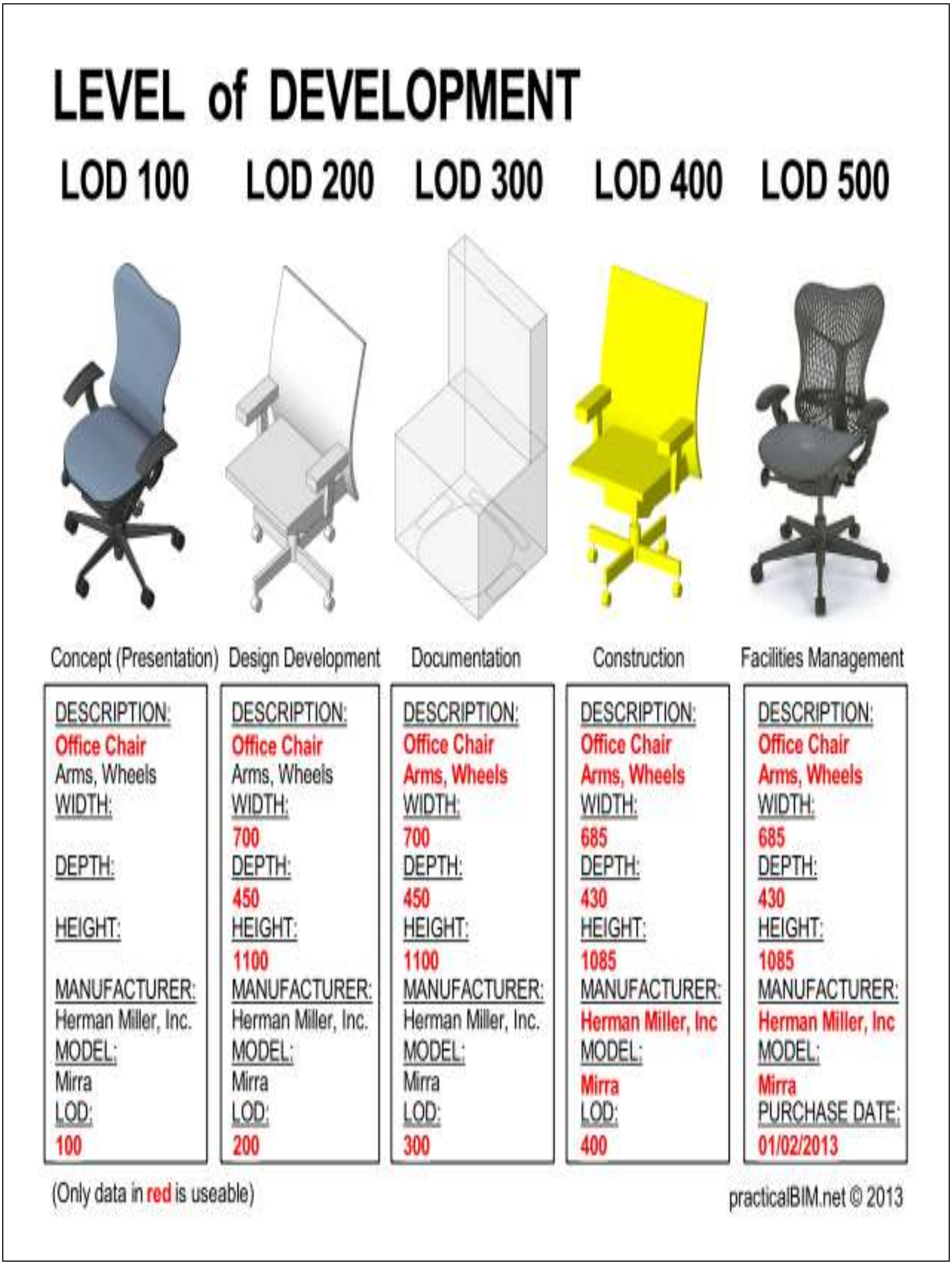



**Figure 71: Example 1 of LOD. Construction Projects Activities[91]**

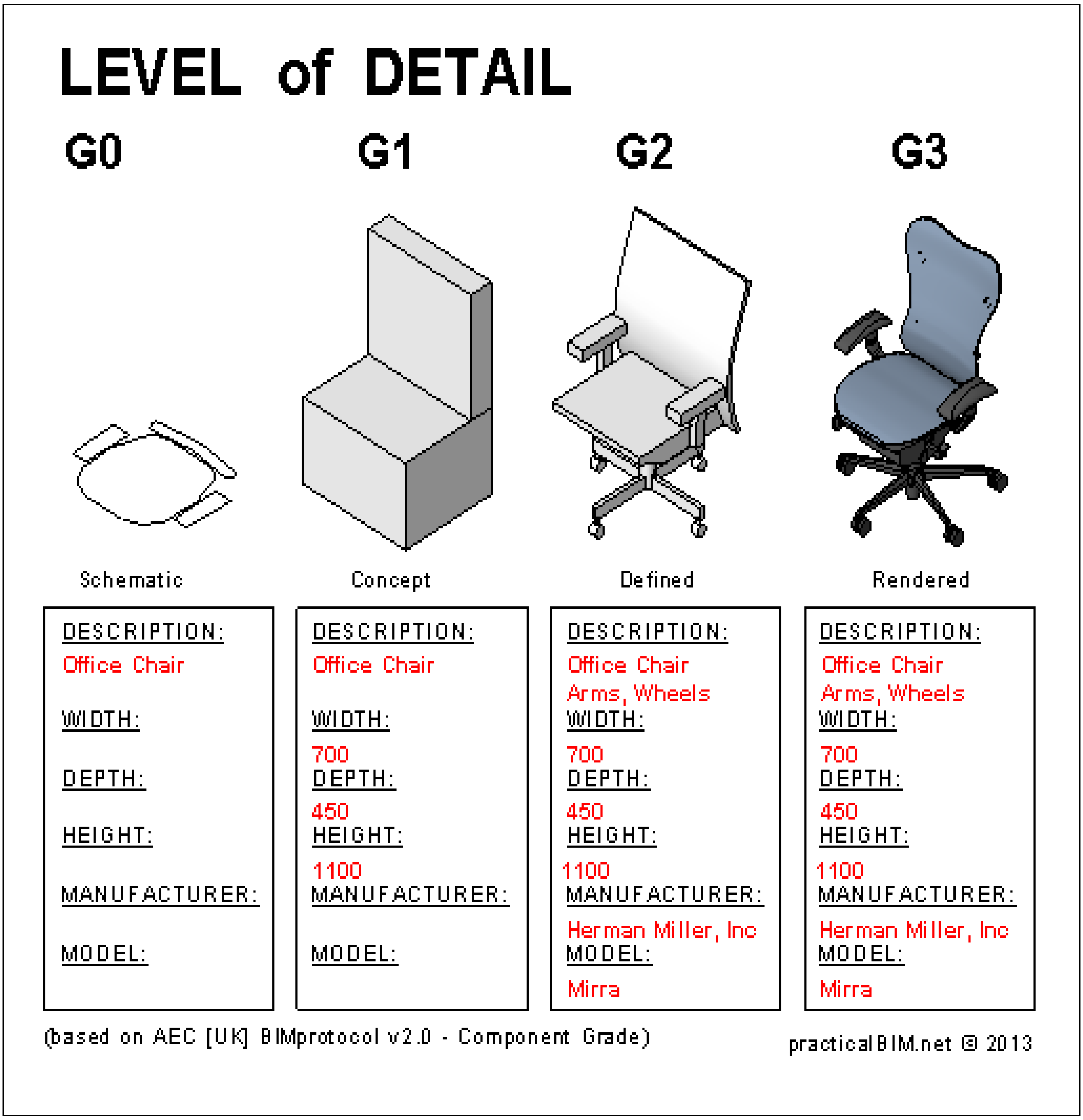



**Figure 72: Example 2 of LOD. Construction Projects Activities**[92]

[91] Source: McPhee,A. (2013)
[92] Source: McPhee,A. (2013)

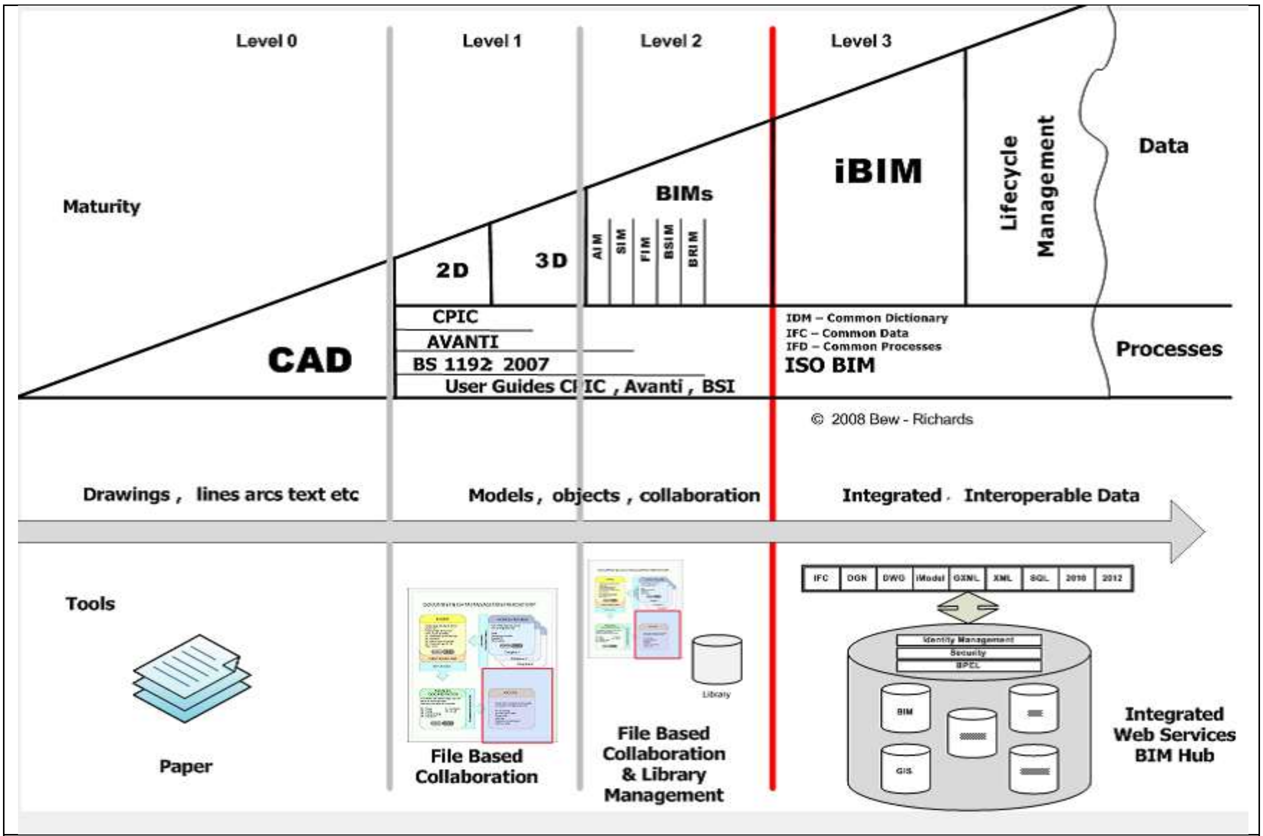
The collaboration increases with the increase in the information level and understandability. Clients will be able to give their inputs only when they can understand the information available.Specification is one part, costs, time, safety, sustainability and productivity information are also important in project management. However, the information is nothing without understanding between participants.The level of information in the BIM model relative to the desired objective is refered to as maturity level. This concept of *maturity* assumes the possibility of distinguishing levels of information using a pre-set characteristics or work practices in any organisation (Scully, Underwood, & Khosrowshahi, 2012).

> *"A maturity model has been devised to ensure clear articulation of the levels of competence expected and the supporting standards and guidance notes (not shown in this diagram), their relationship to each other and how they can be applied to projects and contracts in industry. The purpose of defining levels from 0 to 3 is to categorise the technical and collaborative working to enable a concise description and understanding of the process, tools and techniques to be used. In essence, it is an attempt to take the ambiguity out of the term BIM and to make specifying for it clear and transparent to the supply chain and enable the client to understand precisely what is offered by the supply chain*
> *The production of this maturity index recognizes that differing construction client and their supply organizations are currently at different level of experience with their approaches to BIM and serves as a structured 'learning' progression over a period of time". (BIM Industry Working Group, 2011).*

Conceptually,BIM information level may be differentiated by the term "dimension". In mathematics a point represents a "zero dimension measurement". Joining the two points perpendicularly (shortest line between the two pointa) give a resulting line which is "one dimension measurement". The same process can be used to give a "two dimension measurement", when two similar lines are joined perpendicular. The ability to visualise the dimension gets harder when more planes are joined. By joining the trapeziums ( the two "two dimension measurement" figures) perpendicular the "three dimension measurement" image is formed. The "four dimension measurement", "Five dimension measurement", 6D, 7D and nthD is even harder and harder to visualize through the principle of joining the plane and figures. However, in the BIM world, 3D have two representation, graphical objects and paramentric objects. 3D graphical objects are not 3DBIM objects, because they lack parametric properties. They join 2D and 3D CAD Graphics. The 3D BIM objects can contain an enormous amount of resources and specification information and hence are more collaborative than 3D graphics. They have one thing in common, they represent the image of the facility, and they differ in the ability to manuover the information contained in the image.

The BIM dimensions starts from the 3D BIM. When the represented facility (3D BIM), includes the productivity of resources and hence capable of reflect the relatively realistic duration or time required to construct the activities and the whole building it is a 4D BIM model. The process of ensuring that this can happen and working in the model with such ability are all refered to as 4D BIM modelling. In a simplified vision, the component or building or a structure that occupies space (3D), has been tied to the determinants of its growth through time. 5D BIM, on the other hand, is adding information on the 3D and the components of it, but this time the result is not only the image of the facility as it occupies space only, but also the cost of occupying that space and attaining that quality. The dimensions can continue to 6D,7D and nthD, depending on the ability of the modelers and users to attach the information to the 3D BIM, and differentiate the output in the delivery process of the facility.

BIM can be 3D, 4D (time), 5 D (cost) or expanded to 'nD' to incorporate 6D (procurement), 7D (life cycle) , 8D improving safety and all other factors in the facilities and life time management of the building (Wan, Platten, & Briggs, 2012). In (Migilinskas, Popov, Juocevicius, & Ustinovichius, 2013) this effort or a model with all dimensions included was refered to as Unified Project Management (Building Lifecycle Management (BLM)). BIM is centrally a computer-generated model representing the facility through a three-dimension representation assigned with a informational database that facilitates visualisation of the reality in the facility delivery.This reality is basically the function of the level of information, and so it may be far or close depending of the contextual difference between digital view and site execution (Vanossi, Veliz, Balbo, & Ciribini, 2012). To benefit from the mixed reality of BIM, the critical success factors and knowledge management should well be incorporated with BIM (Scully, Underwood, & Khosrowshahi, 2012). It is believed that careful consideration ensures that optimal BIM level is utilized. Success of any endavour starts with planning. In construction planning starts with Budgeting and tendering estimates As such,the fundamental parameters for the success of the construction projects are centred in costs estimates. The earlier the better. In ((RICS, 2014) and (Eastman, Teicholz, Sacks, & Liston, 2011)), costs guides selection and conformity of the design during projects development.Relative to BIM usage, the model with relative higher project costs information is logically the most optimal BIM level. In general, 5D BIM is the costs master of BIM.




| **Abbreviation and note as in** (Kumar B. , 2012) | | |
|---|---|---|
| IFC | Industry Foundation Classes | *Moving up through the level of technology use leads to seamless working and effective data and process management* |
| IFD | International Framework Dictionary | |
| IDM | Information Delivery Manual | |
| iBIM | Integrated BIM | |
| CPIC | Construction Project Information Committee | |
| AIM | Architectural Information Model | |
| SIM | Structural Information Model | |
| FIM | Facilities Information Model | |
| BSI M | Building Service Information Model | |
| BrIM | Bridge Information Model | |

**Figure 73: BIM Maturity Levels**[93]

[93] Source: BIM Forum, (2013), & Kumar, B. (2012)

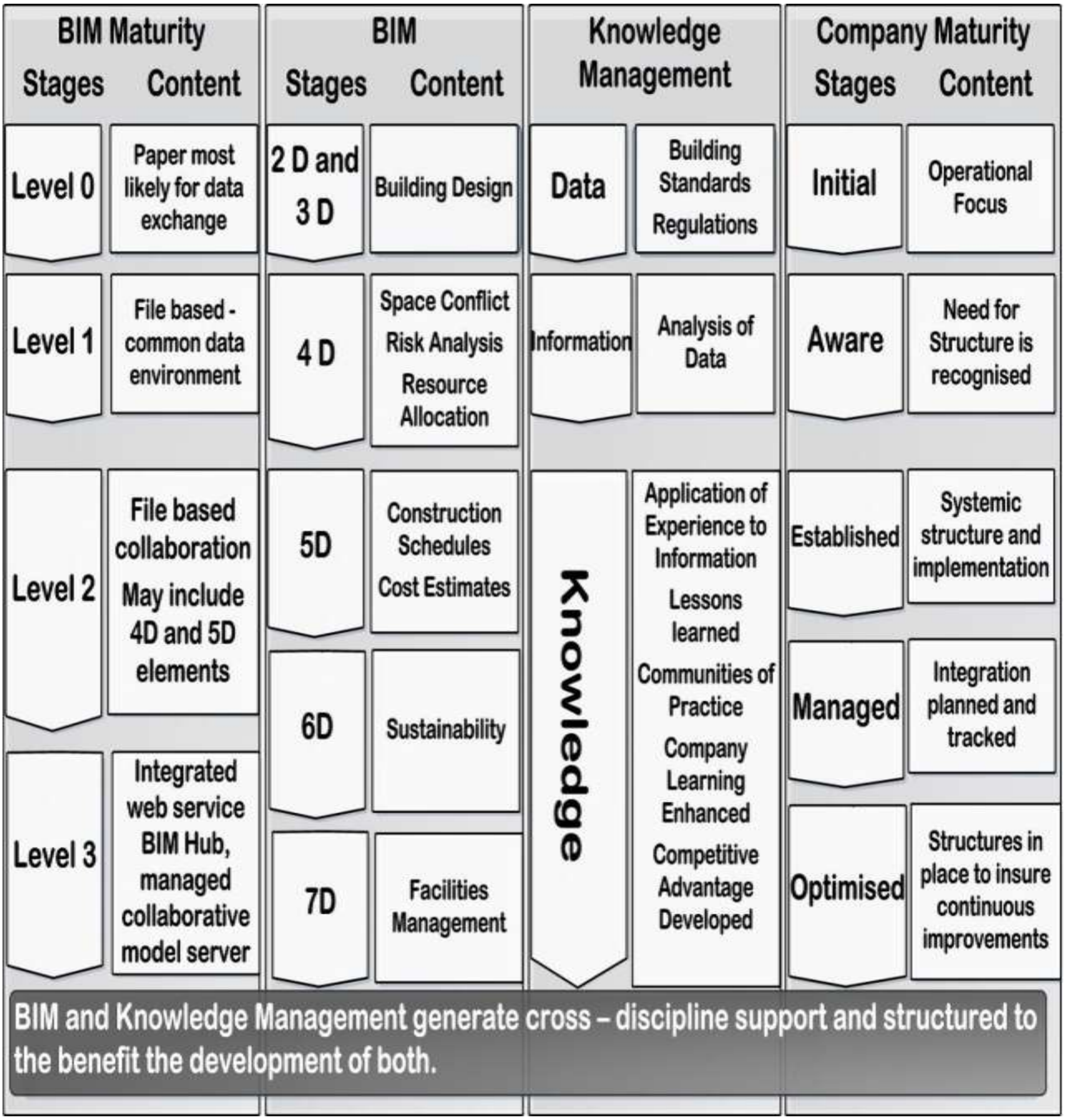



**Figure 74: BIM Maturity Levels and Knowledge Management**[94]

94 Source: Scully, R., Underwood, J., & Khosrowshahi, F. (2012)

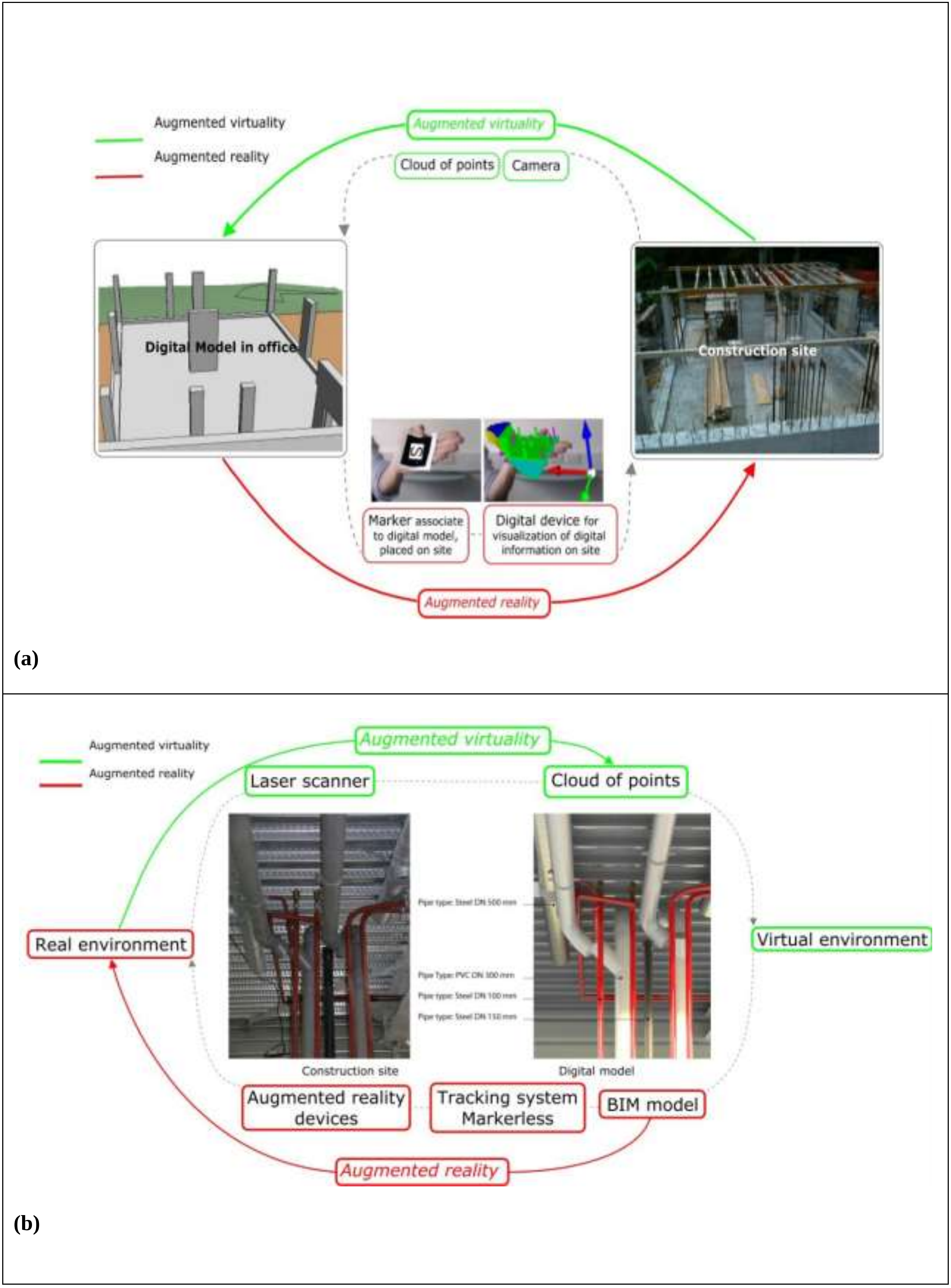



**Figure 75: Example of realities differences between BIM models and Site contexts[95]**

[95] Source: Vanossi, A., Veliz, A., Balbo, R., & Ciribini, A. (2012).

### 1.2. 5D BIM in Total Cost Management

According to (Daisy & Calvin, 2012), cost management activities include Preparation of preliminary cost estimates for feasibility, monitoring designs development within budget, taking off quantities and preparation of Bills of Quantities (BOQ) in tendering stage, assessment of interim payment, valuation of variation, preparation of cash flow forecasting and financial statement and settlement of final account. In order for 5D BIM to be optimal BIM level, one condition is the ability to provide the information needed for the costs management foundation in all project delivery stages. Foundation for making right decisions during inception, planning, execution, use, commissioning, demolition and rebuilding of the project in the future. The construction costs information base that facilitates productivity in sustainable design and delivery of the facility in a win-win situation among players.

> *"Total Cost Management is the effective application of professional and technical expertise to plan and control resources, costs, profitability and risks. Simply stated, it is a systematic approach to managing cost throughout the life cycle of any enterprise, program, facility, project, product, or service. This is accomplished through the application of cost engineering and cost management principles, proven methodologies and the latest technology in support of the management process. The TCM Framework is a representation of that 'systematic approach.*
>
> *Put another way, Total Cost Management (TCM) is the sum of the practices and processes that an enterprise uses to manage the total life cycle cost investment in its portfolio of strategic assets. Costs in TCM include any investment of resources in the enterprise's assets including time, monetary, human, and physical resources. Total refers to TCM's comprehensive approach to managing the total resource investment during the life cycle of the enterprise's strategic assets. The enterprise can be any endeavor, business, government, group, individual, or other entity that owns, controls, or operates strategic assets. Strategic asset is shorthand for any unique physical or intellectual property that is of long term or ongoing value to the enterprise"* (AACE International, 2006)

Among others, the total cost management inputs depends on resources, performance requirements and the working environments. When well considered and modelled the decisions towards desired objectives can far be guaranteed. On top, the critical process in asset planning is the forecast. Forecast model play a central role in structuring the thinking, displaying more detailed and facilitate unbiased judgement. In construction, the process is guided through costing. Translating working environment, performance and resources information into financial picture necessary for the execution of the project. Basically cost of the resource (labour, material, plant, etc) is the result of the *factor (unit cost* *factor or cost of resource per parameter)* multiplied by the *parameter (quantification of the scope item).*

Nevertheless, TCM practice and methods depends on the efficiency of information. Unless the information can be interpreted into knowledge the database or model is functionless. Data management and information control are the bases for knowledge. It is through this knowledge that participants are able to benefit from the model at large, by working out the outputs desired measurably. Any information breakdown between model data and participants is distorting the information productivity to the facility delivery. Today, information technologies including BIM are facilitating the communication effectiveness. In construction projects, this communication does not end into openness of the documents, but also on the understanding of the technical specification among players. The productivity in communication is key to the success of the TCM model. Equally, for the BIM model to be more successful, it needs to ensure that it is easily communicable among players.

### 1.3. 5D BIM in BOQ Preparation

Contractors to tender on the same information, they need Bills of Quantities (Seeley, 1988). A quantity surveyor, is probably the leading expert in preparation of BOQ.In doing so, primary processes include taking-off quantities and working up them out. *Quantities* here is the amount of work already fixed in position as per requirement of the contract. The act of reading, scaling or transfering the dimensions from the drawings or models to the special model or paper is called taking-off. To ensure accuracy in taking-off, the dimensions had to be processed, that is squared and abstracted before the product output (areas,volumes,etc) in definite unit are arranged in a bill format. The process follows the standard method of measurements.The items billed are in a format that displays columns for item serial number,descriptions, description,unit,rate and amount.The format intends to suit the contactors to enter the rates and and prices for each before summing to get the total price or contract sum.

The advantages of BIM in costs estimate starts with the increase in visualisation (Matipa, 2008).BIM is useful in construction costs management (Daisy & Calvin, 2012). By integrating the BIM deliverables, the time consuming construction costs management processes can be eased. BIM facilitates cost estimate and budget setting through the integration of various design and cost data bank and effective cost control against various design revisions . Through BIM, taking-off the quantities of various elements automatically is possible, retrieving dimension and specification of building elements is relatively quicker, preparation of programms, costing variations, preparation of contract cash flow forecast, financial statement preparation and final account settlement is relatively time saving. Despite the existing weaknesses of BIM models in fulfilling the BOQ preparation, still with BIM a significant time can be saved by incorporating the human effort into BIM than otherwise.

It is relatively more advantageous using BIM in BOQ preparation than otherwise. The quantification advantages includes the possibility of exporting object quantities to estimating software (Eastman, Teicholz, Sacks, & Liston, 2011). That leaves costs experts with pricing activities. Former activities like squaring and abstracting quantities are confidently skipped. However there are number of problems are worth noting. In (Wu, Wood, Ginige, & Jong, 2014) *Substandard BIM models and inadequate information*, *Issues related to data exchange and Lack of standardisation* and *inappropriate pricing format* were explained. It was argued that BIM models may never solve all the cost estimating problems,and yet it is a crucial tool because BIM is more time saving and accurate. Quantification can take 50% to 80% of a cost estimator’s time on a project (Sabol, 2008).

BIM models offers the capability to develop project cost information with more accuracy throughout the entire building lifecycle (Sabol, 2008). The question remains on how far the information given to the estimators is adequate for the purpose. The accuracy and quality of BIM based estimates does not depend solely on the competence and technology of the estimator or QS. It relies upon informational level of the project definition.The more valuable and more detailed the information, and the more detailed the construction methods the better the estimate. The BIM model need to be adequately informational to facilitate cost estimate. On the other hand, standardizing quantification is not solving the pricing related problems.The BIM models facilitate automating quantities and prices simultaneously with changes of designs. To changes the price for many other uses, the cost estimator will be influenced by many subjective factors beyond the supply of BIM models. In (Wu, Wood, Ginige, & Jong, 2014), common tools in the UK cost estimating and planning practice, namely, Solibri model checker, Autodesk QTO, CostX and Causeway BIMmeasure were reviewed in order to provide a holistic picture based on a set of criteria. All tools showed necessity of additional manual effort to enhance the informational value as they did not match exactly to the practice and standards.

Daisy & Calvin, (2012) gave out that further development 4D and 5D will realize the automatic post contract cost control process (i.e. cash flow forecast, financial statement and settlement of final account). This is no longer a dream. In (Popov, Juocevicious, & Migilinskas, 2010), 5D BIM environment consists of a virtual model with all necessary information of the project, that is from the manufacturer of structures, their characteristics, peculiarities of maintenance, warranty period and the like. As such 5D BIM allows for more assessment of alternative solutions and calculation of the potential cost management activities including regular maintanance procedures. 5D BIM is a multmodel BIM in essence, as it has the possibility to simulate 3D BIM, time schedule and calculate resources in very high precision.The general accepted accuracy in BOQ preparation dimensions is around 1% basing on the full working drawings (Seeley, 1988). BIM can even go further than this (Eastman, Teicholz, Sacks, & Liston, 2011). 5D BIM automates many contents of BOQ and gives accurate resources information than ever seen before (see the figures below). Professions are already providing clients more user friendly Bills of Quantities and reports, see demostration from (HC BIM QS, 2006) below. With 5D BIM it is possible to provide the clients the clash detection and other value engineering reports, the BOQ gives a more relative better visualisation and transparency. The documents provided are more accurate, flexible and clear than traditional one because the expert using technology,have more time to arrange and present them in the better way. Quantities are more easily traceable and can easily and timely be updated during design changes. The prices and rates can be broken into more components and enhance understanding of the information they contain.

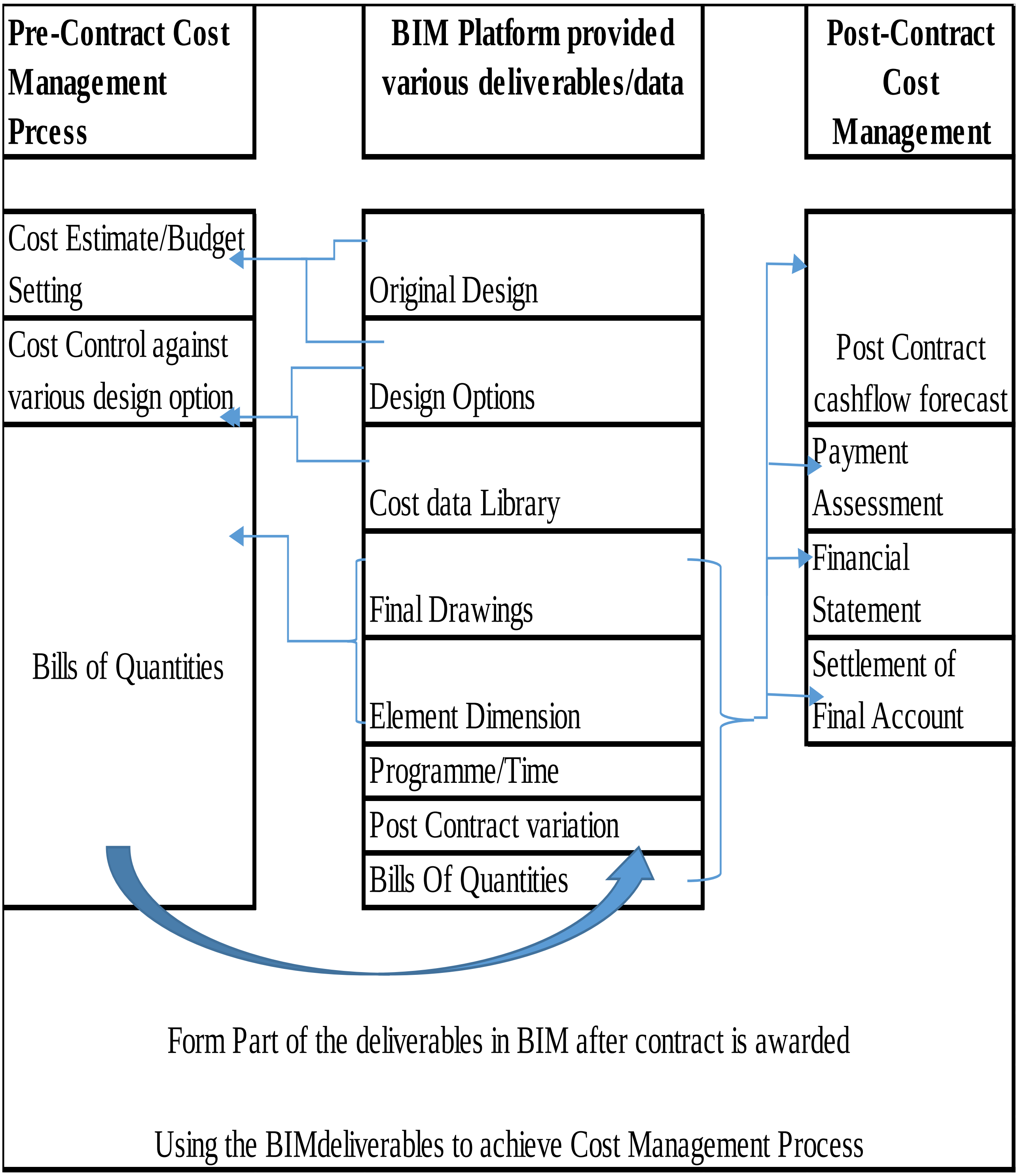
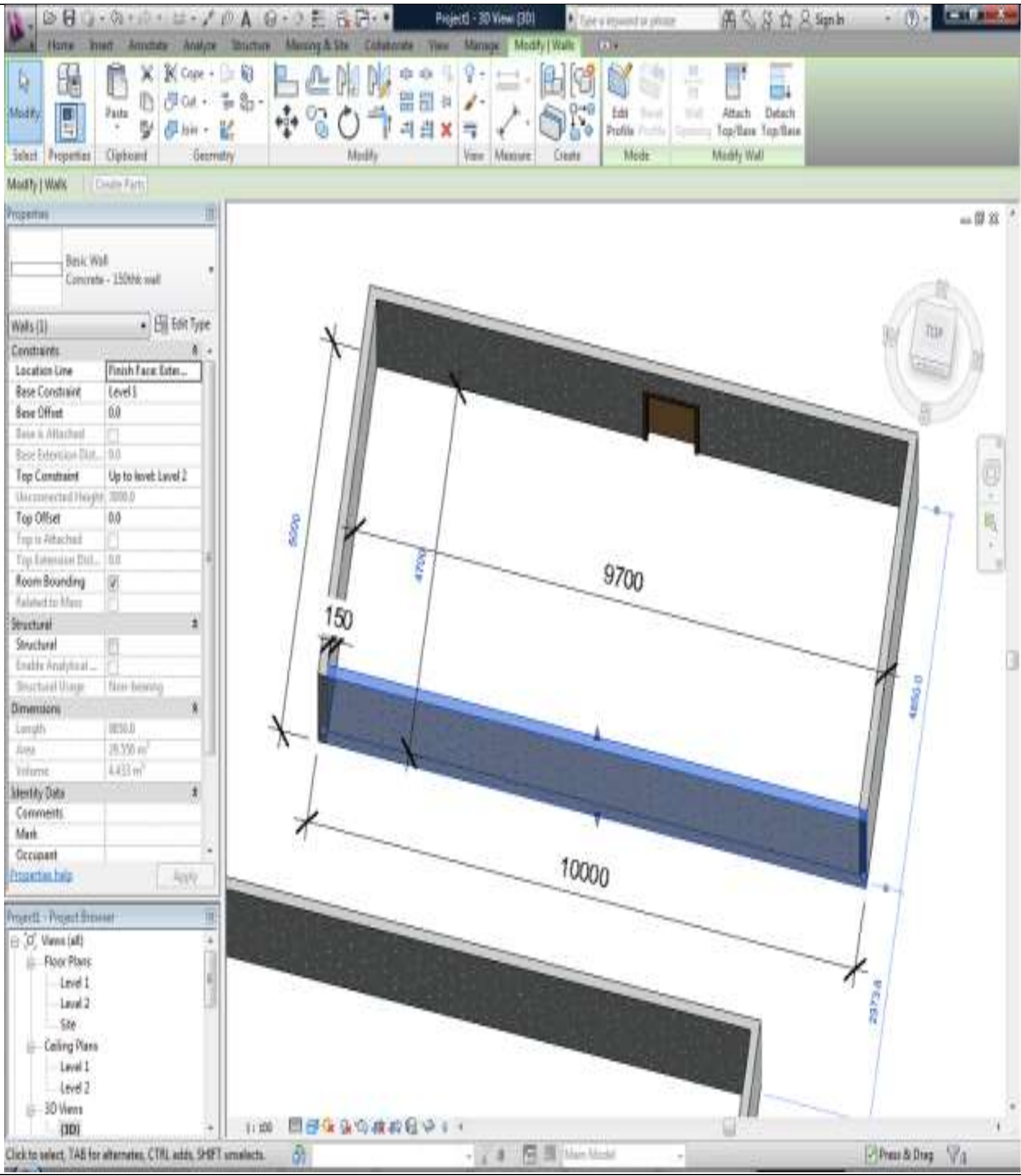



**Figure 76: Construction Costs Management in BIM and the annotation error in BIM[96]**

[96] Source: Modified From Daisy, Y. K., & Calvin, K. C. (2012)




*In focusing the wall dimension in above, the internal dimension for Wall (A) and (B) is 4700mm and 9700mm respectively. The dimension listed in the properties box at the left hand side for wall (A) and (B) is 4850 mm (4700+150) and 9850mm (9700+150). Normally for estimating purpose, cost expert (QS) will use centreline for concrete work and internal and external dimension for plastering works measurement, but the dimensions annotated in BIM cannot match the practice in estimating. This problem can be fixed up by in feeding the estimating rules/ requirement to the BIM during the model design stage.* (Daisy & Calvin, 2012)

**Figure 77: Construction Costs Management in BIM and the Annotation of Error**[97]

[97] Source: Daisy,Y.K.L. & Calvin,C.K.W. (2012)

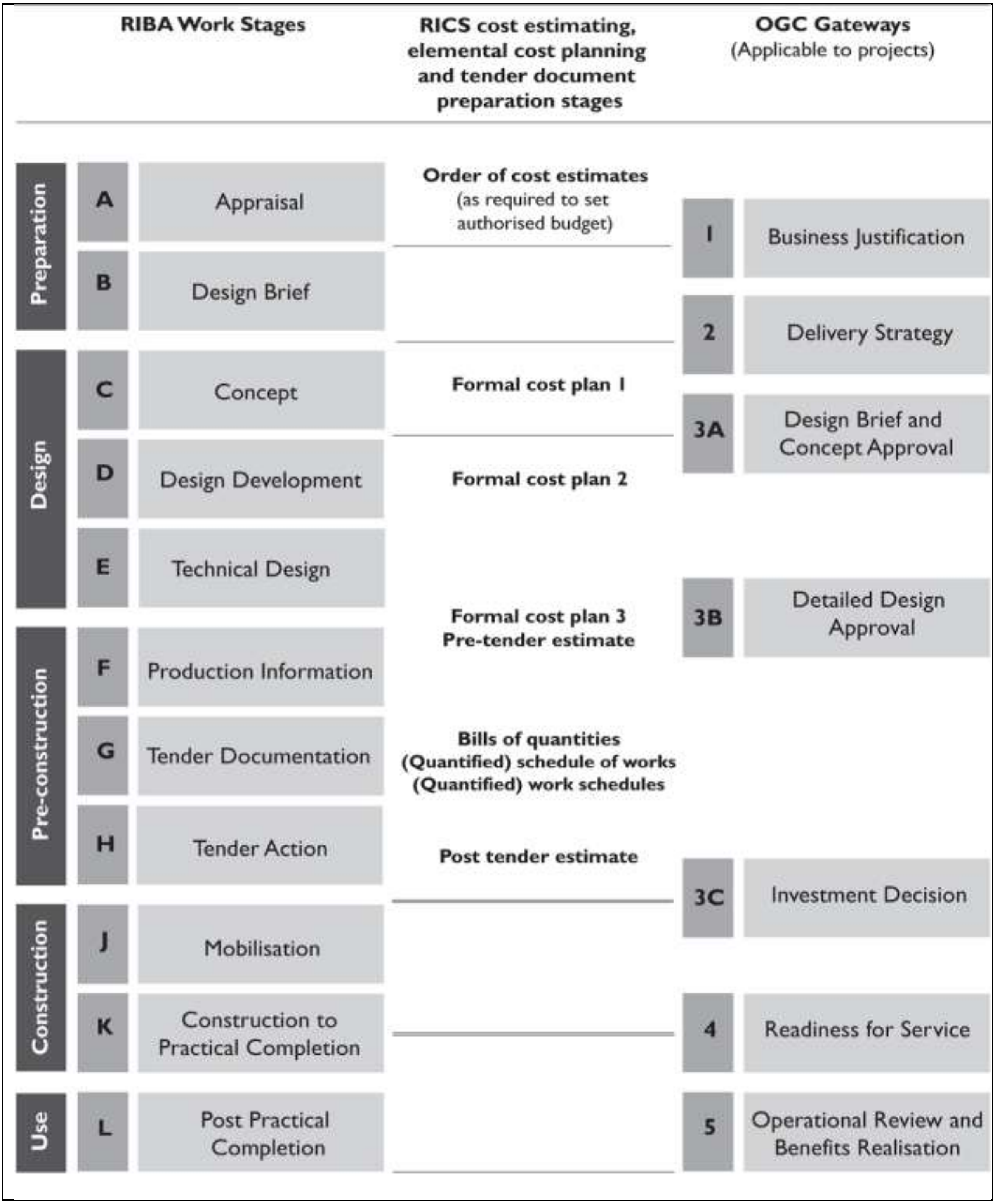



**Figure 78: Costing and Planning in RIBA Work Stages and OGC Gateways**[98]

[98] Source: RICS (2012)

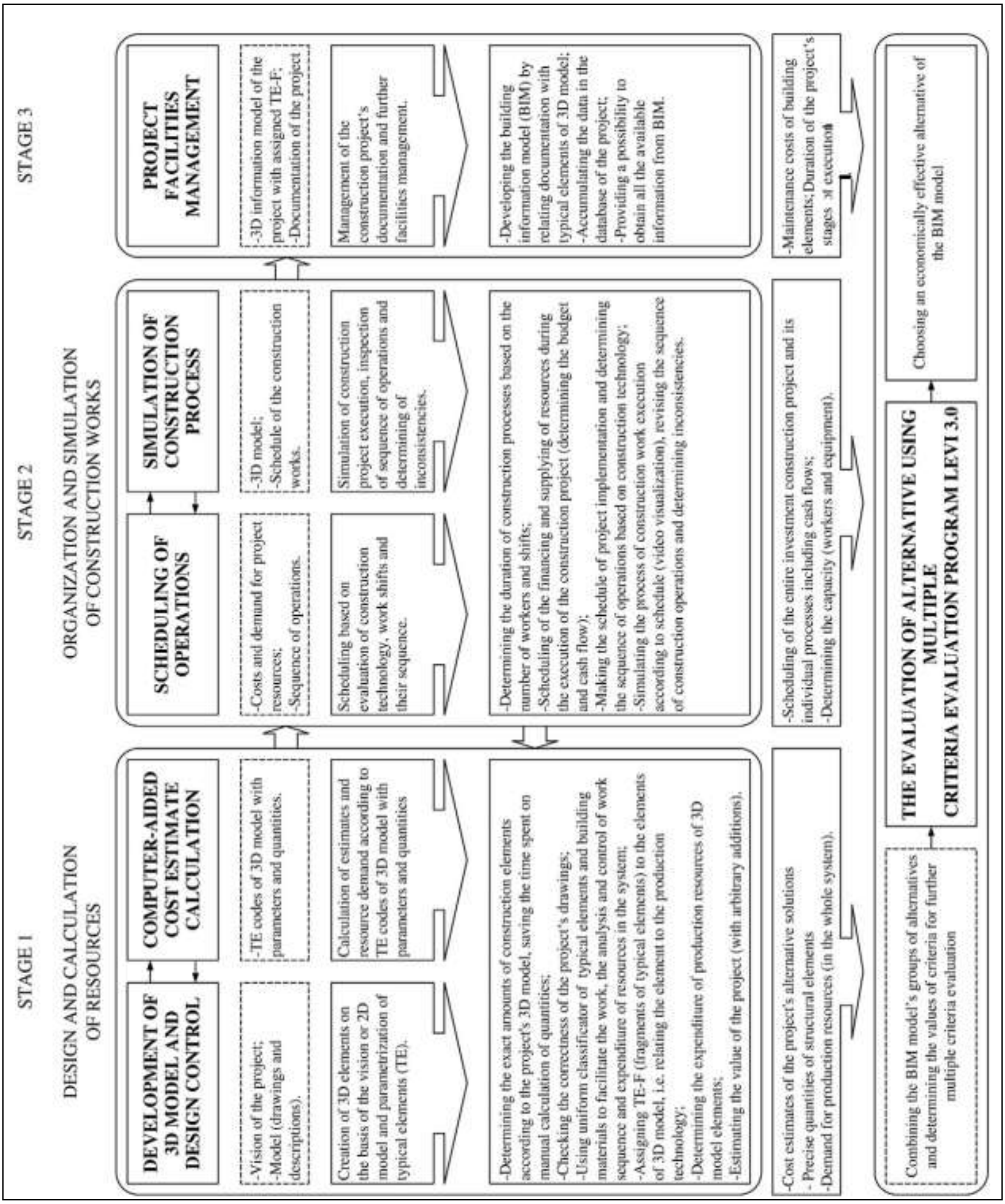



**Figure 79:Stages of project development according to the 5D Concept[99]**

99 Source: Popov, V., Juocevicious, V., & Migilinskas, S. (2010).

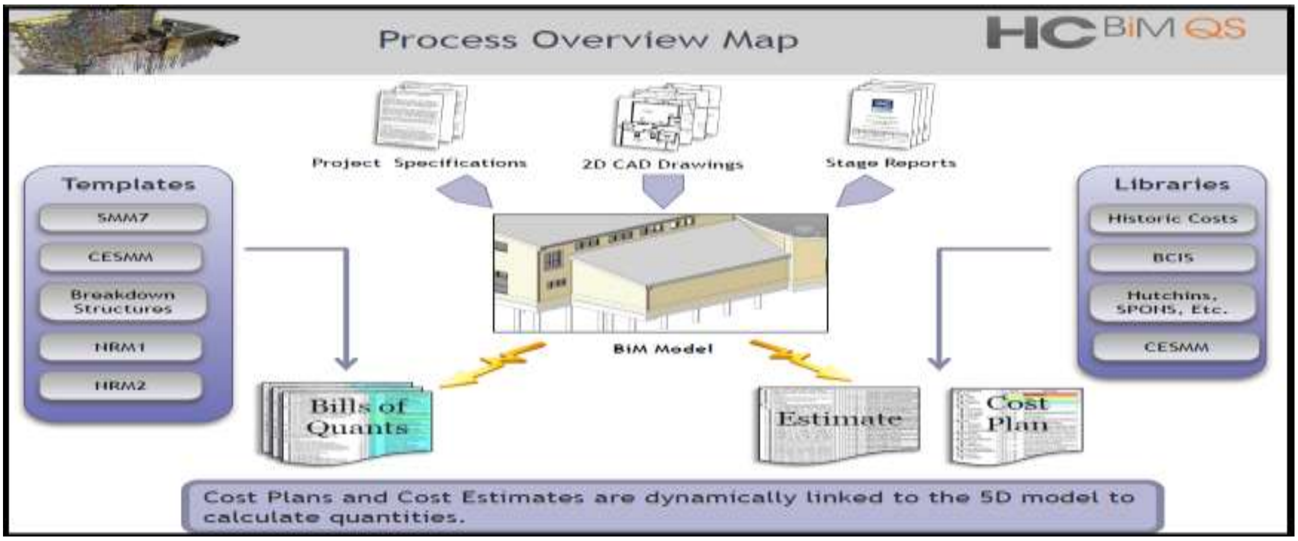



**Figure 80:Example of Documentation capacity of 5D BIM[100]**

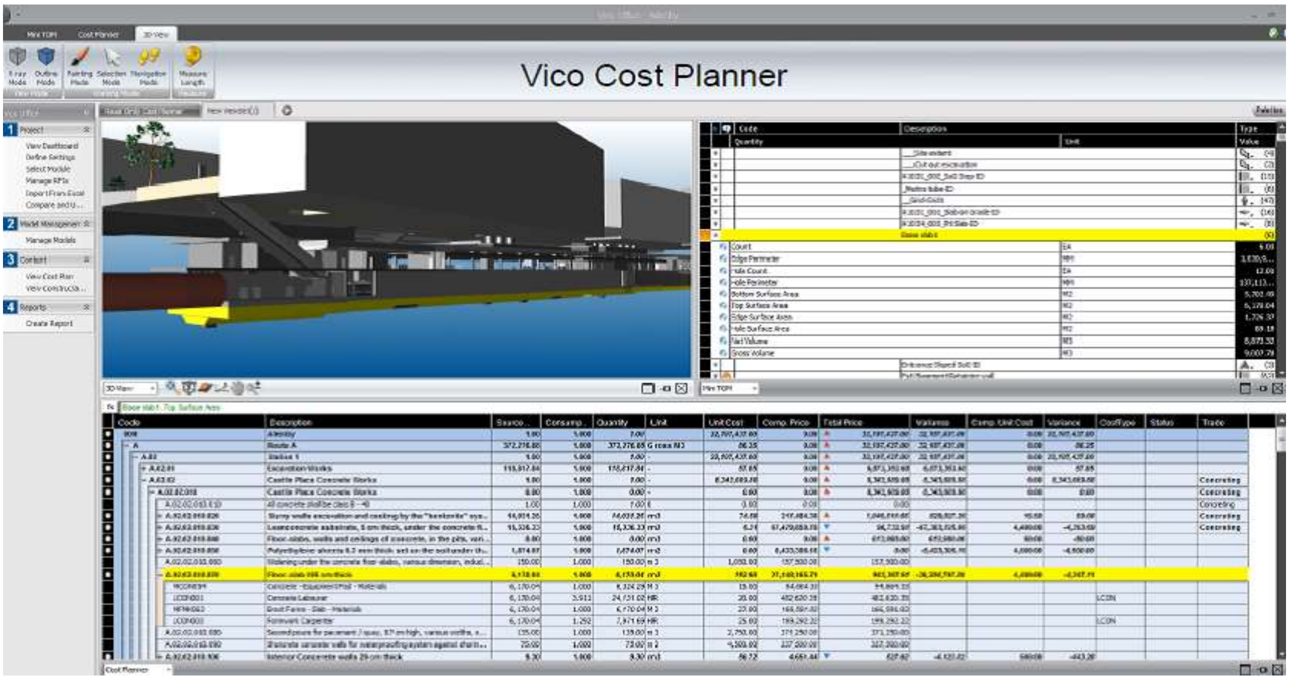



**Figure 81:Example of BOQ contents that 5D BIM software can provide[101]**

[100] Source: HC BIM QS. (2006).
[101] Source: Popov, V., Juocevicious, V., & Migilinskas, S. (2010).

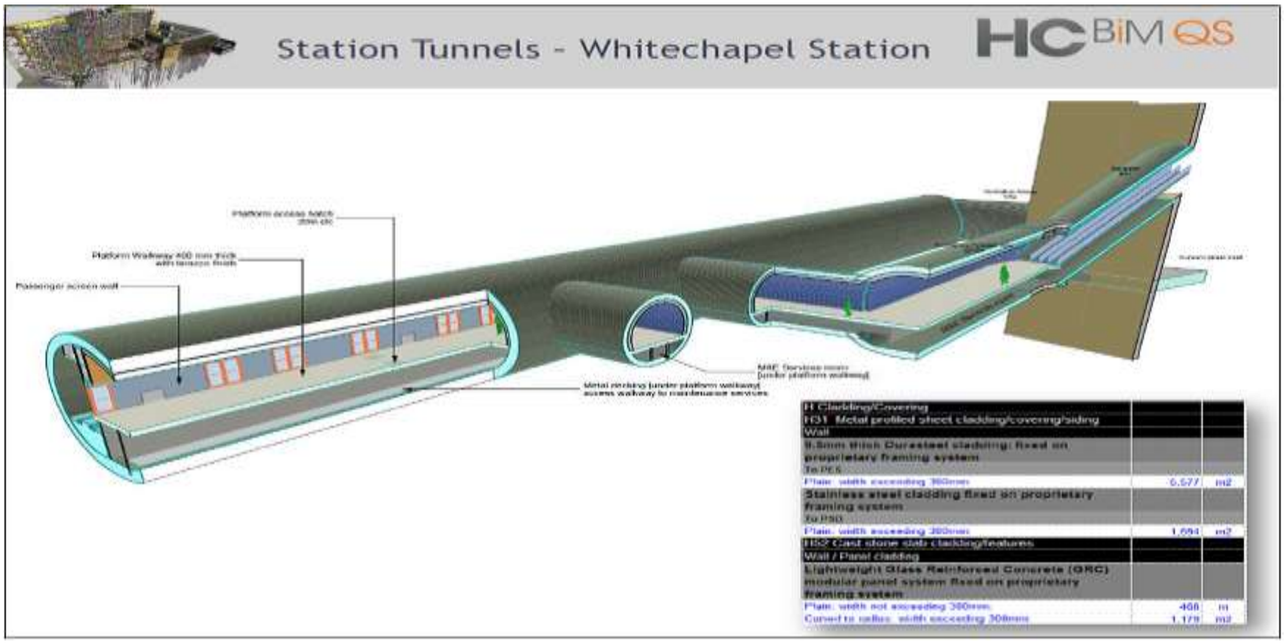
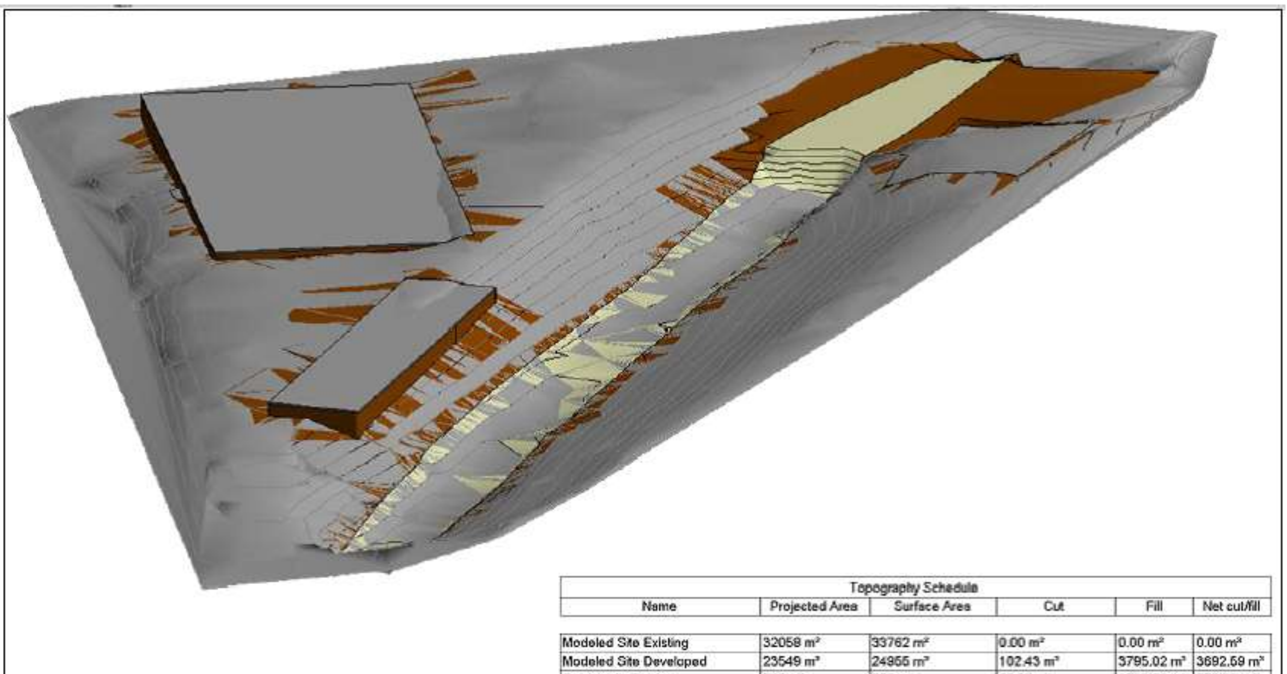



**Figure 82:Example of 5D BIM in Civil Works**[102]



| Topography Schedule | | | | | |
|---|---|---|---|---|---|
| Name | Projected Area | Surface Area | Cut | Fill | Net cut/fill |
| Modeled Site Existing | 32058 $m^2$ | 33762 $m^2$ | 0.00 $m^2$ | 0.00 $m^2$ | 0.00 $m^2$ |
| Modeled Site Developed | 23549 $m^2$ | 24955 $m^2$ | 102.43 $m^3$ | 3795.02 $m^3$ | 3692.59 $m^3$ |
| Community Centre | 968 $m^2$ | 968 $m^2$ | 62.53 $m^3$ | 1039.22 $m^3$ | 976.69 $m^3$ |
| Main Building | 3330 $m^2$ | 3330 $m^2$ | 72.56 $m^3$ | 6440.47 $m^3$ | 6367.90 $m^3$ |
| Contaminated trackside | 3397 $m^2$ | 3575 $m^2$ | 2.61 $m^3$ | 4151.35 $m^3$ | 4148.74 $m^3$ |
| Car Park | 814 $m^2$ | 814 $m^2$ | 2974.25 $m^3$ | 2.27 $m^3$ | -2971.98 $m^3$ |

**Figure 83: 5DBIM in Cut and Fill works Calculation**[103]

[102] Source: Popov, V., Juocevicious, V., & Migilinskas, S. (2010)
[103] Source: Popov, V., Juocevicious, V., & Migilinskas, S. (2010)

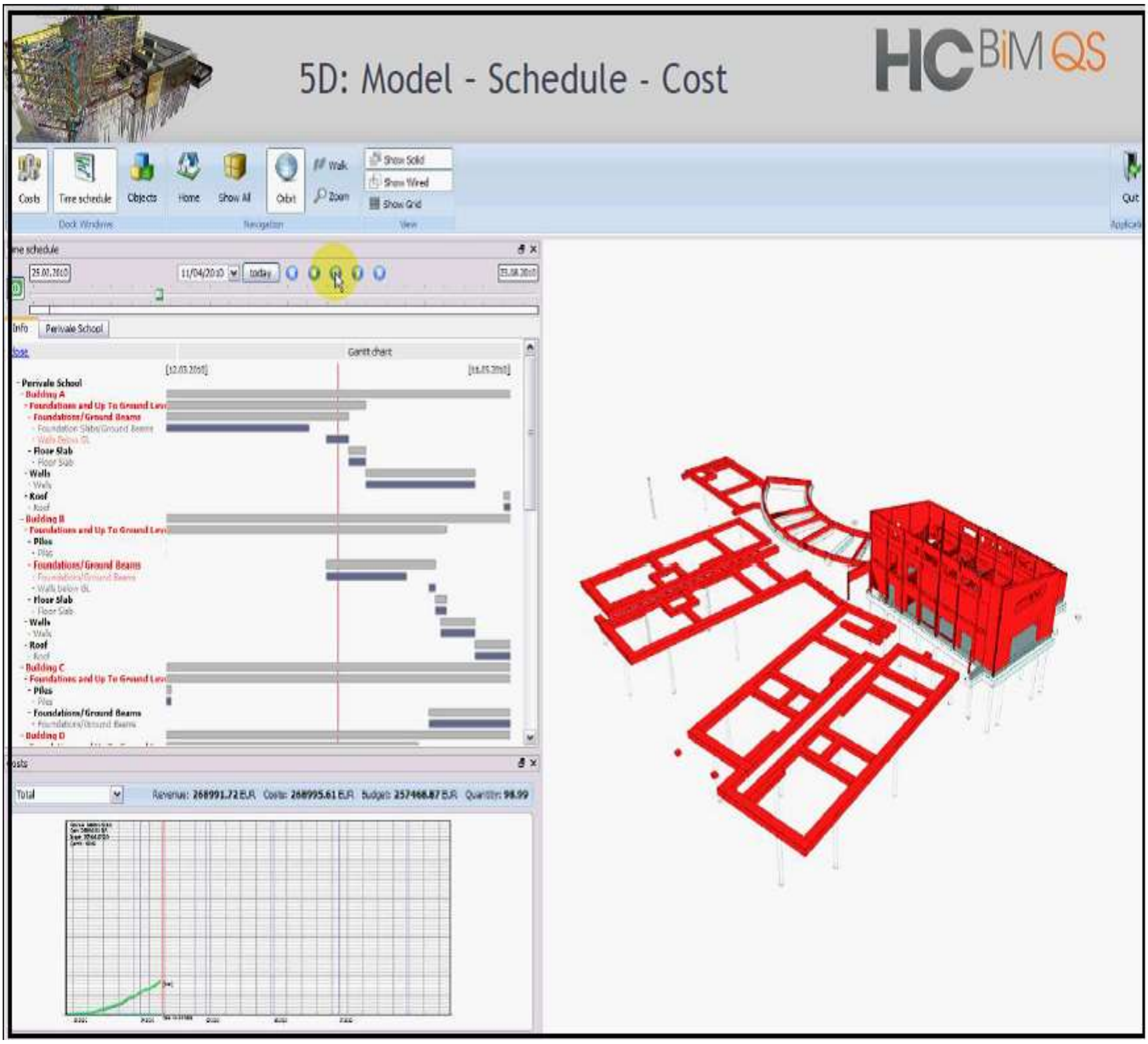



**Figure 84:Example of different Information that 5D BIM can Provide[104]**

[104] Source: Popov, V., Juocevicious, V., & Migilinskas, S. (2010)

## 2. 5D BIM Rationale

### 2.1. 5D BIM efficiency

5D Building Information Modelling is unstoppable. It will keep on flourishing in the future (Rizer, 2012) because it embraces the environment for key aspects of construction project management. It facilitates planning and controlling of cost and time, which are the basic pillars of construction projects. These two activities are said to be continuous tasks (Halpin & Senior, 2012) over the facility delivery.In 5D BIM environment, stakeholders can smoothly collaboration, transparently share graphical and non-graphical information, visualize the process, weigh the responsibilities and commitments and on top, they can get the picture of other related models of the project.

> ***"In order to manage, one should be able to control. In order to control, one should be able to measure. In order to measure, one should be able to define. In order to define, one should be able to quantify".*** **(Quoted from Burchfield, (1970), by (Halpin & Senior, 2012)).**

| 3D | 4D | **5D** | 6D | 7D |
|---|---|---|---|---|
| **Spatial model** | **Scheduling** | **Estimating** | **Sustainability** | **Facility management** |
| Safety and logistics Models | Project Phasing Simulations | Real Time conceptual modeling and cost planning | Conceptual Energy Analysis via DProfiler | Life Cycle BIM strategies |
| Animations | Lean Scheduling | Quantity extraction to support detailed cost estimation | Detailed Energy Analysis via EcoTech | BIM as Built |
| BIM driven prefabrication | Visual validation for payment Approval | Trade verification from fabrication models,e.g structural steel | Sustainable elements tracking | BIM embedded O & M manuals |
| Laser accurate BIM driven field layout | | Value Engineering, e.i what if scenarios and visualizations | LEED tracking | COBie data population and extraction |
| | | Prefabrication Solutions | | BIM Maintenance Plans and Technical Support |
| | | | | BIM file hosting on lend lease's digital exchange system |

**Figure 85: 5D BIM basic information as compared to other BIM dimensions[105]**

[105] Source: Modified from Rizer, S. (2012).

To optimize construction project resources within the specified time period it is necessary to manage the flow of information among the participants. To do this efficiently and effectively all along the project lifecycle 5D is the key. Popov, Juocevicious, & Migilinskas, (2010) agreed this and suggested the concept as a 5D Virtual Project Development. With 5D BIM, quantity take-off is more exact, automatic, collaborative, reliable, sustainable, simple and effective. It is in this light that it is proposed that exploration, description and explanation relative to BIM should primarily focus on the value 5D BIM in the project delivery. What 5DBIM does inherits what real BIM is and why it gives the benefits that are frequently pioneered

## 2.2. Recalling the Study Focus relative to 5D BIM

This study intends to appraise the use of BIM in Tanzania. The central problem of this thesis is in-adequate performance of Bills of Quantities (BOQ) in Public Building Total Cost Management. Bills of Quantities as a *cost* and *quantities* breakdown of the project, it plays as a central *informational* document role in delivery process of the building projects. On the other hand, BIM is all what we need for *information* integration in construction project delivery. While defining BIM is ambiguously possible, developing the right BIM level or model that can improve the BOQ productivity in the Total Cost Management of Public Related Building projects is necessary. Short of that, public facility delivery inefficiencies including time and cost overruns will keep on accelerating.

In Tanzania, adopting and implementing BIM should be economical and technologically affordable. Likewise, BIM is evolving (Ayyaz, Emmitt , & Ruikar, 2012), taking many dimensions and complexities. As such to fit the context of Tanzania, it is suggested that BIM, is viewed as ***what BIM does***. That is, the extent it enhances the informational productivity in total construction projects delivery. Irrespective of context or time frame BIM proposedly can improve the cost models (BOQ in Tanzania) productivity in total cost management. As such a BIM model may subjectively be understood, but objectively be researched, tested, adopted and implemented from Germany or the BIM practicing world to Tanzania. In Tanzania, 5D BIM is to be assumed first, as a visionary environment rather than reality. Then the model is developed basing on the level of information the 5DBIM model can provide. From this the light of the 5DBIM environment a desirable framework BIMBOQ model level for Tanzania is developed. Saying it otherwise, the right 5DBIMBOQ model level for Tanzania, may even be at manual level.

According to (Hardin, 2009) contractors perceive BIM as ***virtual construction of a facility or structure that contains intelligent objects in a single source file that, when shared among project team members, intends to increase the amount of communication and collaboration.*** Within BIM environment, the communication and collaboration shifts from building team to project participants or stakeholders. Likewise, the information focus is extended to cover the whole life cycle of the facility. However, given the limitations, little has been evidenced quantitatively. In (Ilozor & Kelly, 2012), a call for more rigorous quantitative studied were made. The AEC industry has not been able to fully convert BIM outputs into contractually tangible documentation of construction projects. In (Ayyaz, Emmitt , & Ruikar, 2012) it was remarked that BIM adoption currently is not well structured. Countries and professions are slowly adopting compared to appreciation they give on the importance of BIM. Reasons may include the need to change policies, difficulties in defining BIM and lack of enough tangible evidence outside beneficiaries that can differentiate BIM from traditional systems.

Standards and methodologies are being revised and developed to enhance efficiency in the AEC industry. In (Kehily, McAuley, & Hore, 2012) it was shown that a number of internationally established methodologies and standard method of measurements are currently facilitating Whole Life Cycle Costing (WLCC), but with regard to BIM, the current Industry Foundation Classes (IFC) model facing language and definition problems relative to the construction process. Many currently Standards are relatively not comprehensive enough to cover all necessary construction ingredients. They require additional inputs from specific users. In an Industry like that of Germany, with many individually formed construction contracts, BIM is facing a legal challenge from increased roles, interoperability and contractual obligations, see (Boldt, 2015).

> *"In Germany, HAOI is undergoing revision at the moment. Its scope of application is to be restricted to smaller projects through the lowering of the final values in the table, and removal of the work phases 6-9 and the consulting services. Furthermore, the fees should in the future be determined on the basis of building costs agreed in advance."* (Neufert & Ernst, 2012).

Combined performance model is not without *cost* and *schedule* (Ellis, 1997). Value and effectiveness were together mentioned and their importance explained. The reason behind the model combined to include the four element was to provide a global perspective. To model the causal structure in such a way that the project information and complexity can be measured and evaluated from the few tangible meaningful elements. The vital few concept. However, it is very few if any of the cost model reflects this. It is usual practice to include fewer elements of out of the vital elements needed, and so losing the likely global perspective. The argument raised include lack of enough time and claim that the other items are included during consideration of the design. Not only that, the extent at which these models cover the life cycle is more or less, the function of subjective interpretation and consideration. It is not easy to find a construction project cost model where Life cycle costing, is an objective quantifiable and measurable obligation, as (Kehily, McAuley, & Hore,2012) also tried. The consideration of such items, subjectively, hardly measurable in the handover of the project. Other equally important elements like time, taxes and waste are commonly left outside the model.

It may be easier to identify if client is the ultimate beneficiary of BIM than to predict the many more beneficiaries of BIM in the future. BIM is expanding in benefits, use and complexity. The simplest form of BIM model may be equated to a simple drawn plan, which gives a blink of information to the common people trying to build a simple house. The more advanced level can be equivalent to a single imaginary building envisaged by designers, contractor and the client. The model aspect is one side of BIM. Together with the informational complexities, it becomes subjective and more uncertain to clearly define and agree on BIM basing on what it is. On the other hand, scholars and practitioners can fundamentally and objectively agree on *what BIM does* to the construction project delivery process. It is the materiality of the BIM output that matters most to the stakeholders. For instance, if it is because of BIM that an overheads estimation document in the contractual arrangement is possible, then the absence or presence of BIM can easily be questioned even in jurisdiction. On the other hand, if BIM is that which represents information integration digitally, then the question of whether overheads estimation document could be produced by the BIM becomes relatively subjective, contextual and time specific. It even becomes relatively difficulty to test and adopt the basics.

Therefore, concentration in level of information added or omitted by BIM to standards and contract documents may work constructively in standardizing BIM than working in the opposite direction, which seem to be case. To know, test, adopt and implement BIM, it is far better to establish the axioms on *what BIM uniquely does*, than *what BIM is*. As such, optimal information levels defines the BIM models, BIM modellings and BIM environments. That said, within 5DBIM environment, the most efficient 5DBIM Bills of Quantities models with the combined performances can effortlessly be prepared. Nevertheless, the least 5DBIM BOQ model with the combined performances can spiritedly be prepared. The only difference exist on the level of information integration the two BIMs produce. These levels can be called anyhow, D, 2D, 3D, 4D, 5D, 6D, 7D or nth D BIM, depending on the unique level of information integration that can be produced and documented.

Knowing what we know involves scientific endeavor of establishing and proving the existence of both, theoretical truth and practical truth. This study, is limited to theoretical part, with preliminary practical part used as justification of the establishment of the problem. The hypothesis, that “in Total Cost Management (TCM), 5D BIM has positive effect in BOQ Completeness” is stated basing on the existing literature. Then the empirical study is done to check the correlational status between 5DBIM level and BOQ Completeness level before testing the hypothesis in the future. The objective stance with cross-sectional design are basically used. The reason being to acquire context, value and time free Tanzania BIM model.

## VII. Thesis Philosophy, Methodology And Methods

### 1. Thesis Philosophical Stance

Just like tablet prescription, research results require thorough understanding of the accompanying instructions before its usage.Their impact on society is significant, and sometimes it can not be revealed in the short term. The data derived from researches are used to make key decisions, and so they can be very benefiacial and can as well be very harmful (Matipa, 2008).To ensure protection of the patients or Clients, researchers need not only an in-depth skill on how to clearly precribe results,but also they need to follow research ethics, use the right ways and right techniques in doing research. From (Lastrucci, 1963) and (Kothari, 2004), a researcher needs to develop the methodology and methods necessary for the concerned problem. This enhances sense of objectivity to a research ,saves time and it saves cost too. Researches are scientific undertakings to develop knowledge and to give solutions to societal problems, and so they need clear and reliable methodology to explain logical and systematic reasoning behind the relevant methods and techniques used to undertake them.

Research consists of arguments with strong claims, reasons, evidences, acknowledgement and responses (Booth, Colomb, & Williams, 2008).To them doing research is generally "***gathering information to answer a question that solves a problem***".Widening this definition, that information gathering should be *systematic*, *scientific* and well *organised* in accordance to the rulebooks by the scientific research community. Likewise, the question and a problem should also be *scientifically researchable*. A research to be scientific, it must contribute to a body of science through the use of scientific research (Bhattacherjee, 2012). It is agreed as well that through such endavour, the knowledge (powerful one) (Grundmann & Stehr, 2012) is acquired. Whether the researches done contain the powerful knowledge and reliable solutions, to overcome the challenges of the Tanzanian Construction Industry (CI), should form the basic question of all participants, because otherwise problems will keep the current geometrical persistance. It is in the view of this thesis as well, that to research on BIM, requires critical review of the science and its philosophy in order to reliably explain whatever special output that BIM provides when adopted in the construction project.

BIM is a new phenomena world wide, and even newer to many Tanzanians. This is supported by (Monko & Roider, 2014), concluding that *"There is little, if any, adoption of BIM in the AEC community in Tanzania".*It was however concluded that the AEC community is highly interested in using BIM. In order to develop the BIM model relative to the Tanzanian Construction Industry, formulating a right question is basically a step worth a significant time of research. It requires rigorous review of literature world wide and retrospective process of obtaining the scientific questionable model. Spending time to identify the basic question is worthwhile (Yin, 2003). On the other hand, identifying the question and giving the unscientific output, is toxic research contribution to the society development. That means, it is dangerous to rely on Research Methodology and Methods applied anywhere as well, because despite the light they may provide, they may not reliably provide the full picture of what BIM is or how it works or even what it does in the Tanzanian environment.

We need a History to reliably talk about the future. It is equally applicable to an understanding of the philosophical stance of knowledge investigations. Khine, (2012) agrees with (Hanson, (1924–1967)) that *History of Science* and *Philosophy of Science* should not be separated,but rather understanding of both is necessary. The two consist of inseparable knowledge development relation values. In a simple explanation, the *past* contributes in *reliable thinking* and *viewing of* the future. Just like what (Amara, 1978) insisted, present is transitory.

> "*The future objectives is to characterize the degree of uncertainity, to examine the alternatives, to identify precursors or warnings of particular futures, to acquire an understanding of the underlying processes of change and to sharpen our knowledge and understanding of our preferences".(ibid)*

The past in the construction industry productivity improvement researches world wide, helps this thesis to develop a testable BIM model that can among others, help Tanzania Construction Industry participants to meet their objectives sustainably. The philosophies, axiologies, ontologies and methodologies applicable in exploring BIM gives an orientation of the knowledge angle with regard to BIM. The research is *applied* in that, it is only when the BIM is adopted, the community can use the developed model to solve the problems. On the other hand, the research is *pure* because the model at its simplified level, that is the developed BIM model, well grasped and used, it can reduce the intensity of the problems facing the Construction Industry in Tanzania. Otherwise this research has offered insignificantly little to the understanding of BIM in Tanzanian CI. To be a pure research, the solution to a problem should at least, add knowledge to the community of researchers (Booth, Colomb, & Williams, 2008).

Everyone today need Science and Technology. It is hardly possible to find a Construction expert in Tanzania not owning a mobile phone, of which is a very helpful tool in the undertaking of the construction project. At the moment, US is inducing scientific reasoning to citizens all round (American Association for the Advancement of Science (AAAS), 1989, 1990). Yet, to the majority of Tanzania science is all about natural sciences (Economic and Social Research Foundation (ESRF), 2010). Example, a call made by (Kaseva, 2010), that universities are lagging behind the global market and so they need to speed up and redirect their effort towards global competence, can not be fairly responded without insisting on the improvement of the scientific endavour. On top, global competence in any sector requires valid scientific researches, at least. At its heart this thesis, intends to go through scientific stances of researches, in order to provide reliability and replicability of the developed BIM model and to equally support the movement towards BIM adoption and implementation in Tanzania. In concluding, (Ofori, 1993),

> *"There is a need for research work in the field of construction industry development to be intensified. Realistic new approaches are required. There is also the need for works on the field to be coordinated and better disseminated."(Pg 183)*

It is time to change the way of thinking of the participants, as well, because the participants, clients inclusive, are the key path to the recommendable change. So unless, they realise the marginal benefit of new systems over traditional system, they will resist the change. This thesis is faced with this challenge too. To explicitly clarify BIM to Tanzanian participants and alert the Government, as a major client, the supernormal benefit of using BIM process over traditional way in undertaking construction projects.To accomplish such a goal, the theoretical, rational and empirical support is vital to the study.

### 1.1. Setting

Use of assumptions is both the weakness and common practice in scientific undertakings. It may distort the large proportion of reality and hence resulting to harmful research. But also assumptions are necessary in order to reduce the likely ambiguity of observing the full unknowns. In that, being scientist merely require a systematic and carefully approximation of the uknown truth or reality. That is a deep explanation, description, exploration or understanding of the phenomena under some underlying universally proved assumptions. Scientific knowledge is far from the *reality*, because the endavour is made within constraints (McFarlane, 2002). To fully understand the science we need full openness to *unknowns*, that is investigation without *assumptions* at all, which is not the case even in scientific researches.

Construction is all about converting *man-made* and *non-human natural entities* into sustainable productive structures or environments, by the *people* for the *people*.In construction projects, a *need for a facility* determines the existance of the project. A Client or a purchaser approaches experts to define and give guidance on how to acquire the product from a contractor. ***"A construction project is a bird in bush not in hand as a manufactured product***" (Halpin & Senior, 2012) .Construction

Industry is well-known to be a disintegrated process. The common practice is that Architects, Quantity Surveyors, Engineers, and Contractors are working almost independent and do not advantageously cooperate themselves and they hardly involve Facility Managers during the actual construction on site. Because of this, the effective flow of information is hindered and hence reducing the overall performance. Many scholars ((Eastman, Teicholz, Sacks, & Liston, 2011), (Smith, Mossman, & Emmitt, 2011) and (Love & Irani, 2003)) supported this argument. In the world today, construction process should be sustainable (Haselbach, 2010), or saying it otherwise, construction undertakings today should not negotiate the likely future benefits of the environment to the society.

At its core, construction project involves *people* manipulating *physical entity* for meeting human desire and facilitating human undertakings. It is Multi dimensional complex process involving human resources, materials, plants, technology, institutions and documentations ( Ofori, 1993 and 2000). To embrace the reality in such complex phenomena within academic research time, it may be unimaginable challenge. Instead, the duty of this thesis is to approximate the objective truth with regard to *what BIM does* in the successful construction projects world wide.From such an approximation, it is possible to develop a model that reflects that approximated reality of BIM in the image of the Tanzanian construction industry resources. Knowledge in such a reality comprises both, *objective* and *inter-subjective truth* among the participants. For example, (Forbes & Ahmed, 2010) said, productivity CI is normally qualitatively defined, (Barlish & Sullivan, 2012) added that, the popular productivity measure of key performance indicators in construction is based on subjective observable quantity, and on the other hand, (Low, 2001) quantitatively correlated buildability, quality and productivity and reported a positive relationship. Nevertheless, it is argued that the drivers of construction projects performance, cost or profit, schedule, return on investment, safety,productivty and relationship (Ilozor & Kelly, 2012), need vigorous quantitative test against the use of Building Information Modelling (BIM) or Itegrated Project Delivery (IPD), so as to add more value from the already done qualitative, case based studies.

In the above paragraph, the indication is clear on how difficult it may end when an investigator is trying to set the construction projects studies, in a *Social Science*. The difficulty of reducing phenomena of construction projects in laboratory environment, has not hindered the application of natural science stances. This thesis supports that the process of construction is scientifically more of socially constructed than naturally. But, in order to sustain the contextual and time test of BIM in Tanzania, the effort should be made to embrace the naturalistic view of scientific approaches.

> *"That is, there is general agreement among natural scientists regarding what the aims of science are and how to conduct it, including how to evaluate theories. At least in the long run,*

> *natural science tends to produce consent regarding which theories are valid. Given this evident success, many philosophers and social theorists have been eager to import the methods of natural science to the study of the social world. If social science were to achieve the explanatory and predictive power of natural science, it could help solve vexing social problems, such as violence and poverty, improve the performance of institutions and generally foster human well-being. Those who believe that adapting the aims and methods of natural science to social inquiry is both possible and desirable support the unity of scientific method. Such advocacy in this context is also referred to as naturalism"* (Gorton,William A. , 2010)

As stressed by (Bryman, 2012), *Naturalism* in this thesis takes the view of belonging or prioritising what holds the true nature of the phenomena in question. That is, what ***BIM does*** to the construction project performances is far important before understanding *why* and *how* it helps in dealing with challenges. The former holds BIM reality to the construction project anywhere, anytime and anyhow, while the later questions of how and why may work best and differently in Europe, Asia and America or even in differring projects contexts. On top, their answers may become obsolete with time even within a decade. It is not uncommon to pinpoint the embreyonic or central factor when trying to adopt a complex philosophy or technology. For example, from (Melles, 2007), the use of Lean Production in construction industry requires grasp of the Keizen Principle to the company other than principles like Just In Time. That fact helped adoption of Total Quality Management in western countries, by adding International Standards Organisation (ISO), which intended to cover the difference in culture between the Japan and Western world. Failing to modify that *cultural impact (reality of lean within Kaizen)*, would mean diffculty in adopting Lean production in western world. As such, a *BIM reality or truth* that is not influenced by values of the system, technology or participants in which BIM is used, is what this thesis intends to tranfer by developing a simple model, relative to the environment and resources of the Tanzanian construction industry.

### 1.2. Natural and Social Science

In general view, science, refers to universal disciplined ways of developing, testing or building theories and knowledge. However, (Boutellier, Gassmann, & Raeder, 2011) precautioned that the definitions of science can not easily separate many other branches like religions and astrology,which also seek to understand the world. An attempt includes as well (Bhattacherjee, 2012) who defined science as any systematic and organized body of knowledge in any area of inquiry that is acquired using scientific methods. From (Wikipedia, the free encyclopedia, 2013)

> *"Science (from Latin scientia, meaning knowledge) is a systematic enterprise that builds and organizes knowledge in the form of testable explanations and predictions about the universe. In an older and closely related meaning, science also refers to a body of knowledge itself, of the type that can be rationally explained and reliably applied.*
>
> *The natural sciences are those branches of science that seek to elucidate the rules that govern the natural world through scientific methods, the cornerstone of which are measured by quantitative data. Based on formal sciences, they also attempt to provide mathematical (either deterministic or stochastic) models of natural processes. The term natural science is used to distinguish the subject from the social sciences, which apply the scientific method to study human behavior and social patterns; the humanities, which use a critical or analytical approach to study the human condition; and the formal sciences such as mathematics and logic, which use an a priori, as opposed to factual methodology to study formal systems."*

In (Bhattacherjee, 2012), sciences were also categorised in natural and social. Natural sciences basically deals with non human matters ranging from physical bodies to living organisms. On the other hand Social Sciences comprises of systematic inquiries relative to humankind. It refers to problems related to subject like economics, psychology and management.

In (Ledoux, 2002),

> *"Fundamentally, natural sciences are defined as disciplines that deal only with natural events (i.e., independent and dependent variables in nature) using scientific methods. These disciplines always exclude non-natural events from their considerations…One common misconception involves the use of scientific methods. Status as a natural or social science is not determined solely by a discipline's use of scientific methods. All natural science and social science disciplines use scientific methods. However only some of these disciplines invoke the exclusion of non–natural events from their considerations; those that do so have historically (and contemporarily) earned the title "natural science." Even "creation science" may make use of scientific methods, but it does so while making non–natural events—the will of a mystical, faith–based being whom creation scientists consider supreme—the centrepiece of its considerations; thus it is not, and cannot be, a natural science".*

Despite the similarities with regard to creation of knowledge and understandng the reality, (Boutellier, Gassmann, & Raeder, 2011),also pointed differences of natural and social sciences *(See Figure 86: Table 1: Differences between Natural Science* and Social Science*)*. However the confusion will still be there as (Ledoux, 2002) insists that ***"There was a time when no disciplines were natural sciences.***That is some discipline of which today are natural science, some subgroups were initially social science or non-natural social at some time back. Social Scientist are both descriptivist or rationalist as natural scientists and are prescriptivist as well, seeking understanding of the phenomena (Gorton,William A. , 2010). Resolutely, this thesis proclaims that the process of construction is scientifically more of socially constructed than naturally. Unavoidably, a researcher need to explicitly explore the knowledge with regard to *reality*, *its existence* and the *way to understand it and its sensations*.

| | | Natural Science | Social Science |
|---|---|---|---|
| 1 | Definition view | Focus is on natural events. Driven by or tied to laws of nature. Birth of child or thunderstorm can better be understood from biological and physics point of views | Focus is on Cultural Humanities events. Questions with regard to politics,history,economics and instittional systems are examined. The influence of human endeavors drives the events. |
| 2 | Origin | Early leaders of this 'Scientific Revolution' like Galileo. They were basically concerned with the questions of the origin of the world/universe. | The *social sciences* are much younger than the *natural sciences*, but *social interactions* is the oldest of all. Century with sociological publications including "Suicide" by Émile Durkheim and "Système de politique positive" is mentioned a stone for a positivism in 19th century. |
| 3 | Focus of study | The aim is to discover the laws, rules or forces behind the existing world and our diversities. | It is focusing on the discovery of the laws behind existences of human determined idiosyncrasies or irregularities. |
| 4 | Methods | Consisting in systematic observation, measurement, and experiment". Mathematically based methods are dominant. | Observation, Interviews, surveys, case studies. Observation is a social science counterpart of the Natural sciences experiment. Experiment is difficulty Because of uncontrollability of social environments and *narrative* based methods are argued dominant, but mathematically based method is not dominant. |
| 5 | Philosophical stances | Genarally, the discovery of knowledge is restricted to sufficient scientists agreement that the proposed hypothesis or theory ***may not*** hold water any more. Just that is enough to establish new hypothesis and seek a new knowledge which is objective outside non-naturality. | The non ending debate on what is acceptable knowledge. Positivist side, apply natural sciences methods in seeking social knowledge. Interpretivists, on the other side,say, Social Reality cannot be measured by Natural Science methods. Because it is within *subjective meaning* of social interactions. |
| 6 | Limitations | Technical and Financial boundaries, causes imprecise measurement due to the necessity of working within constraints of capability and affordability of the equipment. The use of laboratory is assumptions supported science. | Uncontrollability of the environment and complexity of people, requaires not only financial and technical support, but also ethical considerations when doing social investigation. The findings can hardly be generalised universally. |

**Figure 86: Table 1: Differences between Natural Science and Social Science[106]**

[106] Source: Extracted and Modified from Boutellier, R., Gassmann, O., & Raeder, S. (2011). What is the difference between social and Natural Science. Doctoral Seminar "Forschungsmethodik I"HS11-10,118,1.00, Fall Semester 2011. Swiss: Swiss Federal Institute of Technology: http://www.faculty.english.vt.edu/ Collier/sciwrite/pdfs/ boutellier_2011.pdf.

## 1.3. Thesis Axiology and Ontology

To a social scientist or social researcher settling the contradiction and similarities between the positivism and interpretivism helps to acquire philosophical view behind universal scientific thinking and reasoning.It gives the social researcher the light to a starting point and a right direction to where an investigation is heading or pulling. In (Hudson & Ozane, 1988,1989), the comparison of the two, with regard to Axiology (Angle, 2009), Ontology and Epistemology was clearly made. It is a never-ending debate worth participating, at least by listening or reading. In (Burrell & Morgen, 1979), it was argued that social sciences can conviniently be conceptualised in terms of four sets of assumptions,that is through ontology, epistemology, human nature and methodology.The two paradigms are not reviewed to identify which one is wrong or right, but rather in order to systematically position a research endavour on the more clear path.

Axiology is the *science of ethical or ultimate choice and values*, ontology is the science of *being* ***(Angle, 2009)*** or simply positioning oneself on what is the truth of what is investigated and whether it is what it is thought to be (is it real). "*Epistemology is the study related to the nature of knowledge and the extent of human knowledge*" (Truncellito, 2007 ), that is the theory of ***how we know that which we know*** (Angle, 2009). Sometimes epistemology is simplified to mean the relationship between the investigator and the truth or knowledge being investigated. Methodology, the lesser philosophical one is in fact, representing the the procedures, methods, tools and assumpitons used during discovery of truth, reality or knowledge in question.

On the other hand, according to (American Association for the Advancement of Science (AAAS Project 2061) , 2013) *"The Nature of Science includes the scientific world view, scientific methods of inquiry, and the nature of the scientific enterprise".* Social researchers,despite their categories, should as well value the need to understand these stances before embarking on their work.Before contributing the new knowledge to the science world, one has to first live the science world. Only communicating scientifically is not enough, one has to acquire the *genetic material* of the scientific world. Otherwise, the contribution may be *unscientific creation of reality,which is so to say, not a knowledge as recognised by scientists*. To acquire such a stance, in this thesis a significant time was spent, in reviewing not only construction and BIM scholarly materials, but also additionally reading and reflecting on the philosophy, science and scientific research endavour. In particular, the focus was on reflecting the appraising of the Building Information Modelling technology in Tanzania.

According to (Bisman, 2010), metaphysics claim of reality is "*materialistic*", in that, reality is *objective* and *concrete*; that is, reality is *material*. Authors uses the term positivism differently

(Bryman, 2012) and sometimes difficulty to precisely explain it. In positivism the single "*objective*" *reality*/*truth,* is an *external truth* and it exists independently of human thought and perception. The basic assumption is that, it is possible to describe and explain the reality/external world in a cause-effect form or using general laws. A *"mechanistic"* claim that human behaviours can as well accurately be reduced into general laws and that human being are not significant (nomothetic) *forms a unique feature in positivistic research*. Epistemologically, positivism advocates the application of the methods of the natural science in the study of social reality and beyond (Bryman, 2012), entailing both deductive (primarily theory testing (Christie, Rowe, Perry, & Chamard, 2000)) and inductive reasoning.

*Realism* is distinguished to positivism with regard to certainty. *Empirical* realism or *naïve* realism, when it is assumed that reality is perfectly closely related to its description, and *critical realism*, when *retroductive* reasoning is used to infer about the causal relationship behind regularities and generative mechanism (Bryman, 2012).That is, uncovering the forces behind the *experienced realities* as purpoted by (Potamaki & Wight, 2000). Critical Realists argue that it is impossible to know with certainity the independent reality (Bhattacherjee, 2012). Only deduction or induction approximation is not enough to give the conditions that causes the perceived events.We need retroduction reasoning, because causes of social events are rooted in the conditions behind those experiencing those events. Retroduction brings new idea, deductively demostrates it and inductively justifies the idea (Chiasson, 2013).

In *idealism* reality is subjective, non-material and it is internally experienced, interpreted and constructed by the mind (Bisman, 2010), and mostly, the human behaviours are ***not*** deterministic. It is important to recognize the *uniqueness of individuals and meanings contextually and historically whenever the knowledge about the phenomena is desired*. In Interpretivism, acknowledgement is made of the differences between *natural sciences objects* and *socially constructed objects.* The understanding of subjective meanings of the social actions is crucial. The understanding of the reality is through subjective interpretation of the different actors involved in the social world (Bhattacherjee, 2012).

Positivism and Interpretivism are not entirely distinguishable in methodology. It is possible to mix quantitative (commonly positivistic method) in interpretivistic study. In (Bisman, 2010), critical realism was suggested to fit the accounting studies with the two paradigms used together.However the two paradigm hardly mixed in ontological stance because ontology stands for self recognition, which means a one or zero stand. Either the single truth/reality exist (realism) or the single truth/reality does not exists (Relativism).

Additionally, today in science, it is important to recognize the societal side of science.The collaborative scientific endavour with the purpose to advance knowledge, address society's intellectual and/or practical needs (Boadu, 2010). That is the complexity nature of the activity, the ethical necessity of the undertakings, the involvement of scientists as human being as well as to consider the sorrounding mutually related societal effects. The modern world desire reliable advanced knowledge and meanings from both sides rather than from edges of both sides,that is positivism and interpretivism.

> *"Thus one of the aims of social inquiry should be to capture that meaning. Also, as the hermeneutical, postmodern and critical theory approaches insist, social inquiry is inherently evaluative. A purely objective, neutral science of the social world is neither possible nor desirable. So, room must be made in social investigation for reflection on the biases, interests and ideologies embedded in various social science methods. And, finally, naturalistic mainstream social scientists are surely right to continue searching for patterns, mechanisms and causal processes in the social world, for they do exist, even if they are only relatively enduring and dependent upon social context, including the shifting self-understandings of human beings.*
>
> *From this vantage, a kind of unification of the social sciences can be envisioned, though not in the sense advocated by naturalism. Unification in this sense requires, as the hermeneutical approach suggests, that we view social science as social practice. The efforts of social scientists should be seen as part of a wider, on-going human project to better understand our world, and ourselves and to make our world better. The facts, patterns and mechanisms that mainstream social science uncovers, the meanings that descriptivism unveils, and the self-reflective awareness of the values embedded in such inquiry that critical theory and hermeneutics counsel, should all be part of this broader human conversation."* (Gorton,William A. , 2010).

In construction industry, physical infrastructure are planned, designed, procured, constructed or produced, altered, repaired, maintained, and demolished ((NCC), National Construction Council, 2013). The CI is too wide and complex in nature from Civil Works and Building, from international to local, and from private to public projects.On top these projects comprise of many stages from design to disposal of the facilities as well as involving human beings with different desires,backgrounds and different values. However, in CI, participants are driven by the professionalism principles combined with rules of both natural and social sciences. An Architect's design needs buildable Structural Engineer's principles, to fit land policies and to be objectively interpretable for costing and the like. Social orders and patterns of the construction industry as such, compels this thesis into *functionalism paradigm*, studying it through objectivists (epistimology) approach (Bhattacherjee, 2012). On the other hand, there are decision oriented phenomena like costs,quality and time that depend totally on the human intellects, and hence consisisting of subjective values. It is in the view of this study, that (Bisman, 2010,pg 15), did not distinguish the *costs figure* and *costs documents*, when concluding that *"accounting information is not objective .....accounting questions are not rooted in a purely objective reality"*.That inform more on the subjectivity than on the objectivity perceptions. Questioning "*Direct costs of materials in a costs accounting statement"* can be subjective while questioning the "*presence of a direct costs of materials figure in a cost accounting statement",* may turn to be objectivity inquiry.

Inducing the use of BIM in Tanzanian environment may be very challenging, and so, *objectively* understanding and explanation of the mechanism and facts is necessary. The reality in construction process spans from natural science, when structural mechanics is thought to, to purely social science when the colours of the building is percieved and judged. Never the less the mechanism in the management comprises of many desires that need intersubjectve agreements. Costs, Time and Quality are among few items that participants will subjectively observe or asssess to decide exactly what is the standard facility. While to Architect, a quality project may mean aethetical building, to clients it may mean usability or timely delivery, and the engineers may be looking for fitness to the structural purposes. Understanding in such fragmentation, multirealities, and professionalistic mechanisms requires methodological pluralism (Gorton,William A. , 2010), as quated above. On the other hand, the problem within this thesis lies in simplicity and reductionism of the whole BIM complexities to a small BIM reality approximation that can be understood, practiced and developed to the world BIM level later after it has undergone several tests.That means the basic focus is not on the explanation of the causes behind *what BIM does*, which necessitates the depth understanding. It is only necessary to appreciate the artifacts produced by the actors, that can have holistic value, which may hardly be approximated individualistically,but yet it is still there. Through assumptions it is possible to discover and correlate the variables. Thus this thesis, chooses individualism in methodology.

To assess costs *artifacts,* it may be necessary to assume a given quality from a given expertise level, which implies the presence of cognitive values. But, given the need of the thesis to cut across the multiapplicability, ontological stance fits better positivistic than interpretivistic stance.To acquire foundations for future testing and critical analysis the critical realism ontology is opted. Positivism guides on the underlying laws and assumptions of the Construction process while post positivism, gives the safety of the modification resulting from the researcher and actors intellectualism or cognitive values relative to the approximated Construction practice and BIM reality. This means this thesis may not absolutely avoid interpretivist values, at least at methodological level or rather a postpositivist ontology (Christie, Rowe, Perry, & Chamard, 2000), where the individual or social mechanism may real affect the facts and understanding.

### 1.4. Epistemology

Epistemology is much philosophical compared to methodology. It entails the connection of how one goes in knowing the unknowns in question. In (Southerland, Sinatra, & Matthews, 2001), Foundationalists, Objectivist, Fallibalists and Radical Constructionivists views were elaborated.

> *"To Socrates' question, "What is knowledge?," !…………….even if one knows that, say, cobbling is "knowledge of how to make shoes," one cannot know what cobbling is, unless one knows what knowledge is (Giannopoulou, 2014)*

From (Truncellito, 2007 ), researcher should concentrate on *prepositional* knowledge and not *procedural* or *acquantance* knowledge. On one hand the epistemology should give the criteria necessary and sufficient to know what is a knowledge and on the other hand, it should be capable of providing ***a priori*** or a prior knowledge grounded on strong reasoning as well ***as posteriori*** or a posterior empirical knowledge grounded on experiences as well. In brief this stand is continuity of what Plato stressed, the reasoned true belief account of knowledge. It requires three conditions: The *truth condition*,which measure the proposition accuracy to the reality, the *belief conditions*, which mesures if the individual believes that the proposition is true and the last is the *evidence conditions*, which stressses the need for *good reasons* for believing that the proposition is true.That is to have knowledge one needs a proposition that can be believed to be true and it can also be evidenced to be a true proposition. From that, the foundationalists require that the evidence be well secured (evidence requiring no further evidence or non-inferential foundation), to avoid circularism (the need for eviedence now and then for the reasoned true belief). For empiricists, this evidence is from direct sense while for rationalists, it is from axiomatic idea.On the other hand, objectivists, categorise materials,mind and science as different worlds. To them, (Southerland, Sinatra, & Matthews, 2001) say, the scientific knowledge is in the third world , that is the world of science far from the thinking or conscious world (at personal level knowledge).

The questions, whether the truth is absolute, the belief is also a knowledge and what comprises of justifiable evidence to be accounted as knowledge are some of the difficulty questions to answer by who is right or wrong. However it is clear,that proposition,beief,truth,justification and knowledge are among the key words the researcher need to be aware

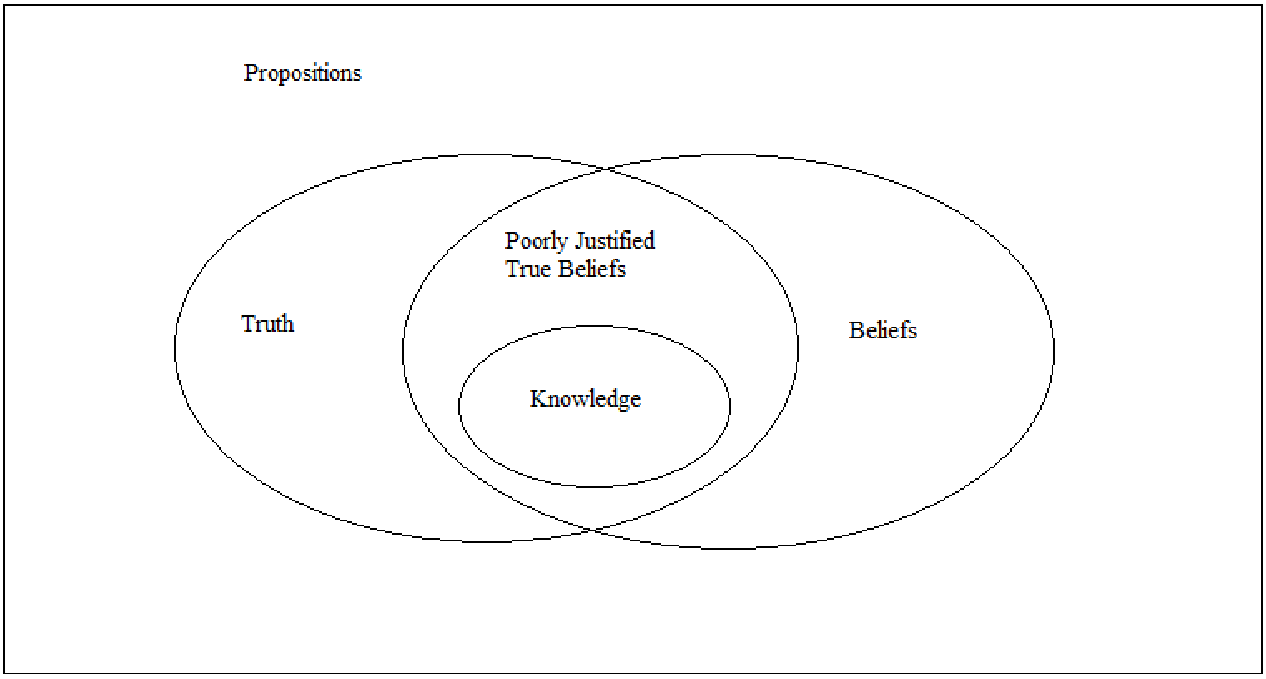



**Figure 87: Knowledge**[107]

Given the facts that construction industry is multifacet undertaking, timely fragmented operation and project specific oriented, the knowledge in this thesis is to be influenced by individuals beliefs (acceptance of intellectual truth as true), difficulties of formulating the true propositions and justifications, and selection of the conditions for the true beliefs and propositions among individuals. Building Information Modelling, is a tool or a process? Does it consist of cognitive values all along? Is it tangible or intangible? Can we know it from the meanings created by the participants or independent of consciousness of participants? Where exactly does BIM come into contact with the Building? Can we distinguish a BIM tool or process and its output in the Building or building process? These and many other questions may be asked in this this endavour.

From the objective of the study, to appraise a simple BIM, that can later grow to the world BIM, it is suggested that the *objectivist Epistemological stance* guide this thesis. Likewise, the thesis takes the *foundationalist* as a modification base of the unlikely absolute truth from the objectivism truth. To be accounted as as knowledge, explanation or rather the proposition need justifiable conditions of both external truth and direct sense evidence.

> *Both the more and the less radical approaches share the central claim that the correct account of knowledge is in terms of reliable processes of belief-acquisition that are themselves*

[107] Source: Modified from The Free encyclopedia,(2014) Euler Diagram representing Classical definition of Knowledge by Krishnvedala (his own work uploaded on 26 August 2014)

> *explicated in empirical, and mainly causal, terms. The true beliefs of cognitive subjects, we might say, are one type of phenomenon that occurs in the natural world. We need not leave the latter in order to explain the former. There is no stand-alone problem of epistemic justification, requiring its own distinctive vocabulary and evidential considerations. Epistemic value, we might say, can be interpreted in terms of naturalistic facts and properties* (Jacobs, 2009 )

This thesis aims at appraising the use of BIM in Tanzania. So, the basic questions with regard to epistemology is whether BIM will work given the environment of construction industry. The target is to deduce a Tanzanian BIM from *World BIM Competence* and to propose the growth route of Tanzania BIM towards world BIM performance. The knowledge of this thesis is BIM a tool or a process such that it is free of *time or context* at least at theoretical level. The core truth to be uncovered is whether BIM can work relatively better in Tanzania CI, despite the influences of participants, politicians,existing technology,policies,laws,practices or academicians.

The epistemological thinking proposed is *retroduction*. The process include proposition development from the world BIM facts and formulating the testable hypothesis after rational, logical and axiomatic deduction of the BIM facts relative to the building component and process. Actually the time frame necessitated to report the thesis up to here. But, the deductive testing and inductive evaluation of the hypothesis to Tanzania Construction Industry continues, bringing the study into recycling the process,while considering the new informations that may emerge that can enhance the tested BIM model.

BIM is at its maturing stage (Eastman, Teicholz, Sacks, & Liston, 2011), as a tool, platform as well as at its environment. Some scholars related BIM with IPD (Ilozor & Kelly, 2012) and some argue that BIM enhances procurement methods efficiencies (Forbes & Ahmed, 2010). Above all,it is agreed that, there is a need to fill the existing gap of knowledge with regard to BIM adoption and implementation by rigourously testing the key performance indicators of BIM in the construction industry ((Ilozor & Kelly, 2012) and (Succar, Sher, & Williams, 2012)), rather than continuing to add on the endless benefits witnessed and promised by the use of BIM in the CI. On the other hand, BIM is seemingly unfamiliar in underdeveloped world, Tanzania inclusive, and the CI stakeholders are even hardly practicing the said related productivity techniques like Lean Management and Total Quality Management philosophy.

### 1.5. Thesis Scientific Settings Summary

| Fundamental Item | Fundamental Belief/Path | Reason (s) |
|---|---|---|
| **Branch of Science** | Social Science | Use of BIM in the construction process is intended to enhance decision making, hence solely relying on intellects and structures |
| **Axiology** | Positivism | The **Reality** of BIM lies in **what BIM does**. This can be apprehended by applying natural science methods irrespective of social values. |
| **Ontology** | Post-Positivism | The truth on ***what BIM does***, can only be **partly approximated** from the material objects. |
| **Epistemology** | Objectivity approximation | The need for Nomothetical based knowledge. Facts confirmed by sense are the key to knowledge on what BIM does |

**Figure 88: Summary of general thesis fundamentals[108]**

### 1.6. Scientific World View

The three words, sceintific, world and view clearly tells what it is all about. A sceintific stand of how one or group of people explicitly perceive the ***establishment*** they live in. For example, this thesis intends to appraise BIM in Tanzania. So as a researcher, it is important to select the right mental self-containment to how and why actions are going to be the way they are. So, the world view is the *mental soul structure* attached to individuals. It consists of decisive and directional power with regard to our imaginary and physical actions.It may be more than, what (Guba, 1990) said, that is, the basic set of ideas and assumptions. Because, basic ideas and assumptions are guiding the research rather than the behaviour of the researcher towards the reality investigation. According to (Cobern W. W., 1989), the communal shared sense assumptions and ideas will only mean *lived world view*, distinguishable from the *articulated world view*, where it goes deeper to the personal level.In Articulated World-View, it is assumed that every ***self*** (individual himself) exists and interacts with ***non self or the***

[108] Source: Own Construct with a help from Hudson & Ozane, (1989)

environments (the universe) (Cobern W. W., 1989, 2000). Scientific world view, in this thesis articulated worldview was embraced. The need to appreciate the value of personal worldview, because in construction, isolating individual human effort is equally challenging. This is not following sustaincentrism of (Gladwin, Kennelly, & Krause, 1995), but rather supporting that, it is difficulty to totally disengage human from the nature. Actually, human is suggested to have the capability to influence the environment than any other creature. Human control their destiny than any other known living specie, (Kibert, 2008) argued in page 23.

The researcher viewed construction industry in Tanzania as comprising of its own world view, totally different from the individuals. Likewise, the world construction industry, consists of the lived world view that may not necessary be similar to that of the Tanzanian CI. However, to share industrial characteristics, means, there are may be shared structures, in Tanzania CI, consisting of some remainder of the world construction industry. The researcher, being Tanzanian, pursued an articulated research world view, in order to cut across the two world views and be able to realize the likely shared mental structure. BIM does a number of goods world wide, that could also be done in Tanzania. Nevertheless, it is only those goods that can withstand different context and time that are worth *realising*. That means, the question of how BIM helps to improve cost, quality or time saving were less prioritised in the thesis. The reality in need was *what BIM does* to enhance all that pionered performances. A materiaristic stand or Positivistic view, believing that this thesis, needed to explain only that part of BIM which is concrete, objective and independent of human values was desirable. However,given the inseparable human intellect or social dimensions in construction and research activities, the articulated worldview was to develop a Tanzanian BIM within a Post-Positivism philosophical stance.That is acknowledging the difficulty of certainity in this endavour.

A number of writing support the assumption of this thesis. According to (American Association for the Advancement of Science (AAAS), 1989, 1990***),*** the world can be understandable through scientific or systematic learning of the existing patterns of events and things. The knowledge gained by studying one part of the universe can be applied anywhere else. It was made clear that, the scientific knowledge can also be modified and the world should not expect science to give complete answer to all the questions.Cautionary, this should not be interpreted that,it is not possible to approximate many answer from a single reality. In (Heisenberg, 1962), it was shown that the contemporary science has close relationship with old scientific thinking, because the very new scientific approaches can be used to tackle very prehistoric problems in a modern way. The more wider the knowledge serves, the more beneficial the scientific effort becomes. Actually, the last benefit one should expect from the world view, is the productive scientific effort. However, it is not uncommon, to have *unscientific world view* *or less productive world view,* (Romain, 2009), called it *inaccurate world view*. It was insisted that, it is not accurate about what is being done, but rather the image of it.

For decades now, the Americans are oriented towards scientific thinking (Cobern, (1989)). Citizens are tought the scientific doubting culture to enlight them into developing answers to questions,with satifactory evidence.World view,is no longer a choice,but a prerequisite to a researcher who values the the primacy of positioning *scientific philosophy and objectivity*.

> *"Worldview refers to the culturally -dependent, generally subconscious, fundamental organization of the mind.This organization manifests itself as a set of presuppositions or assumptions, which predispose one to feel, think, and act in predictable patterns". (Cobern W. W., 1989).*

From ((Cobern W. W., 1989, 2000) and (Aerts, et al., 1994.)), it can be summarised that World View or picture is common in everyday life. People, Groups and Society always have their own way of behaving towards their future. The difference is when the scientific knowledge is used to arrive at the optimal vision for the predictable sailing of a person or a society towards the future. What distnguishes the world view from strategy, is the dependence on the spirit of the people. While strategy acts more formal and governed, world view acts more spiritual and morally oriented. Why one need the world view in any undertaking? The component mostly mentioned *(ibid)* are worth thorough reviewing. These are what comprises of any world view and what it is expected from the world view.

***The Nature and Structural settings.***

First thing a researcher need, is to understand the nature of the research. To grasp this it is necessary to get familiarised with the concerned population historically. Likewise it is necessary to theoretically visualise the structure of the population and the way it functions. Some of the problems are rooted in the structures requiring different approach or justification to those stemming on non structural activities.For example, (Potamaki & Wight, 2000), argued that, to uncover the tendencies and powers behind, scientist need retroduction thinking, and not deduction. Like wise, a researcher, is influenced by educational background, intelligence, sponsorship, working environmental, humanitarian and behavioural world and structure.Without whole-hearted guidance, success may be scientifically unsound.With a world view in mind, the researcher can openly show why the selected design, strategy, methods and tools are worth trusting. On top it may even become more convincing to the scientific communty, on the bases to judge the study, to compare the quality of the study and probably to assess whether the study success is scientifically sound or not.

In this thesis, BIM is to be appraised from first world countries to a third world country. Nevertheless, a junior researcher is taking the initiatives with a number of constraints, time being fixed as well. To resolve this, it would require empirical evidence for all questions. That is, why and how BIM improves the construction industry performance in the first world industries, how can it be applied in the different industries,how can it be adopted in developing countries and probably how can it be applied in Tanzania. Such an effort is necessry to embrace the context and time effects, because the structure function differently not only between continents, but also among countries of the same continent. To support this, as it is known that construction projects are contractually oriented business, and yet while in French Law the term “contract” is defined, in Germany  it is left without legal definition (Jaeger & Hoek, 2010). Nevertheless, differences in technology as well contributes the functioning of the construction industries. In Mbeya (Tanzania), women are commonly involved in pouring concrete, while that may not be the case in Dortmund (Germany). To deal with that, thesis suggested to first identify the unchanging nature or structure, which required positivistic or materialistic world view, guidance towards external, independent, and context free truth. That helped to develop a model that may reliably sustain the different environment like that of Tanzania.

***Doubts  to facts and ideas***

The world view to be scientific, it should drive the society or individual to question everything worth questioning, including their existance. In March 2014,  ( Broberg, 2014), many professionals  who attended a Continous professional Development seminar (CPD) of (Architects and Quantity Surveyors Registration Board (AQRB) wondered what BIM is, as it was presented by a practicing Architect in Sweden. Yet the Continous Professional Development seminar held in September 2014, was but without a BIM discussion (Architects and Quantity Surveyors Registration Board (AQRB), 2014). Wondering is not enough, such ideas need to be subjected to questions,vigourously, however small they may seem to be. Questions of whether, our ideas evolves our industry? Questions on our position relative to the global market? Whether we are competitors or passengers? Do we have concrete explanation of why we are the best or otherwise? Can we identify the principles that has brought us where we are? Are we real enjoying our world? Are we fit for the country`s world view? And many other questions are the reason why one should have the spiritual path or world view too.

As a researcher on BIM, it was necessary to identify the technological, industrial and educational stance with regard to information modelling. It was equally important to note that, the expected results are bound to a number of constraints, including time. Such a situation, does not mean to finish the work with poor quality but rather it means to objectively question the research surroundings,doings and actions in order to refine and remain with the most important axioms. Important in the sense that, the important *lesser important* can be later derived from these researched axioms. The less important truisms are reserved for the contextual testing in Tanzania. This went beyond asking why dealing with cost? It extended to questioning whether costs covers time,quality or safety to a large extent? It actually took the proud of being positivist with regard to this investigation, over not being interprestivist at large.

***The Purpose and  the Future***

Without a purpose, a person is indistinguishable from the dead. A web dictionary gives that a purpose is (the fixed determination,design,idea or reason for which anything is done, created, or exists), human inclusive. From the same dictionary the term “dead” ,see in  (dead, n.d.), has been defined as lacking sensitivity,having lost life and no longer alive (medicine definition); very tired, not operating and  ruined or destroyed (slang definition) and non functional (technology definition). Few things worth noting include, the use of the language to the *meaning*, and the use of the language to the *description of the purpose*. It is possible to be dead in slang world and yet very alive in the medicine world if tiredness feds away or what is considered causing death in technology may be different from that of medicine world. However, one common thing sustaining all situation is the fact that being dead is associated with “ *state of being incapable of doing something mentally or physically relative to the surroundings*” or incapacity to compete against the nearest future challenges and actually borrowing medicine definition gives the safety to assume that, a society or a person without capability to face the future challenges is dead at least at that given time.

According to (Amara, 1978), the future is always confronting and so it need to be opposed by considering the possible choices, probable scientific facts given,known and preferred.That has to be done in a systematic and researchwise skilled manner. It is not easy to discover the opportunities facing our world. It is not easy to define the well being or what it is or whether it is alive or dead. It is even more difficulty to visualize the future effects of the actions done today. It takes a huge outlay of fund to explain justifiably why defforestation is undesirable, because a defforestator is probably dead when the consequences starts. In  ((Kibert, 2008) page 40), “*The United Nations Conservation to Combat Desertification, formed in 1996 and ratified by 179* *countries,reports that over 250 million people are directly affected by desertification"*.The explanation to our stand, actions and predictions require precise principles and refined criteria.Models are needed that can help to solve problems at present while improving the future as well. The past events and future constructs are inseparable resources to the present optimal decision making. Scientific scrutiny of the actions, decisions, ideas and predictions should be measured against the key *purpose*, which is *improvement of future*.

If BIM is to be worthwhile to Tanzania, then questions raised above should be left unanswered at least in the long run. The mental change, the ethical change, the technological change, the structural change,research spirit change and strategic changes are all waiting for BIM. That was the focus, that a researcher needed in selecting the world view, rather than focusing specific problem solving of segments within the industry. It is in the view of this thesis that, a test of BIM be measured from that angle capable of serving the whole industry rather than part of it. The future of the industry as the overall purpose, will never depend on one segment, but integration of all segments. The approximation of such a reality, required a world view capable of guiding a research towards wider viewing of all elements but intelligently reducing or converging all related problems or unknowns of the construction industry in Tanzania to a single or few simple constructs that can be clearly treated or tested to the *"unchanging reality in BIM".* Two facts were suggested to be holding here, the first was the unchanging constructs between industries, nations or time span, and the second was that, which is supposed be *real* within BIM, which is "what BIM does" to any industry, in any country and at any time.

The challenge of matching and focusing the two, needs a push of world view. As (Cobern W. W., 1989,2000), puts it, strong intergrator to help in interpreting, conceptualising and converging the old and new understandings of the phenomena, without prioritising own assumptions or mixing with environmental interference. That is the world view that can guide in finding or developing answers objectively within complex and challenging social dimensions of construction industry. In the light of all this, this thesis purpose was to develop a simple Tanzanian BIM from the big complex world BIM. It is proposed to be *cost* centred, which (Alarcon, 2007) supports to be the key to performance in the construction industry. On other hand the future of the thesis is testing the model on all other qualitative and quantitative elements of performance in construction. It is the reason for selecting materialism world view.

## 2. Scientific Inquiry Overview

Biological Sciences Curriculum Study (BSCS), ( 2005 ) gives that

> *"Scientific Inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world.Inquiry in National Science Education Standards, is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze and interpret data; proposing answers, explanations and predictions; and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking and consideration of alternative explanations"*

Another terminology relative to *inquiry* includes investigation. Some say scientific inquiry refers to constructed explanation of contributed knowledge presented for community critique (Khine M. S., 2012). Investigation like that of theft by the police department to be scientific, it requires an end with a *scientific knowledge,* that is to contribute in the body of laws and theories about a phenomena (Bhattacherjee, 2012). It is argued that scientific disciplines commonly rely on evidence ( American Association for the Advancement of Science (AAAS), 1989, 1990). However, the evidence used in science requires justifications of the necessary conditions, mostly it is *noninferential evidences*, indeed the evidences are those universally acceptable.

In deveoping a BIM for Tanzania, this thesis went through the inquiry process. It was about investigating what is all about BIM, in both practice and theories. Embracing evidences from different reports and writings was not enough to acquire what BIM is to Tanzanian environment. It needed imagination of what BIM does to the benefiting industries and then to reflect the operationability in the Tanzanian environment. Missing a picture of the operationability in practice, could limit the predictability. Such an image brought the study into choosing crossectional design, in order to generate the hypothesis necessary to be tested for the various developed variables.

Bhattacherjee,( 2012) said, that research operates at *theoretical* and *empirical* level or rather theory and observations levels. To think and imagine the operationability of the emerging knowledge. Despite the similarity, researchers differs on the ways of inquiring, mostly due to the differences in the peculiarities of what they investigate. Currently, no single root towards attaining scientifc knowledge, but as (Sikorsk, Winters, & Hamme, 2009) pointed, inquiry is very key to scientific practice, in some circumstances, inquries to research, resembles a heart to human being in functions.It pushes blood to circulate and enhance the bodily activities to flow normal, especially between the brain (theoretical tank) and the body (empirical base). In (American Association for the Advancement of Science (AAAS), (1989, 1990)) it is clear that any researcher need evidence, accurate data from valid and reliable observations and measurements, and logical reasoning or scientific argument that conform to principles of logical reasoning.

Generating a hypothesis is among the important activity in research undertaking. Especially when the problem requires further testing of variables. To be a scientist, requires thinking along the two planes, observations and hypothesis testing or thoery building, as (Bhattacherjee, 2012)supported.

> *To be useful, a hypothesis should suggest what evidence would support it and what evidence would refute it. A hypothesis that cannot in principle be put to the test of evidence may be interesting, but it is not likely to be scientifically useful. ( American Association for the Advancement of Science (AAAS), 1989, 1990)*

It is necessary for the research to be predictive, as it shows the continuity of the former stronger relationships between phenomena (Walliman, 2011). Never the less, there is a need to anticipate or recognize the likely sources of the biasness in research (Hammond & Wellington, 2012; page 11) and avoid authoritarian in science undertakings ((AAAS), 1989, 1990).Science results are open to new truth and criticism. It does not matter, the effort spent in building a theory, it is just a matter of *single scientific doubt*, that may obsolete the theory as a knowledge.

In this thesis, the hypothesis proposed is *"If 5DBIM has positive effect in Bills of Quantities (BOQ) completeness, then the use of 5DBIM can improve Total Cost Management in construction projects procurement in Tanzania"* .At its outer view the hypothesis can be broken into three key phrases, that is 5D BIM, Bills Of Quantities (BOQ) completeness and Total Cost Management (TCM). Internally, this thesis theoretically viewed the hypothesis as containing different BIM levels in different construction projects environments and so enhancing the total cost management by ensuring that various variables like budgeting, tendering, final accounting, activity scheduling and life cycle costing are well performed. These variables are optimally produced when ***5DBIM based BOQ*** is used in the project or otherwise, may be BIM has something else to offer in Tanzania or it offers project intergarated delivery in other ways other than what has been suggested.

The scientific *enterprise* is a collaborative endavour with the purpose to advance knowledge and address the intellectual and/or practice needs of the society (Boadu, 2010).It is important to recognize the societal side of science. The complexity nature of the activity, the *ethical* necessity of the undertakings, the involvement and likely biasness of scientists as human being must well be concieved in science. Scientific undertakings should as well consider the surrounding societal needs because science is mutually related to them for the worse and better. From (Heisenberg, 1962) it was shown how modern physics relates to nowdays human development and the existing dependence of political influence to scientific results was explained.

> *"Science is part of almost every aspect of our lives. …. It tells us about the past, helps us with the present, and creates ways to improve our future. Scientific endeavour is as much about us as it is for us. Its place in society, therefore, is not to unfold quietly at the sidelines but to become a fundamental part of the game. …….. The lack of a common language and rapid progress in many areas of research has increased the public's concern or contributed to ambivalence about the role that science and technology play in everyday life. But science cannot work in isolation, and advances in science and technology are not an objective in their own right." (European Commission, 2012 ),*

Likewise, (World Summit On Sustainable Development (Wssd), 2006), insisted that

> *"Sustainable development is the most daunting challenge that humanity has ever faced, and achieving it requires that the fundamental issues be addressed immediately at local, regional and global levels. At all scales, the role of science and technology is crucial; scientific knowledge and appropriate technologies are central to resolving the economic, social and environmental problems that make current development paths unsustainable. ……… Whatever the cultural, geographical, socio-economic and environmental setting, a strong partnership between the S&T community and other members of civil society, the private sector and governments is a fundamental prerequisite for sustainable development. ………………. However, enhancing the S&T community's capacity to contribute to sustainable development will require significant changes………. These changes include: 1. More policy relevant science:Good science is essential for good governance,2. Broad-based, participatory approaches: Traditional divides between the natural, social, economic, and engineering sciences and other major stakeholders must be bridged. Research agendas must be defined through broad-based, participatory approaches involving those in need of scientific information. 3.Promoting gender equality in science: Historically women have been severely under-represented in science."*

From (Meilaender, 2009) *"The opening chapter on Aristotle centers on the claim that his practical philosophy -- his ethics and politics -- is decisively connected to and shaped by his metaphysics. Knight (Aristotles's work reviewer) focuses on several important Aristotelian concepts, in particular theoria, praxis, and poiesis. Theoria, the noblest form of human activity, is the contemplation of that which is eternal and unchanging. Praxis, by contrast, refers to human action or activity in the realm of the contingent, that which could be other than it is and which we seek to affect by our actions. Poiesis refers specifically to production, the purposeful bringing-into-being of something distinct from its human producer."(2nd Paragraph)*

Supporting this, (Glanz, 2008 ),insisted that science,theory and practice consists of non linear relationship.Other scholars, following Dewey's view, gave out that practice and theory are related through intelligence (Alexander & Dewey, 1987). And (Glanz, 2008 ) suggested that academicians and practitioners equally require research, theories and practice for their professionalism excellence. Theories and practice are in give-and-take relationship. Academic ideas should be viewed as enforcers of practice and the opposite is true. A theory develops concepts and relationship of abstract concepts of the phenomena, while practice tests the theory fitness to the observable (empirical facts) reality with the goal of rebuilding the better theory and enhancing the science knowledge (Bhattacherjee, 2012).

In this thesis, the knowledge contribution to the construction industry went hand in hand with the scientific investigation explanation, partly because of the need to enhance the importance of linking practice and theory among practitioners and academicians in Tanzania. If theorists, expect a change from practice to follow suite, then practitioners must have confidence in and accept the conditions for both the theory set forwards and of theories` justifications before they take the *risky journey* of testing the theories evidentially. Many scholars, including ((Forbes & Ahmed, 2010) (Eastman C. P., 2008,2011 (Oskouie, & Gerber, & Alves, & & Becerik-Gerber, 2012)) did mention that players afraid to embark on BIM quickly because of the huge outlay of financial need, in a risky business of construction, and hence foregoing the far bigger benefits to be derived from the use of BIM. They are waiting the risk takers to prove, that theories set forward by researcher are worth trusting, a component that can as well be facilitated by researchers themselves, if only they leave no *doubts to inquiries*, by writing researches for the *community of practitioners* and not for the *community of researchers*.

In this thesis, the investigation involved interaction with two different environments. The first world (Germany in particular) and third world (Tanzania). In Germany BIM is growing in both practice and awareness. In (WSP Group Limited, 2013) it was insisted that, Germany is almost going its own way with regard to BIM,being dominated by the fragmented software products. VICO, Nemeschek Allplan and BIM4You are examples. The levels of BIM implementation by contractors is estimated to double from 37% in 2013 to 71% in 2015, reported in (McGraw-Hill Construction, 2014). On the other hand, in Tanzania, BIM is just becoming a scholarly discussion,as discussed by ((Broberg, 2014) and (Monko & Roider, 2014)). So to inquire the adoptability of BIM, given the objective of developing a simple BIM, this thesis used crossectional design to correlates variables in BIM environments in order to measure the effect of BIM level to the Contract Documentation, specifically to the level of information in the Bills of Quantities.It was suggested that there is positive relationship between *BIM usage* and *Bills Of Quantities (BOQ) completeness* in Total Cost Management of the construction projects.

### 2.1. Research Ethical Issues

> *"Why is research ethics important? Because, science has often been manipulated in unethical ways by people and organizations to advance their private agenda and engaging in activities that are contrary to the norms of scientific conduct." (Bhattacherjee, 2012)*

Being academic study, somehow assures that the ethical issues will be assessed.The work is supervised and undertaken within accredited university regulations. On the other hand, without consideration of ethical issues, the quality of data may be harmed. In principle, doing a research should not cause any problem to the community. Although scholars like (Fowler, 1984) and (Trochim W. M., 2006) insist on not harming the individuals as people, they are as well refering to the community involved in the research. That can even mean ensuring animals, buildings and plants are equally protected.

The key tool used to collect data from people in this study is self administered questionnaires.Without informing the respondents, the tools may not be effective and efficient. So the design of the questionnaires involved pictorial and descriptive explanation of what is the research all about (See appendices). BIM is an emerging technology, as (Greenhalgh & Squires, 2011) put it, a *relatively new approach in building design,construction and operation that intends to change the way professionals think*.This has been given attentive thought, because it is both a threat and an advantage. Majority of Archtects, Engineers and Contractors for example, ((Eastman, Teicholz, Sacks, & Liston, 2011) and (Construction Industry Council (CIC) Secretariat, 2013)) are using BIM than other participants. In Tanzania, some professionals may be more attracted to participate in BIM studies than others, because whoever believes that BIM is near the corner will be eager to know what it is, while whoever thinks otherwise, may even not bother to listen to the researchers.Such situation, made this thesis spend time on designing the questionnaire and any other writing to improve freely participating willingness.

The challenging part of privacy of the respondents even to the researcher (Trochim W. M., 2006), is the involvement of documentation in the study. To get a Bill Of Quantity from a firm means exposing what went on in the project. Likewise, to skip assessing the BOQs means relying on the less factual data from the participants answers.One way used to protect repondents from this, is to explain clearly the intention of the study and coverage of the study. Random sampling was intended to allow non intentional selection. Additionally, the intended information are briefly explained in advance .Confidential protocol were followed as per respondents requirement or standards,including promise for presenting or reporting the result when so required. Ethical standards do differs between societies (Bhattacherjee, 2012), so it was important to request the permission and ethical consideration before involving the repondents community in the research. This research intended to collaborate with indigenious to ensure ethical data collection. Being part of the goals of this thesis, to appraise BIM in Tanzania, the feedback to the players is the assured phrase of the data collection and motivation to the researcher.

## 2.2. Research Process

The Einstein quotation from the website *"If I had an hour to solve a problem I'd spend 55 minutes thinking about the problem and 5 minutes thinking about solutions." Albert Einstein says it all.*The above saying reminds the importance of formulating the researchable problem. The question that is worth spending effort and huge outlay of fund to uncover the hidden *golden* knowledge. While (Kothari, 2004) gave about eleven fundamentals of research process, starting with formulation of the research problem and including data analysis and presentation of the results, (Kumar, 2005) provided the eight model research process in deciding what, planning how and actual work stages. Bhattacherjee (2012) almost summarised these into observation, rationalisation and validation. The argument by (Bhattacherjee, 2012) is that, scientific research is about observing the phenomena, explaining it logically and using scientific methods to test through different data collection and analysis tools and techniques.

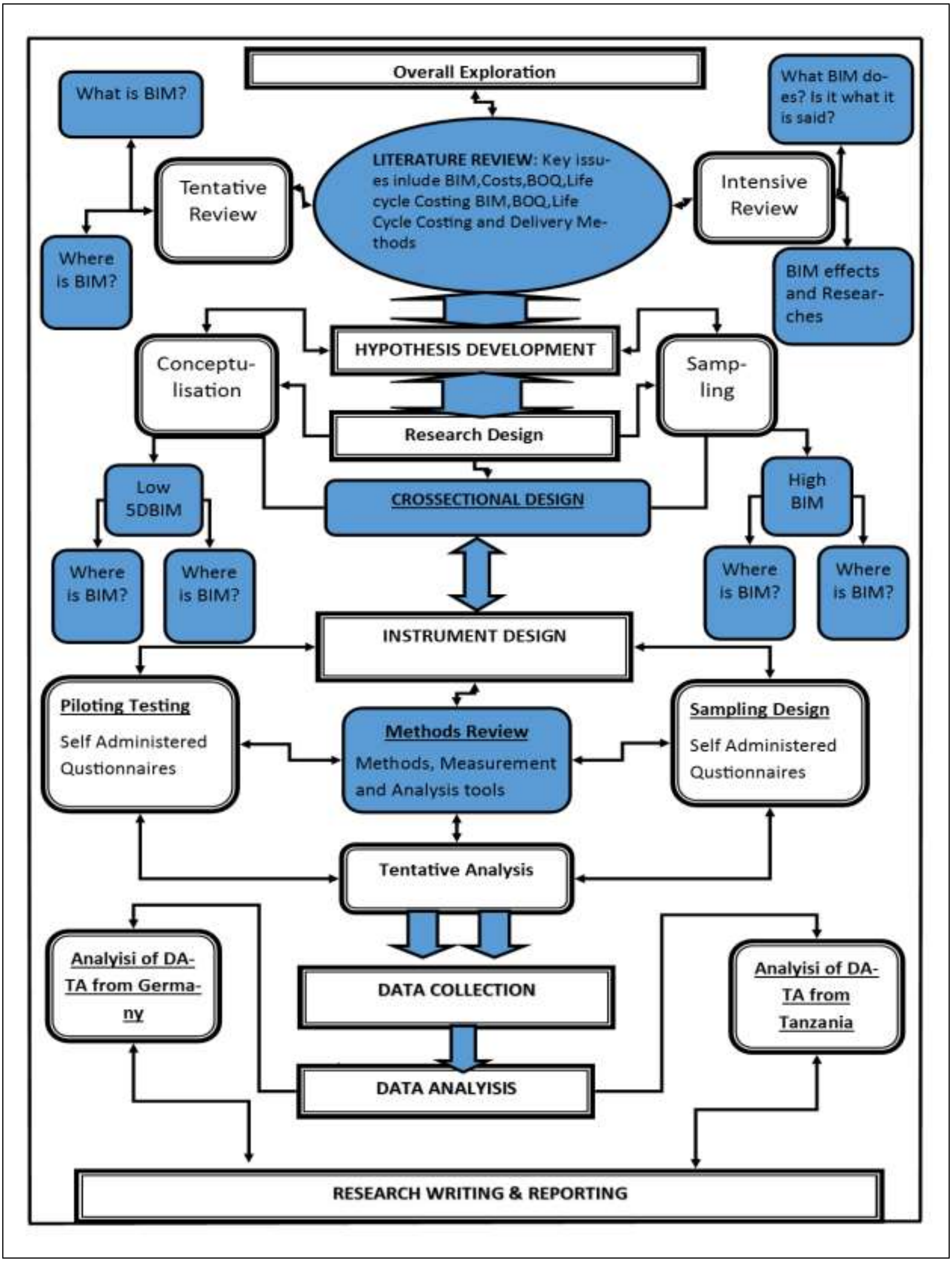



Figure 89: Research Process followed. [109]

[109] Source: Own Construct

On the other hand (Brown, 2006) argued that the research process is not straight as mostly taught. According to (Cengage Learning, 2013), research process stages overlap continuously and so there is no single path towards research answers. Commonly, stages includes formulation of problem, reviewing literature, defining the research objectives, hypotheses and questions, planning a research design, planning a sample, collecting the data, analyzing the data and testing hypotheses, formulating the conclusions and interpretations, and preparing the report ((Kothari, 2004), (Cengage Learning, 2013), (Kumar, 2005) and (Bhattacherjee, 2012)). It can be seen, without the purpose or the problem other stages do lack foundation. What literature to review and what objectives to achieve, stem from the key research problem, because it is what gives the light of researching endeavors. In (Booth, Colomb, & Williams, 2008), page 51 to 64, the research problem has been explained. They insisted that, it is even harder to a an experienced researcher, when it comes to formulating a research problem.However , researchers do not run away from a problem, instead they run towards it, because research problem leads the way to solving practical problems (ibid).

## 2.3. What is a Theory

Theories are primarily concerned with a ***Why*** questions ((Whetten, 2002) (Bhattacherjee, 2012) and (Colquitt & Zapata, 2007)). From (Jones, McLean, & Monod, 2011), generating *good* theories deserves the highest rewards in science and noted that it is difficulty to exactly define theory in scientific research. According to (Weber, 2012), some ontological terms necessary to understand explanation of theory includes

**Thing**: that which make up the world in research. A building project, have many things like people, materials and reports. They can be found in many forms, examples are compound (steel gang or service engineers) and classified forms (contractors class one). Attribute, refers to a property to the representation given to a property (thing with defined characteristics). Example by (Weber, 2012) include Intrinsic attribute (properties of individuals , like individual´s height); Mutual attributes( properties of two or more things (marriage date));Developing Attribute: (attributes of composite thing (productivity of a team));Attribute in general,(class of thing (Height is for every human being)) and Attribute in particular: unique values of particular things in a class of things (“Attribute” Height-180 cm, Of “Thing”John in a “Class of things” people ). Other terminologies include state,event and interaction. A state where an attribute is related to a value of thing by either lawful (obey man made or natural laws) or unlawful (otherwise). Event when a thing undergoes changes and Interaction when things share history as a results of some occurances among them.

| ***Definition of a Theory*** | ***Source*** |
|---|---|
| *A set of interrelated constructs (concepts), definitions, and propositions that present a systematic view of phenomena by specifying relations among variables, with the purpose of explaining and predicting phenomena* | *Kerlinger, 1986, p. 9* |
| *A systematic explanation for the observed facts and laws that relate to a particular aspect of life* | *Babbie, 1989, p. 46* |
| *Knowledge writ large in the form of generalized abstractions applicable to a wide range of experiences* | *McGuire, 1983, p. 2* |
| *A set of relatively abstract and general statements which collectively purport to explain some aspect of the empirical world* | *Chafetz, 1978, p. 2* |
| *An abstract, symbolic representation of what is conceived to Zimbardo, Ebbesen, and be reality—a set of abstract statements designed to "fit" some portion of the real world* | *Maslach, 1977, p. 53* |
| *Is a set of systematically interrelated constructs and prepositions that are advanced to explain and predict a certain phenomena or behaviour within certain boundary propositions* | *(Bhattacherjee, 2012)* |
| *Is an account of some empirical phenomenon* | *(Jones, McLean, & Monod, 2011)* |
| *A particular kind of model that is intended to account for some subset of phenomena in the world. A theory is a social construction. It is an artifact built by human to achieve some purpose. It is a conceptual thing rather than a concrete thing.*<br>• *Phenomena-changes in the attributes in particular of some things in the world*<br>• *Account-theory assist its users to predict or explain its focal phenomena*<br>• *Respresentation of something else (Phenomena) in the world* | *(Weber, 2012)* |
| *A system of constructs and variables in which the constrtcts are relted to each other by and variables are realted to each other by hypotheses.The whole system is bonded by the heorist assumptions.* | *(Bacharach, 1989)* |

**Figure 90: Some definition of Theory**[110]

[110] Source: Modified from Glanz, K.; Rimer,B.K; & Viswanath,K.(2008), Page 27

In this thesis, the theory is used interchangeably, to mean hypothesis intended to be genearated as well as the literature with regard to the pioneering of BIM.The later meaning come from the fact that BIM is growing and being tested worldwide, so viewing it as hypothesis that has undergone enough tests to be a theory proposed to be key to construction industry performance.

Theories and Models are intended to facilitate understanding of the behaviour and suggesting the ways to achieve changes on a given phenomena ((Bhattacherjee, 2012) and (Glanz, 2008 )). With number of theories about a given problem, one can develop a model that can facilitate the way forward on solving the problem.To (Bhattacherjee, 2012), the process of developing the model involves drawing conclusion from set of premises or deduction and that of drawing conclusion from observed evidences or inductions. In theory, Constructs gives Concepts (Kerlinger, 1986). Principles are just general action guidelines that can help to fomulate hypotheses.They are very broad, in such a way that they can not be reliable because of the likeliness of the multiple meanings (Glanz, 2008 ). A construct ***is an abstract concept that is specifically chosen (or "created") to explain a given phenomena*** (Bhattacherjee, 2012). Constructs can be unidimensional like person's *weight* which is a simple concept, or multidimensional like person's *commnication skill.* According to (Glanz, 2008 ), ***variables are the empirical counterparts or operational forms of constructs.*** If the weight is measured in Newtons, then Newtons are variables of a construct weight.The researcher should match these two, in evaluation and assessement of the theories.Thinking like a researcher needs an ability to abstract the constructs/concepts from observations and to visualize their relational links (Bhattacherjee, 2012).This overall network relationship between a set of related constructs was called ***nomological network.***

It was insisted that the relationships between construct stated in declarative form is propositions, while such relationships between variables is called hypothesis,which is empirical formulation of propositions. Propositions are non testable relationship between concepts while hypothesis is the empirically testable relationship between variables intended to test the validity of the corresponding proposition. As stated in (Kerlinger, 1986), a theory is not complete without the prediction of the behaviour of the phenomena. Propositions and hypothesis enhances the scientific theory by providing such an explanation and necessary predictions between constructs**.** Predictors or independent variable or causes and outcomes or dependent variables or effect are among the key terms in research (Field, 2009).

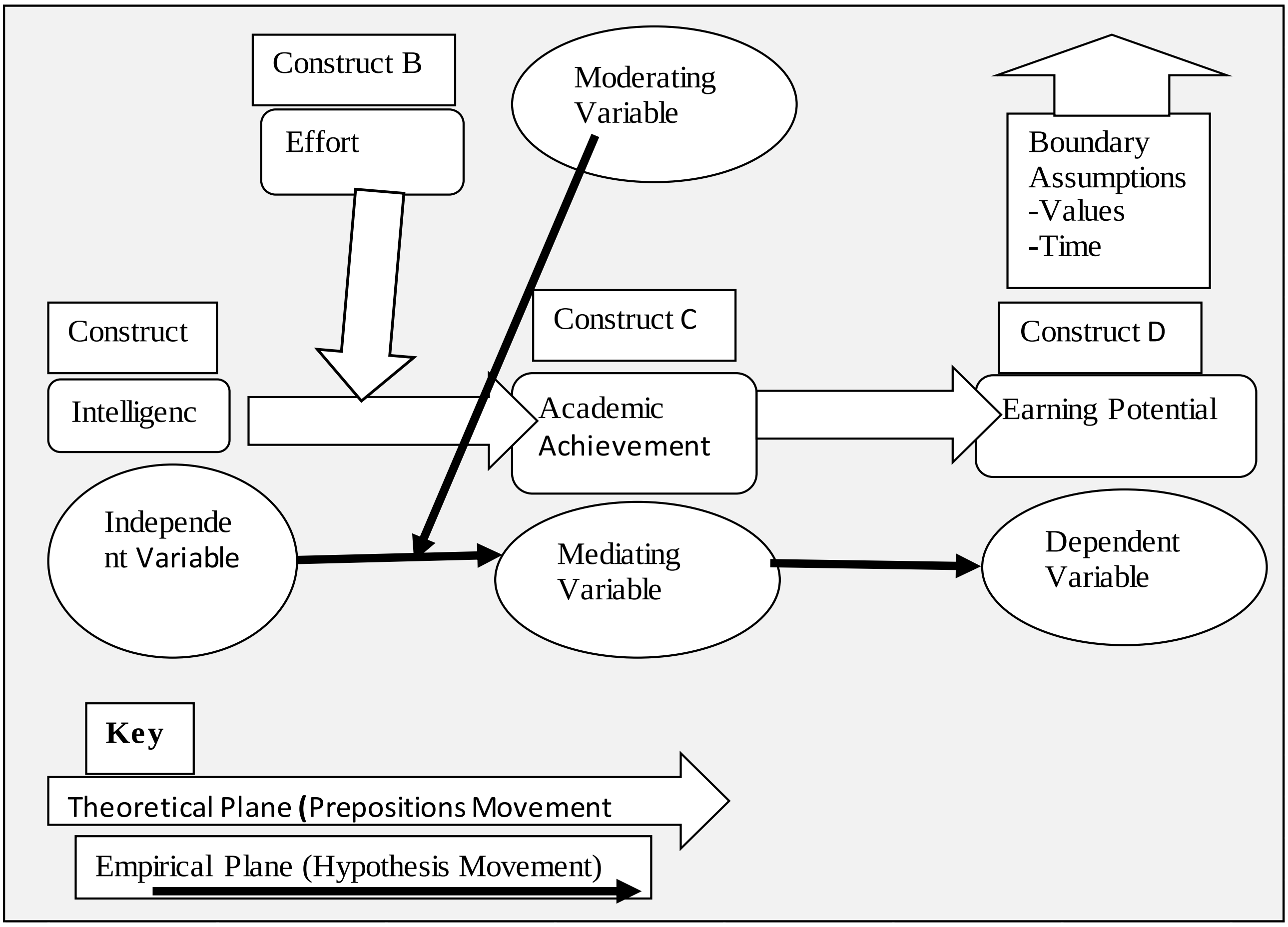



**Figure 91: Theory and Nomological Network of Constructs [111]**

[111] Source: Modified from (Bhattacherjee, A. (2012). Social Science Research: Principles, Methods, and Practices. Zurich, Switzerland: The Global Text Project and Bacharach, S. B. (14. October 1989). Organisational Theory: some criteria for Evaluation. Organizational Theories: Some Criteria for Evaluation-Academy of Management. The Academy of Management Review;, S. 496.)

According to (Bhattacherjee, 2012) *theories are not data,facts,typologies or empirical findings,because they include propositions,explanations and boundary conditions basing on logics and not observations.* Likewise, a hypothesis that "*In TCM, 5D BIM has positive effect in BOQ completeness"*, is purely mental activity statement. It is just explaining that it is highly probable that when using BIM, the use of 5D BIM ensures increased completeness of the prepared Bills of Quantities. That increased BOQ completeness is essential in the improvement of Total Cost Management, because BOQ becomes more informed and collaborative hence more *productive*. Without giving conditions with regard to expertise and relationships of stakeholders, such an hypothesis may not hold at all. The logic of this proposition, is the fact that BOQ is central item in activities of TCM. To mention but few, are Budgeting and Variation Control.The more productive the BOQ is, the more these activities of TCM get better.Total Costs Management is central objective in the construction industry projects and BIM is all about information integration. On the other hand BOQ is the central construction contract documents which at large it is information of the construction project. So, if BIM has anything to do with a construction project, then at its heart it is affecting Cost item effort of the project or specifically BOQ in Tanzania.

Actually hypothesis, just like a theory, it is a simplified explanation of the image of the reality of the researcher. Theories are simplified than the actual reality (Bhattacherjee, 2012), as it was precautioned that, theories when relied upon may limit the ***range of vision*** of the researcher. From ((Whetten, 2002), (Field, 2009)), good theories are practical and they give scientific statements , bad theories are disfuctional and harmful. It is equally logical to say, bad researchers may as well be harmful to the societies, because giving disfuctional and harmful hypotheses, at least it is a waste of precious national effort. That is the reason, this study tries to devote significant time to acquire and explain the *science* behind this hypothesis generation effort.

Additionally, in theories, terms like prediction,correlation,explanantion and causation should be well understood ((Bhattacherjee, 2012) and (Colquitt & Zapata, 2007)). Predictions requires *correlation* while explanation requires *causation* or understanding of cause-effect relatioship. To establish causation, some conditions necessary are correlation between two constructs, the cause proceed the effect in time and rejection of alternative hypothesis through testing (Bhattacherjee, 2012). Explanations are categorised into *idiographic* when they explain a single situation and *nomothetic* when they explain a class of situations or events. When two events are correlated, it is possible to predict one from another and while in research *causes* can be indirectly linked to observable and then *infered*, *correlations* can directly be observed (Colquitt & Zapata, 2007).When A causes B if, and only if, A invariably or must results into B, the causation is *deterministic* and when it is propably that A results into B,the causation is *probabilistic*.

Stepping from the above, this thesis was in probabilistic way of thinking,because in between BOQ completeness and Total Cost Management performance, there are a number of factors related to project execution that can interrupt the results. On the other hand, in between BIM and BOQ there are number of human and technological factors that may as well be the cause to some extent of the productivity improvement. For example, contractual language understanding, may facilitate bidding and understanding of the project requirements. It may reduces umbiguities, because all the contractual responsibilities and liabilities are clearly understood. Moreover, it is not certain that, it is the use of 5D BIM that guarantee that, there also possibilities of expertise and strong management or close relationship among project participants.That takes this study into probalistic model or hypothesis over deterministic.

### 2.4. Literature Review, Conceptual and Theoretical Framework

In (Rocco & Plakhotnik, 2009), *"The literature review and conceptual and theoretical frameworks share five functions:*

- *To build a foundation,*
- *To demonstrate how a study advances knowledge,*
- *To conceptualize the study,*
- *To assess research design and Instrumentation, and*
- *To provide a reference point for interpretation of findings".*

It was insisted that, inquiries must be well communicated to make sense, emphasizing the the presence of interchangeably usage of the three terms by many researchers. The three terms have close reliationship with the problem, discussion and implications of the study on hand. They help to narrow the knowledge gap and in articulating the problem statement, as well as strengthening the discussion and giving sense to the implication of the study at last. The literature review should substantiate a topic (Creswell J. , 2003), whether it is really important currently in relationship to previous related works. Despite forming the problem foundation, literature review controls the study to what is already known (Merriam, 2009),that is showing relation and deviations of the study from previous works. Literature review should logically show why the study is urgently needed. In research, literature review must connect problem,purpose and discussion (Rocco & Plakhotnik, 2009). In this thesis, the literature review with regard to BIM, was assumed to be a theoretical background. The benefits and function of BIM are assumed to have undergone some significant tests world wide.

Conceptual framework is an abstraction and formulation of plans and important details from specific instance (Tromp & Kombo, 2006).It is a summary of the whole idea about the research undertaken. It explains graphically or in narrative form, the key factors, constructs or variables and the presumed relationships among them (Miles & Huberman, 1994). It is difficult to define exactly what is conceptual framework (White, 1998),although categorising them using research purpose and clusters of research questions,techniques,methods and statistics can help.It was stressed that conceptual framework originates from the *problem* and it operates in two levels, *micro* conceptual frameworks, those giving detailed frameworks that are mostly associated with concrete management and policy problems, that connects to controlled guidance in inquiries. Another one is a *meta* conceptual framework, those operating at macro level or public level. The problem will decide which tool or what conceptual framework to use. A conceptual framework grounds the study in the relevant knowledge bases that lay the foundation for the importance of the problem statement and research questions (Rocco & Plakhotnik, 2009).

According to (Tromp & Kombo, 2006), researchers need theoretical frameworks to help them in execution and findings interpretation. They are collection of interrelated ideas about the nature of phenomena trying to clarify why things are the way they are .Whereas a theoretical framework is used when investigating a specific theory, a conceptual framework is made up of theoretical and empirical work relevant to the study’s purpose, where the purpose is not to further investigate a specific theory.Theoretical framework saves as a researcher’s lens for viewing the world (Merriam, 2009). “*As a type of a manuscript, a theoretical framework synthesizes existing theories and related concepts and empirical research, to develop a foundation for new theory development”* (Rocco & Plakhotnik, 2009). To fully view the position of conceptual framework within theoretical framework it may be necessary to break the term into *theory* and *framework.* In ( Hou Houghton Mifflin Company, 2009), frame work consists of either

- *A structure for supporting or enclosing something else, especially a skeletal support used as the basis for something being constructed.*
- *An external work platform; a scaffold.*
- *A fundamental structure, as for a written work. Or*
- *A set of assumptions, concepts, values, and practices that constitutes a way of viewing reality.*

Connecting with theory as *a set of systematically interrelated constructs and propositions that are advanced to explain and predict a certain phenomena or behaviour within certain boundary propositions* (Bhattacherjee, 2012), it becomes clear that Conceptual framework comes from the researcher imagination on describing what logically are the related variables, while theoretical framework explains why the available guidance is suitable for the knowledge inquiry or research process. In this thesis, the Pareto principle form the theoretical framework. It gives the safety to justify the use of few critical over all factors.

> *"Based on the principle of cost-significant items, 20% of the items in a bill of quantities (BOQs) are supposed to account for 80% of the value (Abed, 1991; Asif, 1988; Harmer, 1983; Mair, 1990; Saket, 1986; Shareef, 1981)" (Dmaidi, 2001)*

First, the Government being suggested to be the main financer and biggest client of the Construction Industry in Tanzania, will have greatest total impact on the productivity as well as adoption of BIM. Of course, it would be equally better to use civil engineering and other projects. But the fact that BIM is more developed in Building Projects, as scholars ((Forgues,Daniel;& Iordanova,Ivanka;&Valdivesio,Fernando and Staub-French,Sheryl, 2012); (Forbes & Ahmed, 2010); (McGraw-Hill Construction, 2014)) substantiate, it was found viable to start with public building project, because the result was likely to cover that of other project than otherwise. Likewise, cost being central to construction project objectives (Matipa, 2008), it is proposed to have the greatest impact to the success of the project *information integration through BIM* in Tanzania as well. BIM improves cost information to estimators (Kehily, Woods, & McDonnell, 2013) and BIM is about information (WSP Group Limited, 2013), communication and collaboration (Azhar, *et* 2012), which is contract documentation at the heart of construction projects. So, it is proposed that the use of BIM does improve productivity of the contract documents (specifically Bills of Quantities) to enhance total cost management in the construction project.

Pareto principle justify the need to concentrate on the few selected key issues with greater impact. From (Bhattacherjee, 2012) and (Sahin, 2006), the *Innovation Adoption Process Theory* of Rogers may form the theoretical base for diffusing BIM in Tanzania at large.It therefore suggested that the Pareto Principle will strengthen the theoretical framework and *together* these two can ensure that the BIM is developed, efficiently adopted and implemented in the environment of Tanzania.

## 2.5. Theory Testing and Theory Building

In their conclusion results, (Colquitt & Zapata, 2007), suggested that *theory testing* and *theory building* largely contribute on growth of knowledge. The contribution comes from good theories (Whetten, 2002).Theory can be evaluated from "parts" and "whole" quality (Weber, 2012).Under parts, constructs, association and boundaries are assessed while in totality,theories should show importance,novelty,parsimony,level and falsiability. At least a theory should be ***logically consistent*** in its constructs,boundary conditions, and assumptions.; it should ***explain or predict the reality*** to a large extent possible and the theory must be ***falsifiable*** or empirically testable with rival explanantions; although (Weber, 2012) alerted on how difficulty it is to test for every combinations of values under given boundaries and constructs. Likewise, theory need to be ***parsimonious***, meaning higher degree of freedom to be generalised to other context (Bhattacherjee, 2012). Additionally (Tibbetts, 2012), said deduction and induction reasoning can help researchers to extract the general truth from ***known principles, observations or experimental data.***

From ((Whetten, 2002) and (Bhattacherjee, 2012)), the buiding blocks of theory are constructs which captures what concepts are important, propositions which captures *how* are these concepts related, logic which represents *why* are these concepts related and boundaries/conditions or assumptions that examines *under what* circumstances will these concepts and relationships work. According to (Colquitt & Zapata, 2007), theory building refers to researches beginning with observations and using *inductive reasoning* to derive a theory from observation while in contrast theory testing starts with a theory and uses *theory* to guide which observations to make or likewise it is using *deductive reasoning* to derive a set of propositions from the theory to prove or refute the prediction .Likewise (Bryman, 2012) and (Bhattacherjee, 2012), stressed that in social research, scientific inquiry may take inductive approach or deductive approach or both. While the former intends to infer theoretical concepts and patterns from the observed data, loosely called theory building, in the later the researcher intends to test concepts and patterns known from theory using empirical data or theory testing process.

While (Colquitt & Zapata, 2007) and (Bhattacherjee, 2012) agreed that theory building and theory testing should form the complete research process, despite their difficulties especially in social sciences,*abduction reasoning* was not mentioned despite the fact that some scientists use it in researches to help refining the explanations necessary to be tested. It is used to cut down the infinite possibilities of explanations to a single or few best explanations relative to the pressuring factors. Abductive reasoning as such can be refered to as inference to the best explanation. It is an intelligent guessing of the explanations for the given information, (Chiasson, 2013) made it more simple by saying it is applied to make a guess that could explain the surprising fact. For example, BIM is an astonishing or surprising information, currently in an AEC industries. A number of propositions can be set forward to explain this, but with abduction, this thesis managed to set aside other performance criteria and remain with cost as key to explaining what BIM does to the construction project.

In research, hypotheses are considered as key instruments in suggesting new experiments and observations (Kothari, 2004). It was defined as "*a proposition set forth as an explanations for the occurrence of some specified group of phenomena either asserted merely as a provisional conjecture to guide some investigation or accepted as highly probable in the light of established facts.* A hypothesis should among others, be clear, precise, testable, state a relation between variables, limited in scope, specific, simple, consistent with known facts, open to testing within reasonable time and it must explain the facts that gave rise to the need for explanations. Science is ideally all about enhancement of hypotheses (Tibbetts, 2012).It is a *what if assumption* (Williams, 2011). According to (Paiva, 2010)

> *A statistical hypothesis is an assertion or conjecture concerning one or more populations. To prove that a hypothesis is true, or false, with absolute certainty, we would need absolute knowledge . That is, we would have to examine the entire population . Instead, hypothesis testing concerns on how to use a random sample to judge if it is evidence that supports or does not the hypothesis.*

From (Weisstein, 2013) hypotheses testing was explained as

> *"Hypothesis testing is the use of statistics to determine the probability that a given hypothesis is true. The usual process of hypothesis testing consists of four steps.*
>
> 1. *Formulate the null hypothesis H_0 (commonly, that the observations are the result of pure chance) and the alternative hypothesis Ha (commonly, that the observations show a real effect combined with a component of chance variation).*
> 2. *Identify a test statistic that can be used to assess the truth of the null hypothesis.*
> 3. *Compute the P-value, which is the probability that a test statistic at least as significant as the one observed would be obtained assuming that the null hypothesis were true. The smaller the P-value, the stronger the evidence against the null hypothesis.*
> 4. *Compare the p-value to an acceptable significance value alpha (sometimes called an alpha value). If p</=alpha, that the observed effect is statistically significant, the null hypothesis is ruled out, and the alternative hypothesis is valid."*

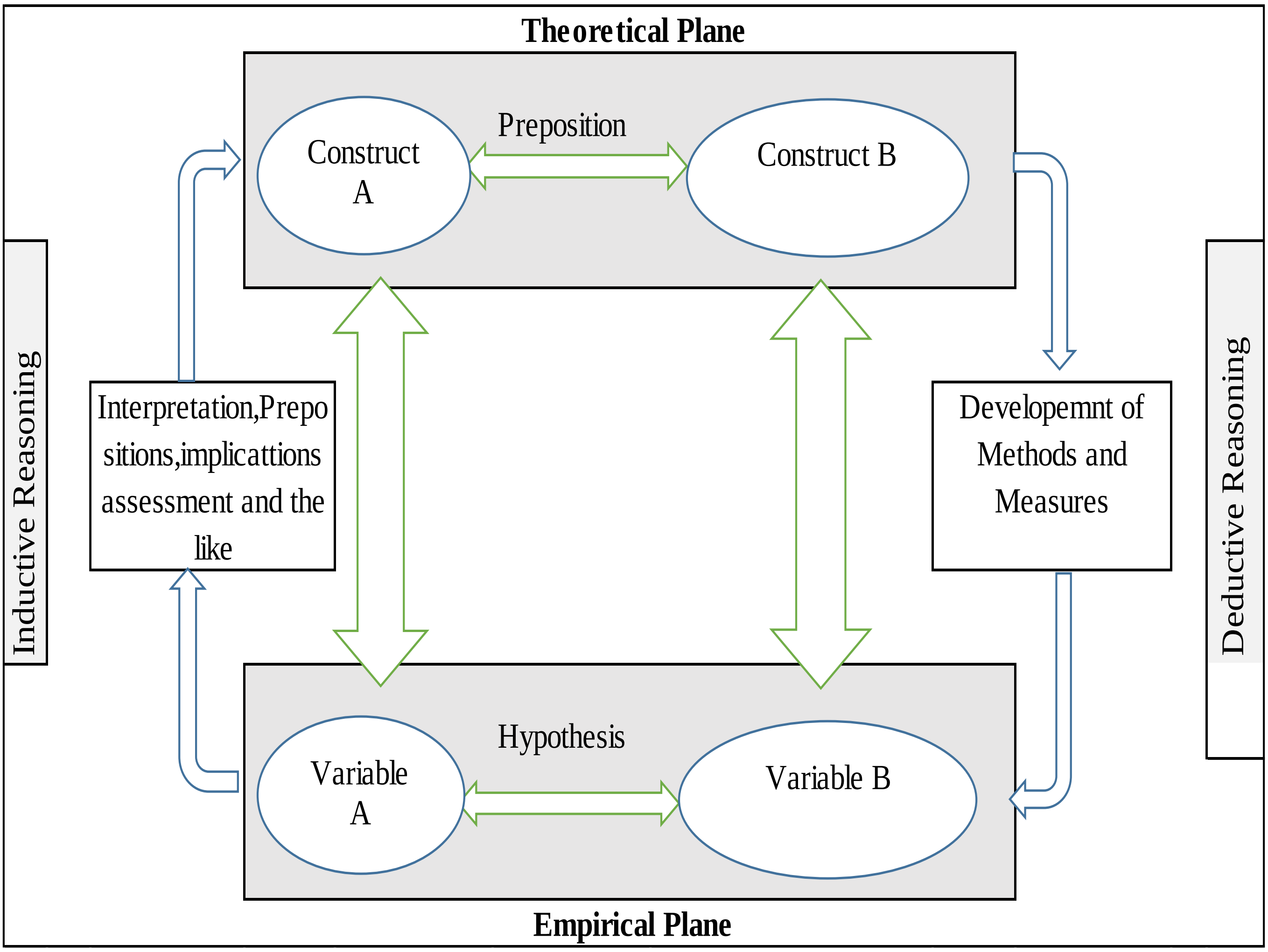



**Figure 92: The Research Cycle of Theory Building and Theory Testing[112]**

[112] Source: Modified from (Colquitt, J. A., & Zapata, C. P.-P. (2007). Trends in Theory Building and Theory Testing: A Five-Decade Study Of The Academy Of Management Journal-University of Florida. Academy of Management Journal, Vol. 50, No. 6, 1281–1303-http://leeds-faculty.colorado.edu/dahe7472/Colquitt%20and%20Zapata-Phelan%202007.pdf.and (Bhattacherjee, 2012),refer 111)

## 3. Research Strategy and Designs

It is not right to equate research designs with quantitative or qualitative method (Colquitt & Zapata-Phelan, 2007). Research designs should be selected and treated as a structured method of investigation. Depending on the goal, research designs can basically be categorised into Positivist or theory testing designs and Intepretivist or theory building designs (Bhattacherjee, 2012). This Thesis takes positivism axiology or belief, hence it is expected that the design is going closer toward experiments. Positivistic design are based on objective view of reality while Intepretivists design are related to subjectivity perspectives of the subjects involved. Example is in case researches.

> "*In planning a study, researchers need to think through the philosophical worldview assumptions that they bring to the study, the strategy of inquiry that is related to this worldview, and the specific methods or procedures of research that translate the approach into practice".* (Creswell J. , 2003).

Many researchers use an overall understanding of the designs as quantitative experiments and qualitative case studies (Colquitt & Zapata, 2007) or even philosophical assumptions behind them (Bhattacherjee, 2012), that is positivists and interpretivists strategies. On the other hand, (Creswell J. , 2003), stressed the need for Mixed Method Design when the balance of the two extremity is useful. In this study for instance, it was primarily assumed that a random selection sampling with self administered questionnaires study, to conform to the positivistic quantitative approaches of data collection. But later, the data collection was done through both, random selection and purposeful sampling of cases and respondents, and semi structured interviews, while holding the positivism actuality.This was so because, asking questions differently does not necessarily mean inquiring about different things,but rather enforcing the approaches. This study, intended to uncover the unchanging reality about what BIM does, external of the interpretation of the individuals. Example, the presence of duration estimate in the BOQ, counts irrespective of the style of questioning or answering because, it may finally be seen or empirically apprehended. That means, if the document produced in BIM environment has that item, the opinions and interpretations from individuals point of views are lesser important in this course.

The strategies, assumptions as well as methods, should be combined to gives the designs as qualitative,quantitative and mixed methods designs (Creswell J. , 2003). Also (Bhattacherjee, 2012),argued that, some designs can be used in both theory building and testing as well.On top, (Crowe & Sheppard, 2010) supported the need to mix over opting among them, as they argued that

> *"….the distinction between qualitative and quantitative research may have had validity at the turn of the 20th century, but as ideas about research have continued to evolve and develop the distinction has become more historical than actual. Whether research is qualitative or quantitative, the techniques are far more similar than they are different and by maintaining the myth of incompatibility researchers may miss important ways of finding answers to their research question"*

Basically the differences are due to the assumptions and arguments which are made by the philosophers about the *nature of reality*. The non-ending debate that is hardly possible to find a convising winner.

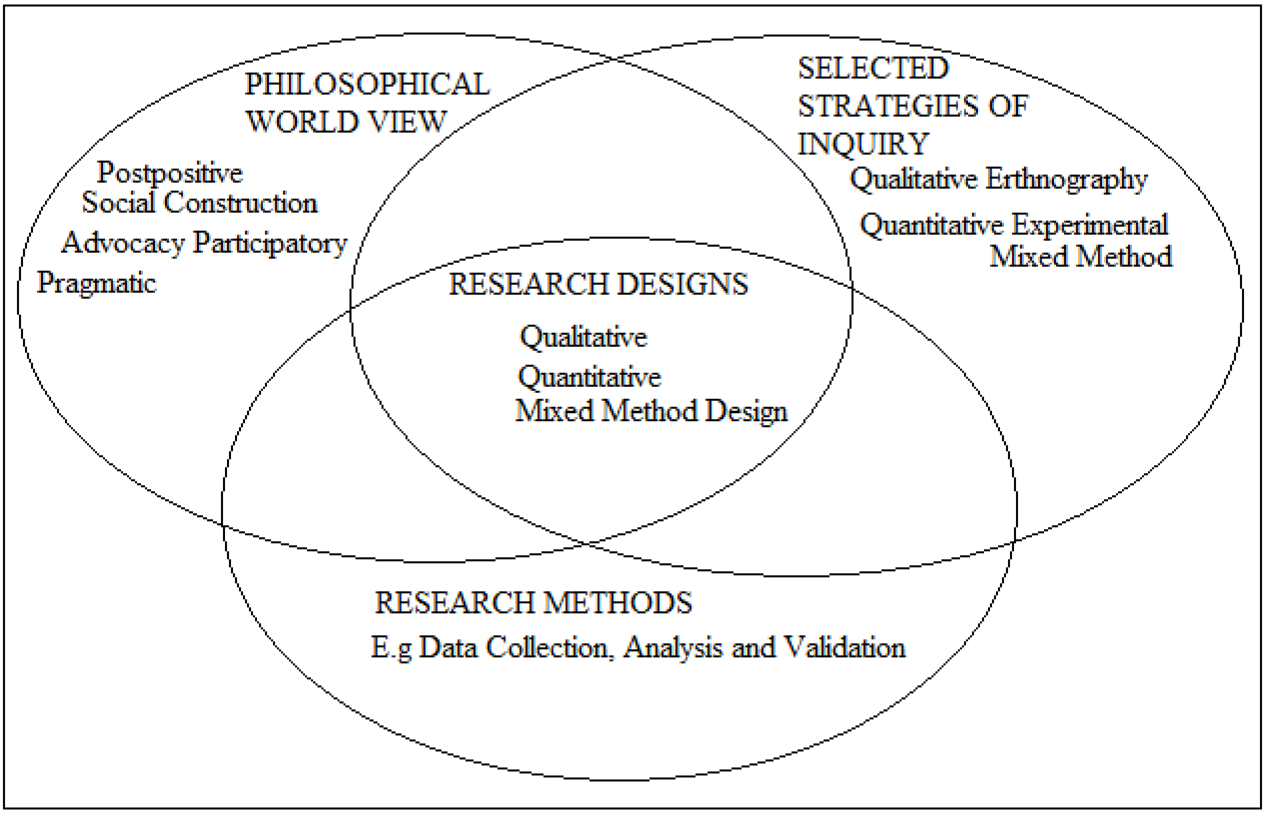



**Figure 93: Research Designs link to Worldviews, Strategies of Inquiry, and Methods.** [113]

[113] Source: Modified from Creswell, J. (2003). Research Design: Qualitative, Quantitative and Mixed Methods Approaches. London: SAGE Publications.

From (Gerring, 2011) the goodness or badness of research design depends on

> *"Theoretical fit -(a) Does the research design provide an appropriate test for the inference (construct validity)? (b) Is the test easy or hard (severity)? (c) Is the research design segregated from the argument under investigation (partition)? (d) Are alternative explanations ruled out (elimination)?; Commutation- (a) Is the research design standardized with other similar research on the topic? (b) Does it replicate extant findings and facilitate future replications by other scholars? (c) Are procedures transparent?; Treatment- Is X (a) varying, (b) simple, (c) discrete, (d) uniform, (e) evenly distributed, (f) strong, and (g) proximate to Y ?; Outcome -Is Y (a) varying, or at least free to vary?; Sample -Are the chosen observations (a) representative, (b) large in number, (c) at the principal level of analysis, (d) independent (of one another), and (e) causally comparable? And Practical considerations - what (a) pragmatic, (b) logistical, or (c) ethical concerns apply to the construction of a research design?*

Design of this thesis was time constrained like many others. The academic duration[114] of three years well planned in advance, before even being clear of the problem statement.To a positivist, that means, compromising some of the efforts, mostly the sampling, data collection techniques and methods. Not compromising the effort toward conceptual framework and statement of the problem[115] because of the weight it carries.The assumption that Total Cost Management is central objective in construction project, comes from theoretical review of all other objectives as well.Never the less, reviewing BIM, entailed much more time because it is a new concept of the construction era.Without such an endevour, it could be difficulty to achieve the constructs and variables that can work closer to the reality.For example, budgets and final accounts in the construction projects are among the items in TCM, that one may not bother to think if they are related to BOQ completeness[116].

From ((Gerring, 2011) and (Trochim, 2006)) a good research design should suite the theory,be flexible and efficient.It should reflect what the researcher intends to measure, it should reflect the flexibility and inquiry in investigation. To attain such a design, means devoting time and effort in reviewing other similar studies and related works in order to identify operationable constructs. From (Alzheimer Europe,(2009)), a quantitative researcher need *hypotheses that help to develop answers through **a clear research design***. The decision of using crossectional design, among others, intended

[114] Please find the Attached Study Schedule from March 2013 to 2016.
[115] "If I had an hour to solve a problem I'd spend 55 minutes thinking about the problem and 5 minutes thinking about solutions." Albert Einstein
[116] Completeness refers level of inclusion of designed and specified contents.

to facilitate the hypothesis through **a snapshot** data collection and analysis. According to (Kothari, 2004), efficient research design can give a collection of relevant evidence with minimal time and money. Its function is to ensure that a researcher obtains evidences capable of answering the questions or testing theories unambiguously (Colquitt & Zapata, 2007).It provides a framework for data collection and analysis (Bryman, 2012). Research needs such conceptual structure.

This thesis hypothesis[117] required measurement of the impact of the BOQ[118] to the Total Cost Management within both, the BIM[119] and Non-BIM environment. It was ideally, necessary to survey the industry with those two environment. Tanzania was selected as an environment proposed to have low level of BIM, which means lesser closer to 5DBIM and Germany was selected as an environment closer to 5DBIM. Total Cost Management or TCM[120] efficiency is high in projects with high level of BIM and otherwise. Because BIM usage is proportionally related to the rise of the informational contents in the BOQ, which at large facilitates the management of cost in the project delivery.

According to Bhattacherjee (2012), research designs are comprehensive plan or blueprints for data collection, developing instruments and sampling processes. It is a roadmap to systematically achieve the research objectives. From (Creswell J. , 2003), a research design gives also the procedures for data analysis, reporting and interpretation.

> *"Research design, which I refer to as the plan or proposal to conduct research, involves the intersection of philosophy, strategies of inquiry, and specific methods "(Creswell J. , 2003).*

However, research designs are not research methods, research strategies, qualitative or quantitative methods ((Colquitt & Zapata, 2007) and (Bryman, 2012)) and any confusion may lead to poor evaluation of the designs. Research design need to atleast specify data collection process,the instrument development process and the sampling process (Bhattacherjee, 2012). From (Kothari, 2004), the research methods refers to all what is needed during research operations undertakings. Methods are used in selecting and constructing the techniques while research techniques are those instruments used in performing the operations. But research designs include undertakings from hypothesis and its operational implications to analysis of data.When broadly speaking of collection of data techniques, the two common categories are quantitative and qualitative designs,with field

[117] In Total Cost Management (TCM), Building Information Modeling (BIM) has positive effects in Bills Of Quantities Completeness

[118] BOQ refers to legal documentation on costs matters of the construction project contract.

[119] BIM environment refers to construction projects where at least 5DBIM related software were used in the BOQ preparation.

[120] Total Cost Management (TCM), represents costs efficiency and effectiveness in the whole delivery process of the construction project from inception to disposal of the facility. Involving Budgeting, Estimation, Tendering, Variations Control, Final Accounting, Operational Costs Control and Life Cycle Costing Assessment.

survey and case research being examples respectively (Bhattacherjee, 2012). Nevertheless, the two approaches, may be *mixed* or employed together to get the in sight view where necessary *(ibid).* Rowley, (2002) viewed a research design as an action plan for getting from the questions to conclusions, and commented that

> *"a research design has the following components: The study's questions, The study's propositions, The study's units of analysis, The logic linking the data to the propositions and the criteria for interpreting findings".*

### 3.1. Experimental Design

This is considered a "gold standard" (Bhattacherjee, 2012).It has the ability to link cause and effect through treatment manipulation with reasonable controlling of spurious extraneous variable effects. They are conducted in laboratories (artificial settings) and field settings like real organization (ibid).True experiment is usually used as a benchmark in assessing other non-experimental researches (Bryman, 2012) that is why it holds importance even in social research. Their strength in internal validity is what makes it very useful, although social researchers cannot make use of it due to the fact that in social researches it is difficulty to equally manipulate independent variable and determine the dependent variables (ibid).

To this thesis, it is possible to observe a ***BOQ productivity in TCM*** in the delivery of *Project B1* with all *BIM resources* and against a similar *Project N1* with *Non BIM resources*. It means keeping all other factors constant and repetitively manipulating independent variable (BIM levels) in order to determine the dependent variables (BOQ Completeness levels).Such an exercise to projects *P(2,3,4,,,,nth)* and *N(2,3,4,,,,,nth)* are likely to result into more closer justification of whether the proposed 5DBIM is the real cause of improved BOQ completeness or otherwise stated, the absence of BIM is the only cause of *low BOQ productivity* in the TCM of Construction of projects. Enough time helps little, because to increase accuracy or internal validity in such an endeavor requires more than time and money. It needs standardized expertise, ethical and contextual settings. In (Mitchell & Jolley, 2004), such efforts are worth left to chemists where laboratory settings is used to isolate other influencing factors to the experiment. Yet, experiment forms the best standard to weigh the efficiency of choosen research design in social science researches. In (Marczyk, DeMatteo, & Festinger, 2005), researchers should strive to achieve this standard,at least the positivists.

### 3.2. Cross-Sectional and Longitudinal Design.

In cross-sectional studies, the researcher observes and compares phenomena on different contexts or groups without interfering (Institute for Work & Health, 2009).This requires more than one case at a ***single point in time*** in order to collect a quantifiable data that will help to obtain patterns of association (Bryman, 2012). Survey research is good at measuring variety of *unobservable data*, suited to extracting data from remotely situated population and may as well be economical in terms of time, effort and cost (Bhattacherjee, 2012). Lack of considerable span of time of observation is *claimed to hinder the cause-effect value* from this design. Longitudinal design, on the other hand, is time spanning. This design resembles cross-sectional with the exception that the comparison is on more or less the same population with significant span of time (Institute for Work & Health, 2009).

This thesis, used cross-section design. The selection was due to the effectiveness needed to accomplish the study within academic duration and budget. On top, the design facilitated the achievement of the key objective of uncovering the *association* of BIM and TCM improvement in the construction projects delivery. Likewise it is possible to logically infer the *causality* (Bryman, 2012), basing on the fact that the relationship is between BIM or rather a technology and cost model against valuable contents in contract documentation. This association is the key toward knowing ***what BIM does*** in the delivery of construction project. Additionally, the cross section design allowed for more flexibility of data collection methods and involvement of various factors helpful in further development or refinement of the hypotheses. The unit of analysis of this thesis was Bills of Quantities. The design allows data collection using structured or unstructured instruments. The possibility to use content analysis on the sample of documents. This flexibility helped in balancing the strength and weaknesses of these quantitative and qualitative oriented methods of data collection and analysis. It was found that random selection of the Bills Of Quantities, was time consuming due to bureaucracy necessary to get permission to the ***on-going building projects,*** hence the use of purposeful selection of the projects and participants helped to rescue the situation through the use of *semi-structured interview.*

| Fundamental Item | Fundamental Belief/Route | Reason (s) |
|---|---|---|
| Axiology | Positivism | The need to embrace Timeless/Non-Specificity. BIM Model should serve as base to all projects' participants and types |
| Ontology | Post-Positivism | BIM is in technological information. BIM is *what BIM does*. It is possible to approximate it separately from participants or researcher values. |
| Epistemology | Objectivity can be approximated | The need for Nomothetical based knowledge. The sources are more from what BIM *does* to the outputs desired and *not how*. |
| Research Design | Cross-Sectional | The need to observe TCM levels resulting from BIM/Non BIM environment in order to generate Hypothesis from variables |
| Research Strategy | Quantitative | The need for testing, to strengthen/develop the hypotheses. |
| Sampling | Simple Random Sampling, Purposeful Sampling | The need to reduce researcher´s values and maximize representation, Saving Time |
| Data Collection Tools | Self-Administered Questionnaires, Semi Structured Interviews | The need to increase objectivity, replicability and representation of the population, Time saving |

**Figure 94: Summary of general thesis strategy as related to fundamentals[121]**

[121] Source: Own Construct

### 3.3. Validity, Reliability, Replicability and Measurements

From ((Bhattacherjee, 2012) and (Rowley, 2002)) it was insisted on the need to ensure *validity* and *reliability* in the *empirical research design*. By empirical, it means relevance to concrete data or real situation, that is more than only logical reasoning. Scientific approach were decisions are based on observations and experiments (Marczyk, DeMatteo, & Festinger, 2005). Actually, some (Mitchell & Jolley, 2004:85) agree that to be a science, a study must prove observable facts publicly. Example can be in the case when the research design intending to project the existing situation of the Bills of Quantities in the industry of construction in Tanzania.The deduction reasoning from the information intergration of BIM to contract documentation and finally to BOQ contents is worthwhile if the *plan* or *research design* can be laid down to ensure what is being evidenced sensibly in the field real relates to what was thought to be. If for instance the evidence needed on BIM as being the source of BOQ completeness and hence productivity in TCM, then collecting many participants that have never used BIM may not *ensure validity* of what is measured. Architects and Engineers may use BIM to produce visualisation to the clients[122] without even producing legal drawings to be used in BOQ preparation. On the other hand,when design focuses on the presence of the BOQ contents that can only be produced by BIM technology, then it is far valid that the design will not miss the target. It is either no use of BIM or BIM helps nothing in that direction. When such a design gives the same or relatively closer to the target irrespective of the Respondent, Project or Context, it is said to be reliable, of ***more reliability***. A research design that correctly measures the presence or absence of life cycle costing contents in the BOQ from the contractors` quantity surveyors point of view and yet it fails to do the same from the consultants quantity surveyors or Architects is not reliable despite being valid. The research design should reflect both, reliability and validity. It is expected that, completeness of BOQ will be related to BIM environment despite the context, repondents or timeframe while diplaying the same variable reponse in respective environments. That is, increased LCC contents in BOQ with increased use of 5D BIM not differently, say with only CAD usage.

The closer the alignment between the research design and the theory being tested the stronger the argument (Gerring, 2011). To fit the theory the research design needs *construct validity* or faithfulness to theory under investigation, severity or demanding tests, partition or falsifiablity, and the elimination of rival hypotheses ***(ibid).*** Gerring, (2011) added that *Construct validity* includes *concept validity*,which is the connection between a key concept and the chosen indicators while from (Bhattacherjee, 2012) they mean the same as construct validity, the process of ensuring measurement

[122] Respondent 4: “We are using Arch CAD 16 and AutoCAD 2012 and Atlantis 3. Atlantis is for showing the visualization of say vegetation, in order to bring the image into more reality”

scales against the measured concepts and *reliability* or *statistical conclusion validity* refers to examining repeatability of the results. That is checking whether the variables correlates to the assumptions of statistical tests used or sometimes it is known as verifying the documentation of procedures and appropriate record keeping (Rowley, 2002). In this thesis, the main objective is to appraise the use of BIM in order to improve Total Performance Delivery of Public Construction Project in Tanzania. Building Information Modelling facilitates information integration and enhances automation in the construction project more than ever before. As such, BIM has passed a number of tests on the ability to improve quality, time and cost efficiency in delivery of projects. Irrespective of what individuals perceive to be BIM, the most important aspect this study was seeking to uncover was the fact behind *what BIM does*.

Conceptually, this study proposed that because BIM strength is on integration of the information vital for the right decision-making in the projects, then by uncovering what BIM adds to the building projects information, it is possible to develop a model that can universally work as BIM in Tanzania as well. In construction projects, information starts with drawings and specification, which are among the basic contracts documents. History of contract documentation supports this ((American Institute of Architects (AIA), 1911) and (American Institute of Architects (AIA), 2007)). However, the central informational documents are costs documents because they are what all other documents are converted to. Cost is a central objective of construction projects, that is why some scholars (Matipa, 2008), argued that BIM can only best be implemented through involvement of Quntity Surveyors.Therefore, it was proposed that BIM relationship with central cost document or BOQ in this case is the best target to focus on.

Furthermore, research design should ensure *Internal validity* (establishing a realistic causal relationship),that is assessing whether independent variable (predictors) or *5DBIM* in this case, is exactly the cause of the change in the dependent variable (outcomes) or *completeness* of the information in the BOQ.The cross-sectional design weaknesses include the inability to directly assure the internal validity. As such, this thesis infered the *directional cause-effect* relationship. Given the fact that, the independent variables include BIM levels specifically 5DBIM or in a simplified language computer software and dependent variables are project information or simply Bills of Quantities (BOQ) contents, the inference of causality are relatively directional. If the contents in the BOQ increases with increase in computer technological usage, then it is more logical to think of improvement in computer technology as the cause of that increase in BOQ contents than otherwise. This is supported in (Bryman, 2012).

> *"It is impossible for the way people vote to influence their age, so if we do find the two variables to be related, we can infer with complete confidence that age is the independent variable" (Bryman, 2012: 341).*

Another important aspect is *external validity* (generalization ability of the population sample) (Bhattacherjee, 2012). According to (Bhattacherjee, 2012), controls to assure external and internal validity is key to strong research design. A researcher need to manipulate (use of control group), eliminate (holding constant the extraneous variables),include (extraneous variables are included in the dependent variables),randomize (sample drawn for generalization) and statistically control (extraneous variables are used as covariates) the variables to ensure or guide against *spurious correlation*, generalisation and faith inspiration of the tested hypothesis. The random sampling in this study intended among others, to assure generalisation of the study, which is the overall goal, especially to quantitative strategists, if the study applicability to be more sensible in the society.

Ideally the plan was to collect data in BIM environment and Non BIM environment. Germany being highly exposed to BIM (Autodesk, 2007) compared to Tanzania was targeted for the best practice and then develop the BIM model to be tested in Tanzania. However the time constraint, the researcher opted to explore the factual opinions from the experts. The effort to try to use the help of TU-Masters/Degree student familiar with the Germany Construction Industry also went unsuccessful, because of the privacy of cost information from the construction industry in Germany. The primary empirical data on this thesis were from Tanzania construction industry. The Target being all Participants and Documents (BOQ) from the ongoing public projects.

To avoid losing internal and external validity, the setting of the thesis repeatitively state and revise the theoretical background,objective of the study and philosophical stance needed.With that in mind, minimization of errors in sampling and instruments designing is further assured. Nevertheless,to achieve the hypothesis, the derivation of the statement of the problem was initially linked to the main objective. Thereafter tentative questions were developed to help abducing the specific objectives and to refine the hypothesis.The constructs,dimensions and indicators are identified before proposing the level of measure to be used.

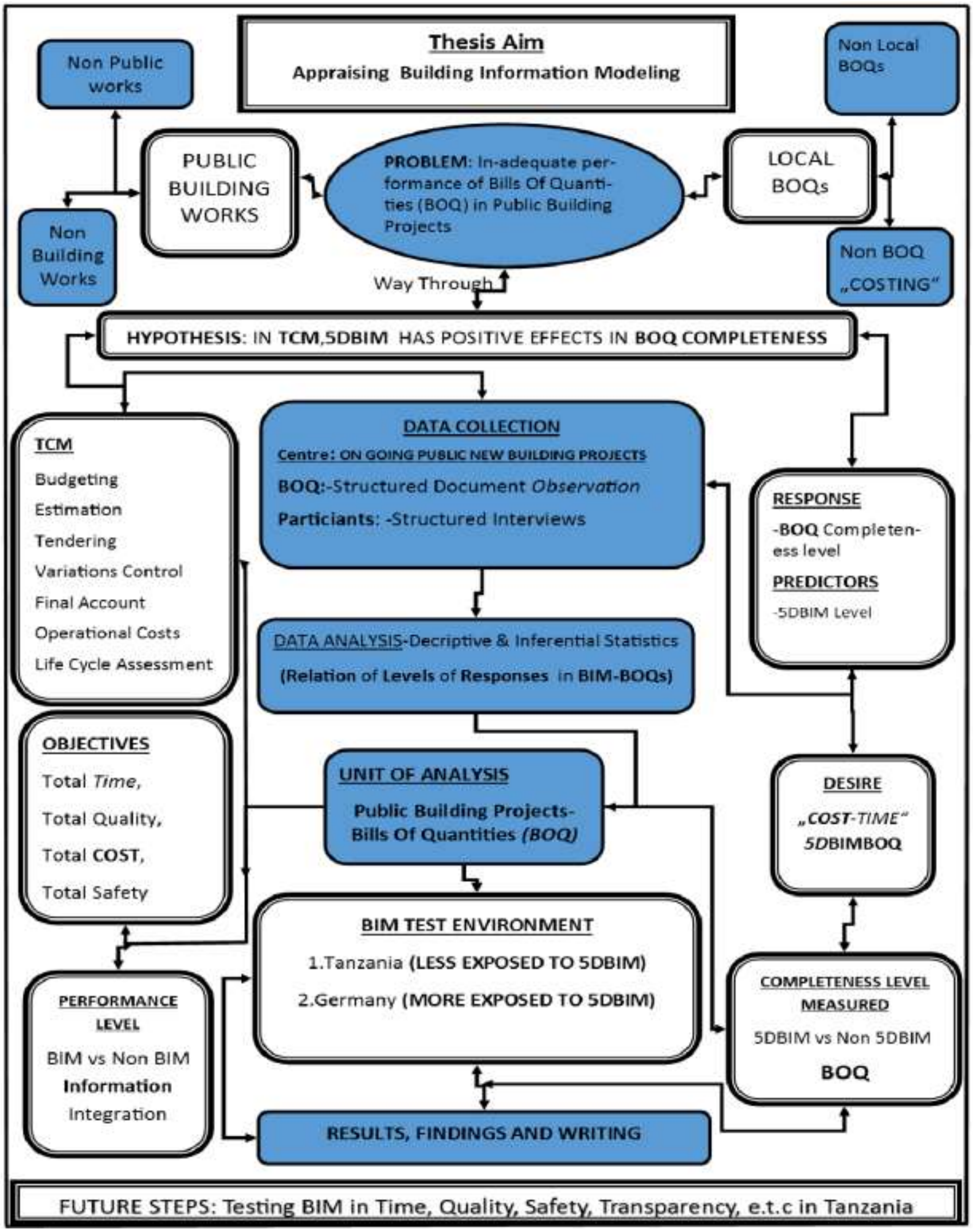



**Figure 95: Thesis Research Design** [123]

[123] Source: Own Construct

In social research, reliability, replicability and validity are key in research evaluation terminologies (Bryman, 2012), they cut across diferent research design as well. Their measurement in social research is very important. Poor measurement can limit validity in conclusions (DeVellis, 2012).Testing theories require scientific measurement of construct (Bhattacherjee, 2012). That is careful, deliberate observation of the real world of the theoretical prepositions.

> *"Measurement is a systematic, replicable process by which objects or events are quantified and/or classified with respect to a particular dimension This is usually achieved by the assignment of numerical values"* (Weiner, 2007).

In measuring constructs or mental world as (Mitchell & Jolley, 2004:20) demostrated, the researcher needs to understand conceptualisation and operationalisation process.That is defining concepts and their components in concrete and precise terms and developing scales or indicators for measuring the concepts or constructs (Bhattacherjee, 2012).For instance, BIM itself is still a debate. It is regarded as a process (National Building Information Model Standard Project Committee,, 2011) or a model in (The American Institute of Architects National (AIA) and AIA California Council, (2007)) and as management of information by (Demchak,et el (2008)). In this thesis BIM is a concept proposed to have impact on the building project performance. Unless it is broken down to an operationalisable or concrete meaning, it is difficulty to go to clearly collect the evidence of whether BIM is being practice or not and to what extent. Given the hypothesis that 5DBIM has positive effect on BOQ Completeness, BIM was operationalized through three levels basing on the computer application in the construction projects execution. First level, it is where only manual and CAD software are commonly applied, this is the lowest level BIM status. Second is when, parametric BIM models are involved in the project executions. This is the BIM level status. The last level is the BIM environment. This is where the 5D BIM or Cost model BIM status is incorporated in the project delivery. It is assumed that, fully utilization of 5DBIM is equivalent to full utilization of BIM in the project delivery. In (Popov, Juocevicius, Migilinskas, Ustinovichius, & Mikalauskas, 2010),this assumption is supported. To them even collaboration can effectivelly be achieved using 5DBIM. In simple language, this thesis proposes that, the environment where 6DBIM or even nthDBIM is involved, is regarded as BIM level unless 5DBIM is involved, such an environment will have optimal or high utilisation of BIM.

On the other hand, the construct BOQ completeness, has been operationalized through levels of BOQ contents. The Completeness is optimal when assumptions, life cycle costing items and Activities Durations are part of Bills of Quantities. It is high when Breakdown of items used in building up the rates are part of BOQ. Completeness is low when BOQ lacks Life Cycle Costing items, Activities

Durations, Breakdown of rates and complete elements that are meant to be included during design stage. In (Bryman, 2012), construct validity reminds a researcher on the need to deductively measure the concept down to the hypothesis. The prepositions holding constructs moves along mental, conceptual or theoretical plane while the hypothesis tends to pin down the constructs on evidences or empirical plane (Bhattacherjee, 2012). The imagination of complete BOQ is mentally, but with concise and concrete definition of completeness in terms contents levels of BOQ, it becomes far easier to separate the incomplete and complete BOQs. Operational definitions help to quantify abstract concepts (Marczyk, DeMatteo, & Festinger, 2005).

*Reliability*, is whether an instrument can be interpreted consistently across different situations (Field, 2009). Reliability implies *consistency* but not *accuracy* (Bhattacherjee, 2012), commonly, the variation in repeated measure or observations is due to *unsystematic events or chance*, *systematic inconsistency* and *actual change in the underlying event being measured* (Weiner, 2007). The common threat to reliability in observations includes subject reliability (factors due to research subject like mood), observer's reliability (obsevers/raters' as examplified by poor interviewer) and situational reliability (conditions under which measurements are made), *Instrument reliability*, the research instrument or measurement approach itself (e.g., poorly worded questions, twist in mechanical device), and Data processing reliability or how data are fingered (e.g., miscoding) ((Weiner, 2007), (Bhattacherjee, 2012)). It is about social science research subjectivity and so the less subjective the data collection techniques and the instrument the better (ibid).Validity, is whether an instrument measures what it is meant to measure (Field, 2009). Validity of measurement procedures is different from validity of *hypotheses testing procedures. (See Figure 96: Validity Movements).*

*To estimate reliability the common ways are*

- *Inter-rater reliability/observer . Comparing two or more of the observers/raters at a point in time. That is, the measure of consistency between two or more independent raters/observers of the same construct.*
- *Test-retest reliability. Comparing two measurements by the same observer/rater at a point in time (Weiner, 2007). Likewise, correlation in obsevations between two tests works the same (Bhattacherjee, 2012)*
- *Spilt-half reliability. The measurement is done between two halves or almost halves of the construct measure.*
- *Internal consistency reliability. Measure of consistency between different items of the same construct.*

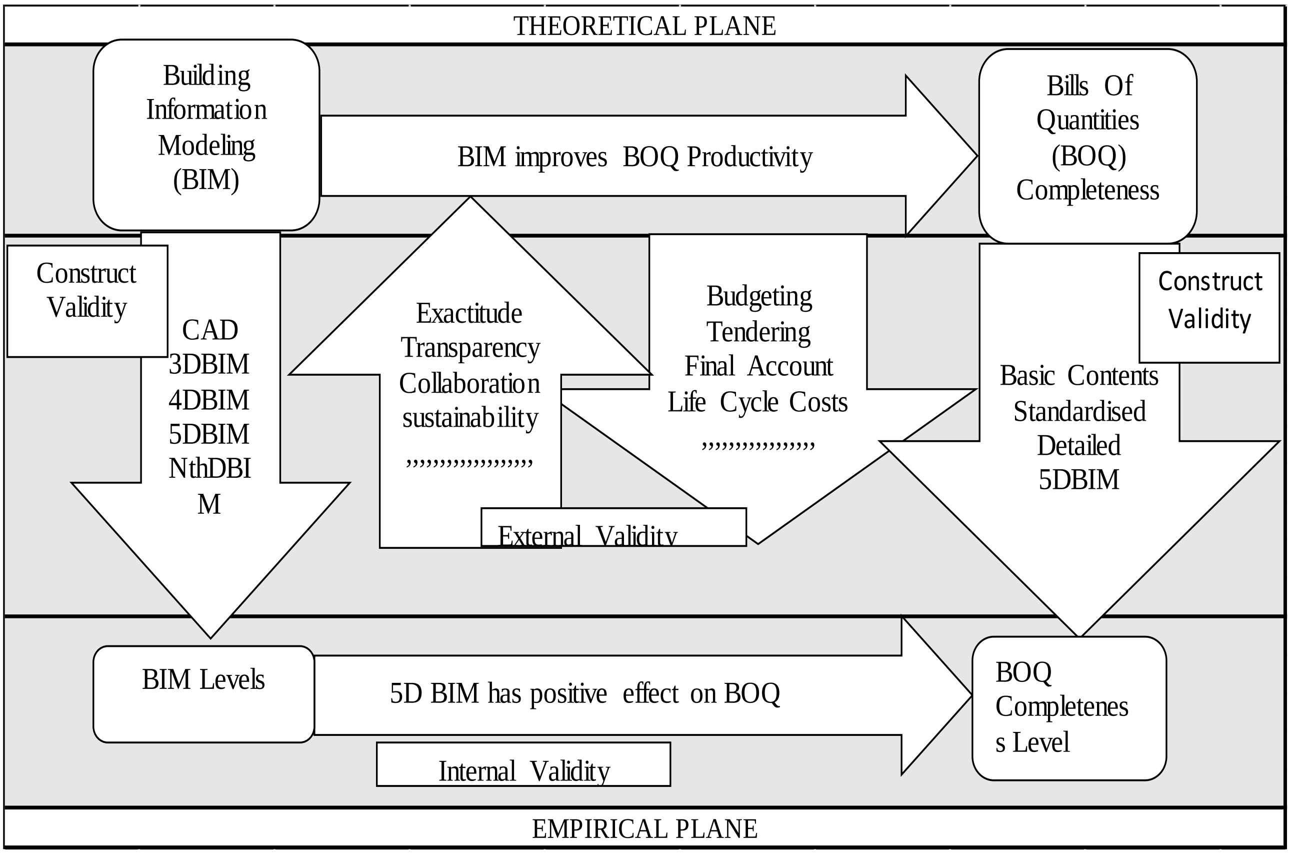



**Figure 96: Validity Movements[124]**

[124] Source: Modified from the work of Bhattacherjee, (2012)

Conceptualisation helps to reduce vageuness while the operationalisation helps to reduce subjectivity. In research the degree the techniques can secure consistent results during measurement is Reliability ((Weiner, 2007) and (Bhattacherjee, 2012)) or how much the results from the devised concepts measures are unquestionably repeatable (Bryman, 2012). The degree to which any measurement approach or instrument succeeds in describing or quantifying what it is designed to measure is the *measure of validity* (Weiner, 2007). Reliability and validity are closely interdependent but it is only possible to have *reliability without validity* and not otherwise ((Weiner, 2007) and (Bhattacherjee, 2012)).

There are four main ways of measurement in social researches or science (Fowler, 1984). A relationship between the measured and the number that represents it. It is refered to as the level of measurement, normally into category or continous forms (Field, 2009). They are the measure used to operationalise the constructs in social science.There are nominal (names and labels to the attributes ),ordinal(ordered attributes/categories), interval (giving the distance meaning),ratio (when it is possible to have absolute zero) (Bhattacherjee, 2012).The researcher should first decide on the *rating scales*, or type of an attribute that an indicator can take. Categorical variables names distinct names, at its simplest form being *binary variable* with two attributes like male or female and two equivalent things with more than two possibilities, the variable is said to be a *nominal variable* (Field, 2009). They are in *unordered* category (Fowler, 1984). Continuous variables (Discrete or taking certain values and Non discrete) are one those giving scores for each person and can take on any value on the measurement scale as examplified on *interval variable and ratio variables*

| SCALE | CENTRAL TENDENCY | STATISTICS | TRANSFORMATION |
|---|---|---|---|
| Nominal | Mode | Chi-Square | One-to-One (equality) |
| Ordinal | Median | Percentile,Non-parametric statistics | Monotonic increasing (Order) |
| Interval | Arithmetic Meaan,range,standard deviation | Correlation,analysis of variance | Positive linear (Affine) |
| Ratio | Geometric mean,harmonic mean | Coefficeint of Variation | Positive similarities (Multiplicative,logarithmic) |
| *NOTE:* | *ALL HIGHER-ORDER* | *SCALES CAN USE LOWER SCALE* | *ORDER STATISTICS* |

**Figure 97: Statistical properties of rating**[125]

Measurement and scientific inquiry are inseparable.

> *"Measurement is important in research design in two critical areas. First, measurement allows researchers to quantify abstract constructs and variables. Second, the level of statistical sophistication used to analyze data derived from a study is directly dependent on the scale of measurement used to quantify the variables of interest." (Marczyk, DeMatteo, & Festinger, 2005)*

Discrepancy between the representative number and actual measurement value of the thing if directly measured, is known as *measurement error* (Field, 2009). Random error refer to those, which are due to *unknown* and *external uncontrollable* factors *affecting randomly* (*equally in compensatory manner*) influencing *some observation* but not others. On the other hand, *systematic errors* are due to factors that systematically (*steadily in progressive or in consistent manner)* affect all the observations of a

[125] . Source: Bhattacherjee, (2012), Page 45

construct across an entire sample. Systematic errors should be corrected because it may change the observed score with consistent negative or positive effects while random error can be ignored because they cancel themselves. However, by increasing *variability* in observations, *random error* reduces reliability of measurement while by shifting the central tendency, systematic error reduces the *validity of measurement*, which is more serious, as it may even be measuring a quite different construct or concept.

Different approaches are available for a researcher to improve validity (Bhattacherjee, 2012).Theoretically this thesis problem is in-adequate performance of Bills of Quantities (BOQ) in total cost management of building projects in Tanzania. The motive behind being to appraise use of BIM in Tanzania. That is, by utilizing the strength of BIM in ***Information Integration***, the contribution of ***Bills Of Quantities (BOQ)*** in Building Project performance delivery can be enhanced. The productive BOQ facilitates the better budgeting, estimation, variations control or otherwise it facilitates *total cost management* of the project. BIM enhances the completeness, exactitude, transparency, collaborative liability and sustainable design coverage of the contract documentation of the project. Cost being central objective of projects **(Matipa, 2008)** and BOQ being central document in contract documentation gives more assurance that construct like completeness of BOQ and BIM are valid measure of the impact of information integration to the project delivery. Nevertheless, when different levels of BIM like 5DBIM are measure against the inclusion in the BOQ completeness of the life cycle costing contents assures the content validity of BIM environment and Total Cost Management coverage. Lack of enough resource hindered the use of sophisticated means of validity improvement, but deductive sorting and dropping of concepts, presentation and discussion with researcher as well as comparison to different studies *(ibid)* was helpful enough to achieve this thesis measurement validity.

On the empirical side, the study involved instrument pilot study. The questionnaires were designed to different participants of building projects from the same constructs and indicators. Only the question were varied to ensure clear dissemination of information to non-cost experts. The mode of question started with general view of the constructs. Example is when a Quantity Surveyor is asked whether BIM is among the technology used in the firm for the contract documentation. That same question can be measured further through the requesting to agree on the common software the QS is using. To many Architect, BIM may mean anything from 2D CAD to parametric BIM models[126].

[126] RESPONDENT 14: “At the beginning it was CADs. They were not compatible. Now we have far compatible software as an advancement. Therefore, I think, that is where the idea of BIM came from. Example is Arch CAD had somehow BIM, but only Architect got this information. I have read about BIM, and seen it in Revit. However, I have not practice.

Without piloting the instrument, the levels necessary to distinguish between the answers that imply the presence of BIM and NONBIM environment would be difficult. Last but not the least, the choice of indicators, utilized the suggestion from (Marczyk, DeMatteo, & Festinger, 2005). Researchers should be simplistic in selecting explanation they wish to measure. The BIM positive effect to the BOQ may vary from subjective level of intangible data related to precision or automation to objective level of tangibles like presence of provisional sums,provisional quantities and inclusion of maintanance costs and disposal costs of different items in the BOQ. This thesis opted positivistic approach and selected primarily objective level tangible costs information level. This enhanced the validity by reducing the need for multidimensional and the use of subjective constructs. On top, this objectivity is a base for ***replication***. Given the instrument of data collection, a scholar can replicate the study by measuring the level of the *electrical installation elements* in the BIMBOQ or in NONBIMBOQ document. On the other hand, to repeat the same measuring exercise to assess how far accurate was the *electrical installation elements priced* becomes difficulty, because sensing pricing precision is less objective than counting the appearance of the elements in the BOQ. Without replicability, the validity of findings are questionable (Bryman, 2012)

**Illustration Box 11: Illustration of Conceptualisation and Operationalisation**[127]

Main objective

***The main objective of this research is to appraise the use of BIM in improving Total Performance Delivery of Public Construction Project in Tanzania..***

The Specific Objectives

- ***i.*** ***To describe the relationship between BIM and Bills of Quantities (BOQ) productivity in Total Cost Management in Public Project in Tanzania***.
- ***ii.*** ***To suggest on the BIM model development contents for Public Project in Tanzania***.

Research Hypothesis

- *i.* *If 5D BIM has positive effect in Bills of Quantities (BOQ) Completeness level, then the use of BIM can improve BOQ Productivity in the Total Cost Management of construction projects in Tanzania.*

  *That is;*

  - *In TCM, 5D BIM has POSITIVE EFFECT in BOQ Completeness level.*
    - *i.* *Ho: The use of 5D BIM <u>has no effect</u> on BOQ Completeness level.*
    - *ii.* *H1: The use of 5D BIM <u>has positive effect</u> on BOQ Completeness level.*
    - *iii.* *Ho: B1 =B2, H1: B1 >B2*

  *Where B1 is Mode 5D BIM BOQ Completeness level in TCM*

  *B2 is Mode Non 5D BIM BOQ Completeness level in TCM*

.

[127] Source: Own Construct

**Illustration Box 12: TCM key areas requiring BOQ productivity[128]**

***Total Costs Management key areas requiring BOQ productivity***

i. *Budgeting – Completeness and Alternative BOQs*
ii. *Estimation- Accuracy of quantities and Descriptions of Construction works in the BOQ*
iii. *Tendering-Completeness of BOQ, (Quantities, Descriptions, Elements and response)*
iv. *Variations –Planned and actual quantities*
v. *Final account-Planned and actual quantities*
vi. *Life Cycle Assessment- Cost In Use*

***Definition of Concepts***

1. *BIM was assumed to be representation and management of a digital database of project whole life cycle information.* Before suggested to be *the representation and management of the level of information integration necessary to facilitate performance improvement in the total facility delivery from inception to demolition.*
2. *BOQ is written contract document containing costs related information of project*
3. *Productivity is OUTPUT/ INPUT with consideration of time and quality.*
4. *INPUT is the 5DBIM Environment or Non 5DBIM Environment in a given project*
   a. *5DBIM environment refers to 5D BIM basic possible information contents*
   b. *Non 5DBIM environment refers to Manual, 2D CAD, 3D CAD, 3D BIM, 4DBIM and 6D, 7D as well as Nth DBIM.*
5. *Time and Quality consideration refers to* ***assumed*** *equivalent duration and quality in any undertaking within 5DBIM and NON 5DBIM environment of the given construction project. The quality of INPUTS, other than change in BIM levels are* ***<u>assumed</u>*** *to be constant.*
6. *OUTPUT considered to be within*
   a. *Completeness of BOQ contents*
   b. *Manipulability of BOQ contents*
   c. *Exactitude of BOQ contents*
   d. *Collaborative liability to BOQ contents*
   e. *Transparency of BOQ contents*
   **f.** *Life Cycle Costing Assessment in BOQ contents*

| Item | Constructs | Type of Construct | Proposed Indicators | Type of measurement |
|---|---|---|---|---|
| 1 | BIM | Unidimensional | **5DBIM levels (***Manual, 2D CAD, 3D CAD, 3D BIM, 4DBIM,5DBIM and 6D, 7D as well as Nth DBIM* | **Ordinal** |
| 2 | Completeness of BOQ | Unidimensional | **Level** of Completed items in BOQ (Elements, Sections, Quantities and Descriptions)<br>**Level** of **Breakdown of Rate** contents in **BOQ**<br>**Level of LCC** contents in **BOQ** contents<br>**Level of reassuring documents** specified in **BOQ** | **Ordinal** |

**Figure 98: Categorisation of the constructs and indicators**[129]

[128] Source: Own Construct
[129] Source: Own Construct

# 4. Sampling

## 4.1. Theoretical Sampling Plan

It is important to identify and scrutinize the population to be studied. In research it is difficulty to cover the whole population, mostly accurate representation is desirable. Population refer to people or items or entity *(a unit of analysis)* that one wishes to study while its subset selected for the purpose of making observations and inferences about that population is a population *sample,* and hence the term *sampling* for this statistical process (Bhattacherjee, 2012). *Sampling consists of selecting some part of population to observe so that one may estimate something about the whole population* (Thompson, 2012). Sampling techniques do differ due to the level of controlling external factors influencing the output (Thompson, 2012). The common steps in sampling include defining a *target* population, choosing the *sampling frame* or accessible section of the target population from where sample can be drawn and choosing a *sample* from a sampling frame, commonly by either *probability* or *non-probability* technique (Bhattacherjee, 2012).

Preferably, the plan was to sample a population frame, from the Authorities, in Tanzania. That is Mainland Tanzania and Zanzibar. Data collection relies on the sampling process (Fowler, 1984). A stratified random sampling was suitable for the selection of participants from both countries and Bills of quantities from different sampled projects. That could enhance the generalisation to all Bills of Quantities from all building experts in Tanzania and improve unbiasedness of the study. Capturing the diversity, differences and variability in population increases reliability of the study (Tromp & Kombo, 2006). As it stood, at least one region in Zanzibar and six regions in Tanzania Mainland was the sample required for the study. Or else, the study could *purposely* select the most accessible cities, that is Dar Es Salaam, Mbeya, Mwanza, Arusha and Tanga for the Tanzania mainland, and at least Mjini Magharibi in Zanzibar, given its growing population. Then followed by stratified random sample of the projects and participants. It is usually difficulty to achieve the *golden standard* random sample due to various practical reasons (Bryman, 2012), time and cost difficulties being among what affected this study.

In quantitative strategies, *random* sampling is the master while in qualitative strategies, it is *purposeful* sampling that can be used as guidance (Bryman, 2012).When every unit has equal chance to be selected it is *probability* sampling. Normally it is simple random sampling (equal probability), systematic sampling (selection is of ordered sampling frame at regular intervals from random sample start) and stratified sampling where random sampling is done to homogenous subgroups, probably to improve proportional representation. Others include Multistage clustering sampling and matched – pair sampling ((Bhattacherjee, 2012) and (Bryman, 2012)). In opposite to probability ,when some units have zero chance to be selected,the techniques are non-probability. Commonly known are convinience (conviniently available sample), snow-ball(convinient sample gives way to a larger convinient sample) and quota sampling (first selection is random,but final selection is left to the interviewer) .

In this research, the main objective was to appraise BIM in Tanzania. That means, at least the research was supposed to be conducted to the whole construction industry, scrutinizing all the artifacts and participants opinions related to BIM based activities. However, given the study contraints, segments of populations and artifacts had to be selected without loosing the study focus of value of the whole industry. From the hypothesis, *"In total cost management, 5$^{th}$ Dimension Building Information Modeling has positive effects on Bills Of Quantities completeness level"*, it is clear that to retain the value of the construction industry to the study, it was necessary to concentrate on the costs expertise and costs artifacts specifically BOQ contents.That is, the involvement of other participants like clients, contractors and designers forms a suppotive evidence of what exactly a researcher can witness when given a chance to go through BOQs. Bills of Quantities,which is the *unit of analysis*, random sampling of ongoing registered projects would help as hard evidence of what the stratified random participant agrees.

In construction, use of stratified sampling is not uncommon. Matipa, ( 2008) used it to ensure reflection of different groups of professionals in the information and communication technology study. On the other hand, depending on the objective (Barlish & Sullivan, 2012) denied the use of survey in studying benefits of BIM, and they insisted that case study gives better results because case studies provide more precisely the contextual output of the project data. They equally argued that business benefits are more of subjective values. In this thesis, the intended option was stratified random sampling, not only because a purely random sampling is hardly achievable in non-experimental researches (Bhattacherjee, 2012), but also because the use of random (stratified) sampling could facilitate representational among the Architects, Engineers, Quantity Surveyors, Contractors and Clients/Developers. However, in this thesis, the purposeful sample of "On going Public Building Projects registered by the Board of Contractors (CRB)" was used to collect the information of Bills Of Quantities from the involved paritcipants. To get a BOQs was difficult, because it was denied as being too confidential documents[130]. Instead, purposefully selected project participants in the selected projects and institutions were interviewed using questionnaires guidelines.

[130] RESPONDENT 18: A colleague interrupted by saying"…. where are you coming from? We are contractually not allowed to dispose any sensitive information, and from what I hear, what you are asking is completely confidential, you know this is Government Project, I am sorry….."

On top, Architects and Quantity Surveyors, stratified randomly sampled population were slowly returning the questionnaires and hence the need to resent and purposefully make follow ups.

### 4.2. Target Population

This thesis intended to study the appraisal of BIM to Construction Industry of Tanzania as a whole. That is reflecting the correlational result of BIM to improved Bills Of Quantities productivity from all construction industry participants and undertakings in 30 regions of the country. That is hardly achievable within this academic period, especially in Tanzania where the communication and infrastructural efficiency is underdeveloped (UNESCO, 2009). With regard to BIM, this thesis target is to infer on the whole population with regard to using BIM to improve the *construction project documentation productivity* in order to reduce the existing inefficiencies in the total project delivery performances. Statistics (National Bureau Of Statistics (NBS), July, 2013) show that construction Industry contributes 24% of the GDP and yet the population Density figures is so diversified. It is 3,133 and 2,581 Dar Es Salaam (Mainland) and Mjini Magharibi (Zanzibar) respectively, while other regions are below 600 and going as far as 13 in Lindi. However, the growth rate showing Katavi the fourth region with 3.2 while the leading Dar Es Salaam city is 5.6 percent inter-censal population growth rate (National Bureau of Statistics & Office of Chief Government Statistician, July 2013) is an indication of the movement of the social activities.The trend of construction projects, though not very much affected with population distribution, has equally concentrated in the cities, where commercial and business activities assures return, even to public related projects[131]. The above trend alerts that sampling big cities may deny a chance of good information from the rapid growing cities.

> *"A total of 510 units will be added to the housing market in Dar es Salaam within the next two and a half years, thanks to three projects worth 124bn/- to be implemented by the National Housing Corporation (NHC)." (Mwakyusa, 2013)*

The first stage in sampling process is to identify the population or the unit of analysis ((Bhattacherjee, 2012).To infer on the contract documents (specifically the The Bills Of Quantities) of all the public building projects around Tanzania was worth an effort on this thesis. The use of *purposeful sampling* techniques to sample on going building projects denied a chance of obtaining varieties of the projects and bills of quantities. This reduces the generalisationability of the BOQ sample. Assuming the population density, both existing and rate of growth, affects the number of on going construction projects.That is because it is related to high availability of social service.Then it is logical to assume that the some potential construction projects which, are the sources of the information with regard to

[131] Unpublished Property Market Survey shows increased focus on investing in Dar Es Salaam."- National Housing Corporation, December 2014 Report

the unit of analysis or BOQs in this case, are more likely to be left aside. Likewise, the need to reflect on Tanzania and Zanzibar, theoretically seemed to fail. On the other hand, the professionals are (((mobile[132])[133])[134]), moving relative to the projects and (Matipa 2007) said, most consultants can manage many projects with small number of professionals. Having an office in a city has little to do with the execution of the project in that city, but rather the convinience of finding the clients. Currently more than 60% of the Quantity Surveying and Architectural firms in Tanzania (Mainland and Zanzibar), are residing in Dar Es Salaam (Architects and Quantity Surveying Registration Boards (AQRB), 2014).

As such making the all QS Firms a target population was necessary to ensure population frame that can disseminate the practical view of the BOQs contents and choosing Architectural firms the supporting target population was intended to represent the clients and designers point of view of the BOQs contents. Conceptually, having facility managers and more participants was the best option, but transforming questionnaires or Bills of Quantities Contents into clear objective languages was necessary. The pilot study proved it time consuming and at least involving Architects was more viable.

### 4.3. Sampling Process

If the intended sample, from Tanzania and Zanzibar, were possible, stratification could be at least one city from Zanzibar, out of (5) five regions means 20% from. To select the one region in Zanzibar, the list of population density growth rate could be a good base. By allocating the numbers from 1 to 5 in correspondence to Mjini Magharibi,Kaskazini Unguja,Kusini Unguja,Kaskazini Pemba and Kusini Pemba. Then repeated five times, to produce 25 outcomes. Then a person is given a chance to randomly select the hidden numbers five times. The leading number forms the selected region. If there is no project registered in that region, the exercise is repeated for the remaining regions until the region is found. To select regions in Tanzania, the percentage of Zanzibar could be used, 20% of the 30 regions in Tanzania is 6. Then, by repeating the same procedure it would mean selecting 6 number out of 17100720 possibilities, which is time consuming. Instead systematic random sampling could be used, for the growth rate list of Tanzania. 30 numbers are listed, and a number between 1 and 4 is selected to be used as a starting point because of (30/6) is 5. At least three days of mixing the

[132] RESPONDET 19: “We have project in Mwanza, We have done project B1,B2 …Nn in Dar, professionals follows the market and clients”
[133] RESPONDENT 18: “I am coming from country xxx, we normally keep maintenance records….”
[134] RESPONDENT 8:n “ I have worked in different countries in Africa”

written pieces of papers, until the writer forgets the shape would be necessary before the selection is made. ***(See** Illustration Box 13: Illustration of Theoretical Sampling Plan)*

**Illustration Box 13: Illustration of Theoretical Sampling Plan[135]**

| S/N | Item | Description of an item | Reasons |
|---|---|---|---|
| 1. | Target/theoretical Population | 1. Construction Contract Documents<br>2. Quantity Surveyors and Architects | 1. Information Integration Centre<br>2. Representation of the Cost Experts and Designers |
| 3. | Population | 1. Public Building Projects´ Bills Of Quantities | 1. The need to analyse BOQ |
| 4. | Sample Frame | 1. Bills of Quantities in On going “New Building” Public Projects that has been currently registered by Architects and Quantity Surveyors Registration Board (AQRB)<br>2. All QS Firms<br>3. All Architectural Firms | 1. By using AQRB list, it is assured that the projects are genuine projects with the presence of a cost expert involvement, and so the Bills of quantities are equally legally genuine. |
| 5. | Sample Size | 1. BOQ Documents Zanzibar –(1)/5 regions Tanzania –(6)/30 regions Zanzibar Projects –X Tanzania Projects-6X Total BOQs-7X<br>2. Total Questionnaires-81 for QS and 181 for Architects | 1. Stratified Random Sampling of 20%<br>2. Stratified Random sampling of 100% |
| 6. | Target Sample Size | 1. 7X BOQs Structured Observations<br>2. 81 Self-Administered Questionnaires<br>3. 181 Architects Self-Administered Questionnaires | 1. Response rate of 50%,Confidence level 95% and margin of error 5% |

•

[135] Source: Own Construct

## 4.4. Actual Sample Selection

However, the above standard process was only possible theoretically. In reality the Bills of Quantities (BOQ) obtained were very few, and mostly not from the Ongoing New Building Public Projects registered by AQRB. It was not long before the researcher discovered the *bad experiences are affecting the process.* First few firms denied completely to show the BOQ documents, and actually this made the whole process to become very bureaucratic and difficult. It was claimed that, it is too risk to show the confidential document to outsiders. That necessitated a change in plan in order to obtain the facts on the existing BOQ documents. The purposeful sampling of the building and civil projects in Dar Es Salaam Ongoing New Building Public Projects undertaken by classes 1,2 and 3 Contractors[136] were opted for the Bills of Quantities documents. The registered projects by Contractors' Registration Board (CRB), were selected starting with those projects supervised and undertaken by the Public Agencies like National Housing Corporation (NHC), National Social Security Fund (NSSF) and Public Service Pensions Fund (PSPF), well known for the construction of big projects in Tanzania. Also the projects that involved the training institutions on Architectural and Quantity Surveying were of priority before considering the number of multimillions projects the firm is involved.

On the other hand, the first online list from Architects and Quantity Surveyors Registration Board (AQRB) helped as pilot study. The simple random selection of the all 81 QS firms and 181 Architectural that were made facilitated the desirable effort devotion to response rates, question designs and other qualities in data collection, as mentioned on last paragraph in (Fowler, 2014) page 38. However in this thesis the overall objective of appraising BIM in Tanzania compelled the involvement of as many experts as possible to ensure they are aware of the ongoing research on BIM. Nevertheless, best sample size is as larger as possible, as it is much more likely to be representative, accurate and precise to the population (Singh, 2006). The supplied questionnaires made through e-mail addresses of the companies before face to face supply and follow ups was done to supplement the exercise facilitated the exercise. As more effort were being made to ensure the validity of the listed firms because there are usually change, deletion and additions of the registered firms now and then, as (Fowler, 2014) support, it turned out that quantity surveying firms were already 105 with one deleted, and Architectural firms summed to 204.

Professionals or Firms usually forms a finite universe, because they are available in registration boards. One can be certain of the number of quantity surveying firms in Tanzania, but not on the

[136] RESPONDENT 1: They supported this, "…. Tanzania, the trend of multi-storey building is high! It is better for you to focus your dissertation in only Class 1-3, where we need BIM in building project…."

number of Bills of Quantities in all projects in Tanzania. The choice was made to use the ongoing Construction projects in Dar Es Salaam at least to reduce difficulties of infinitely selecting the projects for which the Bills Of Quantities and BIM can be studied. Researcher are advised to select reliable and appropriate sample design (Kothari, 2004), not relatively simple design. With Dar Es Salaam as a geographic unit, it was possible to obtain the ongoing class 1-3 building projects list from Contractors Registration Board (CRB). The sample frames used were the list from CRB and that of firms from AQRB. It was important to prepare a sample frame, which is the list containing all units in the population to be sampled (Bryman, 2012).The random sampling of quantity surveying firms was found to be representative, appropriate, correct and reliable because the QSs are the experts in BOQ or costs management. The question of parameters of interest is crucial in designing a sample (Kothari, 2004), see this on page 69-70 where a number of steps are explained. The use of class one to three, was due to the assumption that, huge funded complex public building projects likely to involve BIM expertise are more likely to be executed by the higher classes[137].

### 4.5. Sample Size, Errors and Response rate

The great threat to the sample of professionals was the non-response[138]. The problem that, members were reluctant to give access to the Bills of Quantities. The document were considered confidential. Likewise, the professionals were slow in responding returning the questionnaires, given the academic duration necessary to complete the exercise. The use of registration list gave the way to *modified*[139] *simple random* selection from appropriate sample frame and adequacy of representation. This helped to check the bias in sampling. Sampling bias cannot be reduced by increasing sample size (Bryman, 2012), but sampling error is self-cancelling and so optimal increase of the sample size helps to rectify it. Also the used simple random intended to help in checking the sampling error. On the other hand, to overcome the hurdle in accessing BOQ, the use of *snowball* purposeful sampling were used to select the potential projects and participants. Through this it was possible to collect the opinions of experts with regard to BIM and BOQ objectively. This approach equally worked as a crosschecking mechanism for the non-response through follow ups and resending of the questionnaires to QS Firms. In this thesis the overriding sampling technique used was ***snowball***.

[137] Contractor Registration Board (CRB)- Only Class 1-3 contractors are allowed to undertake specialist projects( Contractors Registration Board (CRB), 2015))

[138] Non Response- a source of non-sampling error that is particularly likely to happen when individuals are being sampled. It occurs when some members refuse to cooperate, cannot be contacted, or for some reason cannot supply the required data.

[139] Modified Simple Random “in this context it refers to a simple random selection mixed or guided by the purposeful goal, specifically snow-ball selection techniques”

Despite of the warning by (Bryman, 2012), that snowball is sort of convenience sampling that suits qualitative strategy, the challenges of fund and time are trivial compared to the need to sample the projects likely to have BIM in Tanzania. In (Kothari, 2004), it was put forward that small researches may use this method, as long as the researcher is impartial, unbiased and experienced in making sound judgement. The fact that, there are situation when the list of sample can hardly be attainable was left unclear. Sampling BIM oriented projects fits better the thesis. First, the sampling of building projects or designers (Architects) could have resulted into projects with lesser exposure to BIM environment. Secondly, interviews strikes the balance of data collection in BIM and BOQ data from the designers than the use of self-administered questionnaires. Architects can fully follow the questions relative to CAD or BIM than BOQ. In addition, there is no registration related documentation that directs the finding of BIM projects in Tanzania[140]. Stepping from that, it was somehow logical to choose a starting point, say the ongoing multibillion projects under government building agency or universities or even professionals conversant with BIM in Tanzania and continue choosing other ongoing projects to interview the participants. The concept of infinite population, as theoretically impossible to enumerate the items in the reasonable time (Kothari, 2004), is here dishonored in that, it is not due to the very large finite population but rather unknown finite population within this reasonable time. With more time it is possible to sample the BIM oriented projects in Tanzania, but with inadequate time as in this thesis, it is very difficult to identify those projects where BIM level is relatively higher without a reliable source of list. Never the less, the used recorded semi-structured interview, using the same questionnaires, reduced the influence of the researcher values into the study because the collected data based only on the objective facts. Content wise a bill of quantity is standardized document, so projects with huge amount is more likely to represent better than the less funded projects. It breaks down the contractual activities in formal and structured form (Davis & Baccarini, 2004)

Large sample are dealt differently from the small sample. In (Kothari, 2004) a sample with 30 or fewer items is small or otherwise it is a large sample. At the absolute sample size in quantity surveying was 83 firms while to architectural firms 134 would be enough. The researcher should strive to optimize the number of elements in the sample and not the percentage of the elements in the sample to the population size. Example, at the time field ends, only 19 questionnaires from Quantity surveyors were in hand and 9 questionnaires from the Architectural firms. The 9 firms selected out of 134 in the confidence interval of 95% may have more meaning in sampling error, than having 201 firms out of 204 Architectural firms.

[140] RESPONDENT 17: What is BIM, if I do not know, it is definitely not legally recognized here, may be people are practicing without knowing it. Is Arch CAD an initial stage of BIM?

> *Specifying a fraction of the population to be included in the sample is never the right way to decide on a sample size. Sampling error primarily depend on sample size, not on the proportion of the population in the sample….An analysis plan that addresses study´s goals is the critical first step (Fowler, 2014) page 39.*

To arrive at the sample size of 83 for quantity surveying firms, the key population were analysed. Quantity surveying firms was the base population because the goal of the study is to improve BOQ productivity. Quantity Surveyors are the legal consultants in building contracts BOQ preparation in Tanzania. Architects and other designers were the second base population because of the importance in the design and specification process of the construction projects. Likewise other participants like facility managers, ICT and procurement experts were given great thought. Fewest population were the Quantity Surveyors (105 as mentioned above), with facility manager and ICT experts having no easier accessible lists to be compared. Engineers were the leading group on top of Architects (204), but a number of varieties that were assumingly inaccessible for random sampling as it would bring many categories. So, assuming a significance level of 5% and probability of success at 50% the two sample sizes attained and used were Architects ( 134 randomly sampled) and Quantity Surveyors (83 randomly sampled).

# VIII. Data Methods

## 1. Data Collection

Data Collection strategy is very much related to sampling process and the availability of the resources in the research (Fowler, 2014).This thesis being quantitatively strategically, stratified random sampling was first opted, expecting among others the time saving and cost efficiency in order to equally fit the academic resource capacities. However, circumstances were different, and then a *modified* simple random sampling and purposeful *snow-ball* sampling were used. Questionnaires were sent and resent to the quantity surveying and architectural firms,targeting all firms in Tanzania. Likewise, the ongoing projects were purposely followed and the participants were semi structured interviewed. To a critical realist, this works for both, collection of data for the validation and understanding of the phenomena in question.A more chance of getting the objective evidence and understanding of the terms used to describe the objective evidence (Bryman,2011).

> *"Where the positivist believed that the goal of science was to uncover the truth, the post-positivist critical realist believes that the goal of science is to hold steadfastly to the goal of getting it right about reality, even though we can never achieve that goal! Because all measurement are fallible, the post-positivist emphasizes the importance of multiple measures and observations, each of which may possess different types of error, and the need to use triangulation across these multiple errorful sources to try to get a better lead on what's happening in reality". ( Trochim W. M., 2006)*

In the hypothesis " 5DBIM has positive effects on BOQ Completeness", a bill of quantity without a given element in it provide a *fact* and not a *data* for the hypothesis.A questionnaire with low level of artifact of 5DBIM and absence of a given element in the BOQ gives a data. Data are purposeful and scientific evidences while facts are not necessarily so (Singh, 2006). The tools for data collection need both measure qualities, that is validity and reliability (Marczyk, DeMatteo, & Festinger, 2005) in order to properly answer the research question. They need to have a close link to the research design and the philosophical stance of the study as well.Such thinking guided the design of tools in this thesis. This thesis intended to use documents and self administered questionnaires. The reason behind was the need for reaching the factual views of the experts and to enhance the objectivity of the study by collecting factual data. However , it was realised later, that it is more efficient to send questionnaires to quantity surveying firms and purposefully administer semi-structured questions to the ongoing selected projects and institutions, in order to interview different project participants.This followed the fact that, as pilot study indicated,BIM practicing individuals and firms were hardly known.

The returned Architectural Firms Questionnaires were very discouraging.Time was not enough to make resend and follow ups for the two types of populations, and hence effort was made to the quantity surveying firms. Not discarded,the architectural firms questionnaires collected were useful in crosschecking as triangulation requires.

> *"The data collection is the accumulation of specific evidence that will enable the researcher to properly analyse the results of all activities by his research design and procedures. The main purpose of data collection is to verify the research hypotheses". (Singh, 2006)*

### 1.1. Tools Construction

Stepping from the decision of sample and level of measurement, the consideration of the philosophy of the study was shifted to the design of the questionnaires. Erroneous questions may distort the inference in survey studies. From (Fowler, 2014), one need to be aware of objective facts and subjective states, because these two form a good base for assessing the validity of the answers a researcher obtained. This thesis focus was on the objective factual data. That is, not only an objective fact, but also an objective data (Vaishnavi & Kuechler Jr, 2008), meaning the scientific research purposeful objective fact. That is, a presence of *precise* preliminary costs in the bills of quantities is a subjective data, but the presence of *section of preliminary costs* in BOQ is an *objective factual data* the research intended. Measuring the *precision* of preliminary costs in the BOQ, is likely to be influenced by many *subjective* perceptions and hence much more distorting the validity, or put it differently, the validity will depend more on the subject than tangible material outside the subject. However, given the focus of the research, testing the association of BIM in the BOQ productivity and lack of enough accessibility to the BOQ documents, it was difficulty to attain that level of measurability. Instead the instruments were focused on attaining of the objective data as reported by the individuals. According to (Fowler, 2014), designing survey instrument starts with the decision on the measurement level. And when it is difficult to attain precision, a researcher can seek factual reports from the respondents using ordinal answers. Using the (*Illustration Box 11: Illustration of Conceptualisation and Operationalisation and Illustration Box 12: TCM key areas requiring BOQ productivity)* and *Figure 98: Categorisation of the constructs and indicators*, the following breakdown were possible.

| Item | Levels | Operational Definition | Tapped Contents | Measurement |
|---|---|---|---|---|
| BIM 1 | Low BIM | Non BIM | Presence and Use of Manual, 2D CAD and 3D CAD tools and software | Likert Scale |
| BIM 2 | BIM Level | BIM | Presence and use of 3D CAD, 3DBIM Software, Tools, and Expertise | Likert Scale |
| BIM 3 | Low 5DBIM Level | Non 5D BIM | Presence and use of 3D BIM, 4DBIM, 6D, 7D as well as Nth DBIM | Likert Scale |
| BIM 4 | BIM Environmental | 5D BIM | Presence and use of 5D BIM Software, Tools, and Expertise together with 3D BIM, 4DBIM, 6D, 7D as well as Nth DBIM | Likert Scale |

**Figure 99: Predictor Variables Measured**[141]

[141] Source: Own Construct

| Item | Levels | Operational Definition | Key Contents | Measurement |
|---|---|---|---|---|
| BOQ1 | In-Complete BOQ | BOQ Missing Designed and Specified Basic Contents level Building Elements | Basic Contents Level: Sections,Elements,Quantities and Descriptions | Likert Scale |
| BOQ2 | Lesser Complete BOQ | BOQ Missing Designed and Specified Standardised Contents of Building Elements | Standardised Contents Level: Local Standards Usage, Referencing, Querry Usage, Critical Elements, Quantities, Unit Rates, Descriptions, Plants costs, Materials and Labour costs | Likert Scale |
| BOQ3 | Complete BOQ | BOQ with enough Breakdown of Designed and Specified Detailed Standardised Contents of Building Elements | Detailed Standardised Contents level: International and Local Standards Usage and Referencing, Querry Sheets Attachment, Breakdown of Elements, Quantities, Basic Price, Material costs, Labour costs, Plant Costs and Descriptions | Likert Scale |
| BOQ4 | More Complete BOQ | BOQ with enough Developed Standardised Contents with Breakdown Rate, Duration and Life Cycle Costing Contents | 5DBIM Standardised Contents Levels: Assumptions, Local and International Standards Attached, Querry Sheets Attached, Elements, Sections, Descriptions, Basic Price, Material costs, Labour costs, Plant Costs, Waste, Taxes, Waste, Activities Duration, Sub Contractors costs, maintenance costs, Replacement costs and Disposal costs. | Likert Scale |

**Figure 100: Response Variables Measured**[142]

[142] Source: Own Construct

| Item | Levels | Operational Definition | Tapped Contents | Measurement |
|---|---|---|---|---|
| 5DBIM1 | Low BIM Level | Non 5D BIM | Use of Manual, 2D CAD and 3D CAD tools and Presence of 3D BIM, 4DBIM, 6D, 7D as well as Nth DBIM | Likert Scale |
| 5DBIM2 | BIM Level | 5D BIM | Presence and use of 5D BIM Software, Tools, and Expertise together with 3D BIM, 4DBIM, 6D, 7D as well as Nth DBIM | Likert Scale |

**Figure 101: Predictor Model Variables[143]**

| **Item** | **Levels** | **Operational Definition** | **Key Contents** | **Measurement** |
|---|---|---|---|---|
| BIMBOQ1 | Less-Complete BOQ | BOQ Missing Designed and Specified Standardised Contents of Building Elements | Standards Usage and Reference, Querry Sheets Usage, breakdown of Elements, Quantities, Basic Price, Material costs, Labour costs, Plant Costs and Descriptions | **Likert Scale** |
| BIMBOQ2 | More Complete BOQ | BOQ with enough Developed Standardised Contents with Breakdown Rate, Duration and Life Cycle Costing Contents | Assumptions, Local and International Standards Attached, Querry Attached, Elements, Sections, Descriptions, Basic Price, Material costs, Labour costs, Plant Costs, Waste, Taxes, Waste, Activities Duration, Sub Contractors costs, maintenance costs, Replacement costs and Disposal costs. | **Likert Scale** |

**Figure 102: Response Model Variables[144]**

[143] Source: Own Construct
[144] Source: Own Construct

## 1.2. Questions validity and Reliability

As mentioned earlier, the ideal data collection was involving all building participants. BIM is about collaboration and information efficiency in the project delivery process. The design of tools equally went through design of tools for clients, contractors, experts and facility managers. Systematically drafted, starting with the QS Firms questionnaire as a golden standard because of the research focus, which, is BOQ productivity improvement in total cost management. On the other hand, Architectural Firms were the focal point from a point of view of designers because of the higher role and the higher use of BIM in building industry (Autodesk, 2007). Reliable answers of instruments depends also on the consistency of language used in the questions. To attain a common understanding of the words or items in “Bills Of Quantities” for example, between QS, Clients,Architects, Structural Engineers, Electrical Engineers and Facility Managers required more than available time for this thesis. It required not only piloting the questions for objective data reporting, which, was done but also ensuring that the terms used real have the same *meaning* from different experts.The pilot study helped to notice that items like *Rate* were differently intepreted and responded. To consistently collect factual information or experience from all experts, a question must mean the same thing as (Fowler, 2014) insisted when explaining the properties of a good question on page 76.Due to that, it was better to separate Quantity Surveyors questionnaires from Architects and use the same QS questionnaire as the guidance to interviews among professionals in the selected projects. The intention being to ensure these measurability qualities are not lost. The results from the few self administered questionnaire of architectural firms played as the neutralising agent of the likely researcher intrusion here.

In this thesis, questions from the questionnaires were drafted, tested and retested by discussion with experts. The first pretest, was done to the respondents ranging from graduates to masters with practicing experience. To obtain them, the emails were sent to friends, known and unknown from the Facebook page[145] specifically opened for BIM discussion. The returned questionnaires were used to scrutinize the understanding of BIM among Tanzania construction experts. The next step was to send the revised questionnaires to the more experienced researchers and professionals (Registered professionals and PhD holders) specifically.

[145] The Facebook Page was open to discussion on BIM and contribution on the Thesis. Members were mostly Architects, Architect technologists, Engineers and Quantity Surveyor from different Universities of Tanzania. Others were reputable individuals from public and private working environment (https://www.facebook.com/groups/190319597824673/)

> *"Probably the best way to pretest the self-administered questionnaire is in person with a group of potential respondents. First respondents are asked to complete the questionnaires. Then the investigator leads a discussion about the questionnaire ((Fowler, 1984) Pg 105)"*

In the drafting and assessing the accuracy and concept measurability of the instruments, many other things were worth considered. Average time required to complete answering is among them (ibid). But in this thesis, the concentration were more on ensuring that the same instrument can withstand time and context of use. So, techniques like multiplicity of questions to asking the same objective data were of first priority. Example are the questions 8, 11, 14 and 42, which give a report on the presence and absence of the designed elements in the BOQ. In (Bryman, 2012) page 164-165, a measure is yardstick that should not be influenced by time or context and so the indicators developed are preferably of multiple questions in order to confidently tap a certain concept. It was insisted that, this process is vital in quantitative research.

## 2. Data Analysis

Bills of Quantities were the unit of analysis in this thesis. In quantitative research data analysis should not be thought as a distinct process (Bryman, 2012), because decisions on the variables and sample size has relationship to the techniques and kind of analysis the researcher intended to use.

> *"Each statistical method is based upon its own or specific assumptions regarding the sample, population and research conditions. Unless these factors are considered in advance the researcher may find that it is impossible to make valid comparison for purpose of inferences".* (Singh, 2006), *on Page 222.*

This thesis was faced with the challenge of learning computer tools for analysis as well as BIM practice. The pilot study was conducted on tools of data collection entirely with the way the collected data can be analysed. Actually, *thinking before doing* is a tool toward effective and efficient achieving of the research objectives. It was necessary to rethink on the philosophical stance of the study as well as the strategy to be employed before designing the tools for data collection because the data analysis quality may be affected badly by the inputs from the respondents. Thinking of the problem in terms of a relatively simpler language and tables that the collected data may give (Singh, 2006). This thesis was ontologically post-positivistic and methodologically the study relied on critical realistic approach to be specific, which may be allowed in quantitative strategically. The choice to use Likert scale, among others, helped to measure the level of agreement on the BOQ contents levels and BIM levels in the construction projects environment of Tanzania through. The tools were designed to capture ordinal level data objectively. The tools and questions were meant to facilitate the editing, coding, classification and entering of data collected in computer software like SPSS, for the further analysis of the frequencies, modes and Non-Parametric tests in the hypothesis evaluation.

### 2.1. Preparation of Data

Among the challenges a researcher is likely to face in data analysis is coding of data. That is setting and using rules that translates answers to numbers (Fowler, 2014).In this thesis, the analysis reliably was done using IBM SPSS version of software. The guidance from (Bryman, 2012) helped to accomplish the exercise smoothly. A missing Likert item was assigned a NOT SURE answer, while when there is a whole Likert scale question missing, the questionnaire were left aside. The codes were made out of sentences from the questions, in order to simplify the distinction between items[146] and analysis. Coding is study dependent (Saldana, 2013). In qualitative coding is intending to capture essence in summative way *(ibid)*. In quantitative, the target is dimensions and categories irrespective of the essence behind the source of data, hence the need for coding manual and coding schedule in content analysis (Bryman, 2012). In this thesis, the semi structured interview content coding derived the same concept. The recorded interviews were first defined in terms of Likert scale, filled in the questionnaire and coded before being analysed *(Sees Appendices)*. Compared to the preliminary coding done during piloting of the tools, the interview codes were slightly different from the actual because some of the questions were reviewed to substitute closer terminologies and some questions were removed to retain few relevant items. For example, when piloting the study, procurement officer were considered relevant, but it turned out that the project investment officers were more relevant and accessible during data collection. Also the need to redefine the categories of measurement levels that is when data are equated to dichotomous and non-dichotomous values[147].

### 2.2. Descriptive Analysis

In quantitative analysis, two common categories of analyzing data are descriptive and inferential analysis. Descriptive statistics describes or presents the basic features in a more manageable way, or what data shows and in inferential statistics, one is approximately concluding from the data (Trochim, 2006). When one variable is analysed at a time it is univariate analysis and bivariate is when two variables are analysed at a time to uncover the relationship (Bryman, 2012). In this study, multivariate analysis was not necessary. The methods is used when it is necessary to check the relationship of three or more variables. Frequency distribution table, measure of central tendency and dispersion are

[146] Question 5: “In Public Building Projects BOQ sections includes Preliminary- coded as PPrBOQ Preliminaries”

[147] In Semi-Structure Schedule, Likert Scale 5: Items mentioned by the Respondent-Equivalent to Strongly Agreed, 4:Items closely related to the sentence of the Respondent- Equivalent to Agreed, 3:Items never mentioned by a Respondent - Equivalent to Not Sure, 2:Items that are indirectly explained by the Respondent- Equivalent to Disagreed,1:Items directly Disagreed by the Respondent-Equivalent to Strongly Disagreed

the common methods in univariate. For the case of bivariate analysis, the common techniques include contingency table, chi-square, Cramer's V and Spearman´s rho, as suggested by the (Bryman, 2012), figure 15.6, on page 340.The use depends on the type of variables. For instance, Spearman´s rho (P) is used for the pair of ordinal variables. When careful followed, chi-square is a good non-parametric test for hypothesis, as it requires no rigid assumptions in regard to type of population and less mathematical details (Kothari, 2004).

The choice of non-parametric or distribution free tests in this study followed the divergence from distributive necessities. Random sampling were replaced by purposeful sampling, the sampled respondents were under 30 and the lower level of measurement used. In (Kothari, 2004), various hypotheses test can be done through without prior assumption or conditions of parameters of the population. Among them is the test of hypothesis of relationship between variables, using spearman rho (continuous variables), Kendall, Tau, Spearman´s rank correlation (not more than two sets of data), Coefficient Gamma, Chi-Square (counted variables) and Kendall´s coefficient of concordance (more than two sets of countable variables). This thesis, conceptually, intends to improve BOQ productivity in Total Costs Management using BIM. The concept BIM and BOQ Completeness have been operationalized through ordinal (categorical data).As such, the central parameters like mean and variation are assumed nonexistence.

In terms of contents, the study had two questionnaires and one structured questions tool. First questionnaire consisted 84 questions divided into eleven sections. The Architectural Questionnaire was organized into twelve sections. Each section contained the expected contents for the respondents to agree or disagree, (*Refer to the appendices*).The items, were derived from the levels of BIM technologies and BOQ informational contents. The level of measurement, were Ordinal for Ordinal for the QS and Nominal and Ordinal for the Architects. The basic information intended included the biographies of the respondents in the first sections, the basic sections of BOQ, Basic contents of BOQ, standard contents of BOQ, additional contents of BOQ like maintenance, use of Computer, Use of BIM, and exactitude opinion of computer technologies and BIM in BOQ preparation. On top, the tools tried to catch the opinions on the presence BIM related software in the industry and on what could BIM serve in the industry.

### 2.3. Distribution Frequencies

Frequency table, intends to provide the number of people and the percentage belonging to each of the categories for the variable in question (Bryman, 2012). In this study, a total of 20 questionnaires were collected from the Quantity Surveying Firms, 13 questionnaires from Architectural Firms and 21 semi-structured questionnaires from ongoing projects in Dar Es Salaam were administered. The total number of registered firms as per AQRB, was 105 for Quantity Surveying and 204 Architectural Firms (*See Figure 103: The Frequency Distribution from the 20 Quantity Surveying Firms in Tanzania)*

Firm Registration Status

| | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|
| Local Firm | 18 | 90.0 | 90.0 | 90.0 |
| Foreign Firm | 2 | 10.0 | 10.0 | 100.0 |
| Total | 20 | 100.0 | 100.0 | |

Professional Status of Respondents

| | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|
| Full Registered | 18 | 90.0 | 90.0 | 90.0 |
| Assistant Registered | 2 | 10.0 | 10.0 | 100.0 |
| Total | 20 | 100.0 | 100.0 | |

Experience in Construction Projects

| | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|
| Less than 5 Years | 1 | 5.0 | 5.0 | 5.0 |
| Between 5 to 15 Years | 10 | 50.0 | 50.0 | 55.0 |
| Between 15 to 25 Years | 4 | 20.0 | 20.0 | 75.0 |
| More than 25 Years | 5 | 25.0 | 25.0 | 100.0 |
| Total | 20 | 100.0 | 100.0 | |

**Figure 103: The Frequency Distribution from the 20 Quantity Surveying Firms in Tanzania**

The distribution in (Figure 103: The Frequency Distribution from the 20 Quantity Surveying Firms in Tanzania) show a good involvement of the fully registered professionals with a working experience of between 5 to 15 years. Within that range of experience, 10 respondents gives a good chance that a great number of fully registered Quantity Surveyors filled the questionnaires, because fully registered professionals were 18 out of 20. Likewise, the response of 18 locally registered firms compared to 2 from foreign firms, gives a relatively good assurance that the response reflects the local market experience. Quantity Surveyors and Building Economists are the only legal professionals for costs consultancy in Tanzania.

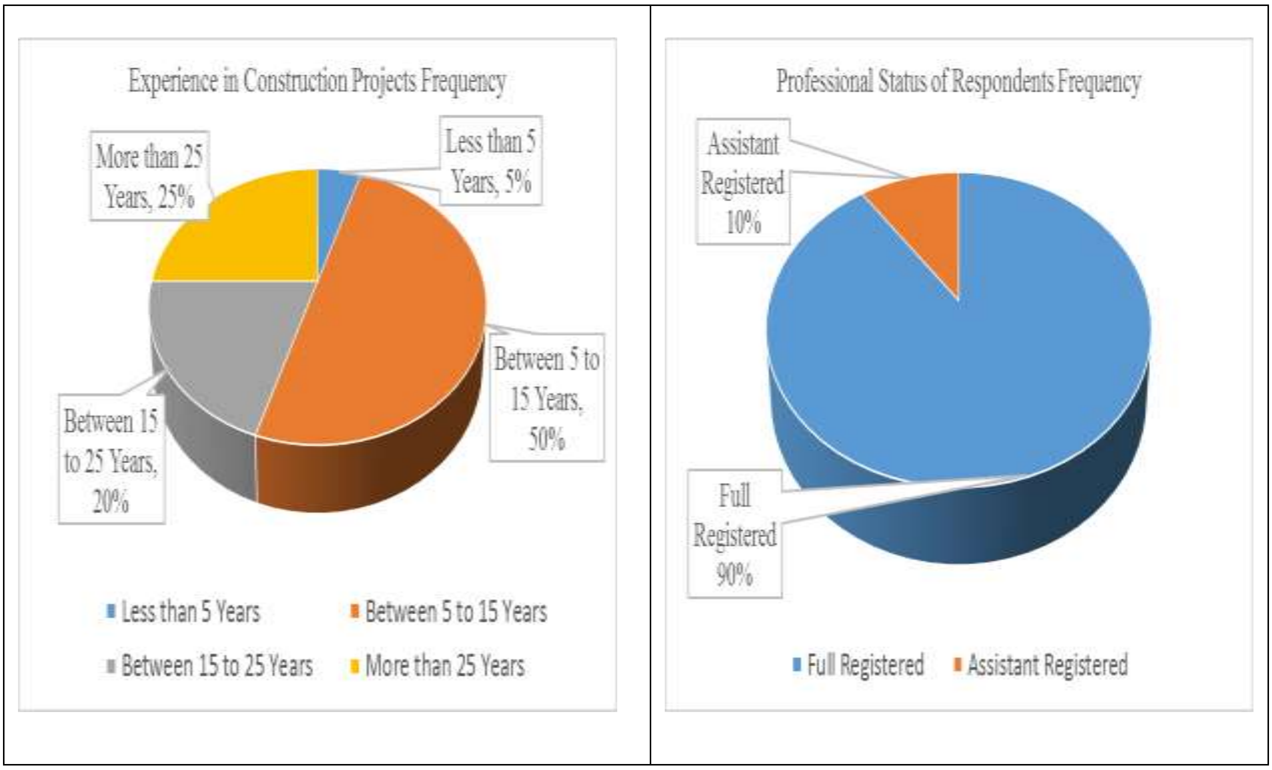



**Figure 104: The Percentage Distribution on Experience from the 20 QS Firms in Tanzania**

Architectural Firms, on the other hand had two categories. Architects and Architects Technologists. The distinction is not so significant, because Architect Technologists is at its infantry stage, and hence the practice is still in Architectural bases.It is in this current regulation that Architects Technologists has been recognized ((Act Supplement, 2010) and (Subsidiary Legislation, 2015)). In (Monko & Roider, 2014), until 2010 only Architects and Quantity Surveyors were known by AQRB. The experience range between 5-15 years shown by the 10 respondents out of 13 give a relatively good assurance that the technology assessed is reflecting the existing situation of the BIM technology, because the CAD design is relatively familiar in Tanzania compared to BIM, and the professionals, especially the new generation professionals are practicing CAD more than manual design. CAD is even now very familiar[148] in the universities. 1 response out of 13 of Architectural Technologist somehow reduces the chance that the new technology was well reflected. Yet the response comes from the Assistant Registered expert, which may imply the young professional in Architecture.

Nevertheless, this study collected data from participants in the ongoing projects, with the intention to objectively obtain the evidence with regard to BIM usage and the Bills of Quantities used in those

[148] Respondent 3: It was added "I finished my Bachelor in Architecture last year, and we were told about BIM but not yet taught at XXX University. I know about Revit (One Graduate commented in the Architectural Office with more than 15 years of experience)"

project. A total of 21 projects were visited, including Road Works, Commercial and Housing Building Works under Government and Private Entities. The focus was on the four key personnel, which were Quantity Surveyors, Architects and Engineers. However, given the situation, any appropriate officer, like facility manager, procurement officer and investment officer for some institution were equally interviewed. Likewise, a group of expert were necessary where all together questioned. It happened so, few times when the firm have a number of projects and sites, and so allocating time to individuals was found to be uneconomical and insecure, as the interview involved Bills of Quantities, which were considered confidential document.

The Area of Profession

| | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|
| Architecture | 12 | 92.3 | 92.3 | 92.3 |
| Architectural Technology. | 1 | 7.7 | 7.7 | 100.0 |
| Total | 13 | 100.0 | 100.0 | |

Firm Registration Status

| | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|
| Local Firm | 13 | 100.0 | 100.0 | 100.0 |

Professional Status of Respondent

| | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|
| Full Registered | 12 | 92.3 | 92.3 | 92.3 |
| Assistant Registered | 1 | 7.7 | 7.7 | 100.0 |
| Total | 13 | 100.0 | 100.0 | |

Experience in Construction Projects

| | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|
| Between 5 to 15 Years | 10 | 76.9 | 76.9 | 76.9 |
| Between 15 to 25 Years | 2 | 15.4 | 15.4 | 92.3 |
| More than 25 Years | 1 | 7.7 | 7.7 | 100.0 |
| Total | 13 | 100.0 | 100.0 | |

**Figure 105: The Frequency Distribution from the 13 Architectural Firms in Tanzania**

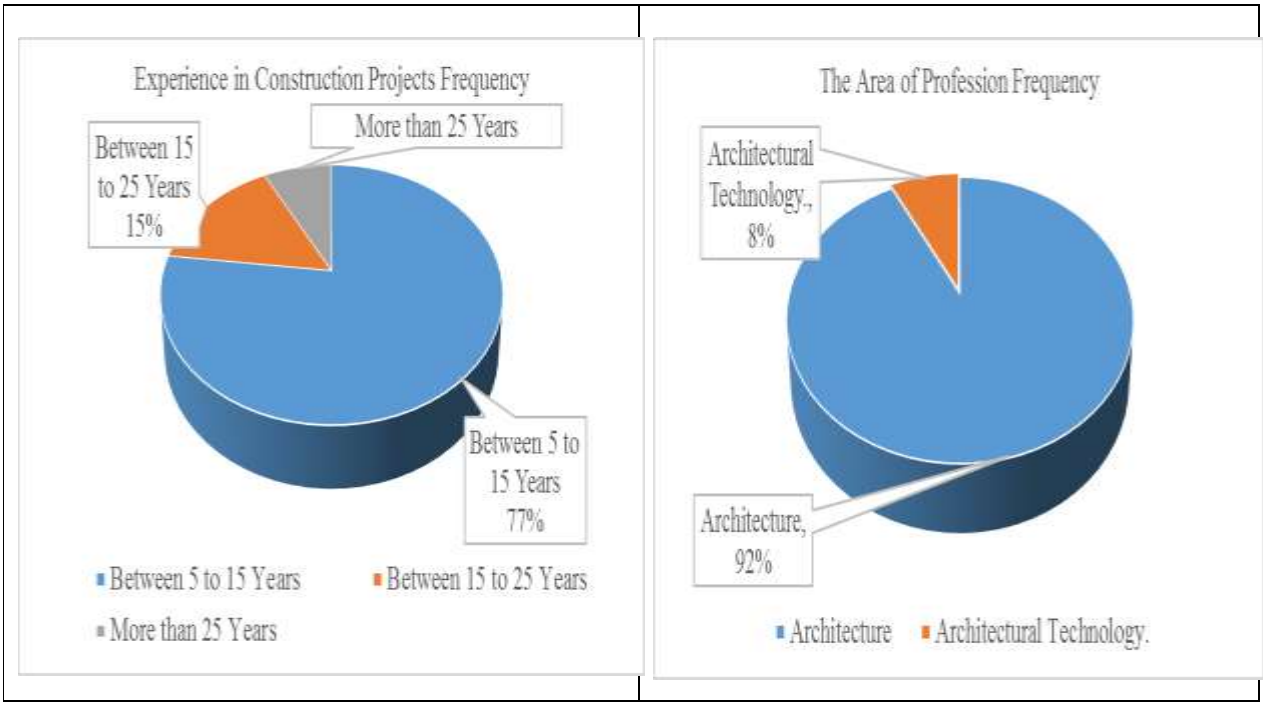



**Figure 106: The Percentage on Experience from the 13 Architectural Firms in Tanzania**

The semi structured interview questions based on the Quantity Surveying Questionnaire. The questions were used to spot the key observable items relative to BIM and BOQ contents. On the other hand, the interviewee was given enough chance to add their opinions on the phenomena in question. The 15 consultants out of 21 projects, is relatively good response because the consultants are the documentation point of the project. This documentation and professional focus was supported in ((Monko & Roider, 2014) (Matipa, 2008)),where documents and theories regarding BIM technology adoption were examined and construction practitioners and educators in AEC community professionals were surveyed and intervieweed, to establish the baseline knowledge, perceptions, and proficiency of BIM and investigate the use of BIM in Tota cost management in design stage respectively.Firms experience is relative impressive, as 9 firms had above 25 years of experience and 8 out of 21 are within a 5 to 15 years of experience and in between, that is 15-25 only 4 firms. Out of 21 respondents, 18 were from local firms, 13 were from firms dealing mostly with building works, 15 were from consultancy firms, 10 were having quantity surveying background and 7 were from Architecture background. The distribution is by some means reliably support the analysis of presence or usage of BIM in the concerned project and firm operations and increases a chance that the responses were from the right people in case of the Bills Of Quantities prepared by the firms.

Respondent Background

| | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|
| Architecture | 7 | 33.3 | 33.3 | 33.3 |
| Quantity Surveying | 10 | 47.6 | 47.6 | 81.0 |
| Group with at least a QS,Architect or S/ Engineer | 2 | 9.5 | 9.5 | 90.5 |
| Other Profession | 2 | 9.5 | 9.5 | 100.0 |
| Total | 21 | 100.0 | 100.0 | |

Nature of Organization

| | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|
| Consultancy | 15 | 71.4 | 71.4 | 71.4 |
| Main Contractor | 1 | 4.8 | 4.8 | 76.2 |
| Construction Subcontractor | 1 | 4.8 | 4.8 | 81.0 |
| Public Agency In Construction Activities | 2 | 9.5 | 9.5 | 90.5 |
| Public Client | 2 | 9.5 | 9.5 | 100.0 |
| Total | 21 | 100.0 | 100.0 | |

Nature of the Firm Registration

| | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|
| Foreign Firm | 3 | 14.3 | 14.3 | 14.3 |
| Local Firm | 18 | 85.7 | 85.7 | 100.0 |
| Total | 21 | 100.0 | 100.0 | |

Experience of the Firm in Construction Project

| | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|
| Between 5-15 Years | 8 | 38.1 | 38.1 | 38.1 |
| Between 15 -25 | 4 | 19.0 | 19.0 | 57.1 |
| Above 25 years | 9 | 42.9 | 42.9 | 100.0 |
| Total | 21 | 100.0 | 100.0 | |

Nature of the Construction Projects the Firm is Mostly Involved

| | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|
| Civil Works | 2 | 9.5 | 9.5 | 9.5 |
| Building Works | 13 | 61.9 | 61.9 | 71.4 |
| All of the Above | 6 | 28.6 | 28.6 | 100.0 |
| Total | 21 | 100.0 | 100.0 | |

**Figure 107: The Frequency Distribution from the Construction Projects Firms in Tanzania**

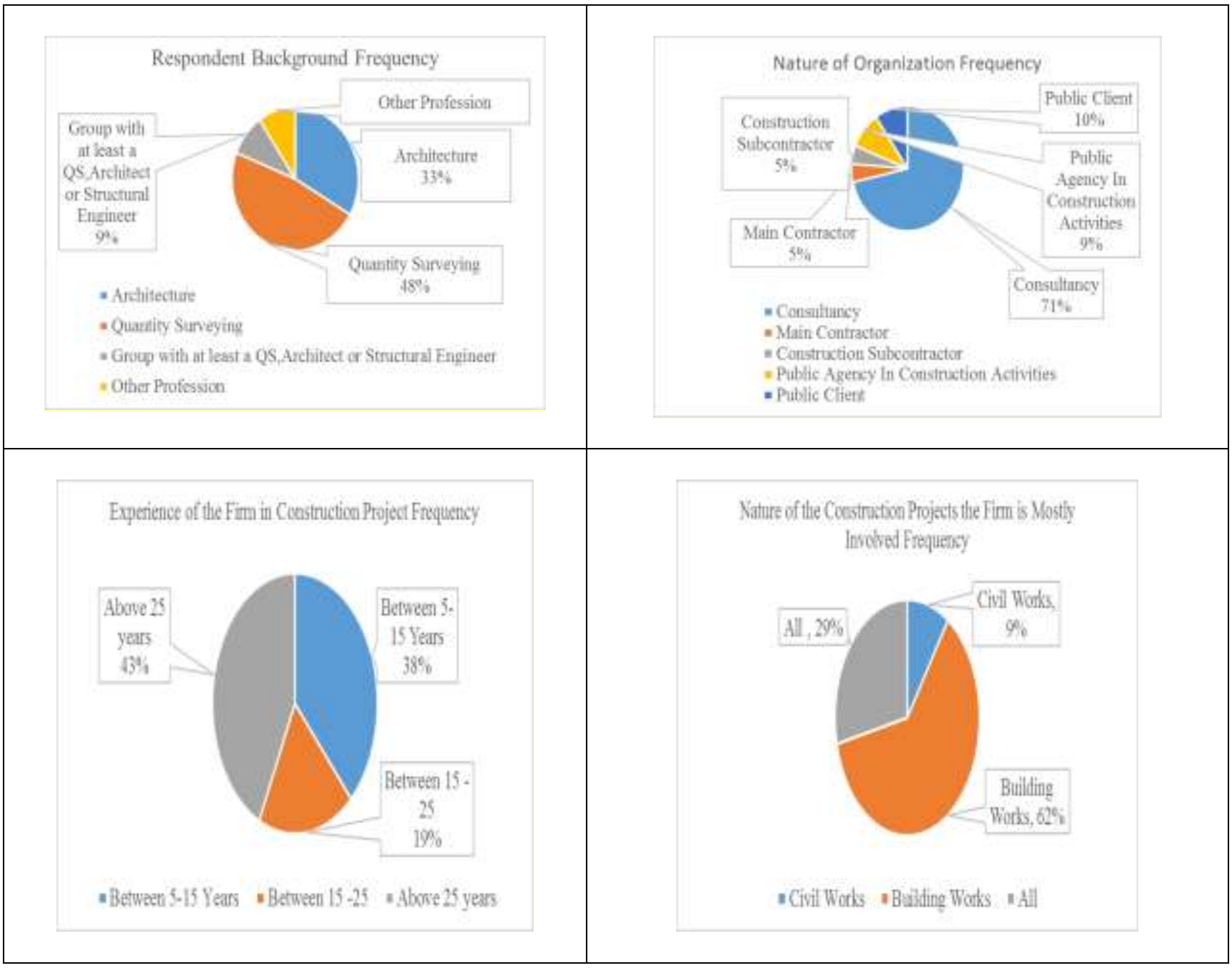



**Figure 108: The Percentage Distribution from the 21 Construction Projects in Tanzania**

## 3. Response on Predictors or BIM levels Responses

The predictor variable is BIM level, specifically 5DBIM levels. The questions targeted to collect the presence of BIM usage and the level of BIM usage through the observation of the CAD and BIM technologies available and frequently used by the respondents and the firms. The QS questionnaire, were all at ordinal level of measurement, while the Architects questionnaires included both ordinal questions and nominal scale questions. The mixture of scales, intended to ensure that the focus of the questions to the respondents is relative friendly with regard to the familiarity of the contents. For instance, BOQ contents, was anticipated that, they may not be very familiar to architects or designers just like BIM technologies to QS. Despite the fact that this preposition was somehow qualified by one interviewee[149], by saying that there are design professionals who prepare their BOQ and then submit to the QS, this was relatively easier than otherwise especially in Tanzanian industry. It is better for an architect to tick a yes or no question on the sections of BOQ than choosing the agreement level. The many architects questionnaires discarded showed impartial on the Likert agreement side questions. The description has been categorized into non BIM or BIM technologies and Non 5DBIM or 5D BIM technologies.

### 3.1. Non BIM(3D CAD) and BIM (3DBIM) Technologies

Local Architectural firms said yes to the presence of CAD related technologies as the existing technology in the construction industry.11 respondents out of 13 indicated that excel is equally present. The responses were more positive to 3DCAD than 3DBIM[150]. According to analysis done in (Monko & Roider, 2014) *"Not many companies in Tanzania own a variety of BIM software, and some said they used it as a personal tool and not for their company"*. Out of 13 responses, 7 respondents said yes to the use of technologies closer to Building Information Modelling (BIM), examples include the Autodesk Revit and Nemetschek. Others said no. All of the Architects said yes to the CAD and 3D CAD usage as well.

This low presence of BIM usage shown from the response of Architects, was relatively supported by the Quantity Surveying Firms. It was disagreed strongly that 3D BIM technologies were present. The Quantity Surveyors agreed strongly on the presence of the use of excel and not on the other related 3DBIM technologies software. Only 2 respondents out of 20 from the over 5 years of experience firms were not sure that excel is the common technology in the construction projects. All 16 agreed

[149] Respondent 10: "We had different professional working as a team. Architect, Engineer, QS and services Engineer. QS is dealing with the Costs, although Services Engineer usually prepare their BOQ and communicate with QS"

[150] Respondent 2: "From what you have described, to be BIM I am sure we are not using BIM at all .May be other companies, which I have not worked with. ARCHCAD, AUTOCAD, and Excel are the few common software we have ever worked with. Drawings from Designers are mostly from such software".

strongly and 3 agreed that excel is the existing technology to QS in most of the construction projects. The response of QSs indicated that most of the respondents are not sure or they strongly disagree on the presence of the usage of 3DBIM in the construction projects. The responses were supported by both experienced and lesser experienced professionals and firms. The common software is excel (*See Figure 109: Presence of BIM and CAD related Technologies in Architectural Firms Responses*).Actually "*Microsoft Excel is the most widely used systems for the preparation of quantities, estimating and cost planning, cost monitoring, and final accounts management"* (Matipa, 2008) supports this results.

### 3.2. Non 5DBIM and 5DBIM Technologies

No Architectural respondent said yes to 4D, 5D or NthD BIM related technologies. However, 1 respondent out of 13 indicated presence of advanced BIM related documentation and technologies. That is the use of Graph iSOFT MEP, ECOTEC Analysis, CISCO IT and COBie. They all said no on the presence of 5D BIM related software like iTwo, Vico and Autodesk QTO. These software are related to costs estimation activities, Architects interpreted differently. For instance the Respondent 10[151] interpreted BIM as just collaboration between the participants, while the respondent 14[152] described as information sharing. *(See Figure 111: Response by Architects on technologies related to 5DBIM. And Figure 112: Other Responses of Architects on the closer technology* used*).* Quantity surveyors responses disagreed strongly that 4D, 5D and NthD BIM related software are commonly used in construction projects. The QS agreed strongly on the presence of the use of excel and not on the other related BIM costs estimates software. *(See Figure 113:QS Responses on the likely presence of 4D,5D,NthD in Construction Projects).*

The fact that 2 out of 20 registered QS agreed that there is 5DBIM related technologies were cross-checked. Because 1 respondent agreed on the 4D BIM and no one agreed on 5DBIM while 2 again strongly agreed on the presence of 3DBIM, it is likely that some professionals possess witnessed software relative to 5DBIM technologies in the construction projects. In (Monko & Roider, 2014), it equally found that individuals use some software for personal use. On the other hand, the difficulty in definition of BIM could have confused the individuals in the answering what output is related to

151 Respondent 10: "We had such a platform (that is BIM) in the (Our Project xxx). Architect did the design, and then gives it to structural engineer and so on. All the experts completes the designs, then we give them to the QS, who calculates the costs, and then we seek the approval from the client. So we had BIM in this project, actually we had a lot of technical meeting to ensure this. We have site meeting, technical meeting and coordination meeting. We do not do in **digital** form. I have worked with a company in (XXX Abroad); everything is done in digital form, from building permit.

152 Respondent 14: "At the beginning it was CADs, but they were not compatible. Now we have far compatible software as an advancement. Therefore, I think, that is where the idea of BIM came from. Example is Arch CAD had somehow BIM, but only Architect got this information. We normally use 3D views to elaborate to the client. I have read about BIM, and seen it in Revit. But I have not practice".

5DBIM technologies. This was found close to the explanation from the respondent 13[153].In semi structured questionnaires, 1 respondent out of 21 agrees that 5DBIM related technologies can be seen in the construction projects. The response was somehow shocking.

Furthermore, the interviews indicated that the 1 response out of 21 supporting the presence of 5DBIM comes from the group of local firms, building works and over 25 years of experience. As such, it is worth further scrutinizing. BIM definition is still a debate in construction, hence professionals have their own imagination on what BIM mean. For instance from Respondent (1[154], 4[155]) the different views can be proposed. Some professionals interpret BIM from their functions, some from a more powerful software perspective and others are real assuming it is just another coming revolution in the building design technology. From the Architects questionnaires, all respondents said no to the likely presence of 4D, 5D and nthDBIM, probably because the terminologies are not related to the software they are using like AutoCAD Revit. Yet, both Architects and Quantity surveying responses indicated that excel is the highly used in construction projects compared to BIM related software.

The *Figure 106* responses gives assurance that from the QS responses, it is lesser likely that the 5DBIM related technologies are present in the construction projects because even designers support the dominance of excel over other technologies. However, there is a great chance that individual QS firms have different software for the facilitation of the cost activities. On the other hand, the response from architects and QS indicate the more likely presence of the CAD related software in the design activities than those of BIM related in the construction projects. In general, all responses insist that BIM related tools and techniques are lesser to Architects, QS and probably other building participants. In (Monko & Roider, 2014) about 91.6% of respondents believed their competitors are either not using BIM at all or are using it to a low extent and 78.3% of respondents believed the reason is that no clients who are mandating BIM on their projects, which was reported as a similar survey in the US that revealed 68.1%, clients are not mandating BIM. Respondent 2[156] agreed to have worked with many companies using Revit and AutoCAD, but not in sense of BIM as described in the introduction

[153] Respondent 13: "For me I used WIN QS TAKE OFF. It prepare Bills and do the calculation. But the drawings I normally take in hard copy. To use softcopy, I need another dimension, which I do not have, I do not know how to use, and it is so expensive. This one I bought in South Africa, and I must pay fees annually".

[154] Respondent 1: "We have BIM but it is at the very basic level, of computer aided design. In our team of experts, Architects are leading the practicing of this lower level of CAD or BIM, and Quantity Surveyor are far from it. We need BIM, and it will improve our way of designing our works. Our level of BIM here is CAD and REVIT."

[155] "We are using Arch CAD 16 and AutoCAD 2012 and Atlantis 3. Atlantis is for showing the visualization of say vegetation, in order to bring the image into more reality. In our country, BIM is not effective. In addition, if there is BIM then, it is only few are practicing. Because, with BIM what I understand is that it is about integration, when I design here my fellow professional see my work direct and so we can share the information"

[156] Respondent 2: "From what you have described, to be BIM I am sure we are not using BIM at all .May be other companies, which I have not worked with. ARCHCAD and AUTOCAD and Excel are the few common software we have ever worked with. Drawings from Designers are mostly from those software"

of the questionnaire and by the interviewer. Respondents strongly agree on the presence of CAD related tools and strongly disagree on the presence of BIM related items.

The response also showed that professionals disagree strongly on the higher levels of BIM. For instance, 1 Architect agreed with regard to 3D BIM, 5 Architects disagreed, while 1 strongly disagreed on this item. But, 6 Architects strongly disagreed on the presence of 5DBIM while only 1 again agreed on this item. Despite the strong statement from respondent 21[157], that BIM is not yet in the industry, the responses from this study indicates the presence of the signs of BIM in the construction projects as supported by respondents (17[158] and 14[159]). In (Monko & Roider, 2014) *"Few professionals used the software like DProfiler, Solibri Model CheckerTM, Digital Project, Tekla BIMsight, Vico, GraphiSOFT ArchiCAD, Bentley, AutoCAD Civil 3Dr, AutoCAD MEP, Autodesk Navisworks, Autodesk Revit. Likewise Master bill QSCad and RIPAC, for Estimators for company use"*.

[157] Respondent 21: "I am telling you, BIM is too advanced for Tanzanian industry. I know it and I have tried to buy it from London. Even there in Europe, they are at the beginning stages. We have been selling QS software for more than 20 years now, so I MEAN WHAT I SAY, WE DO NOT HAVE BIM HERE .It is an ideal practice to come. We sent a person to UK, to look for BIM; we found that it is not possible to adopt it here. BIM is very helpful, and we need it badly! However, we have so many challenges ahead"

[158] Respondent 17: "I remember last year we had a student studying this in USA. We called an expert from Sweden to explain in the (XXX), but we are still not very much knowledgeable. Which countries are using this BIM up to know? Is Arch CAD part or initial stage of BIM?"

[159] Respondent 14: "BIM is just starting to take over. At the beginning, it was CADs, but they were not compatible. Now we have far compatible software as an advancement. Therefore, I think, that is where the idea of BIM came from. Example is Arch CAD had somehow BIM, but only Architect got this information. We normally use 3D views to elaborate to the client. I have read about BIM, and seen it in Revit. However, I have not practice. We real need it, to my views"

| | | In Construction Project Documentation, closer technology used is 2D CAD and 3D Computer Aided Design | Total |
|---|---|---|---|
| | | Yes | |
| The Area of Profession | Architecture | 12 | 12 |
| | Architectural Technology. | 1 | 1 |
| Total | | 13 | 13 |

| | | In Construction Project Documentation, closer vit, Vector works and Allplan Nemetschek | | Total |
|---|---|---|---|---|
| | | Yes | No | |
| The Area of Profession | Architecture | 6 | 6 | 12 |
| | Architectural Technology. | 1 | 0 | 1 |
| Total | | 7 | 6 | 13 |

| | | In Construction Project Documentation, closer technology used is Microsoft Excel | | Total |
|---|---|---|---|---|
| | | Yes | No | |
| The Area of Profession | Architecture | 10 | 2 | 12 |
| | Architectural Technology. | 1 | 0 | 1 |
| Total | | 11 | 2 | 13 |

**Figure 109: Presence of BIM and CAD related Technologies in Architectural Firms Responses**

| | | In Construction Project Documentation, closer technology used is Microsoft Excel | | | Total |
|---|---|---|---|---|---|
| | | Not Sure | Agree | S/ Agree | |
| Professional Status of Respondent | Full Registered | 1 | 2 | 15 | 18 |
| | Assistant Registered | 0 | 1 | 1 | 2 |
| Total | | 1 | 3 | 16 | 20 |

| | | In Construction Project Documentation, closer technology used is 3D BIM | | | | | Total |
|---|---|---|---|---|---|---|---|
| | | S/Agree | Agree | Not Sure | Disagree | S/Disagree | |
| Experience in Construction Projects | Less than 5 Years | 0 | 0 | 1 | 0 | 0 | 1 |
| | Between 5 to 15 Years | 0 | 3 | 3 | 1 | 3 | 10 |
| | Between 15 to 25 Years | 2 | 0 | 1 | 0 | 1 | 4 |
| | More than 25 Years | 0 | 0 | 1 | 0 | 4 | 5 |
| Total | | 2 | 3 | 6 | 1 | 8 | 20 |

| | | In Construction Project Documentation, closer technology used is Auto Desk Revit, Vector works and Allplan Nemetschek | | | Total |
|---|---|---|---|---|---|
| | | Agree | Not Sure | S/ Disagree | |
| Firm Registration Status | Local Firm | 4 | 8 | 6 | 18 |
| | Foreign Firm | 0 | 0 | 2 | 2 |
| Total | | 4 | 8 | 8 | 20 |

| | | In Construction Project Documentation, closer technology used is 3D BIM | | | | | Total |
|---|---|---|---|---|---|---|---|
| | | S/Agree | Agree | Not Sure | Disagree | S/Disagree | |
| Professional Status of Respondent | Full Registered | 2 | 3 | 4 | 1 | 8 | 18 |
| | Assistant Registered | 0 | 0 | 2 | 0 | 0 | 2 |
| Total | | 2 | 3 | 6 | 1 | 8 | 20 |

**Figure 110: QS Response on the Excel, CAD and 3DBIM usage on the construction projects**

| | | In Construction Project Documentation, closer technology used is Graph iSOFT MEP, ECOTEC Analysis, CISCO IT and COBie | | Total |
|---|---|---|---|---|
| | | Yes | No | |
| The Area of Profession | Architecture | 1 | 11 | 12 |
| | Architectural Technology. | 0 | 1 | 1 |
| Total | | 1 | 12 | 13 |

| | | In Construction Project Documentation, closer technology used is Autodesk QTO, Vico,iTWO RIB, DProfiler, BIM Measure from Causeway | Total |
|---|---|---|---|
| | | No | |
| The Area of Profession | Architecture | 12 | 12 |
| | Architectural Technology. | 1 | 1 |
| Total | | 13 | 13 |

**Figure 111: Response by Architects on technologies related to 5DBIM.**

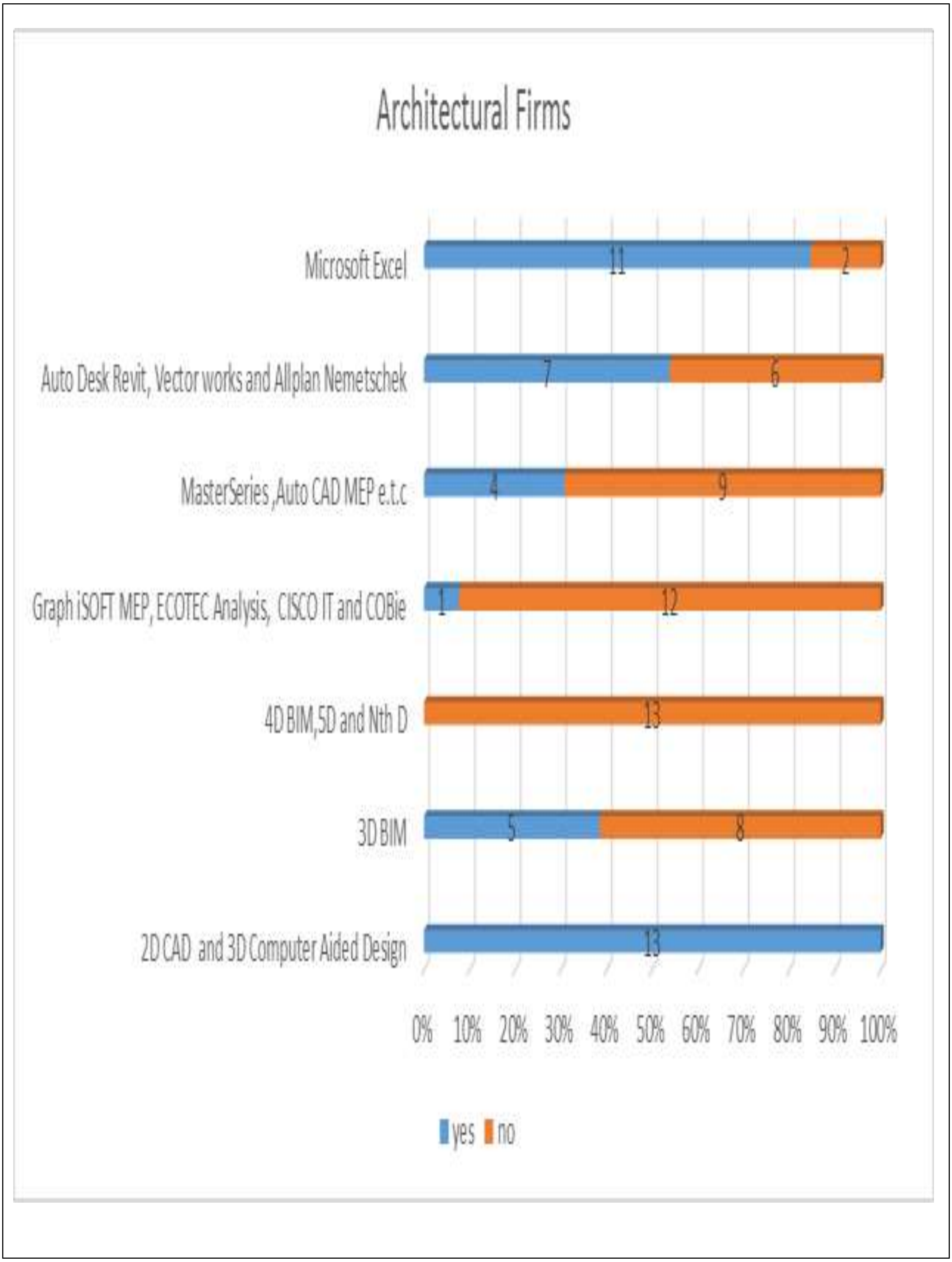



**Figure 112: Other Responses of Architects on the closer technology used**

| | In Construction Project Documentation, closer technology used is 4D BIM | | | | Total |
|---|---|---|---|---|---|
| | Agree | Not Sure | Disagree | Strongly Disagree | |
| The Area of Profession — Quantity Surveying/ Building Economics | 1 | 9 | 1 | 9 | 20 |
| Total | 1 | 9 | 1 | 9 | 20 |

| | In Construction Project Documentation, closer technology used is 5D BIM | | | Total |
|---|---|---|---|---|
| | Not Sure | Disagree | Strongly Disagree | |
| The Area of Profession — Quantity Surveying/ Building Economics | 9 | 1 | 10 | 20 |
| Total | 9 | 1 | 10 | 20 |

| | In Construction Project Documentation, closer technology used is Nth D BIM | | | Total |
|---|---|---|---|---|
| | Not Sure | Disagree | Strongly Disagree | |
| The Area of Profession — Quantity Surveying/ Building Economics | 9 | 1 | 10 | 20 |
| Total | 9 | 1 | 10 | 20 |

| | In Construction Project Documentation, closer technology used is Autodesk QTO, Vico,iTWO RIB, DProfiler, BIM Measure from Causeway | | | Total |
|---|---|---|---|---|
| | Agree | Not Sure | Strongly Disagree | |
| The Area of Profession — Quantity Surveying/ Building Economics | 2 | 8 | 10 | 20 |
| Total | 2 | 8 | 10 | 20 |

**Figure 113:QS Responses on the likely presence of 4D,5D,NthD in Construction Projects**


**Figure 114:Response on the usage of BIM in the construction projects**

| | | On BIM Level, Using 5D BIM | | | | Total |
|---|---|---|---|---|---|---|
| | | Agree | Not Sure | Disagree | S/Disagree | |
| Nature of the Construction Projects the Firm is Mostly Involved | Civil Works | 0 | 0 | 1 | 1 | 2 |
| | Building Works | 1 | 0 | 0 | 12 | 13 |
| | All of the Above | 0 | 1 | 1 | 4 | 6 |
| Total | | 1 | 1 | 2 | 17 | 21 |

| | | On BIM Level, Using 5D BIM | | | | Total |
|---|---|---|---|---|---|---|
| | | Agree | Not Sure | Disagree | S/ Disagree | |
| Nature of the Firm Registration | Foreign Firm | 0 | 0 | 1 | 2 | 3 |
| | Local Firm | 1 | 1 | 1 | 15 | 18 |
| Total | | 1 | 1 | 2 | 17 | 21 |

| | | On BIM Level, Using 5D BIM | | | | Total |
|---|---|---|---|---|---|---|
| | | Agree | Not Sure | Disagree | S/Disagree | |
| Experience of the Firm in Construction Project | Between 5-15 Years | 0 | 0 | 0 | 8 | 8 |
| | Between 15 -25 | 0 | 0 | 0 | 4 | 4 |
| | Above 25 years | 1 | 1 | 2 | 5 | 9 |
| Total | | 1 | 1 | 2 | 17 | 21 |

**Figure 115: Responses from the construction projects interviewees on 5DBIM technologies**

| | | On BIM Level, Using 5D BIM | | | | Total |
|---|---|---|---|---|---|---|
| | | Agree | Not Sure | Disagree | S/ Disagree | |
| Respondent Background | Architecture | 1 | 0 | 0 | 6 | 7 |
| | Quantity Surveying | 0 | 0 | 2 | 8 | 10 |
| | Group with at least a QS,Architect or Structural Engineer | 0 | 0 | 0 | 2 | 2 |
| | Other Profession | 0 | 1 | 0 | 1 | 2 |
| Total | | 1 | 1 | 2 | 17 | 21 |

**Figure 116: Structured Interviewed on the presence of 5DBIM from the ongoing projects (1/2)**

| | | In Construction Project Documentation, closer technology used is 2D CAD and 3D Computer Aided Design | Total |
|---|---|---|---|
| | | Yes | |
| Firm Registration Status | Local Firm | 13 | 13 |
| Total | | 13 | 13 |

| | | In Construction Project Documentation, closer technology used is 3D BIM | | Total |
|---|---|---|---|---|
| | | Yes | No | |
| The Area of Profession | Architecture | 5 | 7 | 12 |
| | Architectural Technology. | 0 | 1 | 1 |
| Total | | 5 | 8 | 13 |

| | | In Construction Project Documentation, closer technology used is Graph iSOFT MEP, ECOTEC Analysis, CISCO IT and COBie | | Total |
|---|---|---|---|---|
| | | Yes | No | |
| The Area of Profession | Architecture | 1 | 11 | 12 |
| | Architectural Technology. | 0 | 1 | 1 |
| Total | | 1 | 12 | 13 |

| | | In Construction Project Documentation, closer technology used is MasterSeries ,Auto CAD MEP e.t.c | | Total |
|---|---|---|---|---|
| | | Yes | No | |
| Firm Registration Status | Local Firm | 4 | 9 | 13 |
| Total | | 4 | 9 | 13 |

**Figure 117: Architectural Firms Response on CAD and BIM presence in construction projects**

| | | On BIM Level, Using 3D BIM | | | | Total |
|---|---|---|---|---|---|---|
| | | Agree | Not Sure | Disagree | S/ Disagree | |
| Respondent Background | Architecture | 1 | 0 | 5 | 1 | 7 |
| | Quantity Surveying | 1 | 0 | 2 | 7 | 10 |
| | Group with at least a QS,Architect or Structural Engineer | 1 | 0 | 1 | 0 | 2 |
| | Other Profession | 0 | 1 | 0 | 1 | 2 |
| Total | | 3 | 1 | 8 | 9 | 21 |

| | | On BIM Level, Using nthD BIM | | | | Total |
|---|---|---|---|---|---|---|
| | | Agree | Not Sure | Disagree | S/Disagree | |
| Respondent Background | Architecture | 1 | 0 | 0 | 6 | 7 |
| | Quantity Surveying | 0 | 0 | 2 | 8 | 10 |
| | Group with at least a QS,Architect or Structural Engineer | 0 | 0 | 0 | 2 | 2 |
| | Other Profession | 0 | 1 | 0 | 1 | 2 |
| Total | | 1 | 1 | 2 | 17 | 21 |

**Figure 118: Responses from interviewees on BIM presence in the construction projects**

| | | S/Agree | Agree | Not Sure | DisAgree | S/ DisAgree | |
|---|---|---|---|---|---|---|---|
| 60 | In Construction Project Documentation, closer technology used is 2D CAD and 3D Computer Aided Design | 2 | | | 6 | 12 | BIM 1 |
| 61 | In Construction Project Documentation, closer technology used is 3D BIM | 2 | 3 | 6 | 1 | 8 | BIM 2 |
| 62 | In Construction Project Documentation, closer technology used is 4D BIM | | 1 | 9 | 1 | 9 | BIM 3 |
| 63 | In Construction Project Documentation, closer technology used is 5D BIM | | | 9 | 1 | 10 | BIM 4 |
| 64 | In Construction Project Documentation, closer technology used is Nth D BIM | | | 9 | 1 | 10 | BIM 4 |
| 65 | In Construction Project Documentation, closer technology used is Graph iSOFT MEP, ECOTEC Analysis, CISCO IT and COBie | | 1 | 8 | 1 | 10 | BIM 3 |
| 66 | In Construction Project Documentation, closer technology used is MasterSeries ,Auto CAD MEP e.t.c | 1 | 1 | 9 | 1 | 8 | BIM 2 |
| 67 | In Construction Project Documentation, closer technology used is Auto Desk Revit, Vector works and Allplan Nemetschek | | 4 | 8 | | 8 | BIM 2 |
| 68 | In Construction Project Documentation, closer technology used is Autodesk QTO, Vico,iTWO RIB, DProfiler, BIM Measure from Causeway | | 2 | 8 | | 10 | BIM 4 |
| 69 | In Construction Project Documentation, closer technology used is Microsoft Excel | 16 | 3 | 1 | | | BIM 1 |

**Figure 119: Summary of the QS on BIM Levels Technologies presence**

| | | Yes | No | Total | |
|---|---|---|---|---|---|
| 39 | In Construction Project Documentation, closer technology used is 2D CAD and 3D Computer Aided Design | 13 | | 13 | BIM 1 |
| 40 | In Construction Project Documentation, closer technology used is 3D BIM | 5 | 8 | 13 | BIM 2 |
| 41 | In Construction Project Documentation, closer technology used is 4D BIM | | 13 | 13 | BIM 3 |
| 42 | In Construction Project Documentation, closer technology used is 5D BIM | | 13 | 13 | BIM 4 |
| 43 | In Construction Project Documentation, closer technology used is Nth D BIM | | 13 | 13 | BIM4 |
| 44 | In Construction Project Documentation, closer technology used is Graph iSOFT MEP, ECOTEC Analysis, CISCO IT and COBie | 1 | 12 | 13 | BIM 3 |
| 45 | In Construction Project Documentation, closer technology used is MasterSeries ,Auto CAD MEP e.t.c | 4 | 9 | 13 | BIM 2 |
| 46 | In Construction Project Documentation, closer technology used is Auto Desk Revit, Vector works and Allplan Nemetschek | 7 | 6 | 13 | BIM 2 |
| 47 | In Construction Project Documentation, closer technology used is Autodesk QTO, Vico,iTWO RIB, DProfiler, BIM Measure from Causeway | | 13 | 13 | BIM 4 |
| 48 | In Construction Project Documentation, closer technology used is Microsoft Excel | 11 | 2 | 13 | BIM 1 |

**Figure 120: Summary of the Architects on BIM Levels Technologies presence**

## 4. Responses on Response (Dependent) Variable or BOQ Contents levels

Unlike the predictor, the response variable or dependent variable consisted of a number of dimensions that need to be broken down into measurable information levels. Questions were categorized in order to tap the corresponding levels of information. For instance, basic sections of the Bills of Quantities (BOQ) were displaying the first level of information grouping. The target is to measure the completeness level, through the contents of the Bills of Quantities. In this regard, response that sections present do not include impartial contents or provisional sections were referred to as an indication of the more completeness of the BOQ. The level continues to a more detailed tangible items that are present contractually. Later the level of information takes the account of the unusual items that BIM can facilitate its inclusion in the contractual BOQ. For instance, the inclusion of maintenance costs is proposed desirable but, mostly requiring sophisticated effort, which BIM may be one of them.

### 4.1. Basic Contents level

Quantity surveying firms respondents strongly agreeing on presence of preliminaries, preambles measured sections were 19, 14 and 19 out of 20 respondents respectively. Other sections include, provisional sums and prime costs and the day work section. Provisional Sums and Prime Costs responses were 18 strongly agree, 1 agree and 1 not sure to both. *(Figure 121: QS Responses on the preambles and Day works sections in the BOQ)*.

| | | In Public Contract; BOQ Sections Include Preliminaries | | Total |
|---|---|---|---|---|
| | | Agree | Strongly Agree | |
| The Area of Profession | Quantity Surveying/ Building Economics | 1 | 19 | 20 |
| Total | | 1 | 19 | 20 |

| | | In Public Contract; BOQ Sections Include Measured | | Total |
|---|---|---|---|---|
| | | Agree | Strongly Agree | |
| The Area of Profession | Quantity Surveying/ Building Economics | 1 | 19 | 20 |
| Total | | 1 | 19 | 20 |

**Figure 121: QS Responses on the preambles and Day works sections in the BOQ**

The lowest response was on the Day-Works section were 3 respondents agreed strongly while 10 respondents disagreed strongly (*See Figure 122: QS response on Prime costs, Provisional sums, Preambles and Day works Section* ). The response is supported by the interviewees. Respondent 1[160] for example, claiming that "*most of the BOQs are coming with the Provisional Sums".* In (Matipa, 2008) complexity in most cases, compels QS to apportion lumps sums of specialized works like of Mechanical and Electrical (M&E) to specialist.

Day-works, Prime Costs and provisional sums responses of QSs were supporting the hypothesis very much. Local and Foreign firms of QSs indicated the absence of Day-Works sections and presence of provisional sums. This was from both registered and assistants of the experienced firms . 10 out of the 20 respondents who disagreed strongly on the presence of the day works sections in the bills of quantities used in the construction projects, 9 were full registered professionals in status. Three responses indicated that, day works is usually present by agreeing strongly.2 of these 3 response were from local firms and all of the responses were from the group of more than 25 years of experiences in construction projects. In works of (Monko & Roider, 2014) this was not mentioned as an important advantage of BIM usage and (Monteiro & Martins, 2013) showed that BIM tools often are unable to manage and process that data during quantity take off. So it is likely that the presence of low BIM usage is not related to the provisional sums. However this, shows likeness of the low cost information during design, which (Kinney & Soubiran, 2004) showed to be important in cost management.
On the provisional sums and prime costs, the responses were closely relating. 16 full registered strongly agreed their presence in the BOQs. 2 out of 20 respondents who also strongly agreed were assistant. Of all those 18 responses strongly agreeing on the presence of provisional sums, only 1 response were from the less than 5 years of experience status. Architects response likewise, supported the presence of the preliminaries, measured works, provisional sums and prime costs sections. On the preambles the response were on the balance between YES and NO, while many said NO to the presence of day works section. Only 1 response of Architect Technologist said NO on the prime costs compare to all YES from the Architects on the provisional sums *(See Figure 125: Example of the response of Architects on the presence of basic sections of BOQs)*

Never the less, the interviewees supported the questionnaires. Provisional sums or provisional quantities and re-measurement were mentioned strongly as unavoidable in the construction

[160] Respondent 1: "Some specified materials are not easily found, without standards. Quantity Surveyor will depend mostly on the service experts; hence, this can cause copy and paste of the information from the service experts to Bills Of Quantities, which is why in that particular Area, most of the BOQ are coming with the Provisional Sums. It is difficult to find a Quantity Surveyor who can quantify services competitively".

(Respondent1[161], 17[162] and 11[163]). *(See Figure 126: Interviewees response on provisional sums and quantities in the BOQs).*

### 4.2. Standardized Contents level

The common items that QSs responses indicated include the serial items, description, quantities, unit, rate and the total amount of an item measured. 19 responses out of 20 strongly agreed on the use of items, description, measurement units and quantities measured as standard contents of BOQ. The remaining 1 response was an agree as well. Number of responses supported the study on the standard items of the BOQ. The first item was duration, only 1 response was NOT SURE, while 4 disagreed and other 15 strongly disagreed duration to be part of standard contents in the BOQ.These item are in line with (Monko & Roider, 2014) analysis, where participants indicated that time overruns is highly perceived to be the impact of lack of BIM. Other items include presence of costs materials, labour materials and plants costs .The response on the inclusion of items that are used to build up a rate, was almost in balance because when 8 respondents disagree strongly, 7 respondents agree strongly and when 9 disagree strongly, then 6 agree strongly. Likewise for the inclusion of the references of the suppliers, the battle is 5 to 3 for strongly disagree and strongly agree respectively.

The response on the items included as standard items in BOQ was supportive of the study. When viewed from the status of registration, 15 full registered QS disagreed strongly on the presence of duration as standard item in the BOQ, 4 of them being from the experience of more than 25 years category and none of the foreign firm. With regard to the inclusion of the items that are being used in the buildup of the rate, the experienced QS firms' responses indicated a relative balanced agreement and disagreement levels between 5-15 years and 15-25 years of experience

Architects responses indicated relative support of the QS respondents. YES responses were high on the items, description, quantities, unit and rate items, the lower number being 11 YES responses on the quantities, while NO responses were high on the presence of the duration and Rate build up contents *(See Figure* 132:Architects Responses on the Durations and Rate contents in the standard BOQ*)*.On contrary to Architects and QSs, the response from the interviewees on the duration, items used in the rate build up and were high on NOT SURE *(See Figure 133:The interviewees on the presence*

[161] Respondent 1: "Variations in our projects is almost a standard, every project must have significant variations. If we could even manage to attain the increase of costs due to variation not to exceed 10%, it would be a success project. Of course, we cannot avoid but 4% would be reasonable". (Refer also previous foot note number 47 )

[162] Respondent 17: "Principally, we QS there are things you cannot measure. Planking and Strutting. Another thing, I know we QS normally do not quantify, is Services Works. You cannot quantify correctly something you do not know how it is being constructed. In addition, we cannot do that, otherwise we have to be electrical engineers and all other profession".

[163] Respondent 11: "Designers have no time, to produce enough details, because they do not know how much they will get. This gives inadequate information give the QS trouble and as a result he put provisional sums to cover the likely items"

*of Duration in the standard items of BOQ).* However, some respondents (20[164], 17[165], 9[166]and 5[167]) explicitly insisted on the need to have more standardized items like duration and material costs.

### 4.3. Detailed Standardized contents Level

Responses from the quantity surveying firms indicated strongly disagreement on the presence of the query sheets used in the take-off activities in the construction projects. 17 respondents out of 20 replied so, and all of them were from the experience of more than 5 years in the industry. Respondents indicates that they are not sure on the presence of the use of international standards of measurements in the construction projects. 8 response of *Not Sure* against 7 responses of the *Strongly Agree* of QS were collected. Again 11 responses from local firms and 2 responses from foreign firms strongly disagreed the likely presence of the critical activities duration in the Bills of Quantities used in the construction projects. That is 13 responses out of 20 respondents, but yet there was 1 local firm respondent that strongly agreed on this while another 1 respondent only agreed, compared to the 3 who disagreed and 2 who were not sure *( See Figure 136: Example 1 of the QS responses on the detailed standardized items in the BOQ.).*

Furthermore, QS responses indicated presence of the provisional sums, provisional quantities and the use of local standards in the construction projects. 9 respondents agreed strongly on the use of standard descriptions like Ditto. 13 respondents strongly agreed on the use of local standards while 4 responses disagreed.15 full registered QS strongly agreed on the presence of the provisional quantities to be re-measured, 1 assistant strongly agreed too and 2 full registered disagreed strongly. *(See Figure 137:Example 2 of the QS responses on the detailed standardized items in the BOQ).*Architects responses supported the QS responses on all the provisional items and duration of activities. However, 1 full registered Architect and 1 assistant Architect technologist responded NO on the presence of provisional quantities to be re-measured *(see Figure 138: Responses from Architects on the detailed standardized items on BOQ).*

From the interviewees, the *Not Sure* response dominated.3 respondents agree strongly on the presence of the ISO usage in the construction projects while 9 respondents out of 21 were not sure. 3 response

[164] Respondent 20: “Even the issue of TIME, we normally generalise. I am very impressed with the Idea of TIME to be included in the BOQ. So I think contractors might also enter in the BIM system”

[165] Respondent 17: “We have items like curing, water and the like. Although they have costs implications. Scaffolds have a lot of money. In our profession, we normally assume. Because a good quantity surveyor must be architect, engineer, plumber, electrical, etc.

[166] Respondent 9: “This contractor is foreign; we were required to give the breakdown of RATEs, in order to help during problems of claiming. In local projects, they do not have time, it is only the RATE, no need of breakdown of labour, material, plant and the like”

[167] Respondent 5: “In the bills of quantities, there is nothing like duration of activities, may be the critical path activities which are in the programme”.

agree on the duration of activities and 10 were not sure. These responses were equally supported by the interviews. Respondents indicated that information in the Bills of Quantities is usually not adequate. A respondent 11[168]mentioned one of the reason to be inadequate information from the designers to the quantity surveyors. The use of query sheet was answered *Not Sure* in most of the responses *(See Figure 140: Responses on the presence of attached query sheets during BOQ preparation).*Respondent 13[169] equally indicated that incomplete information for the preparation of BOQ is common in the construction projects. Some respondents point out directly that BIM could have helped to reveal some of the items that has not been included in the BOQ, which could as well reduce additions and omissions (Respondent 18[170]).

Quantity Surveying firms' response on facilitation from designers to the preparations of BOQ were not direct as it was expected. Agree, disagree and not sure responses were significant. For instance, in whether designers provide digital drawings with automatic quantities, 6 QS out of 20 said strongly disagree, 5 agree, 2 not sure and 7 disagree. Out of these, all 2 foreign firms responded strongly agree, while the other 4 were local firms. The professional status of the respondents who said strongly agree were all 6 full registered QS, 3 from the group of 5 to 15 years of experience and 3 from the over 25 years of experience

The questions also asked on the whether designers provide detailed schedule, instructions, images and the like, that can facilitate the preparation of BOQ. Responses equally were in balance relative to supporting and not supporting the study. Architects responses on the facilitation from the designers with regard to the preparation of BOQ indicated the same trend. Some say YES and some say NO to both direction. For instance, on whether *Designers provide Automatic Detailed Schedules of Building Components,* there were 6 NO and 7 YES. Both from local firms, but with 1 NO response being from the Architect Technologist. All other No and YES were from Architects, registered in full with experience of more than 5 years *(See the Figure 143:Examples from the Architects on the Facilitation in the BOQ preparation).* Other items included schedules for components and detailed digital drawings. In essence the result indicate that mostly QS do not use or rely on the common BIM or CAD related software used by designers in BOQ production, which is also supported in the work of (Matipa, 2008),as it

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[168] Respondent 11: ".Designers have no time, to produce enough details, because they do not know how much they will get. This results into giving inadequate information to the QS,which brings trouble them. As a result QS put provisional sums to cover the likely items"

[169] Respondent 13: "It is very difficult to get complete information. We, QSs are last in the chain of design. As a result, we do not have time. It is very common, to have the INCOMPLETE information from designers, not necessarily that they cannot produce it, but they do not have time"

[170] Respondent 18: "If you think of the future project, BIM is very important to it. Design issues, have been the biggest problem, so many items ware forgotten. The information required in this project was never fully understood until the implementation started. This lead to more additional quantities and additional costs"

was also claimed that Quantity Surveying has been slow to embrace the 3-D capabilities of various software packages in AEC.

Quantity Surveyors questionnaires, asked about the help of computer on the preparation of BOQ information. Respondents indicated to agree that computer may help to reduce under and over measurement of quantities but not sure about the elimination of provisional quantities and provisional sums. Yet many of the respondents were not sure whether the use of computer can facilitate the estimation and inclusion of the activities duration in the BOQ. With regard to detailed standardized items included in the BOQ, responses from the questionnaire were not straight forward as it was from the interview.

**Illustration Box 14: Respondent 7-Explaining on standardised BOQ Completeness**

*In standard description, like DITTO and the like, in Public Building, we DO NOT use these, at least in the projects I was involved. The Architects tries their best to mention everything, if possible the supplier of the material and the address. Because we want to reduce changes.*

*In the Bills of Quantities, we do not put the duration of activities. Provisional Sums are normally there because; there are so many special requirement that sometimes, when we are preparing the BOQ they are not yet known. With only use local standards, we never attach anything relative to what we assumed during the take-off process.*

*With regard to cost of labour and materials or plants, we normally include in the RATE. Usually designers do provide some components that are helpful in taking off, but not very much. Because we do not have technology that can help to have digital linkage and automation. Computer helps to obtain information necessary in the BOQ. It helps through internet.*

## 4.4. 5DBIM BOQ contents Level

Quantity Surveying Respondents with experience of more than 25 years status indicated that the breakdown of the Rate is not reflected on the BOQ. These are 4 respondents out of 9 who strongly disagreed, other 4 were of 5-15 years of experience and 1 was of 15-25 years of experience. Yet 8 QS disagreed and 3 were not sure *(see Figure 145: QS responses on the presence of the Detailed Standardized Contents of BOQ)*. Likewise, QS responses indicated that BOQ include lesser life cycle related contents like replacement costs and maintenance costs. Preliminaries costs breakdown into time or progress based were almost equally responded with 4 strongly agree and 4 strongly disagree. Shocking responses were 1 Local firm QS and 1 foreign that indicated strongly agree on the presence of the international standard organization (ISO). However, 5 local firms QS and 1 foreign firm QS disagreed strongly. Others were the 6 responses who disagreed, 3 who were not sure and 3 who agreed. As such the response was not so indicative of the trend. Of more support to the study, were the 13 strongly disagree response on the presence of the maintenance costs in the BOQ. All the 13 were fully registered QS. The others, were 4 full registered QS who disagreed and 1 who was not sure, while the assistant registered QS were 1 who was not sure and 1 who disagreed *(See Figure 148:Example 1-QS responses on the components of life cycle costing on the BOQ).*

11 QS out of 20 disagreed strongly on the presence of the alternative suppliers in the BOQ. However 1 QS strongly agreed, 4 agreed, 1 was not sure and 3 disagreed. The responses were similar to that of the presence of the warranty of the materials in the BOQ,where 8 disagreed strongly,3 agreed,4 were not sure and 5 disagreed. All are not very direct on the trend of the responses. The more direct response was that of the presence of the future replacement costs, where 13 responses indicated to strongly agree, 5 to disagree, 1 not sure and 1 to agree. Presence of the References to local standards in the BOQ, QS responses were 13 strongly agree against 4 disagree and 3 agree. While only 1 respondent agreed strongly on the International standards. The 1 strongly agreeing on the international standards was of local firms' status.8 other responses from the local firms' status QS were not sure. Again, while 2 of responses from the over 25 years of experience were not, 3 responses disagreed strongly. Interesting responses were on the presence of the attachments of querry sheets and assumptions used in take-off in the BOQ. No one agree and many indicated that they are disagreeing and strongly disagreeing. *(See Figure 152: QS Responses on the querry sheets and take-off assumptions in BOQ)*. With regard to the use of computer, 6 QS responded strongly disagree. 6 responses agreed that computer helps in including maintenance costs in the BOQ. 5 QS were not sure and 3 disagreed. Surprisingly, 5 respondents disagreed strongly that computer use helps in including maintenance costs in *building works* BOQ, while 6 were not sure, 7 agreed and 2 disagreed. In civil works, on the other hand, the responses indicated 1 strongly disagree, 4 agree, 12 not sure and 3

disagree. As such it is not directly observable from the questionnaires whether the trend is to support the study or not

On the use of computer in the preparation of Bills of Quantities, responses indicated unawareness of the effects. A *Not Sure* responses dominated on the undermesurement elimination, over measurement elimination, breakdown of rates, Preliminaries costing, duration calculations, life cycle related items inclusion and even provisional sums eliminations. Few respondents agreed strongly on both, civil and building works. For instance on the use of computer on the elimination of provisional sums, 2 full registered QS Strongly agreed on the building works.

From the QS response, respondents were not sure on civil works BOQ, on whether computer helps in rate wastage costing, inclusion of the life cycle related items, warranty or even preliminaries breakdown costing. Experienced professional were not sure as well. For instance out of all five responses from professionals with more than 25 years, only 1 agreed on the computer helping in inclusion of maintenance and wastage costs components. Architects responses indicated to support the QS on the likely absence of the life cycle related items and detailed breakdown of rates in the BQO. For instance all 13 Architects said no to the presence of future replacement costs of the building components in the BOQ.Architects responses on whether computer could facilitate the presence of various information in the BOQ gave modes of 2 and 3 out of all the 12 categories. 2 is agree and 3 is not sure. Again from the response on the likely presence of various information in the BOQ as a result of the use BIM in construction projects, were 2 and 3 out of all 16 questions responded. However, while in using computer, strongly disagree response were high, in using BIM, no *strongly agree* responses were found.

From the Interviewees, the Architects and QS responses were strengthened. With the exceptional of responses on the lack of maintenance costs in the BOQ, all responses found to be within mode number 3 that is a response of *Not Sure*. The interviewees indicated to support the study, by agree strongly that there is likely lack of maintenance costs items in the BOQ. On top, interviewees indicated doubts on where BIM is more viable, in building works or civil works. The interviewee responses indicated that the respondents *Not Sure* as also seen in QS and Architects responses is of much concern because tangible evidence intended during interviews were not mentioned by the respondents. However the opinions show that it is less likely that these information are produced in the BOQ preparation either manually or using the existing technology. Respondents (21[171], 19[172] and 11[173]) give examples of the responses. It was declared to the interviewer that, there is no life cycle cost thinking and the standard method of measurement used does not include LCC. Respondent 15[174] explained that the use of standards depends on the clients and computer simulation is usually graphical only. It does not reflect realistic time or cost simulation. Respondent 8 claimed that maintenance is the problem of Africa, not only Tanzania, as shown in the below following illustration.

**Illustration Box 15: Respondent 8 explained the perception of BIM usage**

*BIM is Wonderful in project. For structure BIM can work. African countries have problem with Maintenance.  I have been to Botswana and South Africa. Only when project is over. Structural issues like electrical earthing, those sitting under roads and many challenges like crashes of utilities, gullies on the wrong place in XXX, which is the main station could have been sorted out quickly by BIM. The positioning of the retaining wall. This lead to more additional quantities and additional costs.*

171 Respondent 21: “If your background is building economics, you should know that we are still using the same Standard Method of Measurement (SMM) of 1977. That means No such thing like duration or life cycle costing. We do not have life cycle costing thinking at all. Our mentality is only on the Bills Of Quantities”

172 Respondent 19: “Life cycle costing is not included in BOQ. We normally do consider in our calculation but not writing in the BOQ. Maintenance. When the budget has been exceeded, architect may try to explain why we chose materials with long life span. The answer usually, maintenance is not you part (not part of design team”

173 Respondent 11: “Designers have no time, to produce enough details, because they do not know how much they will get. This gives inadequate information that give the QS trouble and as a result he put provisional sums to cover the likely items”

174 Respondent 15: “Normally it depends on the sponsor; say African Development Bank or World Bank. Such organisation usually use FIDIC. However, in usually Tanzania Projects, we normally use PPRA.The simulation I have witnessed, usually consists of few graphics items but not REALISTIC, and does not involve TIME and COST on the model. That one I HAVE NEVER SEEN. Here we normally take care of the requirement, But we do not have the model like that you have demonstrated”.

| | In Public Contract; BOQ Sections Include Provisional Sums | | | Total |
|---|---|---|---|---|
| | Not Sure | Agree | Strongly Agree | |
| The Area of Profession Quantity Surveying/ Building Economics | 1 | 1 | 18 | 20 |
| Total | 1 | 1 | 18 | 20 |

| | In Public Contract; BOQ Sections Include Prime Costs | | | Total |
|---|---|---|---|---|
| | Not Sure | Agree | S/ Agree | |
| The Area of Profession Quantity Surveying/ Building Economics | 1 | 1 | 18 | 20 |
| Total | 1 | 1 | 18 | 20 |

| | In Public Contract; BOQ Sections Include Preambles | | | Total |
|---|---|---|---|---|
| | Not Sure | Agree | S/ Agree | |
| The Area of Profession Quantity Surveying/ Building Economics | 2 | 4 | 14 | 20 |
| Total | 2 | 4 | 14 | 20 |

| | In Public Contract; BOQ Sections Include Day Works | | | | Total |
|---|---|---|---|---|---|
| | S/ Disagree | Disagree | Not Sure | S/Agree | |
| The Area of Profession Quantity Surveying/ Building Economics | 10 | 5 | 2 | 3 | 20 |
| Total | 10 | 5 | 2 | 3 | 20 |

**Figure 122: QS response on Prime costs, Provisional sums, Preambles and Day works Section**

| | | In Public Contract; BOQ Sections Include Day Works | | | | Total |
|---|---|---|---|---|---|---|
| | | Strongly Disagree | Disagree | Not Sure | S/ Agree | |
| Professional Status of Respondent | Full Registered | 9 | 4 | 2 | 3 | 18 |
| | Assistant Registered | 1 | 1 | 0 | 0 | 2 |
| Total | | 10 | 5 | 2 | 3 | 20 |

| | | In Public Contract; BOQ Sections Include Day Works | | | | Total |
|---|---|---|---|---|---|---|
| | | S/ Disagree | Disagree | Not Sure | Strongly Agree | |
| Firm Registration Status | Local Firm | 9 | 5 | 2 | 2 | 18 |
| | Foreign Firm | 1 | 0 | 0 | 1 | 2 |
| Total | | 10 | 5 | 2 | 3 | 20 |

| | | In Public Contract; BOQ Sections Include Day Works | | | | Total |
|---|---|---|---|---|---|---|
| | | S/Disagree | Disagree | Not Sure | S/ Agree | |
| Experience in Construction Projects | Less than 5 Years | 1 | 0 | 0 | 0 | 1 |
| | Between 5 to 15 Years | 5 | 4 | 1 | 0 | 10 |
| | Between 15 to 25 Years | 3 | 1 | 0 | 0 | 4 |
| | More than 25 Years | 1 | 0 | 1 | 3 | 5 |
| Total | | 10 | 5 | 2 | 3 | 20 |

**Figure 123: QS firms response on the presence of Day-works sections on the BOQs**


**Figure 124: Example of QS response on Provisional Sums and Prime Costs Section**

| | | In Public Contract; BOQ Sections Include Preliminaries, Provisional Sums &Measured Works (Same Response) | Total |
|---|---|---|---|
| | | Yes | |
| The Area of Profession | Architecture | 12 | 12 |
| | Arch/Technology. | 1 | 1 |
| Total | | 13 | 13 |

| | | In Public Contract; BOQ Sections Include Preambles | | Total |
|---|---|---|---|---|
| | | Yes | No | |
| The Area of Profession | Architecture | 9 | 3 | 12 |
| | Arch/Technology. | 0 | 1 | 1 |
| Total | | 9 | 4 | 13 |

| | | In Public Contract; BOQ Sections Include Day Works | | Total |
|---|---|---|---|---|
| | | Yes | No | |
| The Area of Profession | Architecture | 3 | 9 | 12 |
| | Arch/Technology. | 0 | 1 | 1 |
| Total | | 3 | 10 | 13 |

**Figure 125: Example of the response of Architects on the presence of basic sections of BOQs**

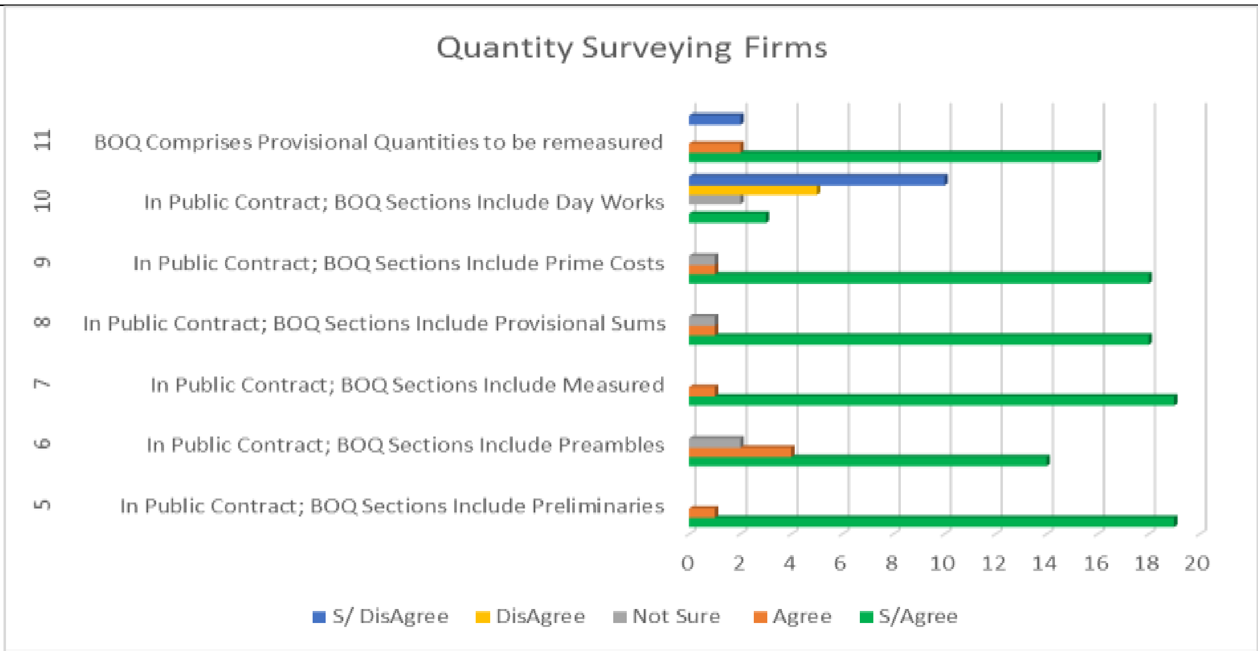
| | | On Bills Of Quantities Information Completeness, Presence of Provisional Sums of Special Works | | | Total |
|---|---|---|---|---|---|
| | | Not Sure | Agree | S/ Agree | |
| Respondent Background | Architecture | 0 | 2 | 5 | 7 |
| | Quantity Surveying | 1 | 5 | 4 | 10 |
| | Group with at least a QS,Architect or Structural Engineer | 0 | 0 | 2 | 2 |
| | Other Profession | 0 | 1 | 1 | 2 |
| Total | | 1 | 8 | 12 | 21 |

| | | On Bills Of Quantities Information Completeness, Presence of provisional Quantities, to be Re-Measured | | | Total |
|---|---|---|---|---|---|
| | | Not Sure | Agree | Strongly Agree | |
| Respondent Background | Architecture | 0 | 2 | 5 | 7 |
| | Quantity Surveying | 1 | 1 | 8 | 10 |
| | Group with at least a QS,Architect or Structural Engineer | 0 | 0 | 2 | 2 |
| | Other Profession | 0 | 1 | 1 | 2 |
| Total | | 1 | 4 | 16 | 21 |

**Figure 126: Interviewees response on provisional sums and quantities in the BOQs**

| | | Yes | No | Total |
|---|---|---|---|---|
| 11 | In Public Contract; BOQ Sections Include Preliminaries | 13 | | 13 |
| 12 | In Public Contract; BOQ Sections Include Preambles | 9 | 4 | 13 |
| 13 | In Public Contract; BOQ Sections Include Measured | 13 | | 13 |
| 14 | In Public Contract; BOQ Sections Include Provisional Sums | 13 | | 13 |
| 15 | In Public Contract; BOQ Sections Include Prime Costs | 12 | 1 | 13 |
| 16 | In Public Contract; BOQ Sections Include Day Works | 3 | 10 | 13 |
| 17 | In Construction Projects,BOQ Comprises Provisional Quantities, to be re-measured | 11 | 2 | 13 |

**Figure 127: Architects responses on the Items used to measure the Basic Contents of BOQ**



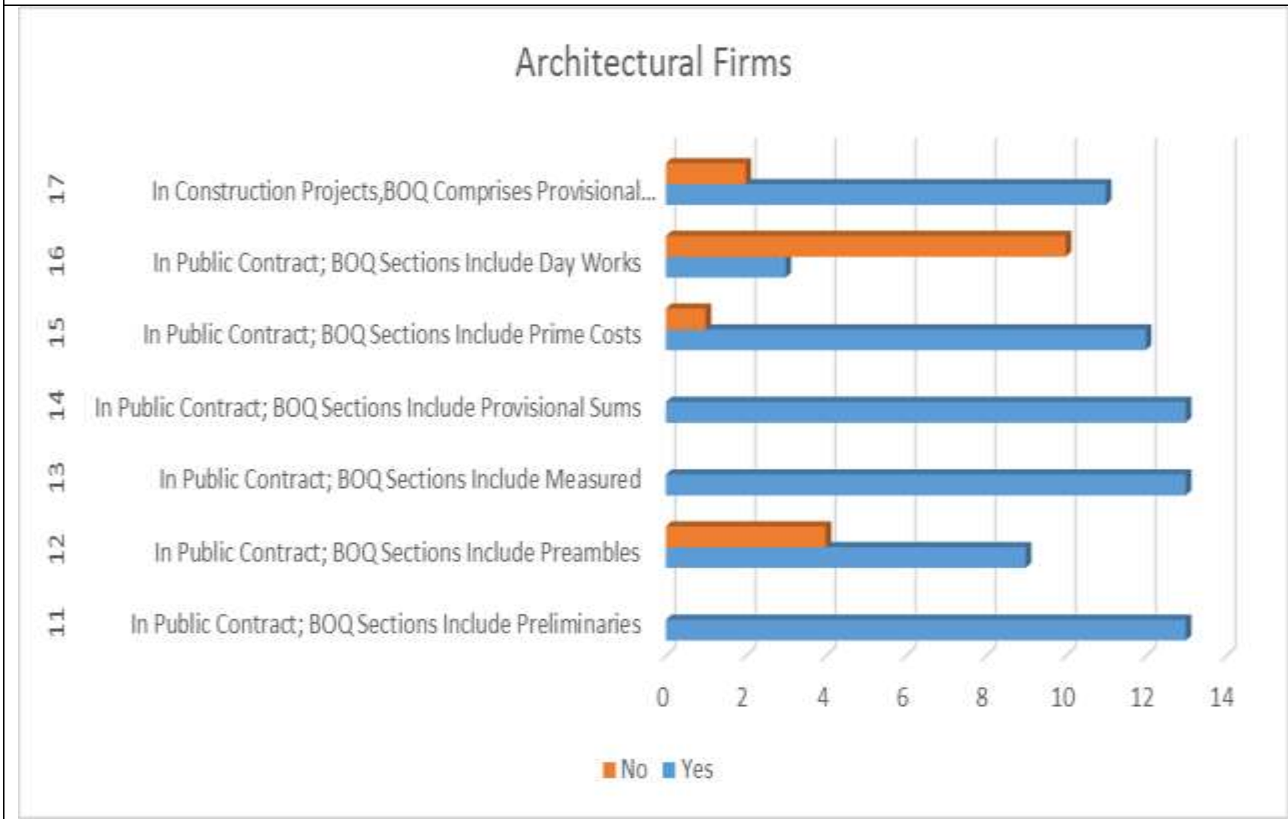




**Figure 128: Pictorial Responses on the Items used to measure the Basic Contents of BOQ**

| | BOQ, Standard information include Serial Number of Items.descritpiton,unit and Quantities | | Total |
|---|---|---|---|
| | Agree | Strongly Agree | |
| The Area of Profession Quantity Surveying/ Building Economics | 1 | 19 | 20 |
| Total | 1 | 19 | 20 |

| | BOQ, Standard information include Rate | | Total |
|---|---|---|---|
| | Agree | Strongly Agree | |
| The Area of Profession Quantity Surveying/ Building Economics | 5 | 15 | 20 |
| Total | 5 | 15 | 20 |

| | BOQ, Standard information include Total Amount of Items | | Total |
|---|---|---|---|
| | Agree | Strongly Agree | |
| The Area of Profession Quantity Surveying/ Building Economics | 4 | 16 | 20 |
| Total | 4 | 16 | 20 |

| | BOQ, Standard information include Total Amount of Items | | Total |
|---|---|---|---|
| | Agree | Strongly Agree | |
| The Area of Profession Quantity Surveying/ Building Economics | 4 | 16 | 20 |
| Total | 4 | 16 | 20 |

**Figure 129: Response from QS on the standard contents agreed to present on the BOQ**

| | BOQ, Standard information include Estimated Duration for each measured Activities | | | Total |
|---|---|---|---|---|
| | Not Sure | Disagree | S/ Disagree | |
| The Area of Profession Quantity Surveying/ Building Economics | 1 | 4 | 15 | 20 |
| Total | 1 | 4 | 15 | 20 |

| | BOQ , Standard information include Materials, Labour and Plant Costs included in the RATE | | | | | Total |
|---|---|---|---|---|---|---|
| | S/ Agree | Agree | Not Sure | Disagree | S/ Disagree | |
| The Area of Profession Quantity Surveying/ Building Economics | 7 | 1 | 2 | 2 | 8 | 20 |
| Total | 7 | 1 | 2 | 2 | 8 | 20 |

| | BOQ , Standard information include Waste, Subcontractor or Taxes Costs estimate included in the RATE | | | | Total |
|---|---|---|---|---|---|
| | S/ Agree | Not Sure | Disagree | S/Disagree | |
| The Area of Profession Quantity Surveying/ Building Economics | 6 | 2 | 3 | 9 | 20 |
| Total | 6 | 2 | 3 | 9 | 20 |

| | BOQ , Standard information include Suppliers or Manufacturers Description references | | | | | Total |
|---|---|---|---|---|---|---|
| | S/ Agree | Agree | Not Sure | Disagree | S/ Disagree | |
| The Area of Profession Quantity Surveying/ Building Economics | 3 | 9 | 1 | 2 | 5 | 20 |
| Total | 3 | 9 | 1 | 2 | 5 | 20 |

**Figure 130: QS responses on the presence of Duration as standard item in the BOQ**

| | | BOQ , Standard information include Materials, Labour and Plant Costs included in the RATE | | | | | Total |
|---|---|---|---|---|---|---|---|
| | | S/ Agree | Agree | Not Sure | Disagree | S/ Disagree | |
| Experience in Construction Projects | Less than 5 Years | 1 | 0 | 0 | 0 | 0 | 1 |
| | Between 5 to 15 Years | 4 | 1 | 0 | 1 | 4 | 10 |
| | Between 15 to 25 Years | 1 | 0 | 0 | 1 | 2 | 4 |
| | More than 25 Years | 1 | 0 | 2 | 0 | 2 | 5 |
| Total | | 7 | 1 | 2 | 2 | 8 | 20 |

| | | BOQ , Standard information include Waste, Subcontractor or Taxes Costs estimate included in the RATE | | | | Total |
|---|---|---|---|---|---|---|
| | | S/ Agree | Not Sure | Disagree | S/Disagree | |
| Experience in Construction Projects | Less than 5 Years | 0 | 0 | 1 | 0 | 1 |
| | Between 5 to 15 Years | 3 | 1 | 1 | 5 | 10 |
| | Between 15 to 25 Years | 1 | 0 | 1 | 2 | 4 |
| | More than 25 Years | 2 | 1 | 0 | 2 | 5 |
| Total | | 6 | 2 | 3 | 9 | 20 |

| | | BOQ , Standard information include Suppliers or Manufacturers Description references | | | | | Total |
|---|---|---|---|---|---|---|---|
| | | S/Agree | Agree | Not Sure | Disagree | S/ Disagree | |
| Experience in Construction Projects | Less than 5 Years | 0 | 0 | 0 | 1 | 0 | 1 |
| | Between 5 to 15 Years | 2 | 6 | 0 | 0 | 2 | 10 |
| | Between 15 to 25 Years | 1 | 2 | 0 | 0 | 1 | 4 |
| | More than 25 Years | 0 | 1 | 1 | 1 | 2 | 5 |
| Total | | 3 | 9 | 1 | 2 | 5 | 20 |

**Figure 131: Responses from QS on the standard contents used in the build-up of the Rate**

| | | BOQ, Standard information include Estimated Duration for each measured Activities | | Total |
|---|---|---|---|---|
| | | Yes | No | |
| The Area of Profession | Architecture | 1 | 11 | 12 |
| | Architectural Technology. | 0 | 1 | 1 |
| Total | | 1 | 12 | 13 |

| | | BOQ , Standard information include Materials, Labour and Plant Costs included in the RATE | | Total |
|---|---|---|---|---|
| | | Yes | No | |
| The Area of Profession | Architecture | 1 | 11 | 12 |
| | Architectural Technology. | 0 | 1 | 1 |
| Total | | 1 | 12 | 13 |

| | | BOQ , Standard information include Waste, Subcontractor or Taxes Costs included in the RATE | | Total |
|---|---|---|---|---|
| | | Yes | No | |
| The Area of Profession | Architecture | 1 | 11 | 12 |
| | Architectural Technology. | 1 | 0 | 1 |
| Total | | 2 | 11 | 13 |

| | | BOQ , Standard information include Suppliers or Manufacturers references | | Total |
|---|---|---|---|---|
| | | Yes | No | |
| The Area of Profession | Architecture | 3 | 9 | 12 |
| | Architectural Technology. | 0 | 1 | 1 |
| Total | | 3 | 10 | 13 |

**Figure 132:Architects Responses on the Durations and Rate contents in the standard BOQ**

| | | On BOQ Information Completeness, Lack Of Estimated Duration of Activities Measured | | | Total |
|---|---|---|---|---|---|
| | | Not Sure | Agree | S/Agree | |
| Respondent Background | Architecture | 3 | 3 | 1 | 7 |
| | Quantity Surveying | 3 | 5 | 2 | 10 |
| | Group ( QS,Architect or S/ Engineer) | 2 | 0 | 0 | 2 |
| | Other Profession | 2 | 0 | 0 | 2 |
| Total | | 10 | 8 | 3 | 21 |

| | | On Bills Of Quantities Information Completeness, Lack Of Breakdown of Items Used in RATE like Waste, Taxes and Plant. | | | Total |
|---|---|---|---|---|---|
| | | Not Sure | Agree | Strongly Agree | |
| Respondent Background | Architecture | 7 | 0 | 0 | 7 |
| | Quantity Surveying | 3 | 6 | 1 | 10 |
| | Group ( QS,Architect or S/ Engineer) | 2 | 0 | 0 | 2 |
| | Other Profession | 2 | 0 | 0 | 2 |
| Total | | 14 | 6 | 1 | 21 |

**Figure 133:The interviewees on the presence of Duration in the standard items of BOQ**

| | | S/Agree | Agree | Not Sure | DisAgree | S/ DisAgree | Total |
|---|---|---|---|---|---|---|---|
| 12 | BOQ Comprises Standard Descriptions like Ditto | 9 | 6 | 2 | 1 | 2 | 20 |
| 14 | BOQ Comprises Provisional Sums Costs for Special works | 12 | 5 | 2 | | 1 | 20 |
| 16 | BOQ Comprises Local Standard Measurement Reference | 13 | 3 | | 4 | | 20 |
| 19 | BOQ, Standard information include Serial Number of Items | 19 | 1 | | | | 20 |
| 20 | BOQ, Standard information include Descriptions items | 19 | 1 | | | | 20 |
| 21 | BOQ, Standard information include Quantity measured | 19 | 1 | | | | 20 |
| 22 | BOQ, Standard information include Estimated Duration for each measured Activities | | | 1 | 4 | 15 | 20 |
| 23 | BOQ, Standard information include Measurement Units | 19 | 1 | | | | 20 |
| 24 | BOQ, Standard information include Rate | 15 | 5 | | | | 20 |
| 25 | BOQ, Standard information include Total Amount of Items | 16 | 4 | | | | 20 |
| 26 | BOQ , Standard information include Materials, Labour and Plant Costs included in the RATE | 7 | 1 | 2 | 2 | 8 | 20 |
| 28 | BOQ , Standard information include Suppliers or Manufacturers Description references | 3 | 9 | 1 | 2 | 5 | 20 |

**Figure 134: QS responses on the presence of the Standardized Contents of BOQ**

| | | Yes | No | Total |
|---|---|---|---|---|
| 19 | In Construction Projects,BOQ, Comprises Provisional Sums Costs for Special works | 13 | | 13 |
| 21 | BOQ, Standard information include Serial Number of Items | 13 | | 13 |
| 22 | BOQ, Standard information include Descriptions items | 13 | | 13 |
| 23 | BOQ, Standard information include Quantity measured | 12 | 1 | 13 |
| 24 | BOQ, Standard information include Estimated Duration for each measured Activities | 1 | 12 | 13 |
| 25 | BOQ, Standard information include Measurement Units | 13 | | 13 |
| 26 | BOQ, Standard information include Rate | 13 | | 13 |
| 27 | BOQ, Standard information include Total Amount of Items | 13 | | 13 |
| 28 | BOQ , Standard information include Materials, Labour and Plant Costs included in the RATE | 1 | 12 | 13 |
| 30 | BOQ , Standard information include Suppliers or Manufacturers references | 3 | 10 | 13 |

**Figure 135: Architects responses on the presence of the Standardized Contents of BOQ**

| | | BOQ Comprises Duration of Critical Elements | | | | | Total |
|---|---|---|---|---|---|---|---|
| | | S/ Agree | Agree | Not Sure | Disagree | S/ Disagree | |
| The Area of Profession | Quantity Surveying/ Building Economics | 1 | 1 | 2 | 3 | 13 | 20 |
| Total | | 1 | 1 | 2 | 3 | 13 | 20 |

| | | BOQ Comprises International Standard Measurement Reference | | | | | Total |
|---|---|---|---|---|---|---|---|
| | | S/ Agree | Agree | Not Sure | Disagree | S/ Disagree | |
| The Area of Profession | Quantity Surveying/ Building Economics | 1 | 1 | 8 | 3 | 7 | 20 |
| Total | | 1 | 1 | 8 | 3 | 7 | 20 |

| | | BOQ Comprises Query Sheet used in Take-Off | | Total |
|---|---|---|---|---|
| | | Disagree | S/Disagree | |
| The Area of Profession | Quantity Surveying/ Building Economics | 3 | 17 | 20 |
| Total | | 3 | 17 | 20 |

**Figure 136: Example 1 of the QS responses on the detailed standardized items in the BOQ.**

| | | BOQ Comprises Local Standard Measurement Reference | | | Total |
|---|---|---|---|---|---|
| | | Disagree | Agree | Strongly Agree | |
| Firm Registration Status | Local Firm | 4 | 3 | 11 | 18 |
| | Foreign Firm | 0 | 0 | 2 | 2 |
| Total | | 4 | 3 | 13 | 20 |

| | | BOQ Comprises Standard Descriptions like Ditto | | | | | Total |
|---|---|---|---|---|---|---|---|
| | | S/Disagree | Disagree | Not Sure | Agree | S/ Agree | |
| The Area of Profession | Quantity Surveying/ Building Economics | 2 | 1 | 2 | 6 | 9 | 20 |
| Total | | 2 | 1 | 2 | 6 | 9 | 20 |

| | | BOQ Comprises Provisional Quantities to be remeasured | | | Total |
|---|---|---|---|---|---|
| | | S/Disagree | Agree | S/Agree | |
| Professional Status of Respondent | Full Registered | 2 | 1 | 15 | 18 |
| | Assistant Registered | 0 | 1 | 1 | 2 |
| Total | | 2 | 2 | 16 | 20 |

| | | BOQ Comprises Provisional Quantities to be remeasured | | | Total |
|---|---|---|---|---|---|
| | | Strongly Disagree | Agree | S/ Agree | |
| Experience in Construction Projects | Less than 5 Years | 0 | 1 | 0 | 1 |
| | Between 5 to 15 Years | 1 | 0 | 9 | 10 |
| | Between 15 to 25 Years | 0 | 1 | 3 | 4 |
| | More than 25 Years | 1 | 0 | 4 | 5 |
| Total | | 2 | 2 | 16 | 20 |

**Figure 137:Example 2 of the QS responses on the detailed standardized items in the BOQ**

| | | In Construction Projects, BOQ Comprises Provisional Quantities, to be re-measured | | Total |
|---|---|---|---|---|
| | | Yes | No | |
| The Area of Profession | Architecture | 11 | 1 | 12 |
| | Architectural Technology. | 0 | 1 | 1 |
| Total | | 11 | 2 | 13 |

| | | In Construction Projects, BOQ, Comprises Calculations Breakdown used in Quantities Take-Off. | Total |
|---|---|---|---|
| | | No | |
| The Area of Profession | Architecture | 12 | 12 |
| | Architectural Technology. | 1 | 1 |
| Total | | 13 | 13 |

| | | In Construction Projects,BOQ Comprises Duration Estimate of the Critical Elements | Total |
|---|---|---|---|
| | | No | |
| Experience in Construction Projects | Between 5 to 15 Years | 10 | 10 |
| | Between 15 to 25 Years | 2 | 2 |
| | More than 25 Years | 1 | 1 |
| Total | | 13 | 13 |

| | | In Construction Projects,BOQ, Comprises Provisional Sums Costs for Special works | Total |
|---|---|---|---|
| | | Yes | |
| Firm Registration Status | Local Firm | 13 | 13 |
| Total | | 13 | 13 |

**Figure 138: Responses from Architects on the detailed standardized items on BOQ**

| | | On Bills Of Quantities Information Completeness, Lack Of International Organization Standards (ISO) References | | | | Total |
|---|---|---|---|---|---|---|
| | | Disagree | Not Sure | Agree | S/ Agree | |
| Experience of the Firm in Construction Project | Between 5-15 Years | 1 | 4 | 2 | 1 | 8 |
| | Between 15 -25 | 0 | 1 | 2 | 1 | 4 |
| | Above 25 years | 0 | 4 | 4 | 1 | 9 |
| Total | | 1 | 9 | 8 | 3 | 21 |

| | | On Bills Of Quantities Information Completeness, Lack Of Estimated Duration of Activities Measured | | | Total |
|---|---|---|---|---|---|
| | | Not Sure | Agree | S/ Agree | |
| Respondent Background | Architecture | 3 | 3 | 1 | 7 |
| | Quantity Surveying | 3 | 5 | 2 | 10 |
| | Group with at least a QS,Architect or Structural Engineer | 2 | 0 | 0 | 2 |
| | Other Profession | 2 | 0 | 0 | 2 |
| Total | | 10 | 8 | 3 | 21 |

| | | On Bills Of Quantities Information Completeness, Presence of Standard General description like as per instructions | | | | Total |
|---|---|---|---|---|---|---|
| | | S/ Disagree | Not Sure | Agree | S/ Agree | |
| Nature of Organization | Consultancy | 1 | 8 | 6 | 0 | 15 |
| | Main Contractor | 0 | 0 | 1 | 0 | 1 |
| | Construction Subcontractor | 0 | 0 | 0 | 1 | 1 |
| | Public Agency In Construction Activities | 0 | 0 | 1 | 1 | 2 |
| | Public Client | 0 | 1 | 1 | 0 | 2 |
| Total | | 1 | 9 | 9 | 2 | 21 |

**Figure 139: Structured interviewees response o detailed standardized items present on BOQ**

| | | On Bills Of Quantities Information Completeness, Lack of attached Queries Raised during Taking-Off | | Total |
|---|---|---|---|---|
| | | Not Sure | Agree | |
| Nature of Organization | Consultancy | 11 | 4 | 15 |
| | Main Contractor | 0 | 1 | 1 |
| | Construction Subcontractor | 0 | 1 | 1 |
| | Public Agency In Construction activities | 1 | 1 | 2 |
| | Public Client | 1 | 1 | 2 |
| Total | | 13 | 8 | 21 |

**Figure 140: Responses on the presence of attached query sheets during BOQ preparation**

| | | Designers provide digital drawings with automatic quantities | | | | Total |
|---|---|---|---|---|---|---|
| | | Agree | Not Sure | Disagree | S/ Disagree | |
| The Area of Profession | Quantity Surveying/ Building Economics | 5 | 2 | 7 | 6 | 20 |
| Total | | 5 | 2 | 7 | 6 | 20 |

| | | Designers provide digital drawings with automatic quantities | | | | Total |
|---|---|---|---|---|---|---|
| | | Agree | Not Sure | Disagree | S/ Disagree | |
| Firm Registration Status | Local Firm | 5 | 2 | 7 | 4 | 18 |
| | Foreign Firm | 0 | 0 | 0 | 2 | 2 |
| Total | | 5 | 2 | 7 | 6 | 20 |

| | | Designers provide digital drawings with automatic quantities | | | | Total |
|---|---|---|---|---|---|---|
| | | Agree | Not Sure | Disagree | S/Disagree | |
| Professional Status of Respondent | Full Registered | 5 | 2 | 5 | 6 | 18 |
| | Assistant Registered | 0 | 0 | 2 | 0 | 2 |
| Total | | 5 | 2 | 7 | 6 | 20 |

| | | Designers provide digital drawings with automatic quantities | | | | Total |
|---|---|---|---|---|---|---|
| | | Agree | Not Sure | Disagree | S/ Disagree | |
| Experience in Construction Projects | Less than 5 Years | 0 | 0 | 1 | 0 | 1 |
| | Between 5 to 15 Years | 2 | 1 | 4 | 3 | 10 |
| | Between 15 to 25 Years | 2 | 0 | 2 | 0 | 4 |
| | More than 25 Years | 1 | 1 | 0 | 3 | 5 |
| Total | | 5 | 2 | 7 | 6 | 20 |

**Figure 141:Responses from QS on the facilitation of Designers on the preparation of BOQ**

| | | Designers provide Detailed Schedules of Critical Elements | | | | Total |
|---|---|---|---|---|---|---|
| | | S/ Agree | Agree | Disagree | S/ Disagree | |
| The Area of Profession | Quantity Surveying/ Building Economics | 3 | 7 | 3 | 7 | 20 |
| Total | | 3 | 7 | 3 | 7 | 20 |

| | | Designers provide Detailed Schedules of components. Example: Bolts | | | | | Total |
|---|---|---|---|---|---|---|---|
| | | S/ Agree | Agree | Not Sure | Disagree | S/Disagree | |
| Firm Registration Status | Local Firm | 3 | 7 | 1 | 2 | 5 | 18 |
| | Foreign Firm | 0 | 0 | 0 | 0 | 2 | 2 |
| Total | | 3 | 7 | 1 | 2 | 7 | 20 |

| | | Designers provide Manual Instruction through Query Sheet and Instruction Books | | | | | Total |
|---|---|---|---|---|---|---|---|
| | | S/ Disagree | Disagree | Not Sure | Agree | S/ Agree | |
| Professional Status of Respondent | Full Registered | 5 | 1 | 3 | 4 | 5 | 18 |
| | Assistant Registered | 0 | 1 | 0 | 0 | 1 | 2 |
| Total | | 5 | 2 | 3 | 4 | 6 | 20 |

| | | Designers provide realistic dimensions and Images | | | | Total |
|---|---|---|---|---|---|---|
| | | S/ Agree | Agree | Disagree | S/Disagree | |
| Experience in Construction Projects | Less than 5 Years | 1 | 0 | 0 | 0 | 1 |
| | Between 5 to 15 Years | 2 | 4 | 1 | 3 | 10 |
| | Between 15 to 25 Years | 1 | 2 | 0 | 1 | 4 |
| | More than 25 Years | 1 | 0 | 1 | 3 | 5 |
| Total | | 5 | 6 | 2 | 7 | 20 |

**Figure 142: QS on the facilitation from the designers on the BOQ preparation**

| | | Designers provide Automatic Detailed Schedules of Building Components | | Total |
|---|---|---|---|---|
| | | Yes | No | |
| The Area of Profession | Architecture | 7 | 5 | 12 |
| | Architectural Technology. | 0 | 1 | 1 |
| Total | | 7 | 6 | 13 |

| | | Designers provide Automatic Detailed Schedules in Critical Elements | | Total |
|---|---|---|---|---|
| | | Yes | No | |
| The Area of Profession | Architecture | 3 | 9 | 12 |
| | A/ Technology. | 1 | 0 | 1 |
| Total | | 4 | 9 | 13 |

| | | Designers provide digital drawings with automatic quantities | | Total |
|---|---|---|---|---|
| | | Yes | No | |
| The Area of Profession | Architecture | 3 | 9 | 12 |
| | A/ Technology. | 0 | 1 | 1 |
| Total | | 3 | 10 | 13 |

| | | Designers provide Automatic Detailed Schedules in Critical Elements | | Total |
|---|---|---|---|---|
| | | Yes | No | |
| Firm Registration Status | Local Firm | 4 | 9 | 13 |
| Total | | 4 | 9 | 13 |

**Figure 143:Examples from the Architects on the Facilitation in the BOQ preparation**

| | | Use of Computer in BOQ Preparation helps Inclusion of Estimated Duration of Activities of the project | | | | Total |
|---|---|---|---|---|---|---|
| | | Agree | Not Sure | Disagree | S/ Disagree | |
| Experience in Construction Projects | Less than 5 Years | 0 | 0 | 1 | 0 | 1 |
| | Between 5 to 15 Years | 2 | 5 | 2 | 1 | 10 |
| | Between 15 to 25 Years | 0 | 3 | 0 | 1 | 4 |
| | More than 25 Years | 3 | 0 | 1 | 1 | 5 |
| Total | | 5 | 8 | 4 | 3 | 20 |

| | | Use of Computer in BOQ Preparation helps Elimination of provisional sums | | | | | Total |
|---|---|---|---|---|---|---|---|
| | | S/ Agree | Agree | Not Sure | Disagree | S/ Disagree | |
| Professional Status of Respondent | Full Registered | 2 | 4 | 4 | 3 | 5 | 18 |
| | Assistant Registered | 0 | 0 | 1 | 1 | 0 | 2 |
| Total | | 2 | 4 | 5 | 4 | 5 | 20 |

| | | Use of Computer in BOQ Preparation helps Elimination of UNDER Measured quantities | | | | | Total |
|---|---|---|---|---|---|---|---|
| | | Strongly Agree | Agree | Not Sure | Disagree | Strongly Disagree | |
| The Area of Profession | Quantity Surveying/ Building Economics | 4 | 8 | 4 | 2 | 2 | 20 |
| Total | | 4 | 8 | 4 | 2 | 2 | 20 |

**Figure 144: Examples of QS responses on the use of Computer on the BOQ preparation**

| | | S/Agree | Agree | Not Sure | DisAgree | S/ DisAgree | Total |
|---|---|---|---|---|---|---|---|
| 13 | BOQ Comprises Duration of Critical Elements | 1 | 1 | 2 | 3 | 13 | 20 |
| 15 | BOQ Comprises International Standard Measurement Reference | 1 | 1 | 8 | 3 | 7 | 20 |
| 17 | BOQ Comprises Query Sheet used in Take-Off | | | | 3 | 17 | 20 |
| 22 | BOQ, Standard information include Estimated Duration for each measured Activities | | | 1 | 4 | 15 | 20 |
| 28 | BOQ , Standard information include Waste, Subcontractor or Taxes Costs estimate included in the RATE | 6 | | 2 | 3 | 9 | 20 |
| 29 | Designers provide Detailed Schedules of components. Example: Bolts | 3 | 7 | 1 | 2 | 7 | 20 |
| 30 | Designers provide Detailed Schedules of Critical Elements | 3 | 7 | | 3 | 7 | 20 |
| 31 | Designers provide realistic dimensions and Images | 5 | 6 | | 2 | 7 | 20 |
| 32 | Designers provide digital drawings with automatic quantities | | 5 | 2 | 7 | 6 | 20 |
| 33 | Designers provide Manual Instruction through Query Sheet and Instruction Books | 6 | 4 | 3 | 2 | 5 | 20 |

Figure 145: QS responses on the presence of the Detailed Standardized Contents of BOQ

| | | Yes | No | Total |
|---|---|---|---|---|
| 18 | In Construction Projects,BOQ Comprises Duration Estimate of the Critical Elements | | 13 | 13 |
| 20 | In Construction Projects, BOQ, Comprises Calculations Breakdown used in Quantities Take-Off. | | 13 | 13 |
| 24 | BOQ, Standard information include Estimated Duration for each measured Activities | 1 | 12 | 13 |
| 28 | BOQ , Standard information include Waste, Subcontractor or Taxes Costs included in the RATE | 2 | 11 | 13 |
| 29 | BOQ , Standard information include Suppliers or Manufacturers references | 3 | 10 | 13 |
| 31 | Designers provide Automatic Detailed Schedules in Critical Elements | 4 | 9 | 13 |
| 32 | Designers provide Automatic Detailed Schedules of Building Components | 7 | 6 | 13 |
| 33 | Designers provide digital drawings with automatic quantities | 3 | 10 | 13 |

**Figure 146: Architects responses on the Detailed Standardized Contents of BOQ**

| | | BOQ include Breakdown of the Items used to build up RATE | | | Total |
|---|---|---|---|---|---|
| | | Not Sure | Disagree | S/ Disagree | |
| The Area of Profession | Quantity Surveying/ Building Economics | 3 | 8 | 9 | 20 |
| Total | | 3 | 8 | 9 | 20 |

| | | BOQ include Breakdown of the Items used to build up RATE | | | Total |
|---|---|---|---|---|---|
| | | Not Sure | Disagree | S/ Disagree | |
| Firm Registration Status | Local Firm | 3 | 8 | 7 | 18 |
| | Foreign Firm | 0 | 0 | 2 | 2 |
| Total | | 3 | 8 | 9 | 20 |

| | | BOQ include Breakdown of the Items used to build up RATE | | | Total |
|---|---|---|---|---|---|
| | | Not Sure | Disagree | S/Disagree | |
| Professional Status of Respondent | Full Registered | 1 | 8 | 9 | 18 |
| | Assistant Registered | 2 | 0 | 0 | 2 |
| Total | | 3 | 8 | 9 | 20 |

| | | BOQ include Breakdown of the Items used to build up RATE | | | Total |
|---|---|---|---|---|---|
| | | Not Sure | Disagree | S/ Disagree | |
| Experience in Construction Projects | Less than 5 Years | 1 | 0 | 0 | 1 |
| | 5 to 15 Years | 1 | 5 | 4 | 10 |
| | 15 to 25 Years | 1 | 2 | 1 | 4 |
| | More than 25 Years | 0 | 1 | 4 | 5 |
| Total | | 3 | 8 | 9 | 20 |

**Figure 147:Responses from QS on the items used in Rate build up in the BOQ**

| | | BOQ include (ISO) example (ISO 16739,15926 and 15686) | | | | | Total |
|---|---|---|---|---|---|---|---|
| | | S/ Agree | Agree | Not Sure | Disagree | S/Disagree | |
| Firm Registration Status | Local Firm | 1 | 3 | 3 | 6 | 5 | 18 |
| | Foreign Firm | 1 | 0 | 0 | 0 | 1 | 2 |
| Total | | 2 | 3 | 3 | 6 | 6 | 20 |

| | | BOQ include Future Maintenance Costs for different Building Components | | | Total |
|---|---|---|---|---|---|
| | | Not Sure | Disagree | S/Disagree | |
| Professional Status of Respondent | Full Registered | 1 | 4 | 13 | 18 |
| | Assistant Registered | 1 | 1 | 0 | 2 |
| Total | | 2 | 5 | 13 | 20 |

| | | BOQ include Future Maintenance Costs for different Building Components | | | Total |
|---|---|---|---|---|---|
| | | Not Sure | Disagree | S/Disagree | |
| Experience in Construction Projects | Less than 5 Years | 1 | 0 | 0 | 1 |
| | Between 5 to 15 Years | 1 | 3 | 6 | 10 |
| | Between 15 to 25 Years | 0 | 2 | 2 | 4 |
| | More than 25 Years | 0 | 0 | 5 | 5 |
| Total | | 2 | 5 | 13 | 20 |

**Figure 148:Example 1- QS responses on the components of life cycle costing on the BOQ**

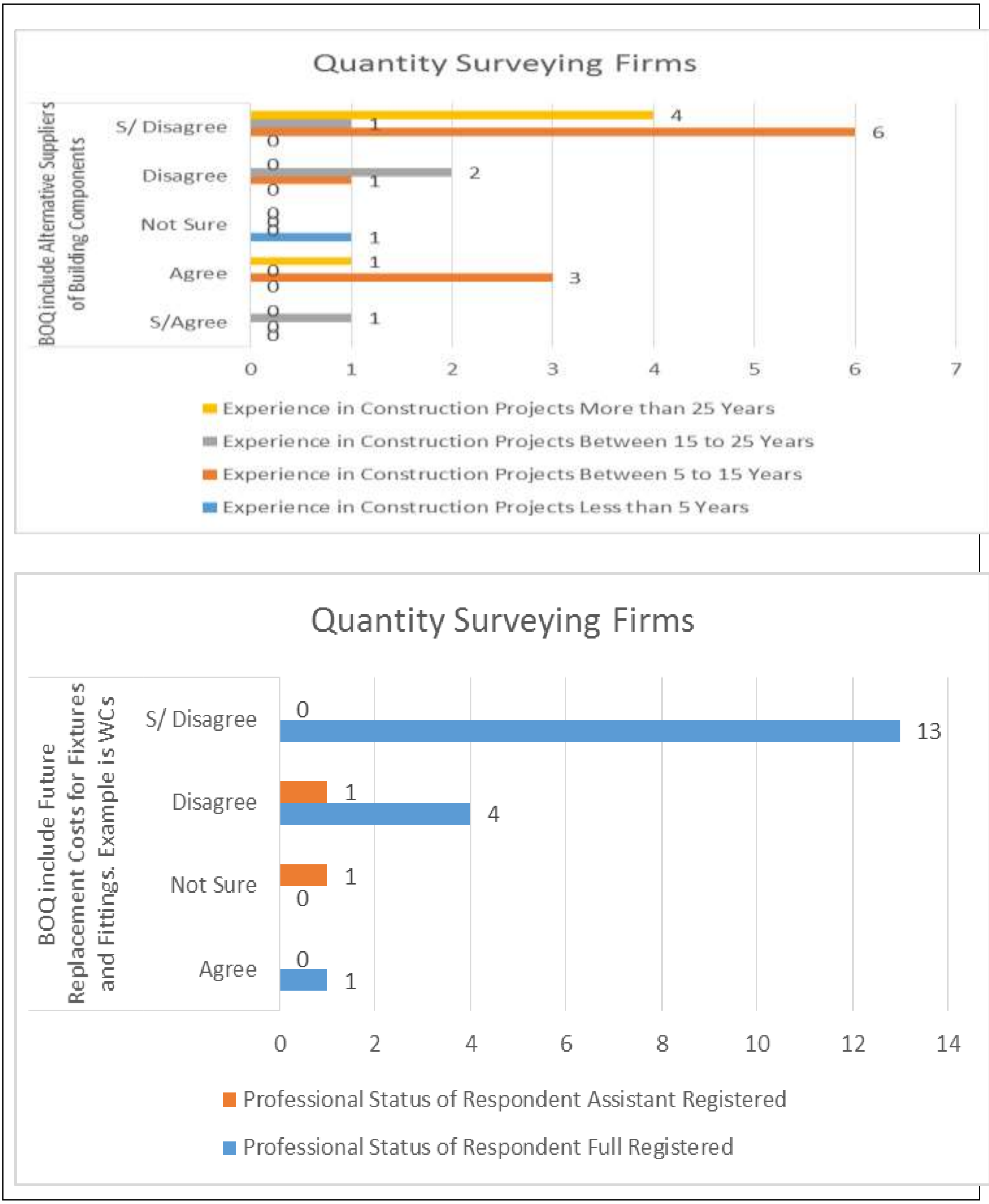



**Figure 149:Example 2-QS Responses on the components of life cycle costing on the BOQ (1/2)**

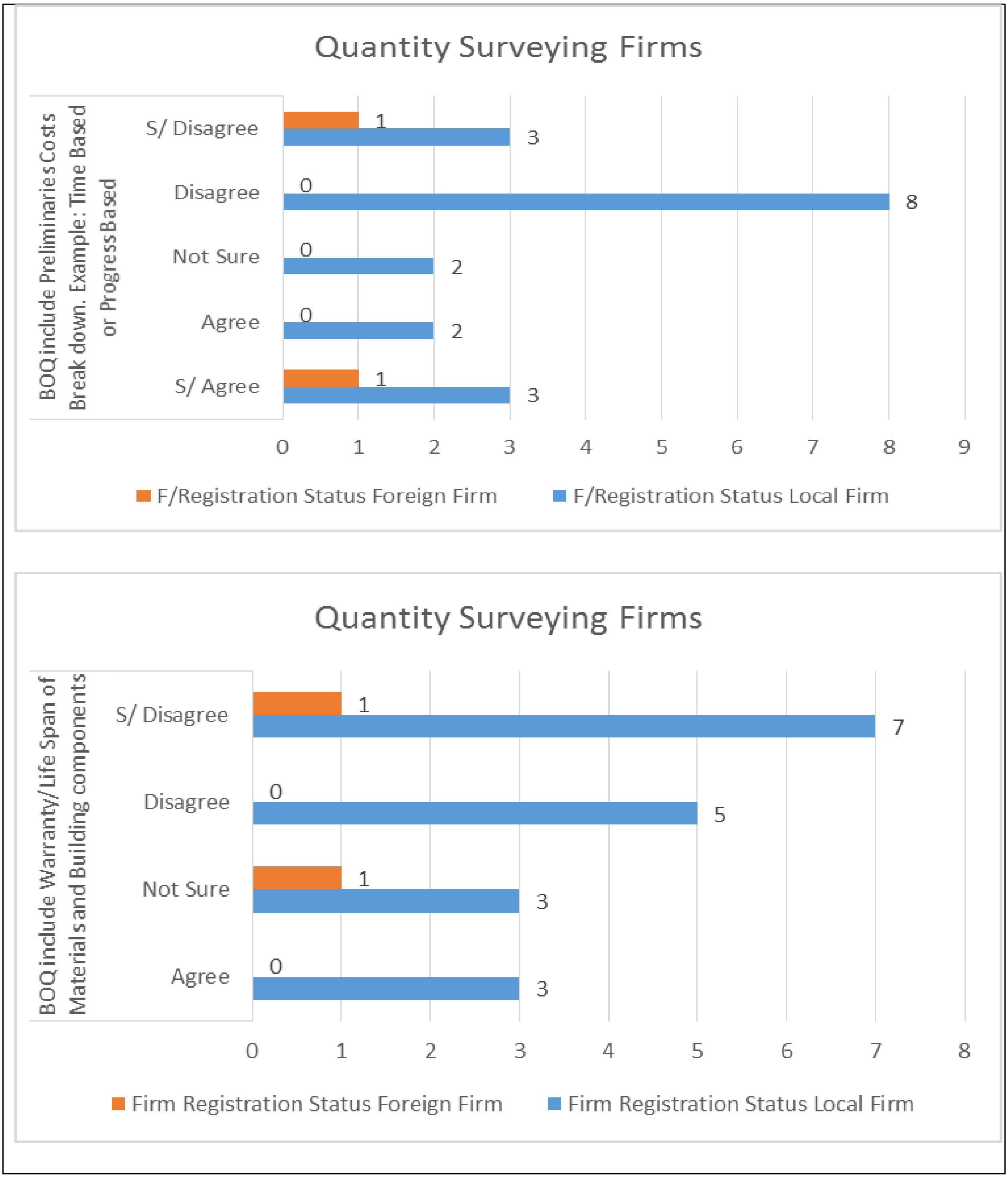



**Figure 150:Example 2-QS Responses on the components of life cycle costing on the BOQ (2/2)**

| | | BOQ Comprises Local Standard Measurement Reference | | | Total |
|---|---|---|---|---|---|
| | | Disagree | Agree | S/Agree | |
| The Area of Profession | Quantity Surveying/ Building Economics | 4 | 3 | 13 | 20 |
| Total | | 4 | 3 | 13 | 20 |

| | | BOQ Comprises International Standard Measurement Reference | | | | | Total |
|---|---|---|---|---|---|---|---|
| | | S/ Agree | Agree | Not Sure | Disagree | S/ Disagree | |
| The Area of Profession | Quantity Surveying/ Building Economics | 1 | 1 | 8 | 3 | 7 | 20 |
| Total | | 1 | 1 | 8 | 3 | 7 | 20 |

| | | BOQ Comprises International Standard Measurement Reference | | | | | Total |
|---|---|---|---|---|---|---|---|
| | | Strongly Agree | Agree | Not Sure | Disagree | S/Disagree | |
| Firm Registration Status | Local Firm | 1 | 1 | 8 | 3 | 5 | 18 |
| | Foreign Firm | 0 | 0 | 0 | 0 | 2 | 2 |
| Total | | 1 | 1 | 8 | 3 | 7 | 20 |

| | | BOQ Comprises International Standard Measurement Reference | | | | | Total |
|---|---|---|---|---|---|---|---|
| | | S/ Agree | Agree | Not Sure | Disagree | S/ Disagree | |
| Experience in Construction Projects | Less than 5 Years | 0 | 0 | 0 | 1 | 0 | 1 |
| | Between 5 to 15 Years | 0 | 1 | 4 | 1 | 4 | 10 |
| | Between 15 to 25 Years | 1 | 0 | 2 | 1 | 0 | 4 |
| | More than 25 Years | 0 | 0 | 2 | 0 | 3 | 5 |
| Total | | 1 | 1 | 8 | 3 | 7 | 20 |

**Figure 151:QS response on the referencing to the standards measurement in the BOQ**

| | | BOQ Comprises Assumptions used in Take-Off | | Total |
|---|---|---|---|---|
| | | Disagree | S/ Disagree | |
| The Area of Profession | Quantity Surveying/ Building Economics | 3 | 17 | 20 |
| Total | | 3 | 17 | 20 |

| | | BOQ Comprises Assumptions used in Take-Off | | Total |
|---|---|---|---|---|
| | | Disagree | S/Disagree | |
| Professional Status of Respondent | Full Registered | 2 | 16 | 18 |
| | Assistant Registered | 1 | 1 | 2 |
| Total | | 3 | 17 | 20 |

| | | BOQ Comprises Assumptions used in Take-Off | | Total |
|---|---|---|---|---|
| | | Disagree | Strongly Disagree | |
| Experience in Construction Projects | Less than 5 Years | 1 | 0 | 1 |
| | Between 5 to 15 Years | 1 | 9 | 10 |
| | Between 15 to 25 Years | 1 | 3 | 4 |
| | More than 25 Years | 0 | 5 | 5 |
| Total | | 3 | 17 | 20 |

| | | BOQ Comprises Query Sheet used in Take-Off | | Total |
|---|---|---|---|---|
| | | Disagree | Strongly Disagree | |
| Firm Registration Status | Local Firm | 3 | 15 | 18 |
| | Foreign Firm | 0 | 2 | 2 |
| Total | | 3 | 17 | 20 |

**Figure 152: QS Responses on the querry sheets and take-off assumptions in BOQ**

| | Use of Computer in BOQ Preparation helps Inclusion of Maintenance Costs | | | | Total |
|---|---|---|---|---|---|
| | Agree | Not Sure | Disagree | S/ Disagree | |
| The Area of Profession Quantity Surveying/ Building Economics | 6 | 5 | 3 | 6 | 20 |
| Total | 6 | 5 | 3 | 6 | 20 |

| | In Building Works BOQ,Computer helps Including maintenance Costs | | | | Total |
|---|---|---|---|---|---|
| | Agree | Not Sure | Disagree | S/ Disagree | |
| The Area of Profession Quantity Surveying/ Building Economics | 7 | 6 | 2 | 5 | 20 |
| Total | 7 | 6 | 2 | 5 | 20 |

| | In Civil Works BOQ,Computer technologies helps Including Maintenance Costs for different Components | | | | Total |
|---|---|---|---|---|---|
| | Agree | Not Sure | Disagree | S/ Disagree | |
| The Area of Profession Quantity Surveying/ Building Economics | 4 | 12 | 3 | 1 | 20 |
| Total | 4 | 12 | 3 | 1 | 20 |

**Figure 153:QS responses on usefulness of computer in the maintenance costing in BOQ**

| | | Use of Computer in BOQ Preparation helps Inclusion of Estimated Duration of Activities of the project | | | | Total |
|---|---|---|---|---|---|---|
| | | Agree | Not Sure | Disagree | S/Disagree | |
| Professional Status of Respondent | Full Registered | 5 | 8 | 2 | 3 | 18 |
| | Assistant Registered | 0 | 0 | 2 | 0 | 2 |
| Total | | 5 | 8 | 4 | 3 | 20 |

| | | Use of Computer in BOQ Preparation helps Elimination of provisional sums | | | | | Total |
|---|---|---|---|---|---|---|---|
| | | S/ Agree | Agree | Not Sure | Disagree | S/Disagree | |
| Professional Status of Respondent | Full Registered | 2 | 4 | 4 | 3 | 5 | 18 |
| | Assistant Registered | 0 | 0 | 1 | 1 | 0 | 2 |
| Total | | 2 | 4 | 5 | 4 | 5 | 20 |

| | | In Civil Works BOQ, Computer technologies helps Identifying more information about the Rates E.g. Materials, Labour, Plants, Waste, Depreciation, Taxes and like, used to build it | | | | | Total |
|---|---|---|---|---|---|---|---|
| | | S/ Agree | Agree | Not Sure | Disagree | S/Disagree | |
| Professional Status of Respondent | Full Registered | 1 | 3 | 10 | 2 | 2 | 18 |
| | Assistant Registered | 0 | 1 | 1 | 0 | 0 | 2 |
| Total | | 1 | 4 | 11 | 2 | 2 | 20 |

| | | In Civil Works BOQ,Computer technologies helps Calculating Materials, Labour and Plant Costs | | | | Total |
|---|---|---|---|---|---|---|
| | | Agree | Not Sure | Disagree | S/Disagree | |
| Professional Status of Respondent | Full Registered | 5 | 11 | 1 | 1 | 18 |
| | Assistant Registered | 1 | 1 | 0 | 0 | 2 |
| Total | | 6 | 12 | 1 | 1 | 20 |

**Figure 154: Example 1- QS responses on usefulness of computer in BQO preparation**

| | | In Civil Works BOQ,Computer technologies helps Including Maintenance Costs for different Components | | | | Total |
|---|---|---|---|---|---|---|
| | | Agree | Not Sure | Disagree | S/Disagree | |
| Experience in Construction Projects | Less than 5 Years | 1 | 0 | 0 | 0 | 1 |
| | Between 5 to 15 Years | 0 | 9 | 1 | 0 | 10 |
| | Between 15 to 25 Years | 2 | 0 | 2 | 0 | 4 |
| | More than 25 Years | 1 | 3 | 0 | 1 | 5 |
| Total | | 4 | 12 | 3 | 1 | 20 |

| | | In Civil Works BOQ,Computer technologies helps Calculating Wastage Costs | | | | Total |
|---|---|---|---|---|---|---|
| | | Agree | Not Sure | Disagree | S/ Disagree | |
| Experience in Construction Projects | Less than 5 Years | 1 | 0 | 0 | 0 | 1 |
| | Between 5 to 15 Years | 0 | 9 | 1 | 0 | 10 |
| | Between 15 to 25 Years | 2 | 0 | 1 | 1 | 4 |
| | More than 25 Years | 1 | 3 | 0 | 1 | 5 |
| Total | | 4 | 12 | 2 | 2 | 20 |

| | | In Civil Works BOQ,Computer technologies helps Including Warranty/life span of Materials and components used | | | | Total |
|---|---|---|---|---|---|---|
| | | Agree | Not Sure | Disagree | S/ Disagree | |
| Experience in Construction Projects | Less than 5 Years | 1 | 0 | 0 | 0 | 1 |
| | 5 to 15 Years | 0 | 9 | 1 | 0 | 10 |
| | 15 to 25 Years | 1 | 3 | 0 | 0 | 4 |
| | More than 25 Years | 0 | 4 | 0 | 1 | 5 |
| Total | | 2 | 16 | 1 | 1 | 20 |

**Figure 155: Example2-QS responses on usefulness of computer in BOQ preparation**

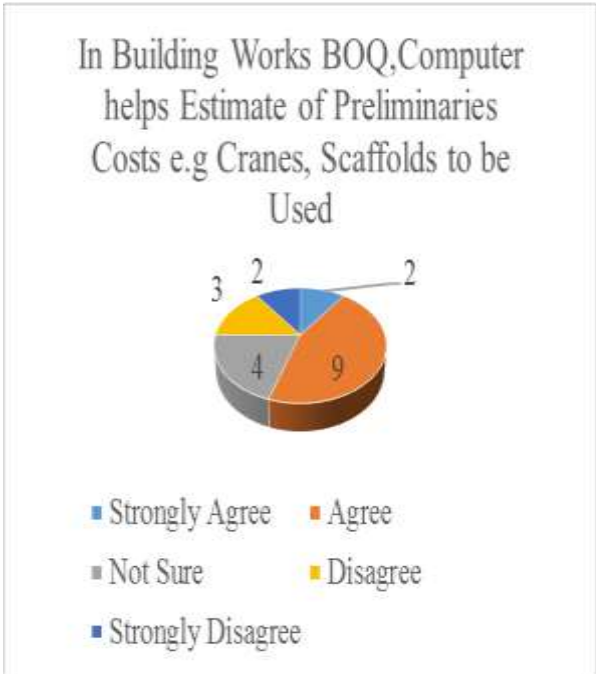
| | | BOQ include Future Replacement Costs for Fixtures and Fittings. Example is WCs | Total |
|---|---|---|---|
| | | No | |
| The Area of Profession | Architecture | 12 | 12 |
| | Architectural Technology. | 1 | 1 |
| Total | | 13 | 13 |

| | | BOQ include Future Maintenance Costs for different Building Components | | Total |
|---|---|---|---|---|
| | | Yes | No | |
| The Area of Profession | Architecture | 2 | 10 | 12 |
| | Architectural Technology. | 0 | 1 | 1 |
| Total | | 2 | 11 | 13 |

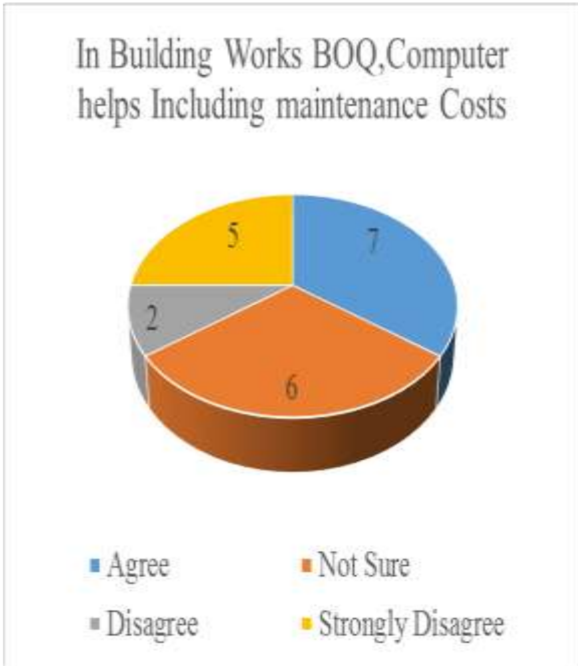
| | | BOQ include Breakdown of the Items used to build up RATE | | Total |
|---|---|---|---|---|
| | | Yes | No | |
| Professional Status of Respondent | Full Registered | 1 | 11 | 12 |
| | Assistant Registered | 0 | 1 | 1 |
| Total | | 1 | 12 | 13 |

| | | BOQ include Warranty/Life Span of Materials and Building components | | Total |
|---|---|---|---|---|
| | | Yes | No | |
| Experience in Construction Projects | Between 5 to 15 Years | 0 | 10 | 10 |
| | Between 15 to 25 Years | 0 | 2 | 2 |
| | More than 25 Years | 1 | 0 | 1 |
| Total | | 1 | 12 | 13 |

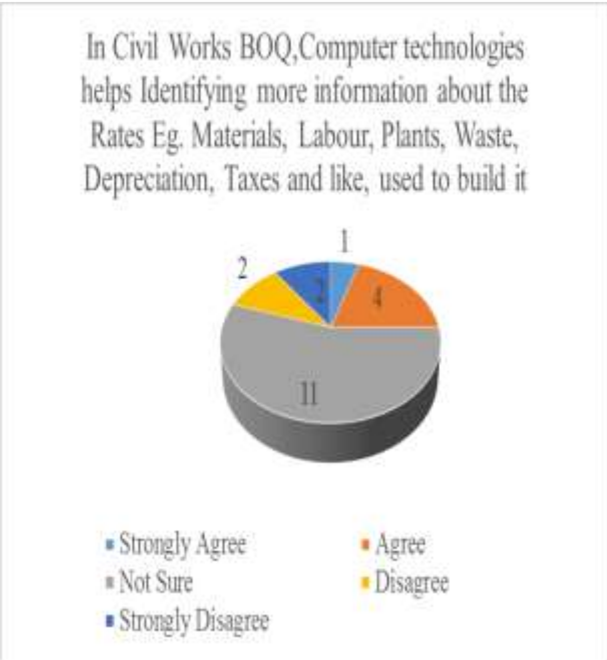
**Figure 156: Architects responses on the life cycle items and rate breakdown in the BOQ**




(a)




(b)




(c )

**Figure 157: Example 1- QS frequencies on the usefulness of Computer in BOQ**

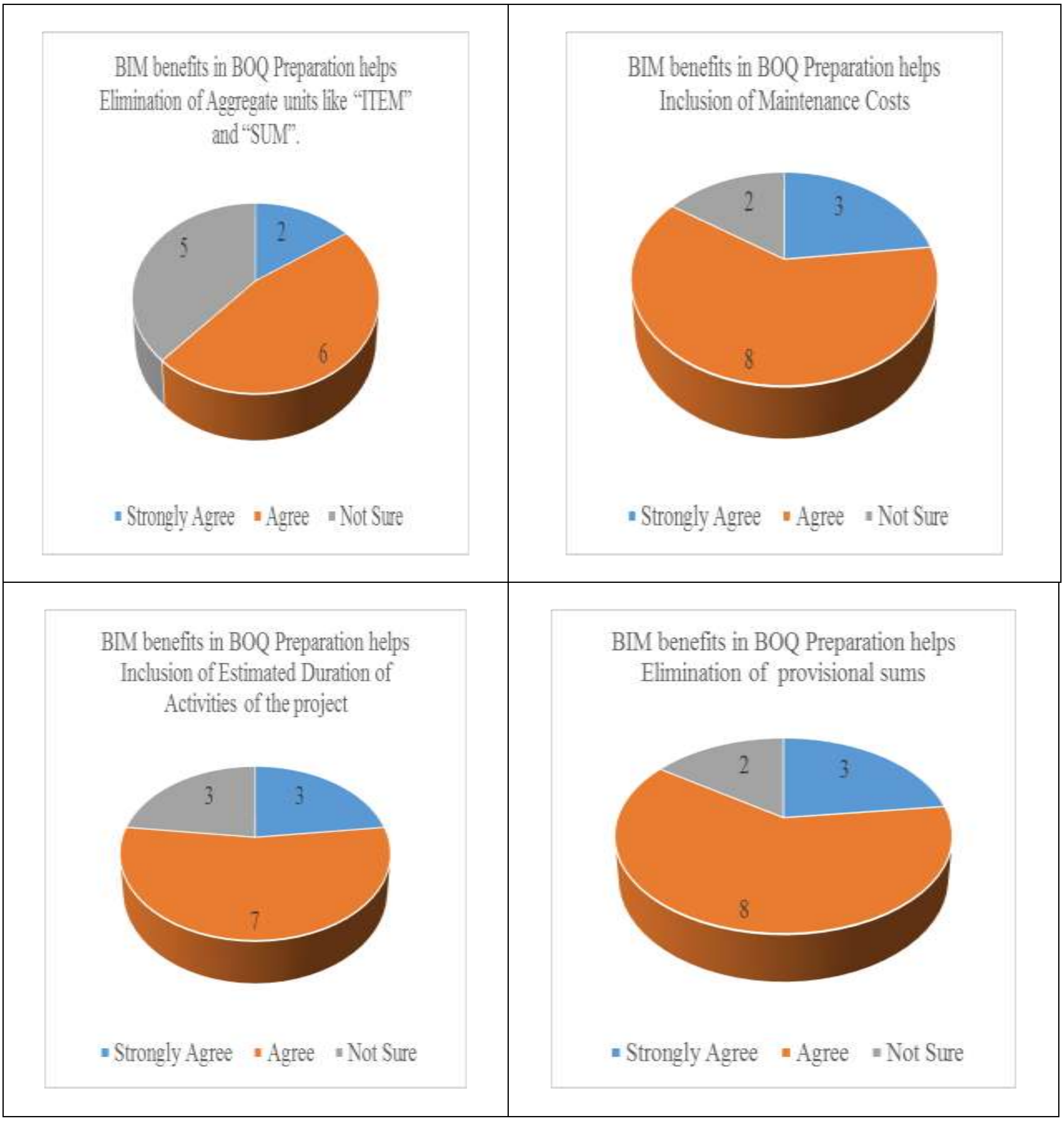



**Figure 158: Example 2- Architects frequencies on the usefulness of Computer on BOQ**

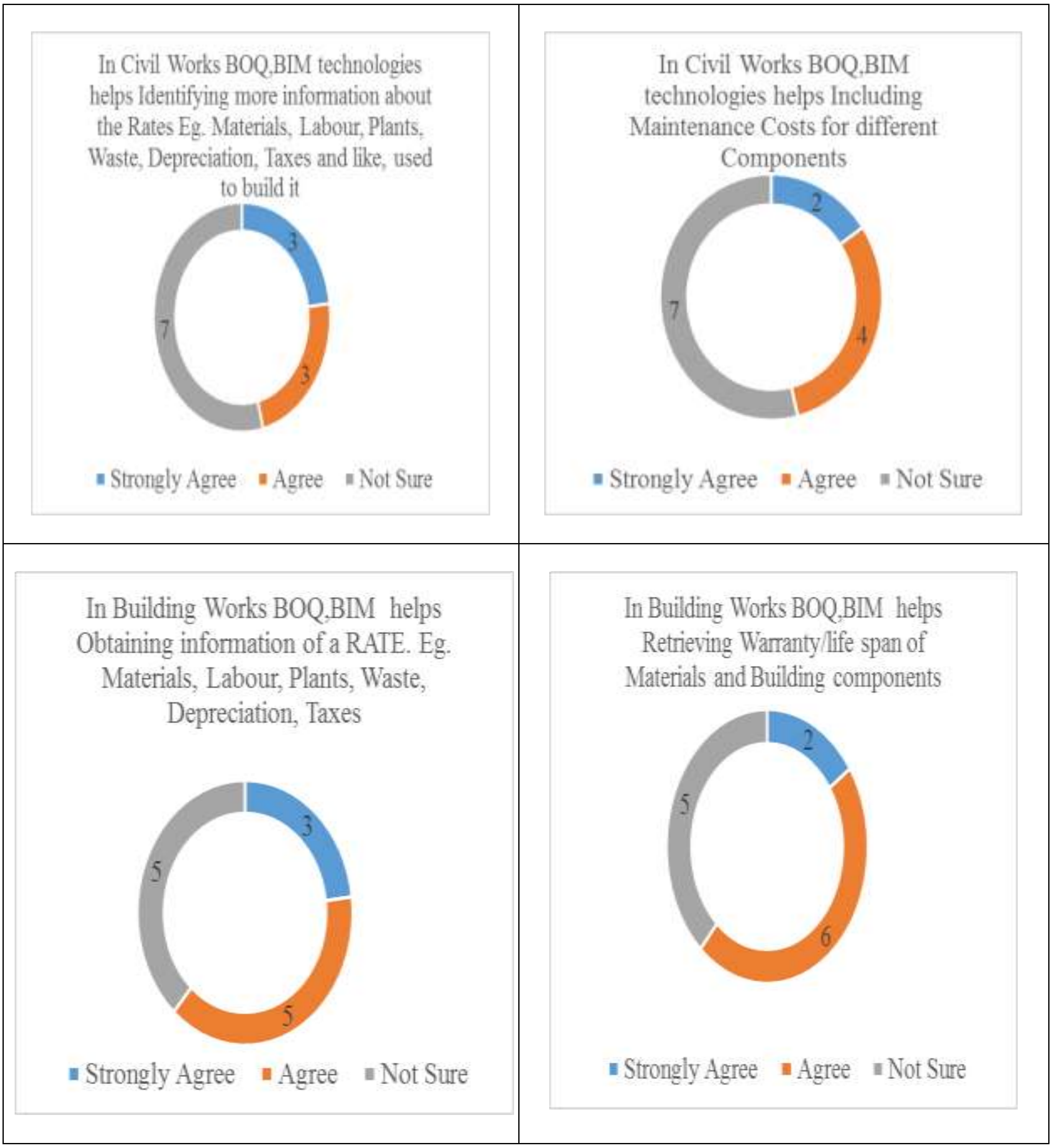



**Figure 159: Example 3- Architects agreement on the usefulness of Computer on BOQ**

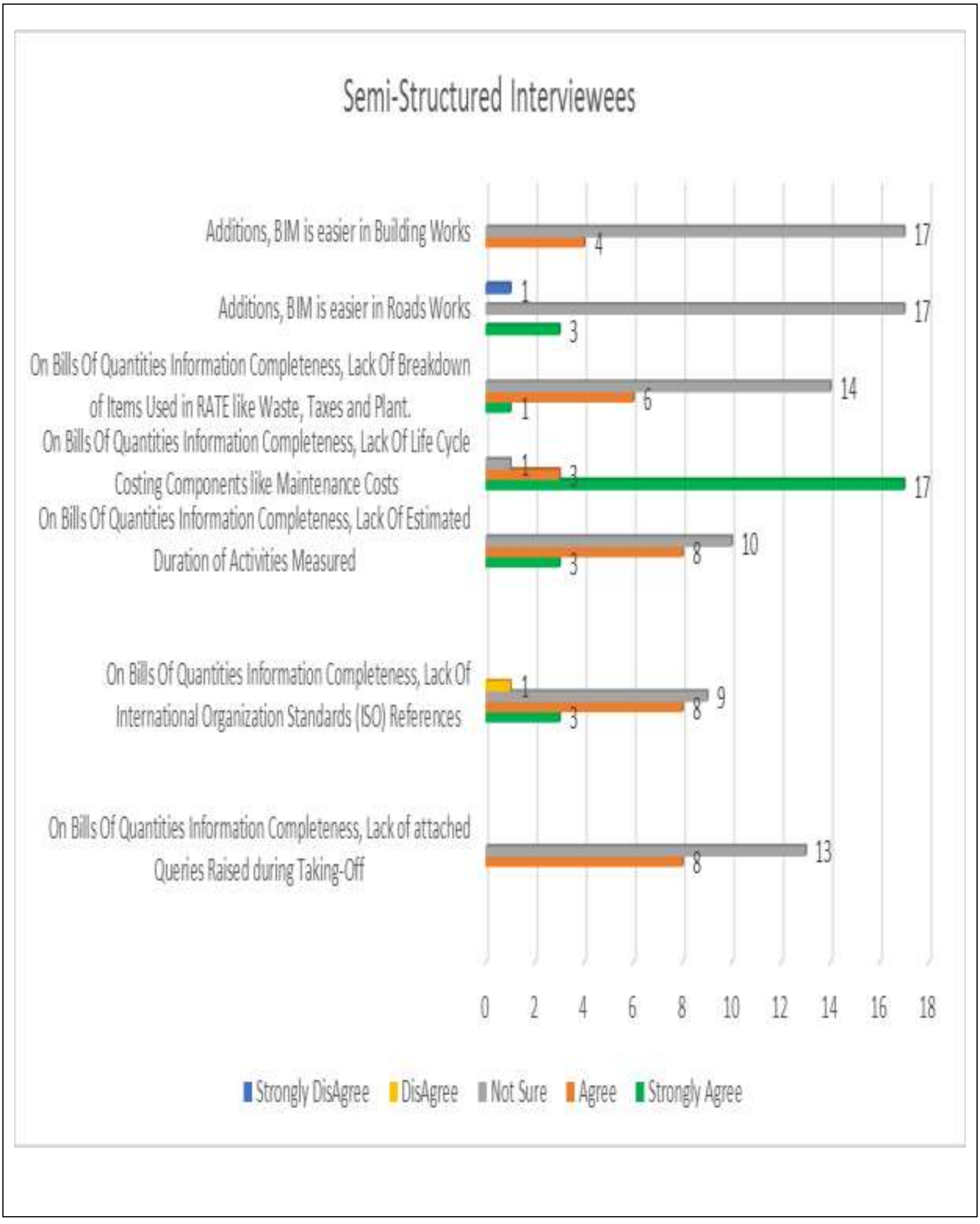



**Figure 160: Interviewees frequencies on BIM use and the presence of extra items in BOQ**

| | | S/Agree | Agree | Not Sure | DisAgree | S/ DisAgree | Total |
|---|---|---|---|---|---|---|---|
| 17 | BOQ Comprises Query Sheet used in Take-Off | | | | 3 | 17 | 20 |
| 18 | BOQ Comprises Assumptions used in Take-Off | | | | 3 | 17 | 20 |
| 34 | BOQ include Future Replacement Costs for Fixtures and Fittings. Example is WCs | | 1 | 1 | 5 | 13 | 20 |
| 35 | BOQ include (ISO) example (ISO 16739,15926 and 15686) | 2 | 3 | 3 | 6 | 6 | 20 |
| 36 | BOQ include Future Maintenance Costs for different Building Components | | | 2 | 5 | 13 | 20 |
| 37 | BOQ include Estimated future Disposal Costs for various Building Components | | | 2 | 5 | 13 | 20 |
| 38 | BOQ include Alternative Suppliers of Building Components | 1 | 4 | 1 | 3 | 11 | 20 |
| 39 | BOQ include Warranty/Life Span of Materials and Building components | | 3 | 4 | 5 | 8 | 20 |
| 40 | BOQ include Preliminaries Costs Break down. Example: Time Based or Progress Based | 4 | 2 | 2 | 8 | 4 | 20 |
| 41 | BOQ include Breakdown of the Items used to build up RATE | | | 3 | 8 | 9 | 20 |

**Figure 161:QS responses on Items used to measure the 5DBIM Contents level of BOQ**

| | | Yes | No | Total |
|---|---|---|---|---|
| 34 | BOQ include Future Maintenance Costs for different Building Components | 2 | 11 | 13 |
| 35 | BOQ include Estimated future Disposal Costs for various Building Components | | 13 | 13 |
| 36 | BOQ include Warranty/Life Span of Materials and Building components | 1 | 12 | 13 |
| 37 | BOQ include Breakdown of the Items used to build up RATE | 1 | 12 | 13 |
| 38 | BOQ include Future Replacement Costs for Fixtures and Fittings. Example is WCs | | 13 | 13 |

| | | S/Agree | Agree | Not Sure | DisAgree | S/ DisAgree | Total |
|---|---|---|---|---|---|---|---|
| 55 | In Building Works BOQ,BIM helps Including maintenance Costs | 3 | 6 | 4 | | | 13 |
| 56 | In Building Works BOQ,BIM helps Calculating the costs of Materials, Labour and Plant in building the rate | 3 | 6 | 4 | | | 13 |
| 57 | In Building Works BOQ,BIM helps Calculating Wastage Costs | 3 | 6 | 4 | | | 13 |
| 58 | In Building Works BOQ,BIM helps Retrieving Warranty/life span of Materials and Building components | 2 | 6 | 5 | | | 13 |
| 59 | In Building Works BOQ, BIM helps Obtaining information of a RATE. Eg. Materials, Labour, Plants, Waste, Depreciation, Taxes | 3 | 5 | 5 | | | 13 |
| 60 | In Building Works BOQ,BIM helps Estimate of Preliminaries Costs e.g. Cranes, Scaffolds to be Used | 3 | 4 | 6 | | | 13 |

**Figure 162: Architects on the Items used to measure the 5DBIM Contents of BOQ**

## 5. Distribution Data Interpretation

The focus of the study is to appraise BIM in Tanzania. To do so, an effort is done to first develop simple model that can be tested refined and retested until the right Tanzanian BIM is satisfactory proposed. As such it was in the view of this study to hypothesize on the core property of BIM in order to explain why Tanzania needs BIM. This study is not addressing why or how BIM does what it does, but rather the study concentrates on what BIM does. Tanzania needs BIM because BIM does best what Tanzanian Construction Industry wants. That is performance improvement through Total Costs Management (TCM) efficiency. The statistical hypothesis of this study was stated as “In TCM, 5DBIM has positive effect on BOQ completeness”. So the study collected data in order to measure the levels of 5DBIM and BOQ contents in the ongoing projects. The intention being to discover the correlation between the two. The study, is not involved in the understanding of why things are the way they are. Neither the study is involved in giving account on the causes of the existing challenges. However, in the course of pinpointing the BIM levels and BOQ contents levels, such supportive arguments and explanation are welcome. Therefore, the focus of the interpretation of the study is toward substantiating the relationship between levels of BIM and BOQ contents.

### 5.1. Biography

In this study, a total of 20 questionnaires were collected from the Quantity Surveying Firms, 13 questionnaires from Architectural Firms and 21 semi-structured questionnaires from ongoing projects in Dar Es Salaam were administered. The total number of registered firms as per AQRB, was 105 for Quantity Surveying and 204 Architectural Firms. The study used mixed methods of data collection. Sampling was of purposeful (snow ball) for the interviews and a modified random for the questionnaires to architects and quantity surveyors. The Architects represented the designers and quantity surveyors represented the costs experts while the structures interviewees were there to represent the physical observation of the BIM and BOQ documentation on the on-going projects. As such, the interpretation of BIM as worldwide defined, were best guided by the Architects or designers while the interpretation of the BOQ contents was under the guidance of the QS responses. The Interviews acted as supportive evidence to both Architects and QS responses.

It was necessary to only involve registered firms in order to ensure authenticity of the information and to be as close as possible to the realistic representation of the market. However, responses was slow compared to what was expected. According to (Monko & Roider, 2014), architects are pioneered to consist of a higher rate of response. As such the follow up was made purposely to improve the responses. That was another reason for more use of snow ball sampling. The involvement of the fully registered professionals and assistants with a mixed working experience intended to acquire opinions from experienced point of view and academic point of view. For instance the respondent (2[175] and 3[176] ) indicated the academic inputs of young professionals to the industry. Likewise, the involvement of the local and foreign firms intended to tap the available experience from international professional practicing in Tanzania (*Refer to Illustration Box 15: Respondent 8 explained the perception of BIM* **usage**). In the ongoing projects, the intention was to objectively obtain the evidence with regard to BIM usage and the Bills of Quantities used in those project. A total of 21 projects visited, including civil and building works increased a chance to obtain the factual opinions primarily from the project Quantity Surveyors, Architects and Engineers and other participants like investment officer (Respondent 16) as well as from a group of expert (Respondent 1).

### 5.2. Predictors or BIM levels Responses

Four 5DBIM levels were assumed in this study. These are a Non BIM level, BIM, Non 5DBIM and 5DBIM level. BIM level 1 which is Non-BIM consist of the basic technology starting from the manual to the 3D CAD usage environment. The BIM level 2 starts from the environment with more use of 3DCAD and 3DBIM software and tools. The BIM level 3 is Non-5DBIM environment, which excludes only 5DBIM related software, but also does not entertain 3DCAD or the lower CAD technologies. BIM level 4 is 5DBIM related environment information integration level. To choose a level, the intersection of the modes from the responses of Architects and Quantity Surveying firms were used. The semi structured interviews were used to assists on the arguments for and against the selection of the tying or contradicting modes.

The respondents indicated the presence of ***BIM level 1 and 2***. All 13 Architects agreeing on the usage of CAD technologies, while only 5 said yes to the presence of 3DBIM technologies usage. QS Responses modes indicate that 16 respondents strongly agree on the use of excel and only 2 QS with experience of 15 to 25 years strongly agreed on the presence of 3DBIM usage and also 2 QS strongly agreed on the presence of CAD usage. The modes show that Architects responses on the presence of BIM related software like Autodesk Revit and Nemetscheck All plan was 7 ***yes*** and 6 ***no***. Also 11 Architects said yes to the use of excel. No architect indicated a YES response to BIM level 3 or 4.

[175] Respondent 2: “On my side, if I were to improve the BOQ, just to add, because we know all life span of the Build ( in Tanzania say it is 100 years), and probably their life expectancy, then it is possible to calculate the future cost and compare with the current costs and show the client. Say, painting as an element can be foreseen its operational costs (repainting say of 5 years) and future costs calculated and compared with the current costs. Therefore, it is possible to add this calculation in the BOQ. This would guide the user during running of the building. If BIM can give at least information just by clicking and help to prepare such calculation, I think it is very helpful”. (A comment came from a near graduate in Construction Economics and Management)

[176] Respondent 3: “I finished my Bachelor in Architecture last year, and we were told about BIM but not yet taught at XXX University. I know about Revit”. (One Graduate Architect comment in the Office)

From the interviewees, the responses showed that 20 respondents *strongly agree* on the presence of CAD related technologies while 1 respondent indicated an *agree* only. On the presence of 3DBIM, only 3 *agreed* while 17 *disagree strongly*. Respondent 6[177] explained what BIM is and yet declared that it is not practiced, even by foreign companies. It was also supported that, it is not yet taught effectively in the training institutions. It is likely that some respondents are owning BIM related software but they are using them at a Non-BIM level as Respondent 12[178] explained. There are a number of software vendors[179] and with different versions, and sometimes vendors claim these software to be BIM, because they are basically capable of providing ***3D graphics***. Actually, they may be right, because having BIM related software does not necessarily mean practice BIM at a higher level. On the other hand respondents indicated presence of effort toward practicing BIM at much higher level possible because, the practice at BIM level 1 is common to them.

From the QS response on BIM level 1 and 2, it was in the view of this study that responses indicate that BIM level 1 is much higher than BIM level 2. BIM level 4 is not indicated at all. Given the intention of the study, 13 was selected to represent Architects response on *BIM level 1* and 2 was selected to represent responses of QS for *BIM level 1*. On the Other hand, 7 was selected to be the representation of *BIM level 2* response from Architects and 2 was for QS responses on *BIM level 2*. Responses for the BIM level 3 for the Architects were 1 from the presence of closer technologies related to Graph iSOFT, Cobie and ECO analysis. QS Responses indicated no presence of both BIM level 3 and 4, while Architect had no BIM level 4. *( See Figure 165: Architects Response frequencies on the likely presence of BIM level ).*The following illustration Box 14 closes well the interpretation of BIM levels from the explanation of the Respondent 7.

177 Respondent 6: “I know BIM but I do not Practice because there is no BIM infrastructures. I am aware, I would say but here in Tanzania we do not have digital data bank in the construction industry. May be foreigners companies as “XXX” may have internal linkages. I doubt even, whether those firms have BIM”.

178 Respondent 12: “In Tanzania BIM has not started. We do not have coordination of the design teams. Here, I use Revit and all other CAD, but I have not worked with 4D or 5D BIM.We need BIM so quickly. Challenge is Technology, people are not aware”

179 Own Exhibition Experience: “There are many providers of BIM platforms among others, ArchiCAD 17 GraphiSOFT, RIB iTWO, BENTLEY, VECTORS, and NEMENSCHEK AND REVIT AUTOCAD. All of these demonstrates the possibility of BIM within construction projects. The difference is on the category of BIM. Some ends up to 3D like ArchiCAD while other provide 5D BIM services like RIB. This means currently there are many levels of BIM and related providers”

Illustration Box 16: Respondent 7-Example of the opinions of the respondents on the BIM level

*"Three Dimension, to us is just drawing the building as picture, to show it all. Building Information Modelling means BIM, no! That we do not have. We do have, CAD 3D. But, 4D, 5D and the nth D. That is not there for sure!"*

***<u>Conversation:</u>***

*Interviewee: Boss! Where are we, in our plan to use software to take-off? Here is an interviewer, asking about BIM.*

***<u>BOSS</u>****: Technically, we are in process. BIM in Europe is a FUTURE. We will eventually catch up, but only when we are forced, actually these CAD are part of it. I do not think if in Tanzania someone is using it. The last CPD (continuous professional development), in Mbeya people came from Sweden and Australia, it speaks well, because it gives life cycle management of the project. But unless we use it we cannot say how good or bad BIM is.*

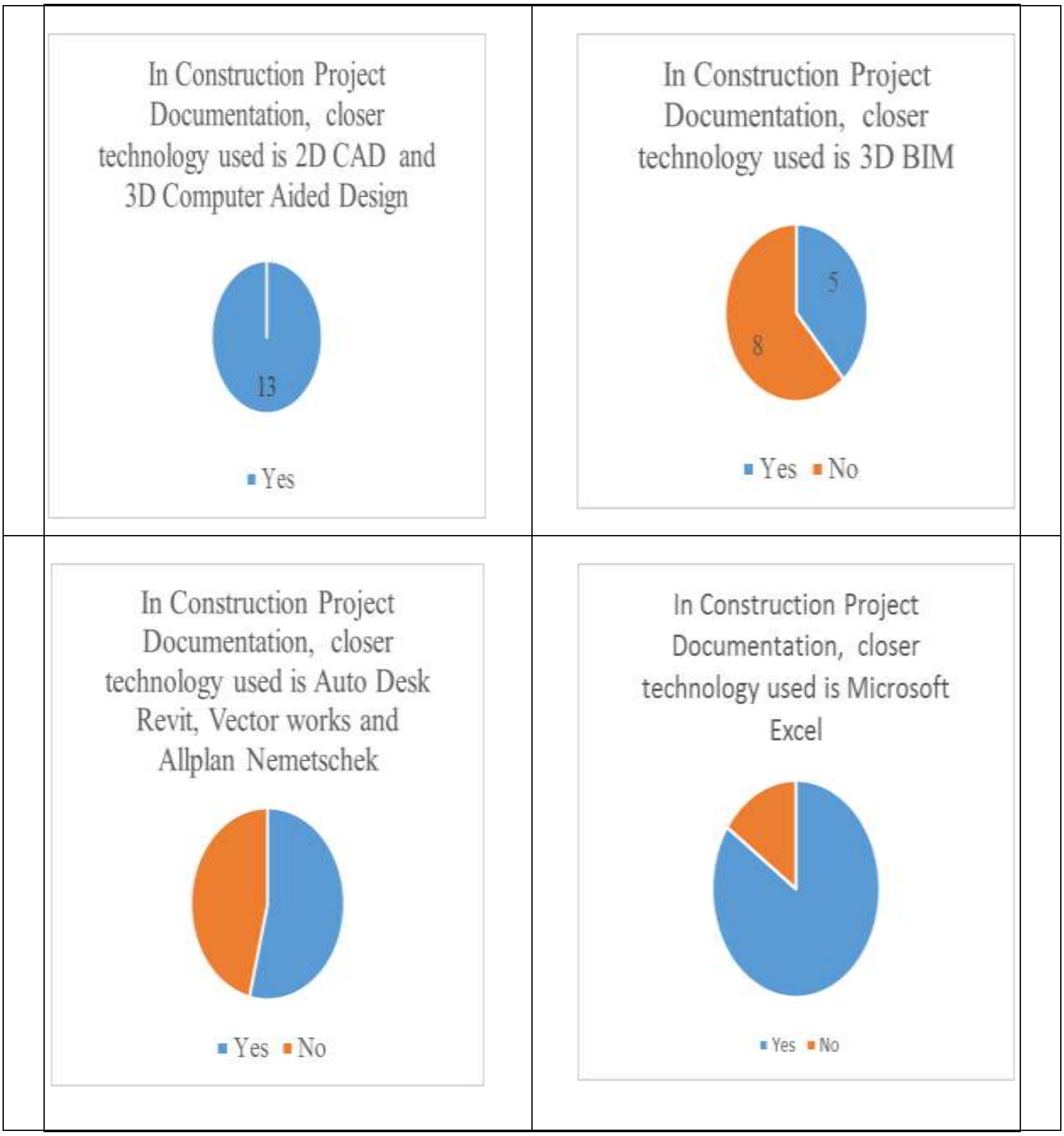



**Figure 163: Architects Response frequencies on the BIM level 1 and 2**

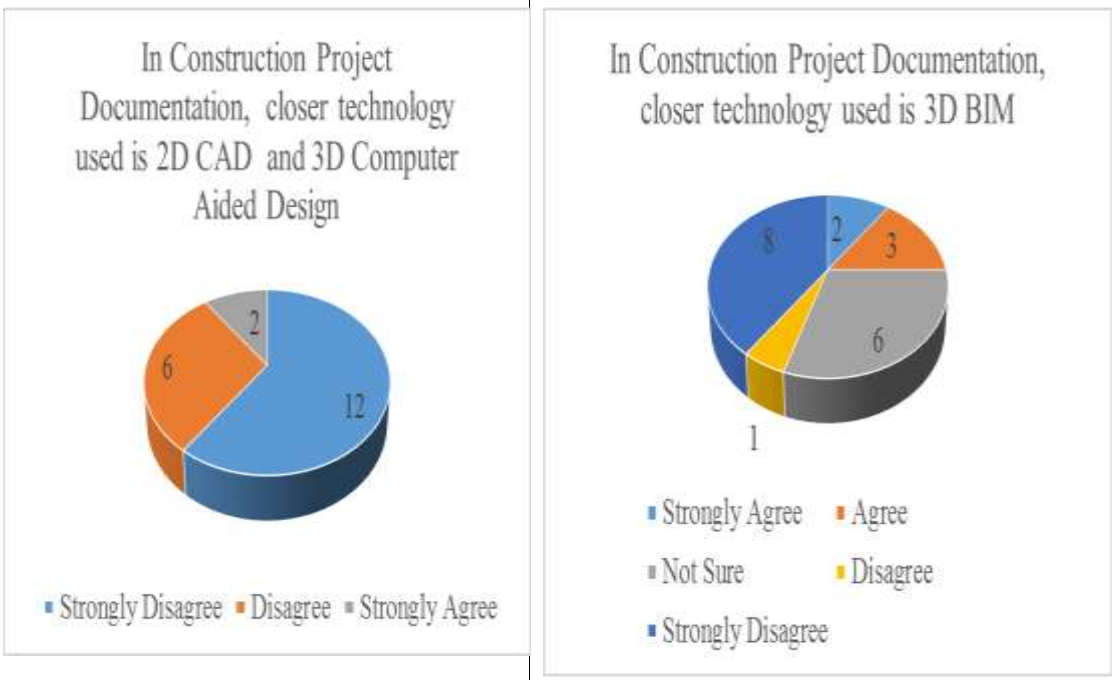



**Figure 164:QS Response frequencies on the BIM level 1 and 2**

**In Construction Project Documentation, closer technology used is Graph iSOFT MEP, ECOTEC Analysis, CISCO IT and COBie**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | Yes | 1 | 7.7 | 7.7 | 7.7 |
| | No | 12 | 92.3 | 92.3 | 100.0 |
| | Total | 13 | 100.0 | 100.0 | |

**Figure 165: Architects Response frequencies on the likely presence of BIM level**

## 5.3. Response Variable or BOQ Contents levels

Breaking down the response variable or BOQ contents levels was not so simple, because a number of dimensions in the information levels do interact. For instance, provisional sums as a BOQ section, it is not easily categorized as incomplete or not. It may be due to a genuine delay in the decision rather than lack of the building element information. However, it was possible to categorise the contents of BOQ by considering the minimal level of information in the standard format and contents as well as the likely improved contents to the existing BOQ that can result from the use of BIM.BOQ 1, referred to BOQ usage with Basic sectional contents, BOQ 2 was a BOQ usage with standard elemental contents, BOQ 3 was detailed standard elemental with improved contents and BOQ 4, refers to BOQ with 5DBIM related contents with life cycle costing. As such the interpretation converged into whether the BOQ information falls into one of the above mentioned contents levels or not.

The highest response on the *BOQ 1* from the Quantity Surveying firms was 19 respondents out of 20 who strongly agreed on presence of both preliminaries and measured works sections. On provisional sums and prime costs there were 18 respondents, while on the preambles there were 14 and 3 agreed strongly for the day works section. The 10 respondents out of 20 who strongly disagreed on the presence of day works from the QS and that 10 Architects out of 13 who said NO on the same item, indicate that day works is not common section in the Bills of Quantities, probably it the reason (Greenhalgh & Squires, 2011) did not mention it on their structure of BOQ.Architects responses saying YES to preambles were 9, while all 13 said yes to the pesence of provisional sums, preliminaries, measured works and 12 said yes to the prime costs. The responses indicate that the most common sections of BOQ include preliminaries,measured works,provisional sums and prime costs. Respondents 16[180] suggested that provisional sums are not desirable,but very difficult to avoid in the current existing system. It requires more than experts´ initiatives.

The study proposed that information in the BOQ is not complete because information integration is low. Apart from Day-works being uncommon, Prime Costs and provisional sums responses supported the hypothesis in that they indicated likely presence of the lesser broken down items in the BOQ. Again, the responses from the both QS and Architects supported that, there are presence of the provisional quantities that need to be remeasured in the BOQ. 16 out of 20 QS agreed strongly and 11 out of 13 Architects said YES. Likewise, QS responses indicated that detailed schedules of components is not highly mandatory, and instruction and manually than digital. The Architects also

[180] Respondent 16: “Provisional Sums, we need to be careful. Reducing is a problem and putting more of it is a big problem. Statutory costs are unavoidable to me.With time we are trying to avoid provisional sums and incompleteness of the information in BOQ. We need statutory initiatives to reduce provisional sums and variations, not only experts”

supported this, as 10 responses said NO to the presence of practice of providing QS with digital drawings with automatic schedules (see tables below for examples of responses). Respondent 11[181] supported this during interview. It was in this light that this study labeled BOQ 1 as 16 for QS and 11 for the Architects.

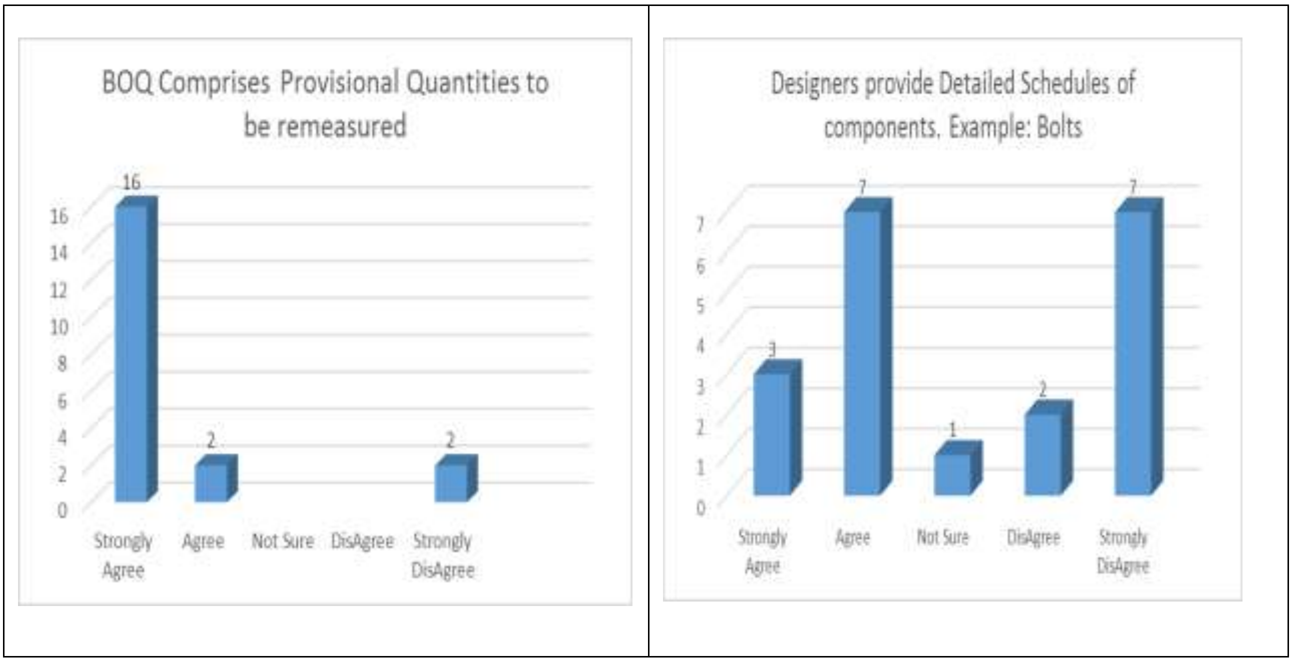



Figure 166: Example of QS responses on the likely presence of provisional items in the BOQ

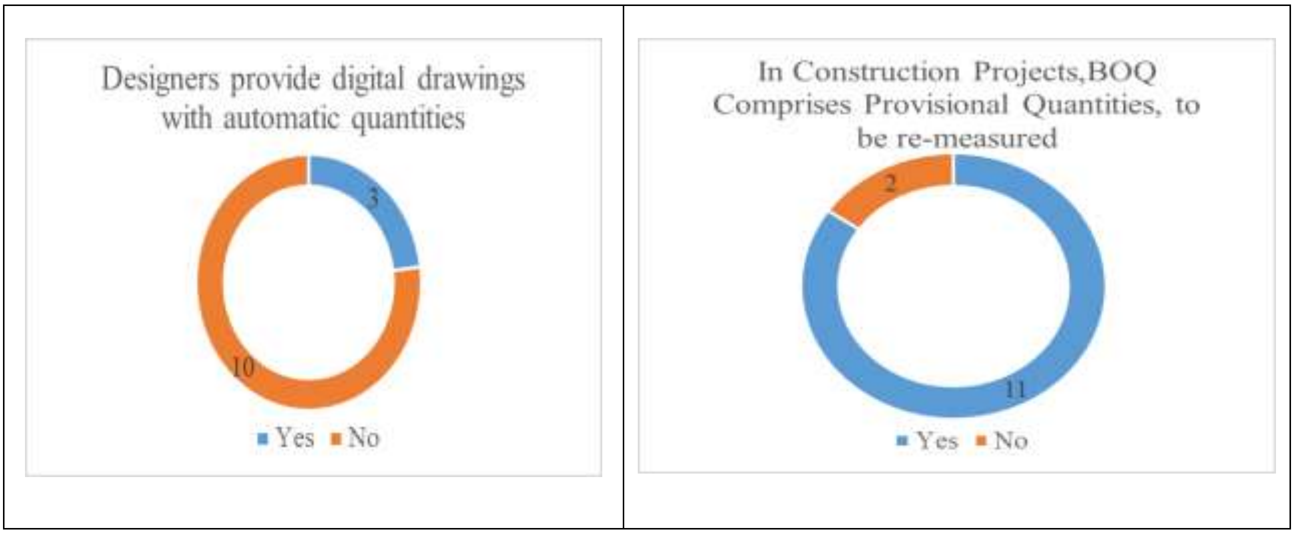



**Figure 167:Example of Architects on the likely presence of provisional items in the BOQ**

[181] Respondent 11: “So many times the projects stops, because a number of information and questions has not been answered during design. We designers normally do not give QSs details, so even the computer technology to them help very little unless the designers can provide complete information. Example is giving a door, without Architrave”.

***BOQ 2*** selection based on the standard information relative to the format commonly used in BOQ preparation. Detailed items were the focus for the BOQ 3.The serial number, description, quantities and unit, of an item measured got the highest responses, where 19 responses out of 20 QS strongly agreed. However, QS responses indicated low presence of the detailed standard items breakdown. Only 7 responses agreed strongly on the presence of materials cost, labour costs and plants costs, while fewer respondents agreed strongly on the inclusion of Taxes, waste and subcontractors costs as standard information of BOQ (see the tables).Architects responses were very supportive on this. All 13 responded yes for the items, descriptions, units and quantities. And it was only 3 Architects who said yes that BOQ standard information include references of the manufacturers, others who said yes on the breakdown items like labour and plants, were less than 3 .

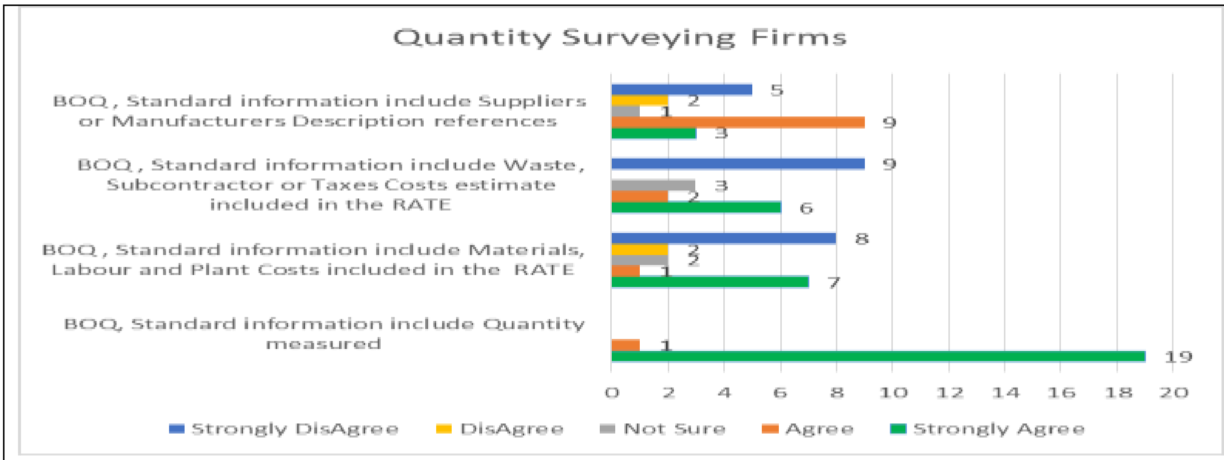



Figure 168:Example of QS responses on the standardised items in the BOQ


**Figure 169: Example of Architects responses on the standardised items in the BOQ**

Interviewees, explained the need to have detailed BOQ. Respondent 12[182] for example, claimed low collaboration resulting into the materials being specified without having enough details of the supplier on hand. This practice, where breakdown items like labour, materials and plants is not common, is also supporting the absence of day works section in most cases. Such practice denies the contractor a chance to improve efficiency in resource planning which may help in costs variations as well (Greenhalgh & Squires, 2011). In Germany and many other European countries, the practice of submitting the breakdown of the rate is common.

***BOQ 3*** contents level was expected to equally indicate the more detailed usage of additional items, like referencing from standards used or more legal usage of query sheets and temporary duration estimates. Unfortunately, the responses indicated the low use of international standards of measurement compared to the local standards. Moreover, additional items mentioned above were strongly disagreed *(refer the previous section of analysis*), indicating that even the use of computer can lowly facilitate their presence. In line with this (Monteiro & Martins, 2013) showed how difficult it is for BIM related Software to facilitate formwork takeoff. It was claimed that having taking off features in software like those of ArchiCAD is not enough because the processing and management of data more than automatic calculation.

Basing on these responses, it was proposed that from the QS, the **BOQ 2** level can be represented by 7 responses on the presence of materials, labour and plants costs in the BOQ. And **BOQ 3** as 6 responses of QS on the presence of lesser standardized items like waste and subcontractors cost. On the other hand, 3 Architects responses of the description of suppliers reflects better the extent of information of BOQ 2, while 1 responses on the presence of labour, materials and plant costs represent **BOQ 3**. The illustration box below explains further.

[182] Respondent 12:“We had a project in XXX University. After BOQ is ready, contractor is onsite, we found that the material we specified without awareness in costs is of higher quotation, and so it brought higher cost and it shocked the project due to the increased cost. Had we collaborated with QS, it would have been solved earlier.”

Illustration Box 17: Respondent 14- Explaining the standardised items in the BOQ

| |
|---|
| *Labour, Plants, Material costs usually vary relative to the environment. Here in Tanzania we do not submit to the tendering process. Day works items sometimes we do not submitting. Provisional works for re-measurement is a usual practice. Duration in the projects is normally set for the entire project not in critical element in the BOQ. At those days, we used to specify, say Sheets from ALAF (Aluminium Africa), but not today. <u>In other countries, manufacturers send the specifiers to the Boards. That simplifies things for us</u>. <u>On the other hand, here we have different clients. Some wish to go and buy by themselves</u>. Under normal circumstances, as designers, we are supposed to write, because we are the one designing and imagining the quality of the product.* |
| |

***BOQ 4*** were indicated the least level in contents. Experienced Quantity Surveying firm of more than 25 years in the industry indicated that the breakdown of the Rate was lowly reflected on the BOQ. Likewise, BOQ include lesser life cycle related contents like replacement costs and maintenance costs. The best Responses from the QS indicated to support ***BOQ 4*** was the presence of the use of ISO documents. On the other hand, the highest response of 2 YES from the Architects indicated the presence of future maintenance costs of the different building components in the BOQ, while on the presence of description and references of manufacturers, responses were 3 YES.

BOQ include (ISO) example (ISO 16739,15926 and 15686)

| | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|
| Strongly Agree | 2 | 10.0 | 10.0 | 10.0 |
| Agree | 3 | 15.0 | 15.0 | 25.0 |
| Not Sure | 3 | 15.0 | 15.0 | 40.0 |
| Disagree | 6 | 30.0 | 30.0 | 70.0 |
| Strongly Disagree | 6 | 30.0 | 30.0 | 100.0 |
| Total | 20 | 100.0 | 100.0 | |

**Figure 170: Example of QS responses on the 5DBIM items in the BOQ**

BOQ 4 items did not end with breakdown of the standardized items of BOQ like that of rate or preliminaries. It included the additional items of maintenance, replacement, disposal, attachments of standards and query sheets. Assumptions used during taking-off and activities duration estimation also formed part of the information expected from the BOQ.QS and Architects responses were in favour of the study in that they indicated low presence of the items. For instance all 13 responses from the Architectural firms said No to the presence of replacement costs in BOQ, while 13 QS strongly disagreed, 5 respondents disagreed, 1 respondent was not sure and 1 agreed.

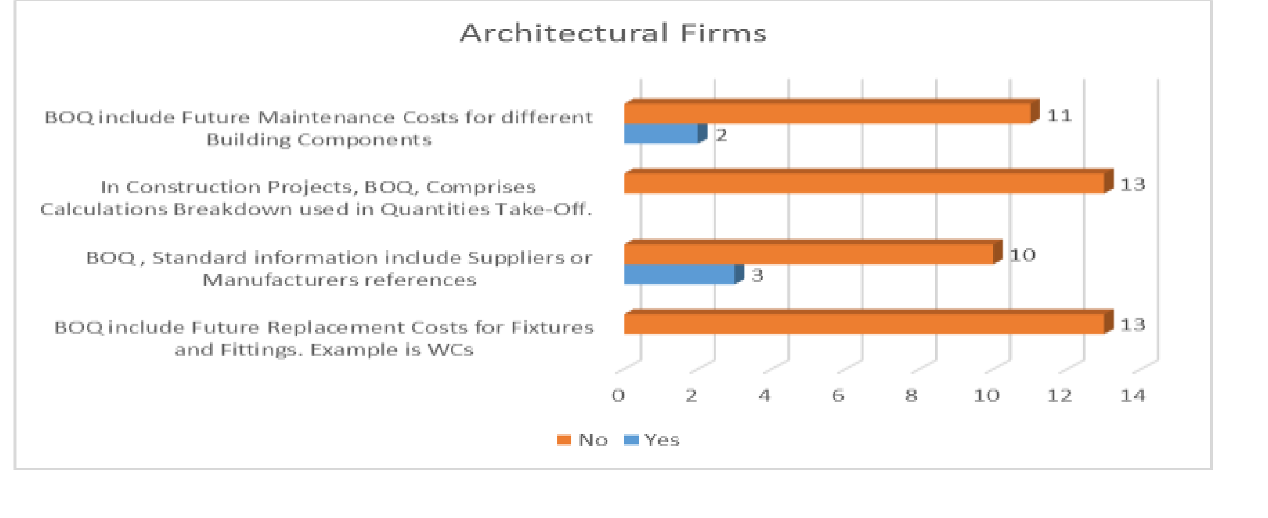



**Figure 171: Example of Architects responses on the 5DBIM items in the BOQ**

Out this description, this study proposed the BOQ 4 for both, QS and Architects to be 2. That is 3 QS responses from table 80, respondents on the presence of ISO. And the 2 responses from Architects in table 81 on the presence of the future maintenance. Interviewees supported this lowly indication of the BOQ 4 (Respondent1[183], 2[184] , 5[185] and 7[186]). The responses indicate that there is awareness of the BOQ 4 items, but the practice is still very low. The items like attachment of assumptions used in the BOQ and international standards organization of life cycle costing were much unfamiliar in the explanation if the respondents.

183 Respondent 1: "We have a big problem in this Area of Life Cost or life Span of the Structure, every expert comes with his or her own specification. So only the warranty from the product manufacturer, gives us hope that the structure will last longer"

184 Respondent 2: "About Cost in Use, our Bills of Quantities (BOQ) does not show directly. It is only within design, because during the design stage, we normally advise the Architect on the selection of materials specified. We normally advise in all element, BUT we do not show in the BOQ, actually even the format of the BOQ has no allowance for that. When you go to the maintenance stage, the project is far over. So it is difficult for them to know what the designers thought. However, there very few projects where the designers are required to produce as built drawings and operational manuals"

185 Respondent 5: "Life cycle costing or maintenance is not in our culture. Actually, I was taught that, maintenance is like repair in the car we use. However, my experience such a practice is difficult, because no one will trust you. For example, if you submit the report of the project this year and then after a short time you are submitting the budget with the request for the maintenance, no one will agree, and mostly they will think that you did not finish the project at the required standard"

186 Respondent 7: "The Life Cycle Costing culture is very low. No any consideration of the future replacement costs or maintenance costs. There are people in the Government, know and want the use of warrant but it is not in the system, so I think it is something we need. We had a government project, and some officials said why the materials specified and supplied do no hat the warranty?"

## 5.4. Prediction Distribution Frequencies on BIM and BOQ levels

In the questionnaires, the last question intended to collect the opinions of the respondents on the likeliness of BIM facilitation in improving overall performance in construction projects. The responses based on the same definition already given in the questionnaire (see appendices).QS responses strongly agreed by more than 50% that BIM is likely to improve detailed drawings, accurate take-off, change order timely costing and handling of provisional sums and quantities. On the items like maintenance and activities duration estimation improvement, QS agreed strongly but with not more than 50% *(See Figure 172: Example of QS responses on whether BIM facilitate performance improvement.).* Architects on the other hand, only strongly agreed that BIM is likely to improve detailed drawings by over 50%, while all other items responded strongly agree were lesser than 50%. All responses from both respondents QS and Architects were mostly of agree or not sure, not of strongly disagree. For instance, responses on the likeliness that BIM may improve pricing of the works, 6 Architects out of 13 responses agreed while 8 QS out of 20 responses agreed, 2 were not sure, 1 disagreed and 9 strongly agreed.

Interviewees' responses also indicated such a perception that BIM may facilitate improvement more of the design oriented activities than costs activities. Respondents (1[187] and 3[188]) give example of opinions from the interviewees that BIM may save time in design and reduce provisional sums resulting from lack of coordination among designers (*See Illustration Box 18: Respondent 6-Explaining the need for BIM in Tanzania).*

## 5.5. Distribution BIM levels and BOQ levels

In general the proposed levels of BIM and BOQ were relative to the responses distribution. However, with close triangulation of the responses it can be seen that, BIM levels 1 and 2 are relatively higher than BIM levels 3 and 4, just like BOQ 1 and 2 as compared to BOQ 3 and 4. Additionally, the cross tabulation between the BIM level items and BOQ level items for both Architects and QS were made. The responses revealed that QS respondents who agreed strongly on the presence of 3DCAD related technology usage and also agreed strongly on the presence of the provisional quantities to be remeasured were 2. On the other hand, the QS respondents who agreed strongly on the measured works section and also agreed strongly on the presence of the use of excel as the existing technology were 16. Again, QS responses indicated low presence BIM 3 and BIM 4

[187] Respondent 1: "*Kuna vitu ambavyo huwezi kuviquantify",* meaning that there are things that you cannot quantify. "There are benefits provided by BIM that cannot be quantified, for example the REWORK, how can you quantify this ITEM, but BIM reduces reworks. We need BIM, and it will improve our way of designing our works".

[188] Respondent 3: "I think BIM will save TIME, because whatever I am going to change, engineers will automatically see and work on it. Not like today, we sometime forget what we told the engineers or we make changes as designers without informing the Quantity Surveyor, at the end is more provisional sums".

levels. No one agreed strongly on both 4DBIM or 5DBIM related technologies and detailed breakdown of the likely BOQ items rate, estimation of duration or life cycle costing items. The figures show the responses on BIM and BOQ items and other are the few of the many cross tabulated items in order to obtain the highest distribution of the BIM against BOQ levels as shown in cross tabulation figures on BIM levels against BOQ levels.

Illustration Box 18: Respondent 6- Explaining the need for BIM in Tanzania

*It is not only about the costs, but also with BIM the variations would be reduced. Because right know what we do is traditional system. Designers, usually Architects, must finish the design first and sometimes they thereafter start to select other professionals. And actually we normally supply drawings at scheme level details. The designs are normally at a very low level of details, and hence the QS cannot even advise on the alternative design. QSs are only used for take-off instead of advising on the cost implications to what designers has given them. Usually Hard Copy is given, or at least today you may give the soft copy. As a result the accuracy of quantities and the information becomes problematic.*

*We designers nowadays are complaining that we are not given time to design. A client gives you an appointment today and wants a design within a months, and in two month a contractor should be on site. And sometime they say we want the building like that of Dubai. Such circumstances, brings copying design and retrieving the former BOQ, as a result too many variations because design is being done on site. BIM will even command the way we practice here in Tanzania. People now are demanding to clients a separate appointment (that is instead of collaboration). They believe it is good for their fees.*

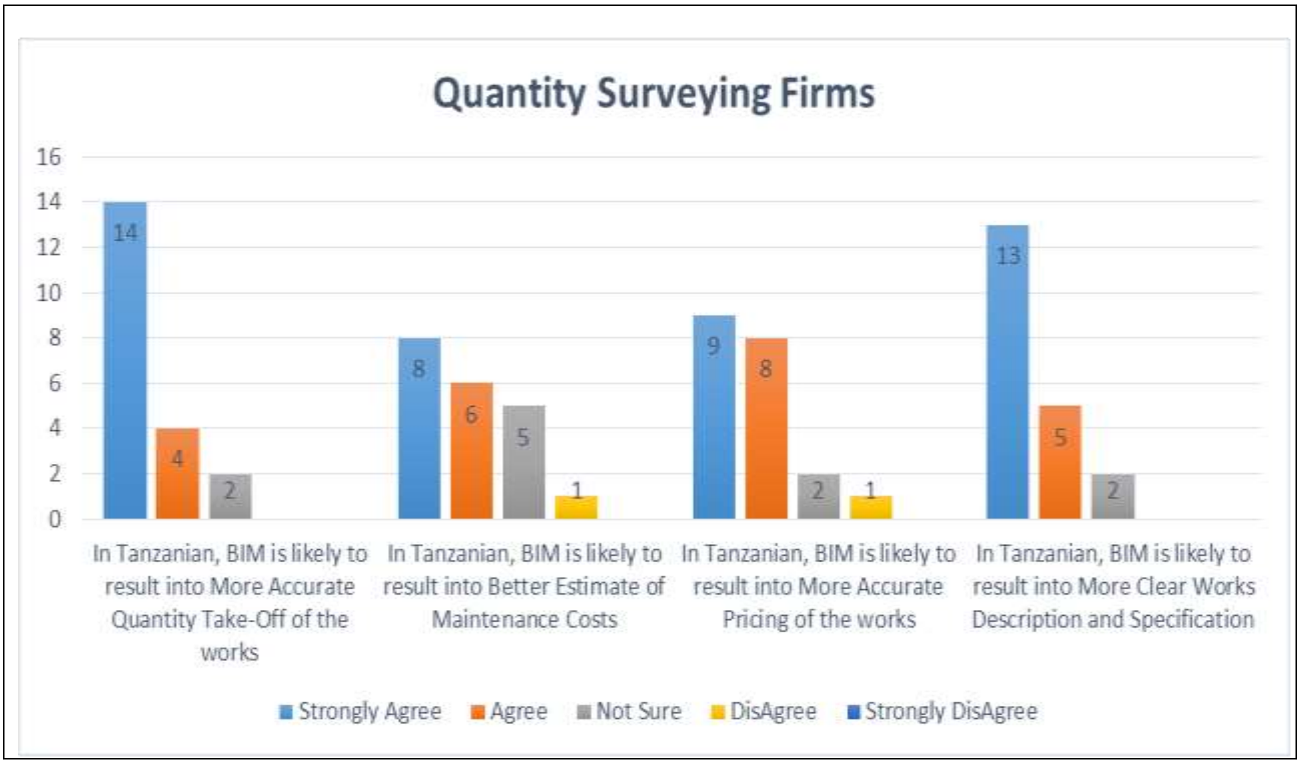



**Figure 172: Example of QS responses on whether BIM facilitate performance improvement**.

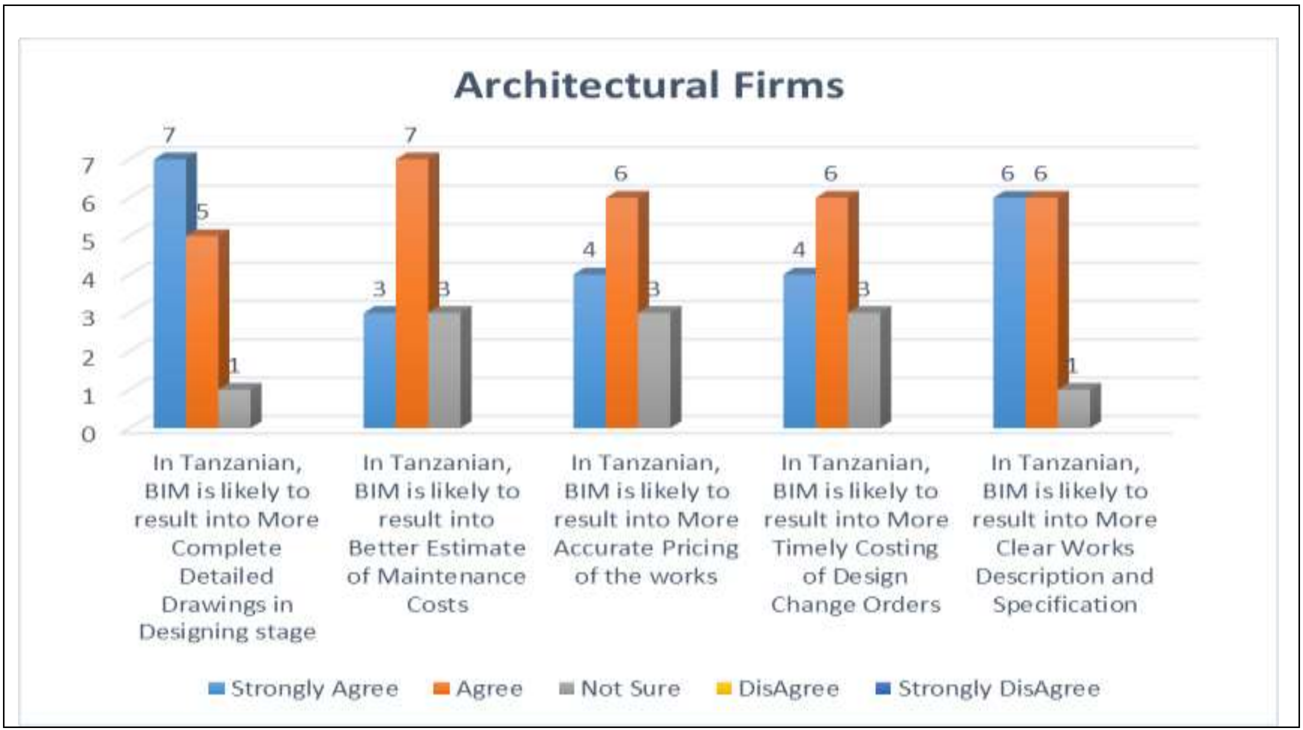



**Figure 173: Architects responses on Likeliness that BIM facilitate performance improvement**.

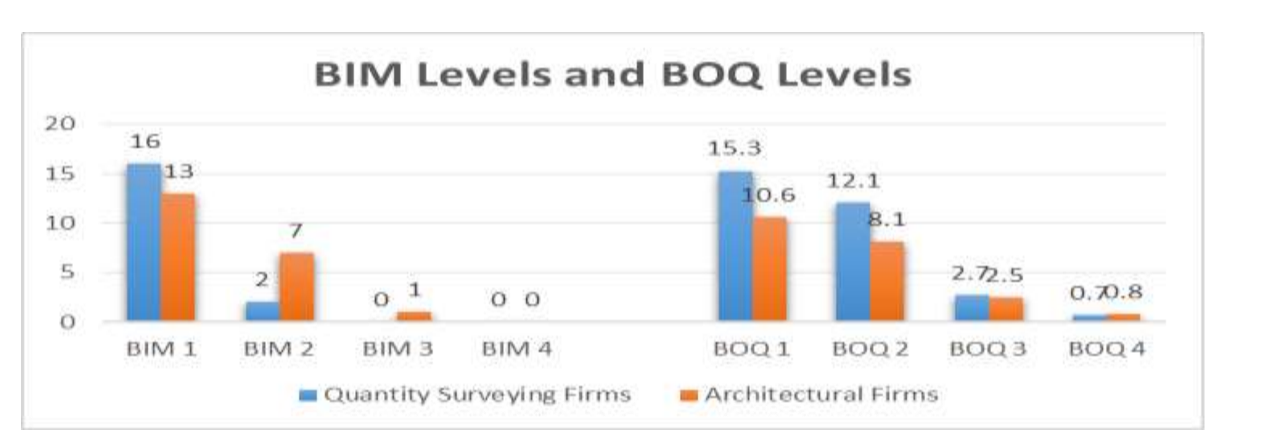



Figure 174: Descriptive Levels of BIM and BOQ (1/2)[189]

| | Items used to measure Basic contents | S/Agree | Agree | Not Sure | DisAgree | S/ DisAgree | Total |
|---|---|---|---|---|---|---|---|
| 5 | In Public Contract; BOQ Sections Include Preliminaries | 19 | 1 | | | | 20 |
| 6 | In Public Contract; BOQ Sections Include Preambles | 14 | 4 | 2 | | | 20 |
| 7 | In Public Contract; BOQ Sections Include Measured | 19 | 1 | | | | 20 |
| 8 | In Public Contract; BOQ Sections Include Provisional Sums | 18 | 1 | 1 | | | 20 |
| 9 | In Public Contract; BOQ Sections Include Prime Costs | 18 | 1 | 1 | | | 20 |
| 10 | In Public Contract; BOQ Sections Include Day Works | 3 | | 2 | 5 | 10 | 20 |
| 11 | BOQ Comprises Provisional Quantities to be remeasured | 16 | 2 | | | 2 | 20 |
| | Average | 15.3 | | | | | |

**Figure 175: Descriptive Levels of BIM and BOQ (2/2)[190]**

[189] Note: The BOQ levels Used in this graph are averages figures of Strongly agrees for QS Firms and Yes for Architectural Firms as shown in the example below.BIM levels only the highest mode of the groups were used.

[190] Note: The BOQ levels Used in this graph are averages figures of strongly agrees for QS Firms and Yes for Architectural Firms as shown in the example below.BIM levels only the highest mode of the groups were used.

| BIM 1 against BOQ 1 | | In Public Contract; BOQ Sections Include Measured | | Total |
|---|---|---|---|---|
| | | Agree | Strongly Agree | |
| In Construction Project Documentation, closer technology used is Microsoft Excel | Not Sure | 0 | 1 | 1 |
| | Agree | 1 | 2 | 3 |
| | Strongly Agree | 0 | 16 | 16 |
| Total | | 1 | 19 | 20 |

| BIM 1 against BOQ 2 | | BOQ, Standard information include Descriptions items | | Total |
|---|---|---|---|---|
| | | Agree | Strongly Agree | |
| In Construction Project Documentation, closer technology used is Microsoft Excel | Not Sure | 0 | 1 | 1 |
| | Agree | 1 | 2 | 3 |
| | Strongly Agree | 0 | 16 | 16 |
| Total | | 1 | 19 | 20 |

| BIM 1 against BOQ 3 | | BOQ , Standard information include Waste, Subcontractor or Taxes Costs estimate included in the RATE | | | | Total |
|---|---|---|---|---|---|---|
| | | S/ Agree | Not Sure | Disagree | S/ Disagree | |
| In Construction Project Documentation, closer technology used is Microsoft Excel | Not Sure | 0 | 0 | 0 | 1 | 1 |
| | Agree | 1 | 1 | 1 | 0 | 3 |
| | Strongly Agree | 5 | 1 | 2 | 8 | 16 |
| Total | | 6 | 2 | 3 | 9 | 20 |

**Figure 176:Example 1- QS responses on the BIM and BOQ items**

| BIM 2 against BOQ 1 | | In Public Contract; BOQ Sections Include Measured | | Total |
|---|---|---|---|---|
| | | Agree | Strongly Agree | |
| In Construction Project Documentation, closer technology used is 3D BIM | Strongly Agree | 0 | 2 | 2 |
| | Agree | 0 | 3 | 3 |
| | Not Sure | 1 | 5 | 6 |
| | Disagree | 0 | 1 | 1 |
| | Strongly Disagree | 0 | 8 | 8 |
| Total | | 1 | 19 | 20 |

| BIM 2 against BOQ 2 | | BOQ, Standard information include Descriptions items | | Total |
|---|---|---|---|---|
| | | Agree | Strongly Agree | |
| In Construction Project Documentation, closer technology used is 3D BIM | Strongly Agree | 0 | 2 | 2 |
| | Agree | 0 | 3 | 3 |
| | Not Sure | 1 | 5 | 6 |
| | Disagree | 0 | 1 | 1 |
| | Strongly Disagree | 0 | 8 | 8 |
| Total | | 1 | 19 | 20 |

**Figure 177: Example 2- QS responses on the BIM levels against BOQ items**

| BIM 3 against BOQ 1 | | BOQ, Standard information include Quantity measured | | Total |
|---|---|---|---|---|
| | | Agree | Strongly Agree | |
| In Construction Project Documentation, closer technology used is MasterSeries ,Auto CAD MEP e.t.c | Strongly Agree | 0 | 1 | 1 |
| | Agree | 1 | 0 | 1 |
| | Not Sure | 0 | 9 | 9 |
| | Disagree | 0 | 1 | 1 |
| | Strongly Disagree | 0 | 8 | 8 |
| Total | | 1 | 19 | 20 |

| BIM 3 against BOQ 3 | | BOQ include Preliminaries Costs Break down. Example: Time Based or Progress Based | | | | | Total |
|---|---|---|---|---|---|---|---|
| | | Strongly Agree | Agree | Not Sure | Disagree | Strongly Disagree | |
| In Construction Project Documentation, closer technology used is MasterSeries ,Auto CAD MEP e.t.c | Strongly Agree | 1 | 0 | 0 | 0 | 0 | 1 |
| | Agree | 0 | 0 | 0 | 1 | 0 | 1 |
| | Not Sure | 1 | 1 | 1 | 5 | 1 | 9 |
| | Disagree | 0 | 0 | 0 | 1 | 0 | 1 |
| | Strongly Disagree | 2 | 1 | 1 | 1 | 3 | 8 |
| Total | | 4 | 2 | 2 | 8 | 4 | 20 |

| BIM 3 against BOQ 4 | | BOQ include (ISO) example (ISO 16739,15926 and 15686) | | | | | Total |
|---|---|---|---|---|---|---|---|
| | | Strongly Agree | Agree | Not Sure | Disagree | S/Disagree | |
| In Construction Project Documentation, closer technology used is MasterSeries ,Auto CAD MEP e.t.c | Strongly Agree | 1 | 0 | 0 | 0 | 0 | 1 |
| | Agree | 0 | 0 | 0 | 1 | 0 | 1 |
| | Not Sure | 0 | 2 | 2 | 3 | 2 | 9 |
| | Disagree | 0 | 0 | 0 | 1 | 0 | 1 |
| | Strongly Disagree | 1 | 1 | 1 | 1 | 4 | 8 |
| Total | | 2 | 3 | 3 | 6 | 6 | 20 |

**Figure 178: Example 3- QS responses on the BIM levels against BOQ items**

| BIM 1 against BOQ 1 | | In Public Contract; BOQ Sections Include Preliminaries | Total |
|---|---|---|---|
| | | Yes | |
| In Construction Project Documentation, closer technology used is 2D CAD and 3D Computer Aided Design | Yes | 13 | 13 |
| Total | | 13 | 13 |

| BIM 2 against BOQ 1 | | In Public Contract; BOQ Sections Include Preliminaries | Total |
|---|---|---|---|
| | | Yes | |
| In Construction Project Documentation, closer technology used is Auto Desk Revit, Vector works and Allplan Nemetschek | Yes | 7 | 7 |
| | No | 6 | 6 |
| Total | | 13 | 13 |

| BIM 3 against BOQ 1 | | In Public Contract; BOQ Sections Include Preliminaries | Total |
|---|---|---|---|
| | | Yes | |
| In Construction Project Documentation, closer technology used is MasterSeries ,Auto CAD MEP e.t.c | Yes | 4 | 4 |
| | No | 9 | 9 |
| Total | | 13 | 13 |

| BIM 1 against BOQ 4 | | BOQ include Future Maintenance Costs for different Building Components | | Total |
|---|---|---|---|---|
| | | Yes | No | |
| In Construction Project Documentation, closer technology used is 2D CAD and 3D Computer Aided Design | Yes | 2 | 11 | 13 |
| Total | | 2 | 11 | 13 |

**Figure 179: Example 1- Architects responses on the BIM and BOQ items**

| BIM 1 against BOQ 3 | | In Tendering; Additional information to BOQ RATE include Subcontractor | | Total |
|---|---|---|---|---|
| | | Yes | No | |
| In Construction Project Documentation, closer technology used is 2D CAD and 3D Computer Aided Design | Yes | 2 | 11 | 13 |
| Total | | 2 | 11 | 13 |

| BIM 1 against BOQ 2 | | BOQ , Standard information include Suppliers or Manufacturers references | | Total |
|---|---|---|---|---|
| | | Yes | No | |
| In Construction Project Documentation, closer technology used is 2D CAD and 3D Computer Aided Design | Yes | 3 | 10 | 13 |
| Total | | 3 | 10 | 13 |

| BIM 2 against BOQ 4 | | BOQ include Future Maintenance Costs for different Building Components | | Total |
|---|---|---|---|---|
| | | Yes | No | |
| In Construction Project Documentation, closer technology used is 3D BIM | Yes | 1 | 4 | 5 |
| | No | 1 | 7 | 8 |
| Total | | 2 | 11 | 13 |

| BIM 4 against BOQ 1 | | In Public Contract; BOQ Sections Include Preliminaries | Total |
|---|---|---|---|
| | | Yes | |
| In Construction Project Documentation, closer technology used is Graph iSOFT MEP, ECOTEC Analysis, CISCO IT and COBie | Yes | 1 | 1 |
| | No | 12 | 12 |
| Total | | 13 | 13 |

**Figure 180: Example 2- Architects responses on the BIM and BOQ items**

| BIM 2 against BOQ 2 | | In Tendering; Additional information to BOQ RATE include Material | | Total |
|---|---|---|---|---|
| | | Yes | No | |
| In Construction Project Documentation, closer technology used is Auto Desk Revit, Vector works and Allplan Nemetschek | Yes | 2 | 5 | 7 |
| | No | 1 | 5 | 6 |
| Total | | 3 | 10 | 13 |

| BIM 3 against BOQ 3 | | In Tendering; Additional information to BOQ RATE include Overheads | | Total |
|---|---|---|---|---|
| | | Yes | No | |
| In Construction Project Documentation, closer technology used is MasterSeries ,Auto CAD MEP e.t.c | Yes | 1 | 3 | 4 |
| | No | 1 | 8 | 9 |
| Total | | 2 | 11 | 13 |

**Figure 181: Example 3- Architects responses on the BIM and BOQ items**

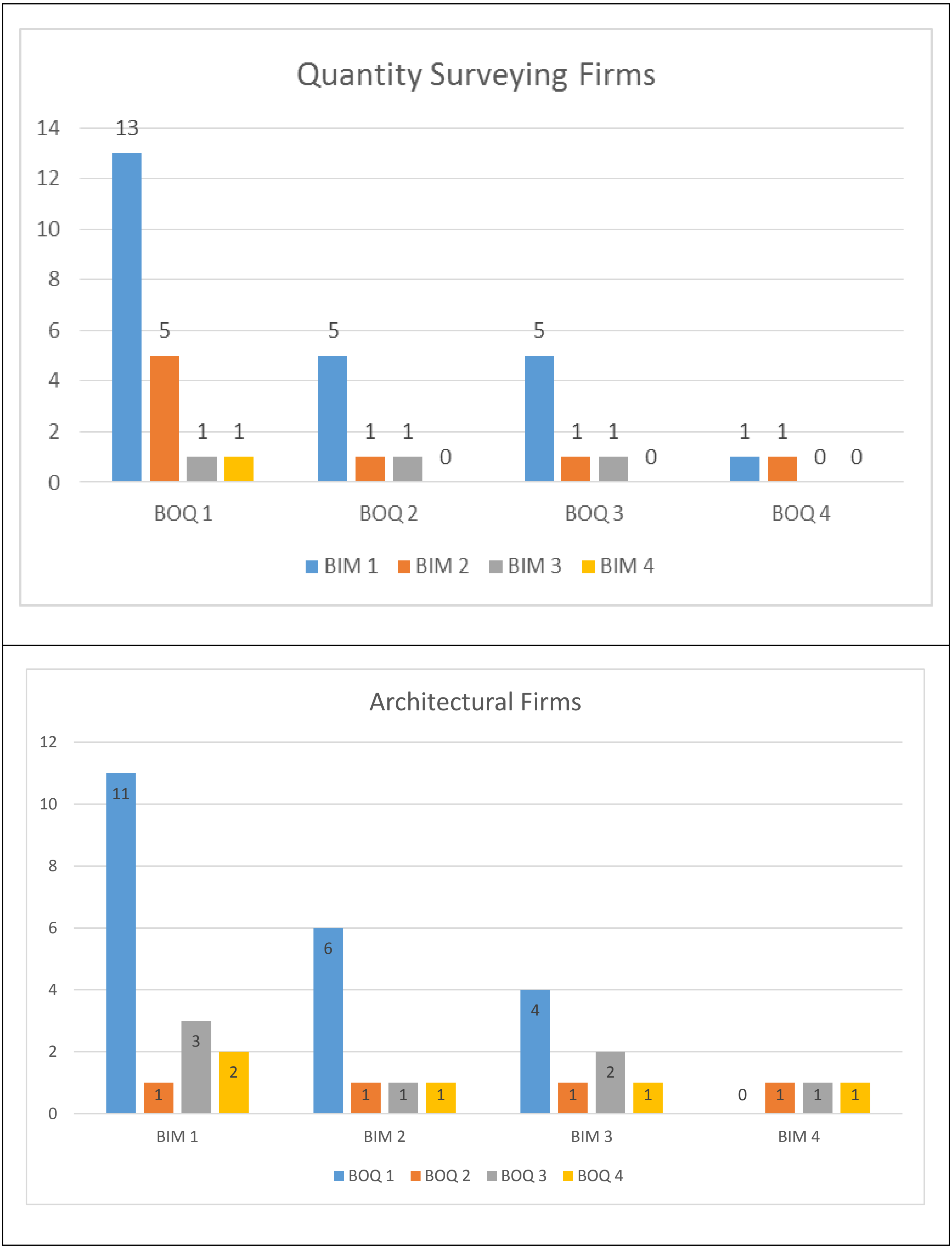



**Figure 182: Cross-tabulation of respondents on the BIM levels against BOQ levels**[191]

191 NOTE: QS Firms responses were those who strongly agreed on the presence of Excel as well.

## 6. Inferential Analysis or Statistical Analysis

The aim of this study is to appraise BIM in Tanzania. The approach used intended to first develop a technologically simple and economical BIM model that can be tested in the environment of Tanzania. There after the model can be developed to the world level capabilities. To attain that, the theoretical hypothesis on the key value of BIM were set forth, which was "In Total Costs Management (TCM), BIM improves BOQ productivity". To test this a research hypothesis proposed was "***In TCM, 5DBIM levels has positive effects on BOQ completeness***". The intention being to test using cross-sectional design whether there is significant relation between BIM and BOQ completeness improvement in the construction industry environment of Tanzania or otherwise stated, whether the absence of BIM usage could be related to the incompleteness of the BOQ used in Tanzania. It was expected that, through such an endavour, more experiments or observations necessary to appraise BIM in Tanzania may as well be developed.

### 6.1. Hypothesis Testing.

Recalling from the *Illustration Box 11: Illustration of Conceptualisation and Operationalisation*, the null hypothesis of this study is *"Ho: The use of 5D BIM has no effect on BOQ Completeness"*, while the alternative is *"H1: The use of 5D BIM has positive effect on BOQ Completeness"*. The hypotheses were chosen well before the data collection, as it is dangerous to derive the hypothesis from the data, mentioned (Kothari, 2004) in page 225. The study was set as a dependent tests of association and so samples were expected to give both predictor and responses scores.

It was calculated that a significance level of 5% and probability of success at 50%,which gave two sample sizes of Architects (134 out of 204 if randomly sampled) and Quantity Surveyors (83 out of 105 if randomly sampled),were sufficient. However the difficulties encountered lead to the need to purposeful effort to suppliment the collection of 13 (15% respponse rate) questionnaires from the Architects and 20 (24% response rate) from the Quantity surveying firms. The difficult to obtain the observational opportunity from the best practice part of the study, that is in Germany, equally lead to the need to only use ordinal scale measurement instead of interval or ratio,and so the use of Nonparamentric tests of hypothesis.Another assumption that lead to the reliance on non-paramentric tests was that the doubt on whether BIM practicing professionals are normally distributed, despite the well officially known sample frame of professionals from the authorities.

To use Gamma coefficient in the hypothesis testing is not different from other ways. It involves among others the stating of the hypotheses, both null and alternative, recalling the assumptions, setting the decision rule, calculating the Gamma coefficient and testing by comparing to the ***z*** or ***t*** tests depending on the assumptions. This study, in testing the significance of the association, assumed the non-normal distribution sampling, small sample and non-random sample. The Null Hypothesis Ho: B1=B2, while the alternative H1: B1≠ B2, specifically stated as H1:B1>B2 (Right Tailed) to indicate the direction. B1 stands as the mode value of *gamma* representing the population supporting the association of 5DBIM levels and BOQ completeness levels in 5DBIMBOQ and Non5DBIMBOQ. As such gamma value of B2=0 in Null Hypothesis. The critical region used were at $\alpha=0.05$, meaning the rejection of the null hypothesis is only when the statistic value of the observed evidences is within right tail of critical value of (t-value) at 5%.Given the degree of freedom, Architectural responses (13-1=12) critical value at t= 0.05 upper tail was found 1.782[192] and QS (20-1=19) firms was 1.729.

Gamma calculation formula is given as ***Gamma (G) = (NS-ND) / (NS+ND).***where ***Ns*** refers to the cases (here refers to *occurrences of the modes*) ranked in the same order on both variables. In this study, these are the modes that when they indicate low BIM level, they equally indicate low BOQ completeness level. ***Nd*** on the other hand, it represents the opposite in that, it represents the pairs ranked differently. When a positive results of Gamma is found, it indicates relationship of variables increasing or decreasing toward the same direction, while a negative sign means the variables decreases and increases towards different directions. According to (Rea & Parker, 2005), (-1 is a perfect inverse association and (+1) is a perfect positive association. From the tables *(Figure 184:Quantity Surveying Observations on the BIM and BOQ Completeness levels and Figure 185: Architects Observations on the BIM and BOQ Completeness levels)*, the Quantity Surveying and Architects observations can be converted into the Gamma test of significance using the highest modes values in Non 5DBIM and 5D BIM exposure against low productive BOQ (Incompleteness in BOQ) and Higher productive BOQ (Completeness in BOQ).

### 6.2. Hypothesis Test Conclusion.

In both tests, from Quantity Surveying and Architectural firms the results of gamma indicates presence of association. The QS responses show a moderate positive association of (+0.52), while Architects responses indicates presence of a low positive association of (+ 0.24). So it may be said that there is a moderate positive correlation between perceived increase in BIM usage and increase in completeness of BOQ contents in the construction projects in Tanzania. On the other hand, the results of the hypothesis tests indicates the fail to reject the null hypothesis, as the observed t-values are ***0.59*** which is lesser to ***1.729*** for QS and ***0.25*** which is lesser to ***1.782*** for Architectural Firms. The association is not significant at 5%.

[192] NOTE: The critical values were from (Kothari, 2004) Page 441

| F | Measure | Interpretation |
|---|---|---|
| 1 | -1.00 | Perfect Inverse Association |
| 2 | (-0.75) to (-0.99) | Very Strong Inverse Association |
| 3 | (-0.60) to (-0.74) | Strong Inverse Association |
| 4 | (-0.30) to (-0.59) | Moderate Inverse Association |
| 5 | (-0.10) to (-0.29) | Low Inverse Association |
| 6 | (-0.01) to (-0.09) | Negligible Inverse Association |
| 7 | 0 | No Association |
| 8 | (+0.01) to (+0.09) | Negligible Positive Association |
| 9 | (+0.10) to (+0.29) | Low Positive Association |
| 10 | (+0.30) to (+0.59) | Moderate Positive Association |
| 11 | (+0.60) to (+0.74) | Strong Positive Association |
| 12 | (+0.75) to (+0.99) | Very Strong Positive Association |
| 13 | 1.00 | Perfect Positive Association |

**Figure 183: Interpretation of the Calculated Gamma. 193**

**Illustration Box 19: Gamma t-Test formula used**

**T- Gamma Value is given by the formula in approximation to be equal to**

$$t = G\sqrt{(NS + ND)/(No(1 - G^2}))$$

**Where**
**..t is the Gamma statistic test Value**
**No is the number of observations found**
**G is the Gamma Value Calculated from the observations (No)**

[193] Source: Rea, L. M., & Parker, R. A. (2005)

| | | | LOW BOQ PRODUCTIVITY | | HIGH BOQ PRODUCTIVITY | | |
|---|---|---|---|---|---|---|---|
| | Definitions Used | | IN-COMPLETE | LESSER COMPLETE | COMPLETE | MORE COMPLETE | |
| | | Numbers | (BOQ1) | (BOQ2) | (BOQ3) | (BOQ4) | |
| Lowly BIM Exposure (NON 5DBIM) | LOW BIM LEVEL (NON BIM) | BIM1 | 16 | 16 | 5 | 1 | 38 |
| | | | | | | | |
| | BIM LEVEL (BIM) | BIM2 | 2 | 2 | 1 | 0 | 5 |
| | | | | | | | |
| Highly BIM Exposure (5DBIM) | LOW 5DBIM LEVEL (NON 5DBIM) | BIM3 | 1 | 1 | 1 | 0 | 3 |
| | | | | | | | |
| | BIM ENVIRONMENT (5DBIM) | BIM4 | 1 | 1 | 0 | 0 | 2 |
| | | | 20 | 20 | 7 | 1 | 48 |

**Figure 184:Quantity Surveying Observations on the BIM and BOQ Completeness levels**

| | | | LOW BOQ PRODUCTIVITY | | HIGH BOQ PRODUCTIVITY | | |
|---|---|---|---|---|---|---|---|
| | Definitions Used | | IN-COMPLETE | LESSER COMPLETE | COMPLETE | MORE COMPLETE | |
| | | Numbers | (BOQ1) | (BOQ2) | (BOQ3) | (BOQ4) | |
| Lowly BIM Exposure (NON 5DBIM) | LOW BIM LEVEL (NON BIM) | BIM1 | 13 | 13 | 2 | 2 | **30** |
| | | | | | | | |
| | BIM LEVEL (BIM) | BIM2 | 7 | 2 | 1 | 1 | **11** |
| | | | | | | | |
| Highly BIM Exposure (5DBIM) | LOW 5DBIM LEVEL (NON 5DBIM) | BIM3 | 4 | 1 | 1 | 1 | **7** |
| | | | | | | | |
| | ENVIRONMENT (5DBIM) | BIM4 | 1 | 1 | 1 | 1 | **4** |
| | | | **25** | **17** | **5** | **5** | **52** |

**Figure 185: Architects Observations on the BIM and BOQ Completeness levels**

| | NON 5DBIM | 5DBIM | |
|---|---|---|---|
| IN-COMPLETE BOQ | 16 | 1 | 17 |
| COMPLETE BOQ | 5 | 1 | 6 |
| | 21 | 2 | 23 |
| | NS=16*1 | 16 | |
| | ND=1*5 | 5 | |

| | | | | |
|---|---|---|---|---|
| G | Ns-Nd | | 11 | |
| | Ns+Nd | | 21 | |
| G | | | 0.52 | |
| t | | 0.587714286 | | |
| G | | 0.523809524 | | |
| Ns | | 16 | | |
| Nd | | 5 | | |
| No | | 23 | | |
| G2 | | | 0.27 | |
| 1-G2 | | | 0.73 | |
| No(1-G2) | | | 16.69 | |
| NS +ND | | | 21 | |

**Figure 186: Gamma Calculation for QS**

| | NON 5DBIM | 5DBIM | |
|---|---|---|---|
| IN-COMPLETE BOQ | 13 | 4 | 17 |
| COMPLETE BOQ | 2 | 1 | 3 |
| | 15 | 5 | 20 |
| | NS=13*1 | 13 | |
| | ND=4*2 | 8 | |

| | | | | |
|---|---|---|---|---|
| G | Ns-Nd | | 5 | |
| | Ns+Nd | | 21 | |
| G | | | 0.24 | |
| t | | 0.25119048 | | |
| G | | 0.23809524 | | |
| NS | | 13 | | |
| ND | | 8 | | |
| No | | 20 | | |
| G2 | | | 0.0566893 | |
| 1-G2 | | | 0.9433107 | |
| No(1-G2) | | | 18.866213 | |
| NS +ND | | | 21 | |

**Figure 187: Gamma Calculation for Architectural firms**

## IX. Results and Discussion

### 1. Findings

The Main objective of this research was to appraise the use of BIM in improving Total Performance Delivery of Public Construction Project in Tanzania. Specifically the study intended to describe the relationship of 5DBIM and (BOQ) productivity in Total Cost Management in Public Project and to suggest a model for the adoption of BIM in Tanzania. As such it was hypothesized that if 5D BIM has positive effect in Bills of Quantities (BOQ) Completeness level, then the use of BIM can improve BOQ Productivity in the Total Cost Management of construction projects in Tanzania. In this study, the findings has been categorized into three main subsections. The findings from hypothesis testing, which intended to give the inferential view found in the study. Another categories are the findings on the presence of BIM and presence of BOQ completeness in the construction of Tanzania.

### 1.1. Inferential Results.

The Quantity Surveyors results of hypothesis testing has indicated the likely perception of moderate positive association (+0.53) between the usage of 5D BIM levels and BOQ Completeness level. Architectural Firms indicated a low positive association of +0.24 Gamma ratio (*See Figure 186: Gamma Calculation for QS and Figure 187: Gamma Calculation for Architectural firms*). Using the (+0.24) low positive association from the Architectural Firms responses, it may be interpreted that there is a chance that when 5DBIM is used in the Tanzanian construction industry, it may lead to at least 24 % increase in the BOQ informational contents. This may proportionally give rise to improved BOQ productivity in Total Cost Management. In (Monteiro & Martins, 2013), BIM has a closer relation to the quantity take-off, which is among the key activities in the project life cycle. Likewise, the study review has shown that 5DBIM is the optimum cost informational generator (Please refer *Figure 85: 5D BIM basic information as compared to other BIM* dimensions), including quantity taking-off activities (*See the Figure 188: Relationship of the Quantity Take-off and other project activities*).Quantities are vital in total costs management (as explained before)[194]. Quantities are the way to work structure breakdown necessary for the time and cost management in the construction projects (Halpin & Senior, 2012).

[194] Literature Review: "In order to manage, one should be able to control. In order to control, one should be able to measure. In order to measure, one should be able to define. In order to define, one should be able to quantify". (Quoted from Burchfield, (1970), by (Halpin & Senior, 2012)).

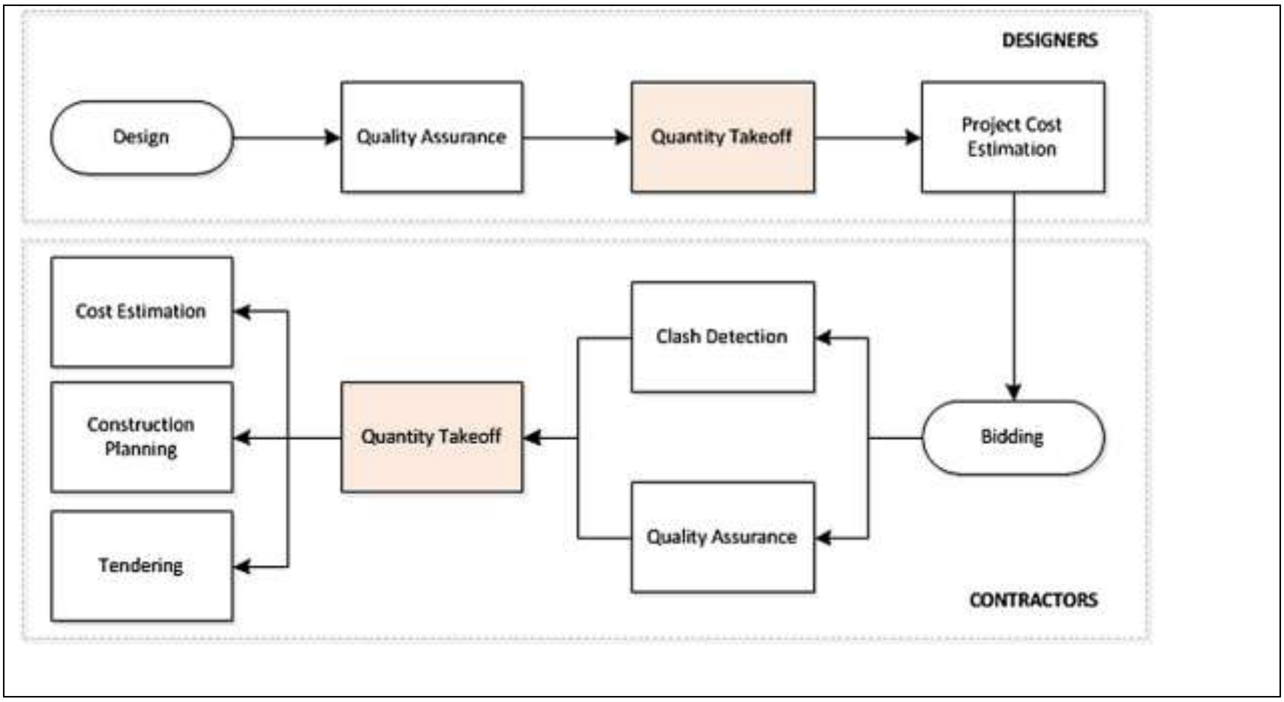



**Figure 188: Relationship of the Quantity Take-off and other project activities[195]**

The search for more evidences for the strong associational and causality effects is equally worth, because these results shown are insignificant at 5%. According to (Monko & Roider, 2014) the future research works of BIM in Tanzania include developing *a country-specific BIM adoption strategy*. In that study, about 81% of the respondents believed that lack of advanced technologies such as BIM has a *large/very large* negative impact on the project performance. A strategy for a country specific BIM is needed, which is logically calling upon the need for more research on the fundamental relation between BIM and construction project performance in order to develop the context specific BIM model for Tanzania. This hypothesis testing has shown a failure to significantly reject the null hypothesis. That is to say, increased BOQ informational level may not necessarily come from BIM usage. It is an indication that the low effect of BIM is still at a very individual level if any at all. The respondent 19[196], for instance, argued that fully implementation of BIM in Tanzania, may take time because the industry is operating in individualistic manner. This indicates that the challenge of BIM model suitable for Tanzanian construction industry may need among others, the solid base of what is real tangible about BIM in Tanzania. In Germany and many other countries, *country- specific* BIMs

[195] Source: Monteiro, A., & Martins, J. P. (2013). A survey on modelling guidelines for quantity take-off-oriented BIM-based design. Automation in Construction 35, 238-253.

[196] Respondent 19: "In our practice, BIM will take time to be in effect because people are business oriented than system oriented. We are doing design on our own way without integration of information. We normally do not have time to discuss the design before going into construction. We normally do not do internal site meeting, or even communicate between one another, until we are on site. BIM will work better in Design and Build. However, here we are not using DB, except XYZ (Firm in RES 1). Although the board has stopped them for the tax reasons. In design and Build, the boss is the contractor. He will prepare BOQ, which will be compared by the consultant BOQ."

are equally said to be at their infant stages, despite the noticeable individual efforts from participants (McGraw-Hill, 2010). This may be because it is difficulty and necessary to find out the common BIM base that can drive the changes to the whole construction system.

### 1.2. Descriptive Results

In this study, a total of 20 questionnaires were used from the Quantity Surveying Firms, 13 questionnaires from Architectural Firms and 21 semi-structured questionnaires from ongoing projects in Dar Es Salaam were administered. The total number of registered firms as per AQRB, was 105 for Quantity Surveying and 204 Architectural Firms. This study collected data from participants in the ongoing projects, with the intention to objectively obtain the evidence with regard to BIM usage and the Bills of Quantities used in those project. A total of 21 projects participants' representatives were interviewed, from Road Works, Commercial and Housing Building Works under Government and Private Entities. The focus was on the selected key personnel, which were Quantity Surveyors, Architects and Engineers. However, given the situation, any appropriate officer, like facility manager, procurement officer and investment officer for some institution were equally interviewed. Likewise, a group of expert where necessary were all together questioned. The findings are structured according to the measured variables. BIM levels as predictors and BOQ completeness levels are response variables. In BIM the non 3D BIM and 3D BIM technologies are described under presence of BIM, while the non 5D BIM and 5D BIM results are described under presence of 5D BIM. BOQ levels on the other hand has been described under basic, standardized, detailed standardized and 5DBIMBOQ contents.

## 2. Presence of BIM and BOQ completeness in Tanzania

The findings indicate the dominance of non BIM technologies. BIM practice is indicated to be ***low*** in Tanzania. The presence of BIM related software was found to be low, although many consultants are using computer related technologies in designing and project documentation. The use of technologies at the level of 3DCAD and 3DBIM related technologies is noticeable among practitioners, especially Architects. This relates to the findings of (McGraw-Hill, 2010), where Architects were the leading professional in BIM adoption. For instance, while all Architectural firms agreed on the presence of CAD and 3D CAD usage, about (54%) or (7 respondents out of 13) Architectural firms agreed to the presence of technologies closer to Building Information Modelling (BIM), like Autodesk Revit and Nemetschek. Likewise responses from QS firms showed a related trend, which suggest the presence of low usage of BIM and BIM related software (See the *Figure 189: BIM presence in Construction Project Documentation, as closer technology.*).According to (BCIS (Building Cost Information Services), 2011), the surveyed quantity surveyors and building surveyors were found mostly not using

BIM. The report showed that surveyors believed that clients are supposed to demand the use of BIM in order to foster the development. Such a responses were equally found in (Monko & Roider, 2014). It was found that over 78% of the respondents believe that lack of demand of BIM from the clients contributes to the low BIM practice in Tanzania. As such, it is likely that professionals assume BIM to be of necessary only when clients wants.

BIM is not distinguished from the normal CAD practice to a large extent. The documentation with less details is becoming a norm in the practice, giving rise to unnecessary provisions and variations as Respondent 1[197] and 14[198] explained. Awareness of both clients and participants, especially designers is important. In Finland for instance, in (Howard & Bjork, 2008) it was reported that the raising of BIM usage over CAD technologies were accompanied by the better realization of the strengths of 3D BIM objects concepts. Therefore, like anywhere else, in Tanzania, the clients need to appreciate the potential of BIM before they embark on fostering the adoption. BIM is here to stay (BCIS (Building Cost Information Services), 2011).

[197] Respondent 1: "We have BIM but at the very basic level, of computer aided design. In our team of experts, Architects are leading the practicing of this lower level of CAD or BIM, and Quantity Surveyor are far from it. We need BIM, and it will improve our way of designing our works. VARIATIONs in our projects is almost standard. If we could even manage to attain the increase of costs due to variation not to exceed 10%, it would be a success project"

[198] Respondent 14: "We normally use 3D views to elaborate to the client. I have read about BIM, and seen it in Revit. However, I have not practice. We real need it, to my views"

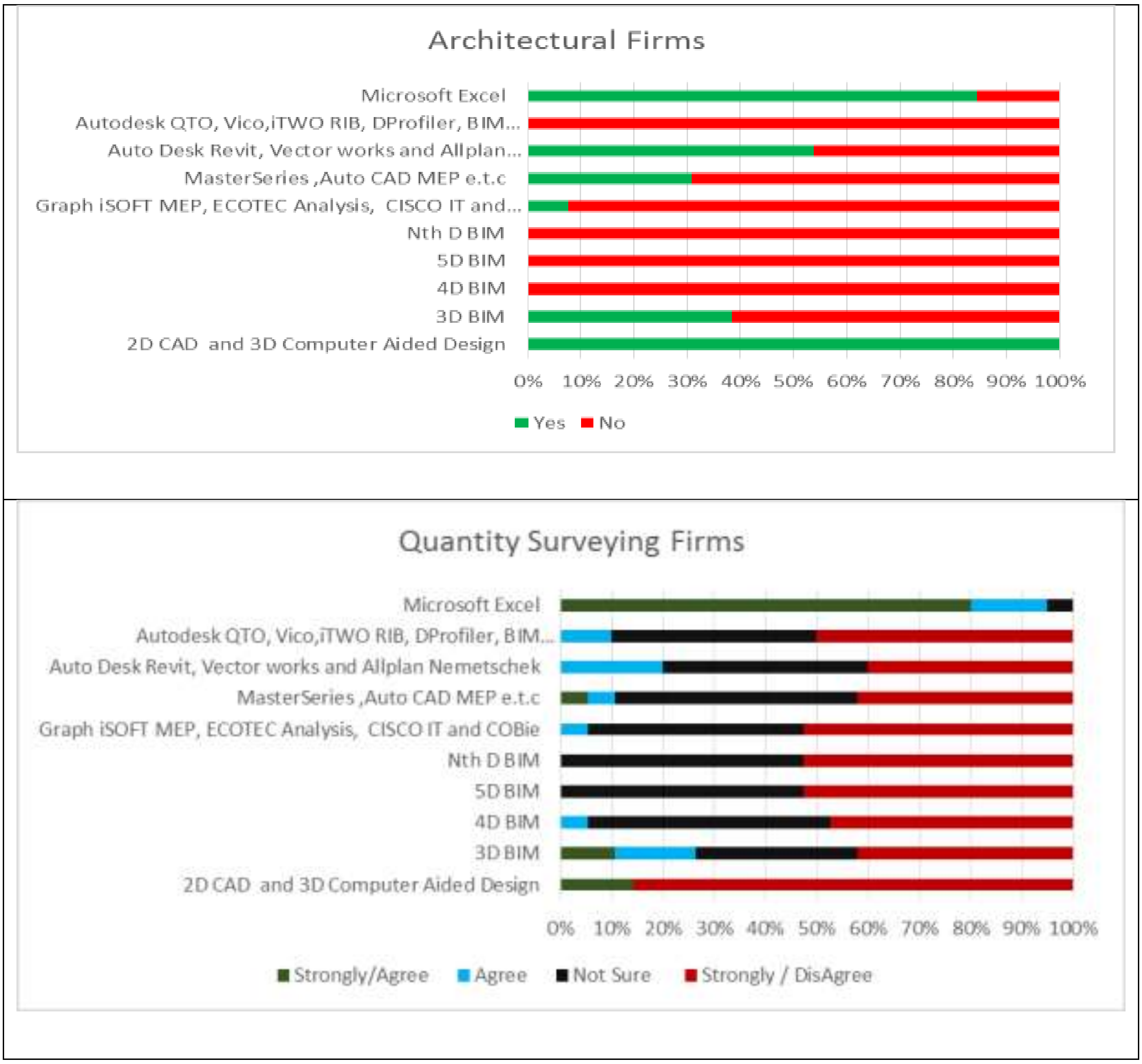



**Figure 189: BIM presence in Construction Project Documentation, as closer technology.**

## 2.1. Presence of 5D BIM

The low level of BIM is clear on the absence of 4, 5 and NthD BIM related technologies practice. This finding indicated the presence of low use of BIM in cost and time construction documentation and communication. It equally support the presence of low practice of BIM in quantity surveyors firms because QS are the key participants in cost documents preparation in Tanzania. The use of a non-real time 3DCAD graphics dominates the industry and the clients are satisfied, and hence the professionals find no need to improve the situation, unless clients demand so. In (RICS, 2014), governmental push, clients and market competitiveness are the key drivers of BIM usage. Commitment of the Scandinavian countries public sector, were cited as an example. Also, it was pointed out that when clients realize the post contract value of BIM, they tend to demand more and more of it. The same applies to a participant who discovers how BIM can raise the competence in the market competition. Clients in Tanzania, may not be aware of the possibilities of the more value adding information that higher BIM level can provide. This informational strength of BIM is found in the $4^{th}$, $5^{th}$ and NthD BIM. The advantages like *real-time* time and life cycle cost simulation, which not only improve *collaboration*, but also increases *transparency* that clients need during project undertaking. Clients need to openly and in a simplified manner understand the information communicated in project. BIM can real facilitate disclosing the hidden contradictions. A respondent 16[199], for instance showed interest on the model, yet declared to have never seen.

Without higher BIM levels, it is difficult to optimally visualize the whole life of the project. The low level of BIM found is a good indication of inadequacy of *life cycle costing* practice. Life cycle costing requires database for the historical data (Ashworth, 1999), which can easily be facilitated by higher level BIM. Life cycle assessment has already been internationally standardized. An industry that is not thinking about life cycle assessment is endangering itself from the international competitiveness. Likewise, inadequacy 4D technologies indicates reliance on the traditional way of designing, which (Halpin & Senior, 2012) suggested that it is no longer facilitating the integrated decisions. 4D technologies help designers to visualize and analyze *real-time* time schedule, which other participants can efficiently understand (*See the Figure 190: Example Scheduling in 4D BIM technologies*).

On top, it is through higher BIM level, the participants can efficiently collaborate to analyze more other critical issues like safety and sustainability. According to (Sabol, 2013), space management, visualisation,energy efficiency and sustainability management, security and display of real time data are among the benefits that facility managers or owners can get from BIM. In Masdar Headquarter

[199] Respondent 16: “I have not seen this Model. I think it is a good idea, because it gives transparency. I as somehow nonprofessional in construction, I can visualise the project more than in drawings. We normally have the preliminary costs mentioned aside and the image or graphic of the building. Where does this BIM work in Tanzania?”

Case Study in Masdar City project in Abu Dhabi, (Hardin, 2009) reported on page 250 that BIM helped to achieve sustainable construction. Among others, the project aimed at achieving zero carbon emissions, zero waste, paperless documentation management system, energy savings and efficiency and zero claims. Apart from trying to use 4D BIM, it was reported that the vision was to use 5, 6, 7 and 8D BIM in full. Although it is still a challenge even in Europe (Motawa & Carter, 2013), where the use of BIM in other purposes was found to be about 36% (McGraw-Hill, 2010), yet it is more dangerous to Tanzania because of the indication that professionals do not even thinking about it. Actually, BIM is prospering to the more diversified use like that of water distribution codification, as explained in (Martins & Monteiro, 2013).

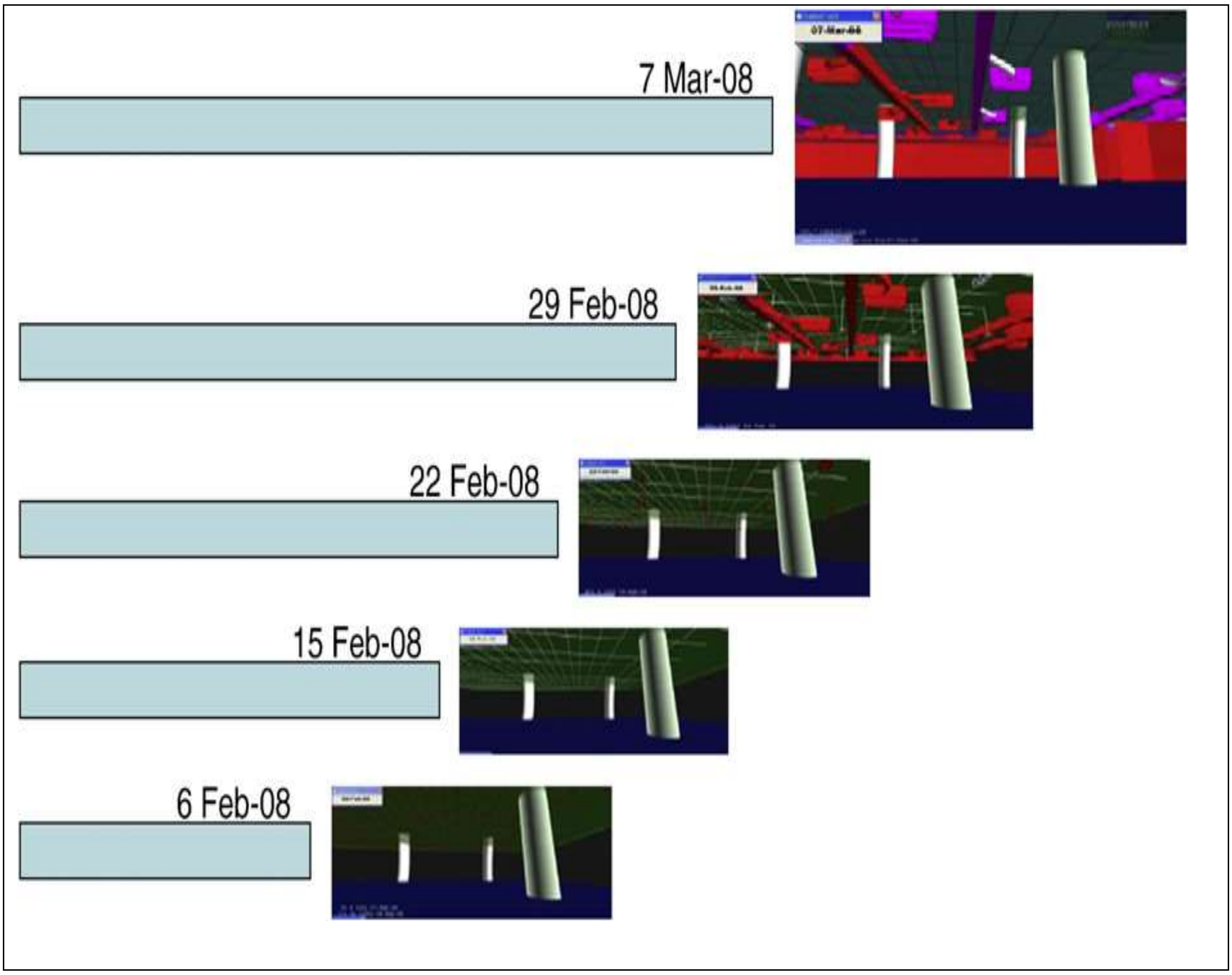



**Figure 190: Example Scheduling in 4D BIM technologies[200]**

[200] Source: Mahalingam, A., Kashyap, R., & Mahajan, C. (2010)

The reliance on CAD technologies indicates inadequacy of *BIM related collaboration* during design and documentation in Tanzania. In BIM, objects are parametric, with high automation and maneuverability. According to (Wang, et al., 2013) BIM objects can be easily amplified to reality.When working in augmented reality, participants can visualise the project together with related environment and hence make better contribution and decision. Although firms have BIM related software, as given by (Respondent 1[201]), still the software are used at individual level and the BIM tools used are non-parametric oriented. Organizations need collaborative mind to perform worldwide (Tapscott & Williams, 2006). This was supported in (Shen, et al., 2010) that without collaboration a firm is in danger of perishing. It was argued that collaboration necessity applies to all types of firms, including those from AEC industry. Construction is time oriented activity. Team members need to work together to attain efficient time management. Quantity surveyors, for instance, need a complete drawing sets on time, well detailed and specified to be able to quantify and return back the estimate for the further valuable timely decisions. The automation and detailing capacity of technologies influences the process to a large extent. CAD technologies are lesser automating compared to BIM, because they are non-parametric in nature. While in BIM a bolt is tied in the universal column, in CAD the bolt need to be drawn manually. That means in BIM, detailing and accuracy is far assured and *time-cost* saving compared to the CAD technologies. Respondent 18[202] supported this, saying with BIM a number of hidden items could have been discovered earlier during excavation. This extends to other participants, and at last to the estimator. An estimate of electrical installation item in BIM model, is just a matter of a click, while in CAD technologies even merging the electrical drawings with architectural is still a challenge, a QS need to work separately and manually mostly. Respondent 20 said it all (See the illustration Box below).

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[201] Respondent 1: "We have BIM but at the very basic level, of computer aided design. In our team of experts, Architects are leading the practicing of this lower level of CAD or BIM, and Quantity Surveyor are far from it. We need BIM, and it will improve our way of designing our works. Our level of BIM here is CAD and REVIT. It is costly to buy advanced complete BIM tools, for example from GRAPHISOFT and use BIM while CAD is enough to do the execution of the projects in our country. It is important that the Government make it as a law"

[202] Respondent 18: "What do you mean by Buildings? We have not used BIM, because we do not have good environment for that. BIM is needed because with BIM or Technology, we could have discovered many underground pipes before break them. This causes delay and increase in costs. What we have is the roads and stations. We do not use anything of high technology. We normally remeasure and claim for payment. 99% of the items we are dealing are within Bills of Quantities. Some of the items were not covered in the Bills of quantities, but are very simple. Showers for example lacked outlets. There are also some differences say, sizes specified are different from what the design require."

Illustration Box 20: Respondent 20 explaining the gap that BIM can fill in the construction

> *"Actually something I am happy with in this study. First, BIM gives collaboration and so it is likely to reduce any sought after variations early. Likewise, Time. This will save time, how? Architect may delay to bring the drawings, and then the clients become mad on us, but with BIM everyone will be seen his competence. Under-measurements, over-measurements and unspecified items which are forgotten by designers and us will be seen openly, and the source easily identified. Contractors are normally required to submit schedule of time, but usually it is not realistic, because they normally miss information and enough time to collect enough information necessary for that. Government should be the first stakeholder to embrace this. Then Institutes or universities. BIM can even help us to reduce corruption and all these problems of buildings falling with no reasons"*

Low BIM level implication goes further than that. It indicates the underutilization of the expertise. In (Eastman, Teicholz, Sacks, & Liston, 2011), it was said that, with BIM quantity surveyor can use a very little time in checking the exactitude of quantities and prices, and spend more time on the implication matters of costs,which are more valuable to the project decisions. Respondent 6[203], gave the likely claim, adding that BIM may help to redirect the way of practice in Tanzania, which CAD seem to be failing to attain.In (RICS, 2014), apart from admitting that QS are the slowest to adopt BIM, it was agreed that BIM can have influence on the standard measurement rules of construction works. Accordinng to (Nagalingam, Jayasena , & Ranadewa, 2013), 5D and 4D BIM is automatically providing BOQ and various value adding reports that are useful during bidding process and construction execution processes. As such,at the current situation the lesser BIM level the lesser dynamic an individual or the firm or the construction industry at large remains.

### 2.2. Presence of BOQ Basic Contents

The completeness level of BOQ were found to be high at the sectional level, which indicated presence of the common use of sections of the BOQ. Variants are possible, but common sections are well known in BOQ because it is prepared from the standard method of measurement (SMM), that usually relates to international standards as well. In (RICS, 2011) for example, preliminaries, measured

[203] Respondent 6: "Whenever BIM is used the construction costs has been reduce and efficiency has been improved. For example in Singapore, even permits are directly applied through BIM. Here, QS is only used for take-off instead of advising on the cost implications to what designers has given them. Usually Hard Copy is given, or at least today, you may give the soft copy. As a result, the accuracy of quantities and the information is problematic.BIM will even command the way we practice here in Tanzania. People now are demanding to clients a separate appointment. They believe it is good for their fees"

works, provisional sums and day-works were mentioned together with risks and credits, which were not parts of the main sections in (Kodikara, Thorpe, & Mccaffer, 1993). The general complete basic sections of BOQ include Preliminaries, measured works and provisional sums sections. Preambles and Day-works sections are included but not guaranteed like the previous mentioned sections (*See the Figure 191: Basic BOQ Sections*). Responses from both, Architects and Quantity Surveyors indicated the presence of the basic contents of the BOQ.Preliminaries section, for instance was support by 19 QSs out of 20 and 12 Architects out of 13. However, it was found that the basic sections indicated inclusion of inadequate elemental information. The use of provisional sums and provisional quantities was found to be high as well. Provisional quantities for instance, were also perceived to be high, indicating the high chance that the preliminaries, measured works and provisional sums may be lacking significant informational contents. Actually it was suggested by respondents (1[204], 3[205] and 10[206]) that provisions are unavoidable, but some of them are unnecessary. And the unnecessary incompleteness of information may lead to high costs and delays due to variations, which it was claimed to almost becoming a standard practice of the industry.

Bidding process requires a thorough communication between clients, consultants and contractors. Inadequate elements in BOQ sections, may hinder other participants to efficiently contribute on the performance to their capacity. BOQ usage cut across participants. Bidders need complete information to be able to prepare method statements of works and other activities during construction programming (Cooke & Williams, 2009). This requires presence of both lesser provisional sums and adequate Day-works, together with complete and realistic measured works, preliminaries and preambles and specification sections. Significant omission of items in one sections affect the whole estimate which affects the overall objective of the construction project.

> *"The broad objectives of cost planning are to ensure that the client receives an economical and efficient project in accordance with the agreed brief and budget, make the design process more efficient thus reducing the time needed to produce a successful design and, ensure that all work arising from the client's brief to the design team is included in the cost planning process. Specifically, cost planning is conducted to predict the contract sum by allocating cost targets to different parts of the building"* (Nagalingam, Jayasena , & Ranadewa, 2013)

[204] Respondent 1: "BOQ contains provisional sums of services. It is difficult to find a Quantity Surveyors who can quantify services competitively"

[205] Respondent 3: "I think BIM will save TIME, because whatever I am going to change, engineers will automatically see and work on it. Not like today, we sometime forget what we told the engineers or we make changes as designers without informing the Quantity Surveyor, at the end is more provisional sums. Of course that is where we eat!"

[206] Respondent 10: "Sometime PC Sums, are unjustifiable to the clients, for example one project, had PC Sum of Doors"

Inadequate elemental information at sectional stage indicates low level of informational details at the design stages. It may mean the existing technologies does not facilitate the individual participants to accomplish or deliver the desired details in time between one another. Likewise, this may imply a low level of BIM related *collaboration* among participants, something that an estimator may need the most. Quantity Surveyors, need information from the designers to be able to deliver a more realistic estimate. With BIM technologies, QSs can automatically and quickly obtain information from the designers, including subcontracting designers. The dominance of non-BIM technologies could be one of the reasons the use of provisional quantities and provisional sums is relatively high (*Refer Figure 193: Example of part of Provisional Sums from an ongoing project in* the BOQs). However, respondent 19[207] indirectly explained how BIM can help to reduce unnecessary provisions in the existing practice. This effort is believed to help in reducing the inadequacy of information during bidding and execution of the project. Although is likely to be a source of increased unnecessary burden to the client. Actually, some respondents (Respondent 3[208]) made it clear that, it is through provisional works, where experts depends, probably to compensate for the low fees as it was claimed by the (respondent 4[209]) . By preparing database or a *personal-BIM* in essence, an estimator may be able reduce the variations orders consequences during project delivery.

207 Respondent 19: "Take an example, the multi-storey building B1, B2, B3 and B4 in this city we did the costs management. From that, we are preparing our Database of the cost or BOQ. This helps us when the designers forget anything; we can just foresee and put it. When that item has not been done, it is a saving to the client, or otherwise when they introduce something that was forgotten, we use it replace"

208 Respondent 3: "….at the end, it is more provisional sums. Of course that is where we eat hahahahaha!"

209 Respondent 3: "Clients do not even know us,…… so such clients; will not afford to pay me legal profession fees for a residential (small project) and hence hindering me to think of expanding."


**Figure 191: Basic BOQ Sections**

According to (RICS, 2011) BOQ provides a coordinated list of items, descriptions and quantities, to empower contractors to prepare tenders efficiently and accurately. Provisional sums gives the lists of non-measurable items at the time tenders are invited, so that a pre-determined sums of money can be set aside for them, while Day works section gives provision for the contractor to competitively tender rates and prices for works, which might be instructed to be carried out on a day work basis. Provisional sums, being higher may hinder a contractor to fully prepare the programme of works because a huge amount of works becomes indeterminate (Greenhalgh & Squires, 2011). Contractors need preambles (materials description and workmanship) in pricing (Seeley, 1988).

From the definitions of provisional sums above, it logically follows that a high level of provisional sums indicate among others, the inadequacy breakdown of the items to a fine and measurable items. It is said, *truth is sometimes relative*. Therefore, items considered non-measurable need a stipulated framework in order to distinguish a genuine provisional sum from the unnecessary one. It may be designing deficiencies, technological problems, estimating difficulties or system originated problem, but the solution may equally be the need for more obligation of individuals to standardization practice. BIM usage could have reduced the effects significantly. Respondents (1[210], 4[211], and 17[212]) in their response, they indicated the effect of inadequate collaboration and standardization to be among the important aspects toward reducing unnecessary provisional sums items in the BOQ contents. Actually a project with 10% costs increase due to variations was claimed to be a success one. One of the ways in reducing this may be introduction of the frame of reference of the provisional sum. The use of standard method of measurement is not adequate because the source of the problem lies more on the commitment of the players than measurement efforts. BIM improves visualization, collaboration and automation, which are necessary for the better and quicker estimation. In lesser technological environment, like that of Tanzania, BIM can help to reduce the problem by improving collaboration among players and introduction of standards. It requires more collaboration and automation

[210] Respondent 1: “VARIATIONS in our projects is almost standard, “every project must have significant VARIATIONS”. If we could even manage to attain the increase of costs due to variation not to exceed 10%, it would be a success project. Of course, we cannot avoid but 4% would be reasonable. One thing that cannot be measured but it is very important is COLLABORATION, it is something that you cannot quantify. Example, World Bank or United Nations projects, (hawataki Kubahatisha) they do not want to GUESS, they make sure Architects and other designers make enough details, and then a Quantity Surveyor does his Job keenly, BUT yet there are VARIATIONS, because there is no ENOUGH SHARING OF INFORMATION among the involved experts.”

[211] Respondent 4: “In design team involving all, after scheme drawings preparation, we as architects do give the other professionals, say electrical, structural and plumbing as well as QS, who will later need the other drawings from those professionals.”

[212] Respondent 17: “Principally, we QS there are things you cannot measure. Planking and Strutting. Another thing, I know we cannot quantify, is Services Works. You cannot quantify something you do not know how it is being constructed. And we cannot do that, otherwise we have to be electrical engineers and all other profession.”

efficiencies. Respondent 5[213] complained to this as well, calling upon the introduction of specific formula.

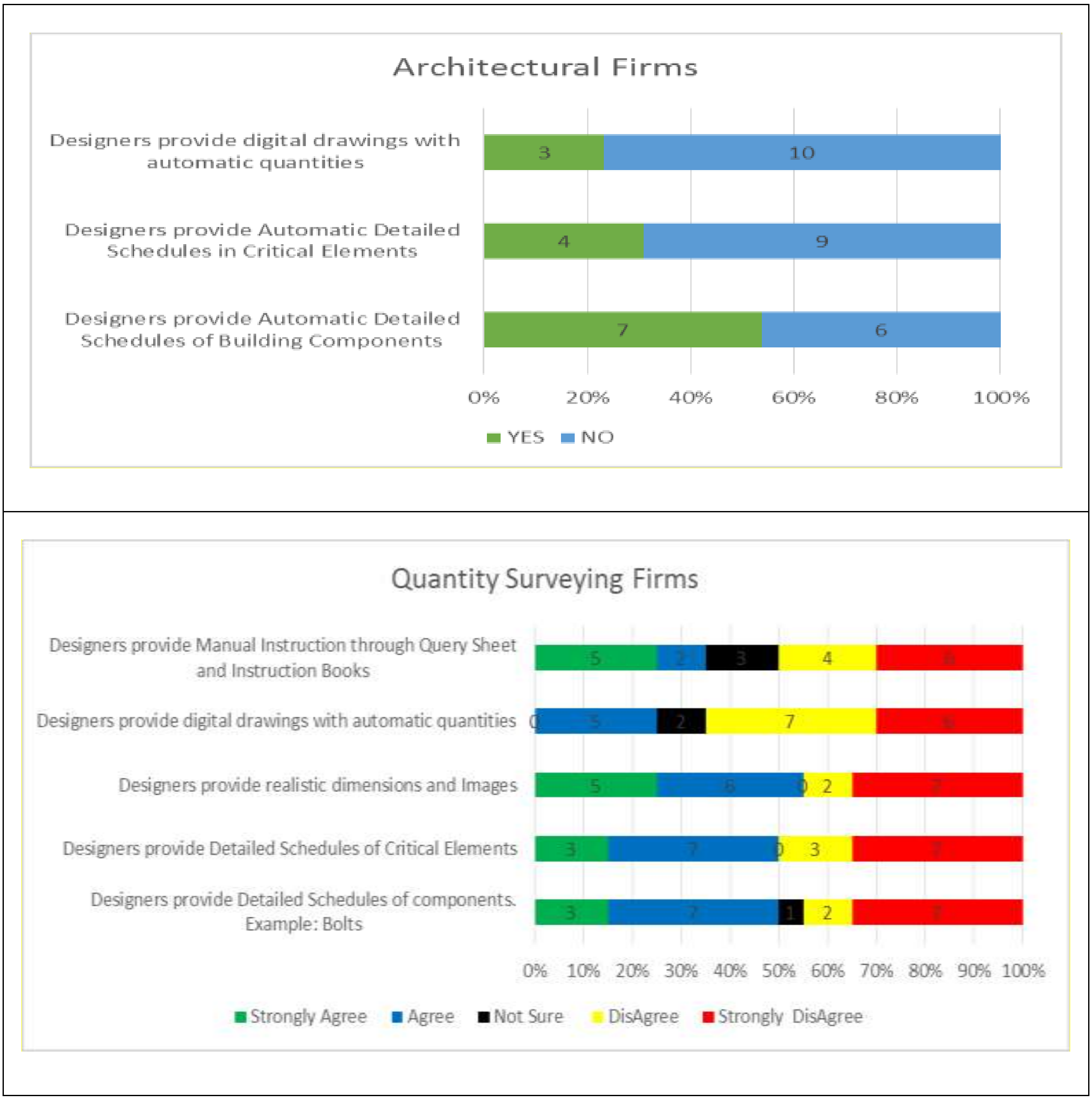



**Figure 192: Facilitation of Designing Details in BOQ preparation**

213 Respondent 5: "There is challenges in PC Sum and Provisional sum. They do not have formula, and as the result, estimators put in contingencies and later they normally cause the increase in the cost. Contingencies is sometime unavoidable because we do not know what we may come across during excavation or the like. It is normally 10-15%.But PC Sums is a big problem in BOQs"

| Item | Description | Qty | Unit | RATE | AMOUNT |
|---|---|---|---|---|---|
| | PROVISIONAL SUMS | | | | |
| | | | | | |
| A | Allow for Demolitions and related activities as per PM instructions | | SUM | | 100,000,000 |
| | | | | | |
| B | Allow for provisional sum for Plumbing and Mechanical Engineering Installation, Waste and Foul water Drainage including Fire Fighting Installations | | SUM | | 125,000,000 |
| | | | | | |
| C | Allow for provisional sum for Electrical Installations including Information and Communication Technology Installations | | SUM | | 85,000,000 |
| | | | | | |
| D | Allow a provisional sum for cost of construction of two Guard Huts and Fence Work of Bout 350 Linear Metres | | SUM | | 155,000,000 |
| | | | | | |
| E | Allow for the cost of construction of Car wash area:including all necessary water riticulation | | SUM | | 10,000,000 |
| | | | | | |
| F | Allow for Extra Costs of Strong Room Construction | | SUM | | 25,000,000 |
| | | | | | |
| G | Allow for Information and Communication Technology (Installations and Equipment) | | SUM | | 15,000,000 |
| | | | | | |
| H | Allow for Site and External Works ( Landscaping,Pavements, Kerbstones and the like) | | SUM | | 65,000,000 |
| | | | | | |
| I | Allow for the Progress Photograph | | SUM | | 2,000,000 |
| | | | | | |
| J | Allow provisional sum for contingency to be expanded or deducted by the project manager | | SUM | | |
| | | | | | |
| | **To collection** | | | | **582,000,000** |
| | COLLECTION | | | | |
| | | | | | |
| | Page No. 1 | | | | 8,520,000 |
| | | | | | |
| | Page No. 2 | | | | 582,000,000 |
| | | | | | |
| | **PROVISIONAL SUMS CARRIED TO GENERAL SUMMARY** | | | | **590,520,000** |

**Figure 193: Example of part of Provisional Sums from an ongoing project in the BOQs (1/2)**

| | | | |
|---|---|---|---|
| | **DED OFFICE BLOCK** | | |
| | **GENERAL SUMMARY** | | |
| | | | |
| a | BILL 1:Preliminaries | 47,900,000 | |
| | | | |
| b | BILL 2:Preambles (Specifications) | - | |
| | | | |
| c | BILL 3:Measured works | 1,199,019,525 | |
| | | | |
| d | BILL 4:PC & Provisional Sum | 590,520,000 | |
| | | | |
| | ***GRAND TOTAL*** | ***1,837,439,525*** | |
| | | | |
| | | | |
| f | ***ADD:*** *V.A.T (18%)* | 330,739,115 | |
| | | | |
| **TOTAL CONSTRUCTION COSTS** | | **2,168,178,640** | |

**Figure 194: Example of part of General Summary from an ongoing project in the BOQs (2/2)**

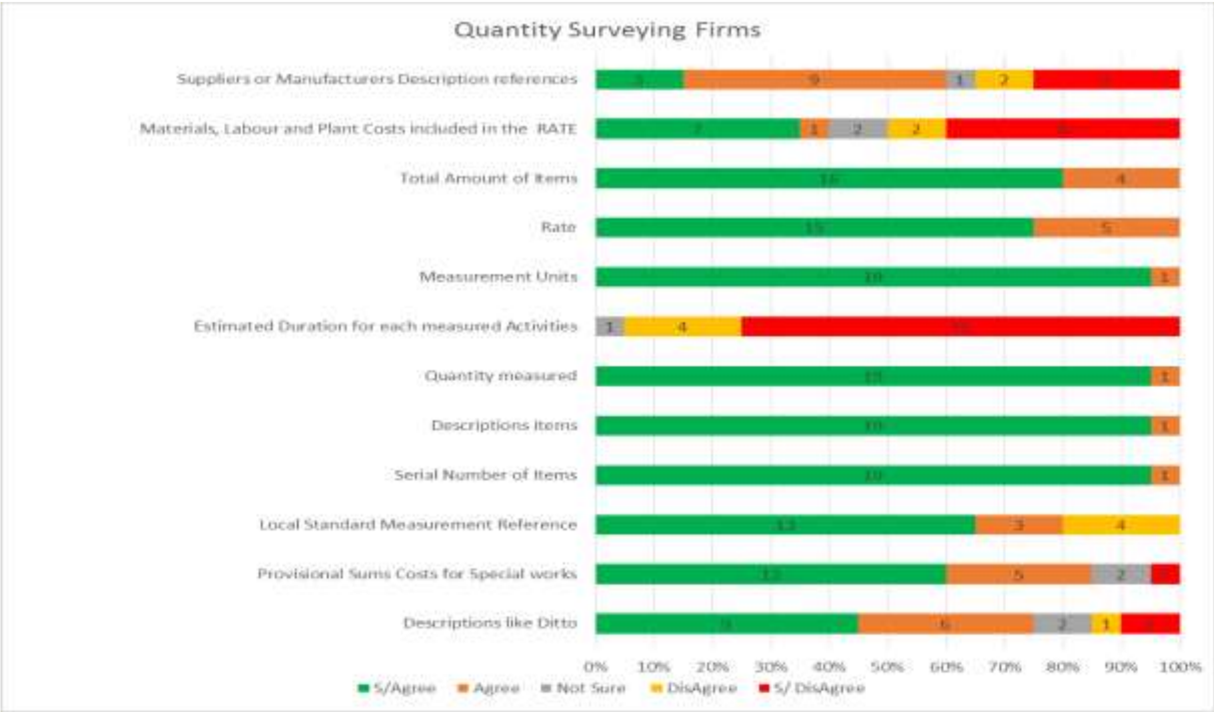
## 2.3. Presence of Standardized Contents

The common *Standardized contents* of the BOQ found were serial items, descriptions, quantities, unit, rate and the total amount. This format is basic, but has been improved by many developed countries. In Germany (Brandt & Franssen, 2007),for instance there are also location and alternative items. The used format in Tanzania does not include even the *location* of the component. When elemental Bills of Quantities are used, somehow the items can easily be identified locational wise. The works are grouped according to their structural position (Seeley, 1988).On the other hand, this indicates that it is likely that BOQ preparation standards may have not been improved currently to match international procedures. Probably the BOQ is serving satisfactorily the local market. Respondent 21[214] showed concern on the use of the old standard method of measurement (SMM).

Given the dynamic nature of the construction industry, not updating the standards and BOQ practice may force the value of BOQ as a total cost management pillar to be lessened. Because, BOQ with lesser contents as expected cannot help to alert the client on the likely loss or it cannot guide the contractor on how to profitably execute the work. The question of the need for extensive information in BOQ is experienced worldwide. For example in the UK, the New Rules of Measurement 2 (NRM2), require significantly more information to be provided to tenderers. The main contract preliminaries section should be submitted with pages of pricing schedule notes. The intention is to obtain a full and detailed preliminaries breakdown that clearly identifies the items, shows how the price for each item, and how the total price for preliminaries has been calculated (Cunningham,2015).

Never the less, BOQ standardised contents did not include the basic breakdown of the rate. The dominant practice found was still inserting the rate from the contractor, without any attachement of the prime contents of the rate like labour,materials and plants. The rate items may only be submitted when needed by the consultants, not during tendering stage like the practice in Germany.This indicates inadequacy usage of Bills of Quantities in activities related to the project planning because BOQ rate usually has amount of information that can help contractors and consultants in planning and assessment of the works. Fees calculation,tender analysis, taxation,valuing variations, asset management and future projects feasibility were among the advantages of BOQ mentioned on page 85 of (Greenhalgh & Squires, 2011). All of these, in one way or another touches the rates used in estimating the total cost.

[214] Respondent 21: "In Tanzania, even if the drawings are not complete the QS will give you the BOQ. Ask yourself how? How can we have complete information? If your background is building economics, you should know that we are still using the same SMM of 1977. That means No such things like duration, location, drawings referencing or life cycle costing in BOQ."



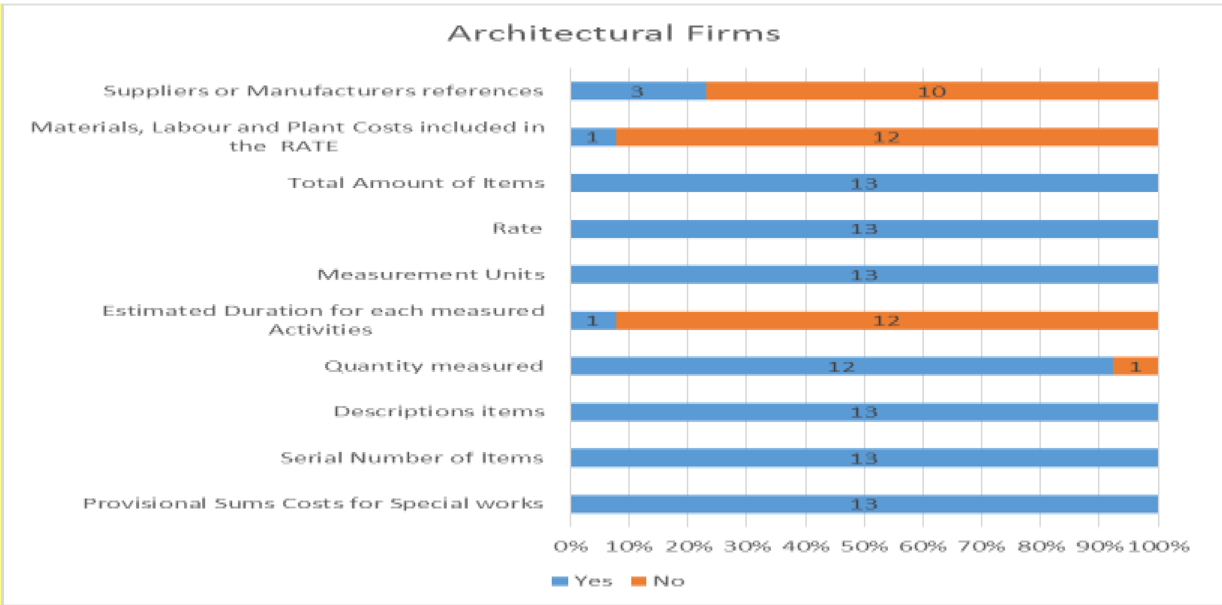




**Figure 195: Standardised Contents used in BOQ**

## 2.4. Presence of Detailed Standardized Contents

According to (Greenhalgh & Squires, 2011),the process of BOQ production can be equated to interrogating the design and specification details prior to *tendering* in order to reduce inconsistencies and inaccuracies,which may be the source of post contract problems. It was equally found that BOQ almost lacked detailed standardised contents. No items such as an estimate of critical duration of activities,wastage,subcontracting fees,taxation,querry sheets, and drawings references. The use of international standards were also at a very low level. Only when forced to use. This indicates the inefficient preparation and use of BOQ in the total cost management of the projects. Worse enough, it may result on hiding some items necessary for the critical decision. *Bills of Quantities need to fully describe and accurately respresent the quantity and quality of the works. It should be reasonable, comprehensive and sufficient to enable estimator to understand so as to provide the realistic price* (Seeley, 1988). The information available determines the extent of accuracy in any estimate. However, in complex estimate like that of BOQ, it is equally important to identify information used clearly so as the intention can be tranfered correctly. Incomplete BOQ causes sustaining problems in the construction projects. Mostly demaging the financial status of the clients who are usually lesser knowledgable of what they are loosing. In (Davis, Love, & Baccarini, 2009) *unit rate* cost data is often used by QSs in valuing progress payments. If it happens that the rate is increased on early trades (front loaded) above a real cost or otherwise a contractor may gain cashflow benefits from rise and fall provisions over the client.

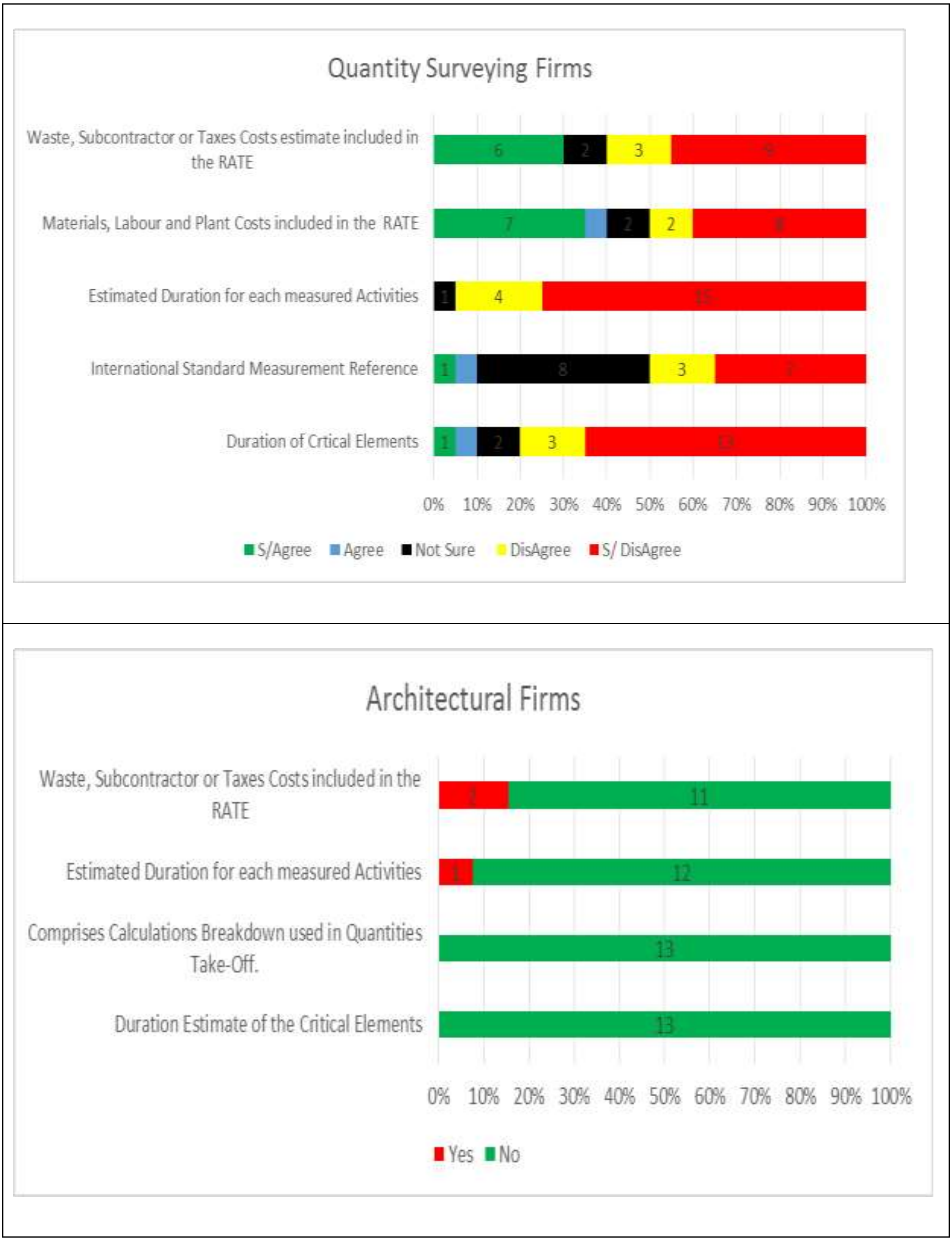


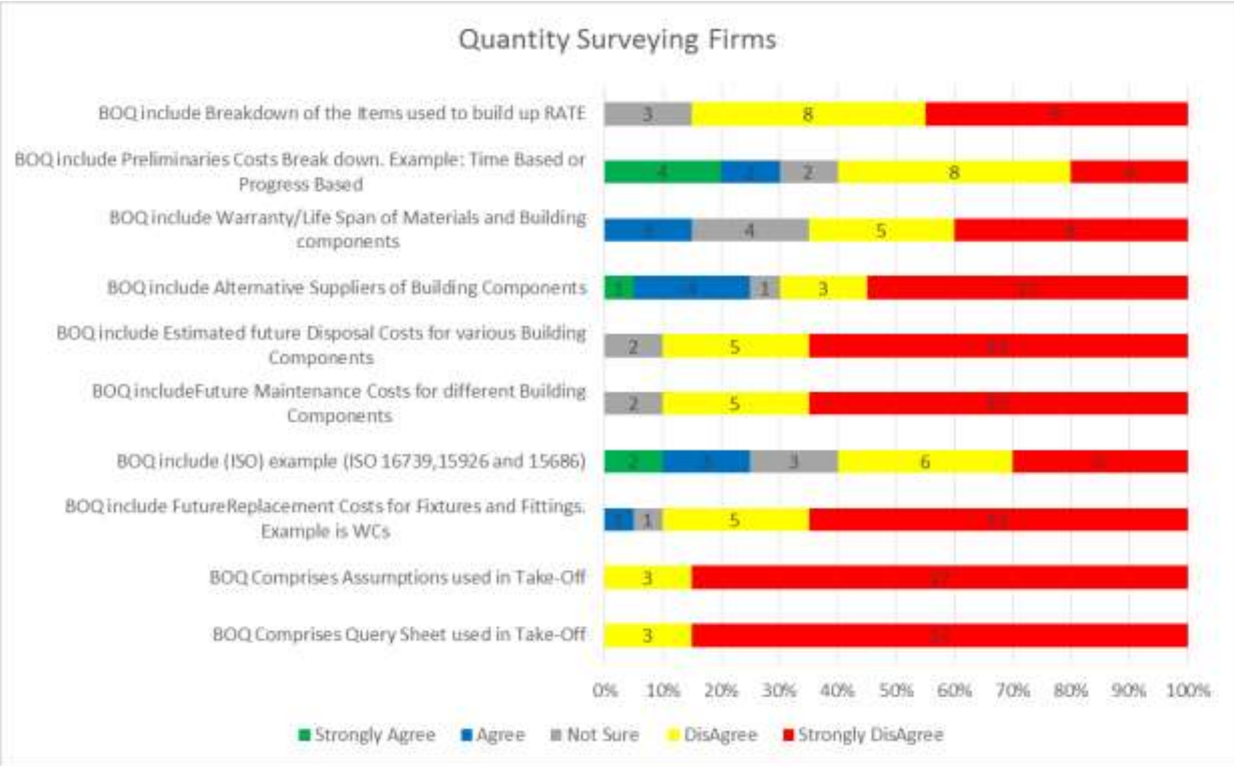

**Figure 196: Detailed Standardised BOQ contents**

## 2.5. Presence of 5DBIMBOQ Contents

Absence of 5D BIM contents found indicates inadequate use of BIM related technologies in BOQ preparation.Basically, modelling comes first before 5DBIM comes into effective play. However, creative cost estimator may utilize the 5DBIM capabilities to enhance the BOQ,by introducing the more value adding items in the BOQ models. Life cycle costing items for example were not found in the BOQ in any form (see the respondent 2[215]). In Germany, the selection of alternative materials is reflected in the BOQ, which is somehow giving a picture of the life cycle consideration through alternative design, as mentioned in (Brandt & Franssen, 2007). However, the BOQ should be able to display clearly and openly the cost comparison between number of alternatives. This undertaking is so time consuming, without high parametric automation and collaboration. 5DBIM provides such services to a quicker and better extent than excel, which most QS strongly agreed to be in use in Tanzania.Using 5DBIM the realtime costs simulation is transparently visualised and the design changes are automatically and instantly checked. Preliminaries breakdown can be improved through realistic site analysis and detailed components cost breakdown that is possible in 5DBIM.

Actually 5DBIM seem to facilitate all functions of a quantty surveyor. In (RICS, 2014) it was explained how working with BIM relates to performing QS duties with improved data. Designers details can easily be transformed into detailled projects information using 5DBIM.This is what gives more value BIM over traditional technologies.According to (Lai, Halvitigala, Boon, & Birchmore, 2010) with enough team commitment and data, BIM specifically 5D BIM can facilitate optimizing of life cycle costing in project deliveries.

[215] Respondent 2: "On my side, if I were to improve the BOQ, just to add, because we know all life span of the Build (in Tanzania say it is 100 years), and probably their life expectancy, then it is possible to calculate the future cost and compare with the current costs and show the client. Say, painting as an element can be foreseen its operational costs (repainting say of 5 years) and future costs calculated and compared with the current costs. Therefore, it is possible to add this calculation in the BOQ. This would guide the user during running of the building. If BIM can give at least information just by clicking and help to prepare such calculation, I think it is very helpful. It is even possible to add LCC as a section in the Bills Of Quantities, not necessary attached for the sake of contract sum calculation."



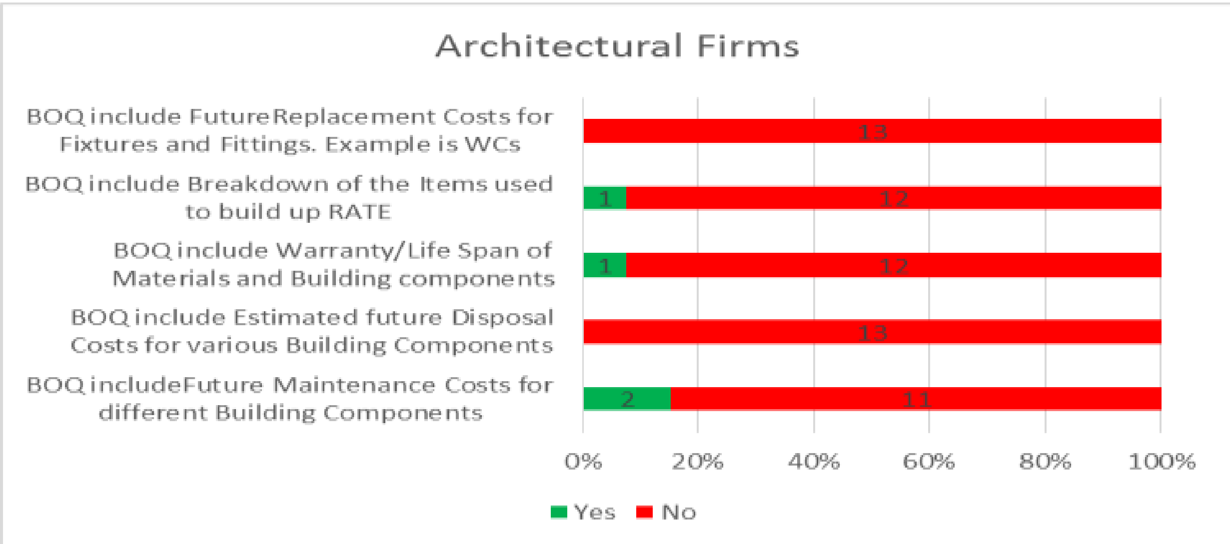




**Figure 197: 5DBIM related BOQ Contents**

## 2.6. Restating the subject

The main objective of the study is to appraise BIM in Tanzania. In doing so, the study hypothesized that, there is a relationship between BIM and BOQ productivity in Total Costs Management (TCM). It was thought that, the major problems of the construction industry in Tanzania stem from inadequacy completeness of the Bills Of Quantities (BOQ).The targeted output is to develop a BIM model through testing and retesting of that hypothesis in order to confirm if the key strength of BIM, which is agreed to be information integration, can be deduced into BOQ information. In doing so, this study starts by specifically describing the relationship between BIM and BOQ completeness and suggesting the contents of the BIM model to be developed. BOQ is central in TCM, which was argued to be a central objective in construction projects performance. In the study the BIM levels were set proportionally to the BOQ contents levels. The assumption was that, the optimal level of information integration will be facilitated by the 5DBIM (*See Figure 199: 5DBIMBOQ Model Development Concept*), because of the capabilities it holds in execution of the cost and quantification activities. However, BIM adoption has among others, technological, economical and legal difficulties, which are equally troublesome elsewhere in the world, where BIM is being applied. Therefore, this study to be useful to Tanzanian environment, it has to try to overcome all the challenges. It is suggested that it should be as simple as possible, testable, economical and technologically inexpensive BIM, as a starting point.

This chapter, consists of the brief explanation of the findings, resulting model development concept and suggested model contents. It stretches the inside view of the found relationship between BIM and BOQ in light of what the developed model can facilitate during construction project delivery. The chapter conveys the few suggested developed model contents by associating the model strengths to the existing benefits, challenges and opinions relative to BIM. It was in the view of this study that the developed BIM, or in this case 5DBIMBOQ should be able at least to enhance performance total costs related items during project delivery. Total Performance Delivery (TPD) assurance items like collaboration, transparency, automation, visualization, sustainability, commissioning, life cycle assessment and exactitude should at least be derivative functions of the model.

## 3. Proposed Model Overview

Stepping from the above, the study has found weak but promising association between BIM levels and BOQ completeness. Individuals' responses has indicated that BIM is lowly practiced and the BOQ completeness is relatively low. It is not shocking to find that BIM is lowly practiced in Tanzania. The same is still the case in country with greater effort towards BIM. According to (McAuley, Hore, & West, 2012), Ireland were far from embracing BIM, despite the awareness explained. Likewise, in (Lai, Halvitigala, Boon, & Birchmore, 2010), it was concluded that without entire industry commitment, BIM cannot facilitate life cycle costing in project delivery. The efforts towards BIM are likely to be at individual level. Respondent 13[216] for example, indicated that individual use of an advanced software still does not give satisfactory information completion. Probably because such effort still lacks improved collaboration.

Actually, BIM in Tanzania may even be lowly understood even by the construction practitioners. Among others, the responses has clearly shown that, lack of enough completeness, collaboration, exactitude, life cycle costing and transparency in the BOQ has a directly notable negative impact to the construction costs management. Such items are well addressed through the use of BIM in construction projects. In other words, professionals believe that presence of "BIM practice effect" has a greater chance of improving BOQ productivity in total costs management (*See Figure 198: Responses on perception of what BIM is likely to result into in Tanzania*). In (Monko & Roider, 2014) the perception of respondents supported that lack of advanced technologies such as BIM has a negative impact on project time, cost, safety and quality. Using the contents from the BOQ levels 1, 2, 3 and 4 it is suggested that at a given BIM technology the information integration is expected to provide certain BIMBOQ level, which is optimal at the 5DBIMBOQ level.

[216] Respondent 13: "We do not have any data bank for the information. It is very difficult to get complete information. We, QSs are last in the chain of design. As a result, we do not have time. It is very common, to have the INCOMPLETE information from designers, not necessarily that they cannot produce it, but they do not have time. Most of the time, we use software not compatible with others. For me I used WIN QS TAKE OFF. It prepare Bills and do the calculation. However, the drawings I normally take in hard copy. To use softcopy, I need another dimension, which I do not have, I do not know how to use, and it is so expensive. This one I bought in South Africa, and I must pay fees annually"

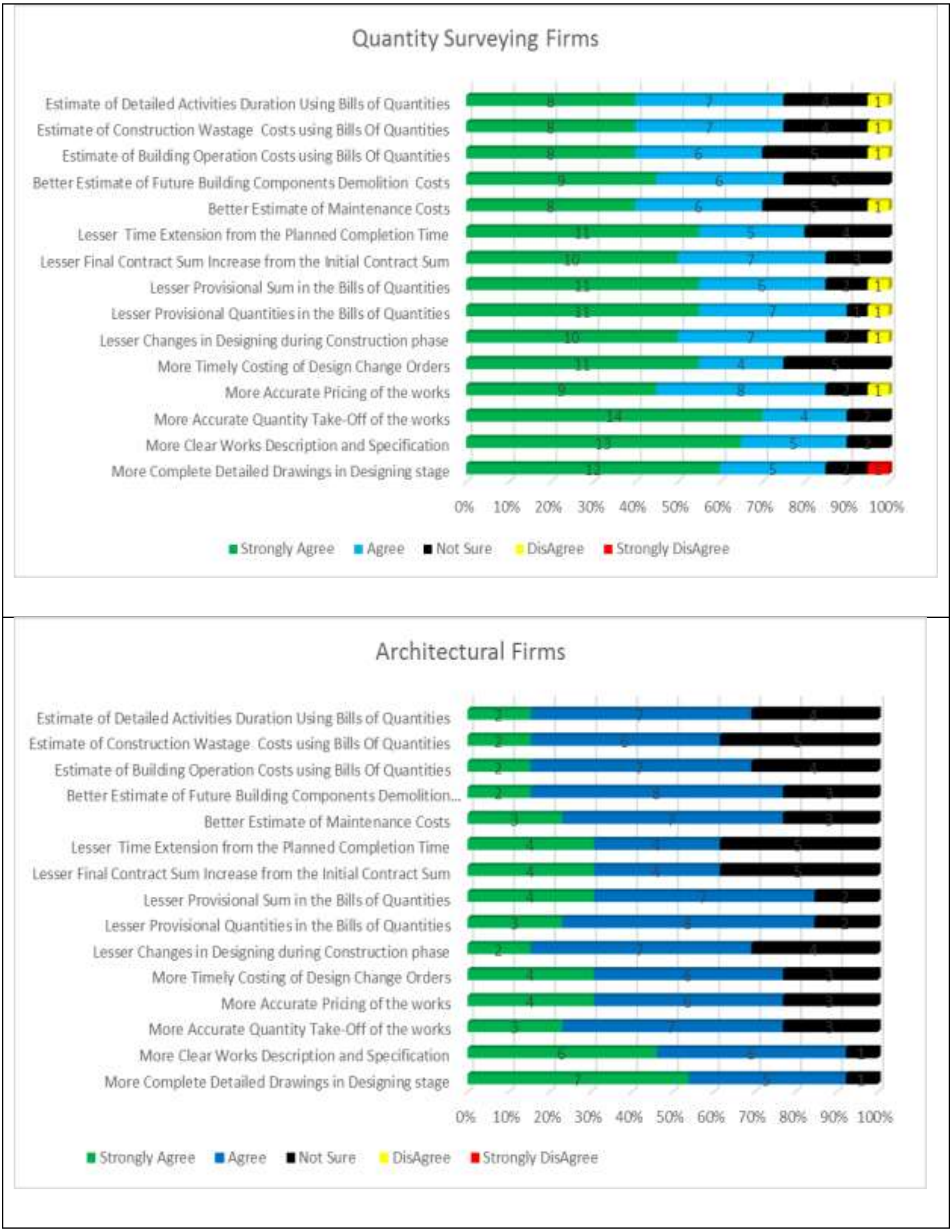
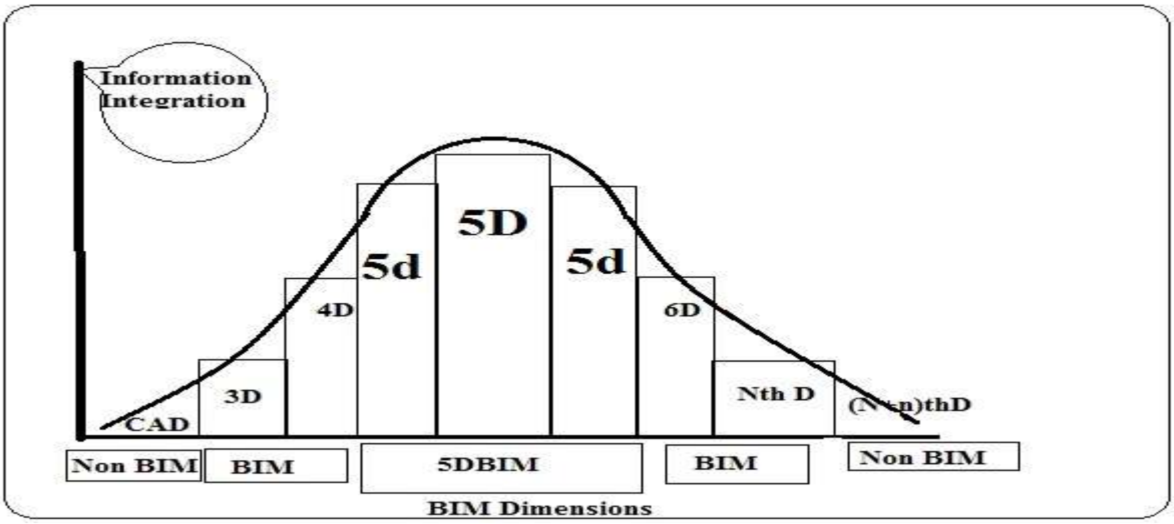



**Figure 198: Responses on perception of what BIM is likely to result into in Tanzania**

The developed model then, is the function of information integration from infinite or zero dimension to NthD BIM in such a way that the optimal information integration is found at 5DBIMBOQ contents level. The model is temporarily named a 5DBIMBOQ to denote the BOQ with centralized standardized contents proportional to the Informational Integration impact provided by 5DBIM model in total project delivery from inception to demolition (See Figure 199: 5DBIMBOQ Model Development Concept).




| 5DBIMBOQ WHOLE LIFE CCLE COSTING | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5DBIMBOQ LIFE CYCLE COSTING | | | | | | | | | | | | | | | | | | | | | | | OTHERS | | |
| 5DBIMBOQ CONSTRUCTION COSTING | | | | | | | | | | | | | | | | | LCC | | | | | | | | |
| ITEM | | | | | QUANTITY | | | | RATE | | | | | | | | | | | | | | | | |
| Serial No 1 | Serial No nth | References nth | DESCRIPTION | Drawings Nr nth | Component | Measured | UNIT | DURATION (DAYS) | Materials | Labour Cost | Plants Costs | Waste Costs | Subcontractor Costs | Compulsory Payments | Rated Amount | AMOUNT | MAINTENANCE | OPERATIONAL | OCCUPANCY | DEMOLITION | FUTURE COSTS | PRESENT COSTS | NON CONSTRUCTION COSTS | INCOME | EXTERNALITIES |
| | | | ELEMENT NR 7: WINDOWS | | | | | | | | | | | | | | | | | | | | | | |
| | | BS x | Metal work | | | | | | | | | | | | | | | | | | | | | | |
| A | XYZ 1 | XYZ 2 | Aluminium (30 Number) | DXYZ 3 | N/A | 108 | SM | N/A | C1 | C2 | C3 | C4 | C5 | C6 | 165,000 | 17,820,000 | L1 | L2 | L3 | L4 | F5 | 17,820,000 | | | |
| Page Sub-Total Carried forward | | | | | | | | | | | | | | | | Total | | | | | | Total | | | |

**Figure 199: 5DBIMBOQ Model Development Concept**

The model basically can be divided into three major parts relative to the life cycle costing of the Project. First part, is when no quantifiable life cycle costing is made. So the part is only dealing with construction cost, which is 5DBIMBOQ Construction Cost. The higher part is the 5DBIMBOQ Life Cycle Costing, when the model considers construction quantitative life cycle costing items. The highest part of the model is 5DBIMBOQ Whole Life Cycle Costing, when the non-construction, income and externalities are brought into play. The model is expected to adopt the (ISO 15686-5 (E), 2008) life cycle costing components standardization at minimum. The documents are available, accessible and recommended internationally (*See Illustration Box 21: Basic document for the WLC Components of the developed 5DBIMModel.* )

Illustration Box 21: Basic document for the WLC Components of the developed 5DBIMModel.[217]

| |
|---|
| *"International Standards Organization, BS ISO 15686 is a multi-part series of international standards giving guidance on various aspects of planning the service life of buildings and constructed assets. Part 5 of the series provides guidelines, definitions, principles and informative text on the application of LCC techniques in the context of service-life planning. In 2008 the British Standards Institute (BSI) and the British Cost Information Service (BCIS) in the UK published a 'Standardized Method of Life Cycle Costing for Construction Procurement, A supplement to BS ISO 15686-5:2008 Buildings and constructed assets – Service life planning – Part 5: Life cycle costing'. The document provides construction cost professionals with a standardized method of applying LCC, applicable to the Irish/UK construction industry and to the key stages of the procurement process. Importantly the document provides a cost data structure and a method of measurement for LCC which aligns with the ISO 15685-5. The taskforce used this methodology and standard format in the production of the suggested LCC template and LCC example. The standard can be bought online from the RICS bookshop at URL; or from the BCIS website at URL; The BCIS also provide cost information on building running costs both online and in standard paperback".* |

Under these headings, the model is expected to consist of differentiated number of items relative to the breakdown levels provided by the professionals. However the breakdown of items and measurement are to be accompanied by the use of standard documents, standard methods of measurement or standard articulated documents. For instance, references to assumptions and querry sheets used during taking-offs are likely to vary compared to the references to SMM and Specification Standards. The same applies to the levels of works breakdown. Items may be broken down to the

[217] Source: Kehily, Guide to Life Cycle Costing, (2010)

varying degree of detail relative to the BIM level used. It may be feasible only to give a one standard item with a known standard construction costs. For example the measurement of glazing and casement windows can be combined to form one component under various standardized specifications. This may give a chance to improve prefabrication of the casement windows, to save time in measuring the casement windows, to standardize the casement components, to give more transparency on the total price of the casement construction and to reduce errors in estimating the casements costs. Quantity Surveyors may use more time on selecting the right alternative casement type for the project instead of working out the quantities of the carriers, glasses and sizes. According to (Sabol, 2008), estimators can save time using BIM and hence spend more time on other value adding activitiies than taking off.

| | | | | | |
|---|---|---|---|---|---|
| | **Metal Work** | | | | |
| | **Aluminium Casement Windows as supplied by Casement Africa Dar es Salaam, or other equal and approved manufacturer** | | | | |
| D | Standard Aluminium frame in sliding window type W7, overall size 3300 x 1400mm high | 2 | NR | 40,000 | 80,000 - |
| E | Ditto type W9,overall size 3900 x 1400mm High | 2 | NR | 46,000 | 92,000 - |
| F | Anodized aluminium adjustable luovre and frames 760 mm long with 5 No carriers for 150 mm wide Glass louvres (glass measured separately) fixed to hardwood with matching screws | 311 | SET | 7,800 | 2,425,800 - |
| G | Ditto 1000mm long with 7 No Carriers ditto | 47 | SET | 8,000 | 376,000 - |
| H | Ditto 1180mm long with 8 No Carriers ditto | 58 | SET | 8,000 | 464,000 - |
| I | Ditto 1280mm long with 7 No Carriers ditto | 264 | SET | 8,500 | 2,244,000 - |
| | **GLAZING** | | | | - - |
| | **Supply and Fix The following Glass as described** | | | | - - |
| J | 6 mm Thick Clear Glass in panes over 0.10 but not exceeding 050 square metres | 4 | SM | 25,000 | 100,000 - |
| K | ditto over 0.50 but not exceeding 1.0 square metres | 20 | SM | 25,000 | 500,000 |

**Figure 200: Example of the Casement BOQ item in the existing BOQ[218]**

[218] Part of Bills Of Quantities used in Construction Project in Tanzania around Year 2000

| 5DBIMBOQ LIFE CYCLE COSTING | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5DBIMBOQ CONSTRUCTION COSTING | | | | | | | | | | | | | | | | | Life Cycle Costing | | | | | |
| ITEM | | Assumptions/Querry Sheets nth | DESCRIPTION | Drawings nth | QUANTITY | | UNIT | Max DURATION (DAYS) | RATE | | | | | | | AMOUNT | MAINTENANCE | OPERATIONAL | OCCUPANCY | DEMOLITION | FUTURE COSTS | PRESENT COSTS |
| Location/Position Codes | Serial Codes | | | | Component | Measured | | | Materials | Labour Cost | Plants Costs | Waste Costs | Subcontractor Costs | Compulsory Payments | Rated Amount | | | | | | | |
| P12.BL1.GF0.RMn | 03.07.02.D | A.37 | Aluminium Casements Type 1; Specification AFRI Dar 1 or Arch AP 037 | D.071 | 2 | N/A | NR | 1 | 50,000 | 25,000 | - | 15,000 | - | 30,000 | 138,000 | **276,000** | L1 | L2 | L3 | L4 | F5 | **273,240** |
| | 03.07.02.E | Q.9 | Ditto: Type 2 | | 2 | | | 1 | 58,000 | 25,000 | - | 17,400 | - | 30,000 | 149,960 | **299,920** | L1 | L2 | L3 | L4 | F6 | **301,420** |
| **(Project,Block,Floor, Room,etc)** | **Bill 3,Element 7,page 2 ,Item D,E,,,,!** | | **Standard Type,Specification, Manufacuter or Approval reference** | | | | | | **Breakdown of Rate** | | | | | | | | **Life cycle Costing Breakdown** | | | | | |

**Figure 201: Reflection of the Casement BOQ item in the 5DBIMBOQ Developed Model**

This effort is not completely new. In ((Smith & Tardif, 2009) and (East, 2013)) COBie, is among the closely related non proprietary BIM. Construction Operation Building information exchange (COBie) is basically the list of spaces and the designed assests basing on the performance specification of the project life cycle. It includes the categories of manageable equipment of the building and the operational and maintanance descriptions necessary for the facility management developed by the team in each phases of the project delivery.For instance, architectural location,level,material and zone of the floor. It is a representational spreadsheet of the one source of information of the visualisable building.Summation of the spaces and the designed assets to be managed like fire extinguishers, capets and furnitures are detailed for the users satifaction in a single composite reference model. Such a model can be linked to different relevant files as well. According to (Hardin, 2009), this is related to what was called the record BIM. COBie facilitates the exchange of information from the designers to the facility managers. It enhances the completeness,exactitude and automation of the information transferred.

## 4. Proposed Model Development Contents

The development of the model contents is based upon the BOQ levels with the focus on the key items in total costs management, which includes budgeting, tendering, cost control and valuation of the variations, final accounting and life cycle costs assessment. The other key objectives like quality and safety of construction projects were assumed to be derivative of the cost objectives.

### 4.1. Information Communication and Management Database

Building Information modelling (BIM) relates directly with the database. It is both visual and database driven (Hardin, 2009). That is a collection of data in a given source usually computer as the most known technology today. Even a building itself is a data at glance. The building displays a number of data that the designers put into it for a given purpose. However, BIM is more of information-base than data-base. Because in BIM the information is a ready-made output when the model BIM is visualized, and the clash detected or time and costs are simulated. In costs modelling, BOQ stands to be the lesser data historical dependent model (Matipa, 2008), which means it has more information and it forms the best base for the future costs information references or database. Even without a higher technology, data-base is important. One respondent (Respondent 18[219]) explained how the presence of systematic record played an important role in their construction industry. Actually, it is said that knowing the history is a good step towards knowing the future. Individual firms and professionals need data base as well. Without total commitment to informational base, the benefits of BIM may not fully realized. In (Lai, Halvitigala, Boon, & Birchmore, 2010), LCC optimization was found low due to low commitment to information sharing industrially.

5DBIMBOQ model is expected to improve the informational base in project delivery as well as database in the construction industry in Tanzania. The model involves items like assumptions and querry sheets, which gives more assurance on the information database. Professionals are willing to use their database because they are far sure that the information derived will be authentic enough to be defended. This authenticity or assurance of provenance (Smith & Tardif, 2009) is important for the betterment of the database at individual level as well as at industrial level. Additionally, the model contents includes detailed breakdown of the standardised contents like rate and units. These detailed breakdown improves the database creation mentality to both the individuals and the industry as the construction councils and board may find it worth preparing standards in advance for the quick retrieval. In Germany, such practice is common. A number of vendors are supplying basic prices and

[219] Respondent 18: "In XXXX (the country the respondent is coming from) we do keep clear our records on the construction costs and life cycle costing, which is maintenance. In local council, there are very accurate records, for about last 20 -50 years ago. In addition, through this, it is possible to reuse the records for maintenance. To go that stage, it is necessary to have the information database and structure to obtain that costs records of structures"

standard factors of productivity. The model includes the key managerial items that can induce a positive change of thinking in the industry. It is through these items, that the more information or facts valuable in making decisions (Smith & Tardif, 2009) can be derived. The data or observable facts necessary to acquire the information pass through the mechanism that forces individual to reliably collaborate, record, store and communicate the information with assurance.***"The big idea for BIM is not only to store the information, but also the ability to communicate it"*** **(**(Hardin, 2009),page 24).

In the symposium introduction, (Gralla, 2015)[220], insisted the view that BIM is more of information management than modeling. Basically, this shows the essence of viewing BIM from the angle of what it is doing than what it is. What BIM does in this perspective is facilitating the building information to be more manageable than before. It becomes easier to plan,organise,control,lead and staff the building information in an efficient way.For instance, (Hanff, 2015)[221], one of the BIM practicioner showed how useful BIM is, in information management. The possibility to give positions of elements, materials and other related quantities of the facility in worksheets was demostrated. The ultimate benefit of such data is the improved manageability of the information during delivery.Nevertheless, (Schumann, 2015) giving the international experience of BIM, pointed out that BIM manager is the fith and most important component of BIM. BIM Manager or the conductor leads and ensures the coordination of all stakeholders and implementation of information in whole delivery process. Management approaches,strategies, training,measurement of performance and involvement of stakeholders are among the key duties of the BIM managers.It is supported in (Hardin, 2009) on page 308, that conventional projects leaders like architects may not be enough to handle the BIM activities. The communication efficiency becomes of high paramount and it requires new line of the whole life cycle thinking with a combined knoweldge from the clients, designers and contractors view. BIM management involves giving the right platform to acquire such capabilities.

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[220] Source: Own creation from Presentation by Gralla, M. (19. November 2015). Building Information Management - Symposium. (Univ.:-Prof. Dr.-Ing. ( Architektur und Bauingenieurwesen), Interpret) Tu Dortmund, Deutschland, Dortmund.

[221] Source: Own Creation from Presentation by Hanff, J. (19. November 2015). Building Information Management- Symposium. (Geschäftsführer Ceapoint aec Technologies GmbH, Interpret) TU Dortmund, Deutschland, Dortmund.

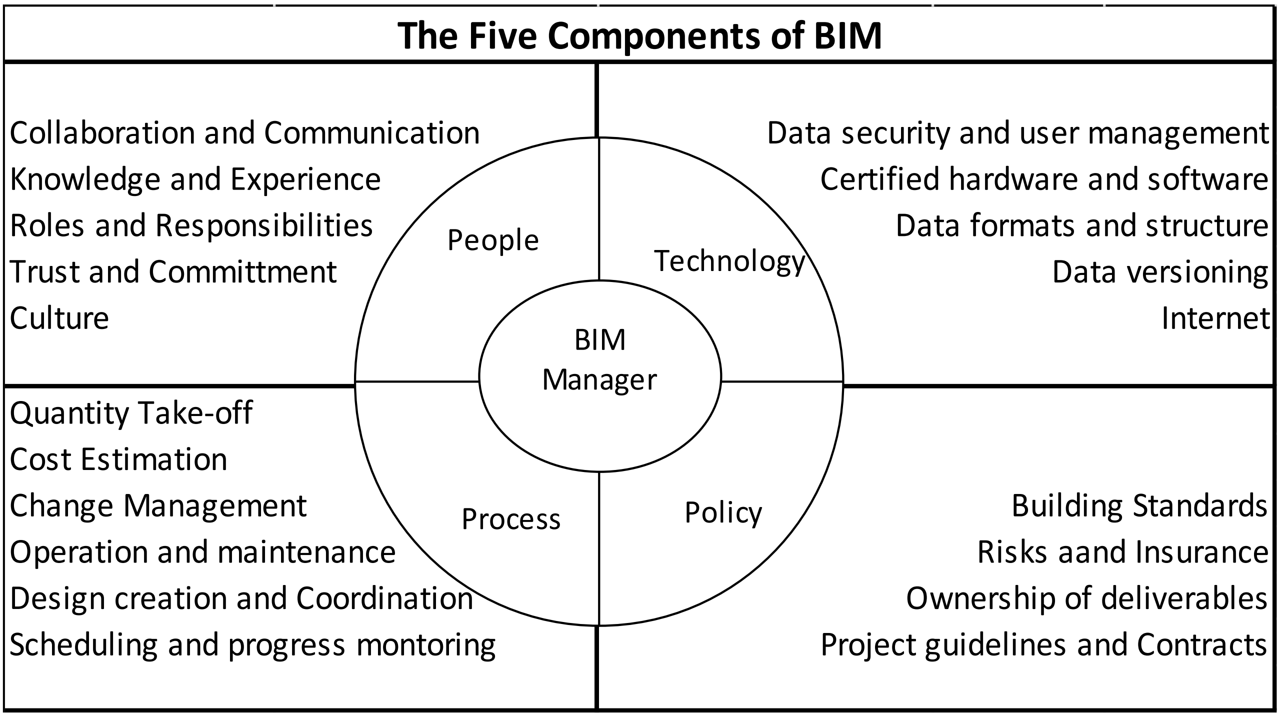


**Figure 202:Basic Components of BIM in Practice[222]**

The fact that, the model requires Life Cycle Costing (LCC) is of great importance to Tanzania.Respondents (16[223],17[224],19[225] and 21[226]) indicated that LCC is important and it is not practiced at all in Tanzania. In simple language, Tanzanian construction industry is still trying to solve current problems using the same thinking that were involved in creating those problems, that is almost impossible according to Einstein. A change is good step and necessary. 5DBIMBOQ model include life cycle related items and calculation that may necessitate the industrial commitment to creation of among others, the historical cost database.The model gives the starting point for both, where the industry was, where it is and where it is supposed to go. Models need to consider the three situations (Cerovsek, 2011).

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[222] Source: Modified from Schumann, R. (19. November 2015). Building Information Management -Symposium. (International Operation Director, HOCHTIEF ViCON, Interpret) TU-Dortmund, Deutschland, Dortmund.

[223] Respondent 16: “We have our Property Managers, although they are not directly involved in designing phases of our new buildings, but we have ways of handling the challenges, say some time to communicate them the designers. To me if we can get that (BIM), it is where we want to go”.

[224] Respondent 17: “Life Cycle Costing is just theoretical item, we do not have it in the practice or contractual documentation”

[225] Respondent 19: “Life cycle costing is not included in BOQ. We normally do consider in our calculation but not writing in the BOQ.Expert are doing their profession by following the market or the requirements of clients and fees the client can pay. It is difficulty to prepare alternative designs or LCC assessment”

[226] Respondent 21: “If your background is building economics, you should know that we are still using the same SMM of 1977. That means No such thing like duration or life cycle costing. We do not have life cycle costing thinking at all. Our mentality is only on the Bills Of Quantities.”

## 4.2. Exactitude

In BIM everything starts with 3D. This means even a floor is modelled as a three dimension item, and in reality it is.According to (Cerovsek, 2011) a model like that of floor is viewed differently. It may represent a problem and the solution (BIM Model) or a property of a building information (BIM Schema). In essence the two stand point of view intend to *communicate* the *building information*. It was suggested that BIM development should be open to the future improvement. In (Smith & Tardif, 2009), it was argued that AEC professionls are concentrating on the model side while the most important side of BIM is schema or informational side. Having a well dimensioned BIM model is far from having a *more exact* BIM model.Facility managers area is different from QS area of use. Exactitude in BIM here, lies on simplicity, clarity and openness of the information to other players and not on the accuracy or precision of the BIM model measurements. 5DBIMBOQ model follows the view point of BIM schema, because it involves a data structure representation in spreadsheet format. BIM *schema* was defined as a non-linguistic data structure that describes abstractions of generalised properties of a collection of states of information about buildings to be used in project communication (Cerovsek, 2011)

BIM improves exactitude compared to normal CAD. It is parametric and so, it ties a number of element together. Manual and 2D CADs taking–off are said to be error prone (Monteiro & Martins, 2013). On the other hand, the precision,literaliness,accuracy,faithfullness and correctness are synonymous terminologies to exactitude. Truth of such terminologies depend on the frame of reference. In 5DBIMBOQ model, improvement of serial items to include location,more references and assumptions improves the commitment of players to *exactitude* in that the measured quantities or descriptions will necessarily be frame referenced. This was supported by Respondent 13[227]by sayng that the use of advanced software reduces error in BOQ preparation, but it does not help much on the reduction of provisional works, because that depends on the collaboration of other participants. Information to be exact, does not end at the individual level. To be *precise information* need to be precisely understood and interpreted in the decision making process.Without it even transparancy is affected.

5DBIMBOQ is expected to enhance exactitude through the use of components as units of measurements. Such an effort has the effect of eliminating chance for errors likely due to complexities of the standardisation. An item that can be measured as one component, when broken down can be of more complexity and hence resulting into less accuracy. Simple example is when decimals are

[227] Respondent 13: "This WIN QS software I am using reduces errors that I would do as human being, but not provisional sums. If you use WIN QS very well, it reduces errors, but I am not sure if it can eliminate provisional sums, because they depend on other professionals"

used over exact numbers. Likewise, information is more exact when sent or displayed in summation terms than details. Requesting a unit item like complete *grilled gate*, is far better compared to the request of number of *grilled gate components* and describing welding process and requirements. Clients who are not conversant with the construction process may have a more chance of participating in a more composite unit oriented measurement than otherwise. Actually, small margin of errors are still found in BIM taking off software today (Monteiro & Martins, 2013), because of the existing standards of measurement.

| Standpoints for the Comparisons of the roles of BIM model and BIM Schema in Project Communication | | |
|---|---|---|
| Stand Point | BIM Model | BIM Schema |
| Communicative Intent | To documents information about a specific building project phases (pre- ,construction, post) | To standardise data structures for the exchange of building information |
| (Semiotics) | (to externalise project ideas for project realisation) | (to specify data structure for the exchange) |
| Authors | Design Office, AEC/O project teams, individual AEC/O practitioners that collaborate on the projects | Standardisation organisation for international or industry standards, ie ISO,IAI, CSL |
| (sender) | (Architects, Engineers, Mechanical Engineers | (AEC/O and computer science experts) |
| Audience | Actual Building Project Stakeholders having different project roles and professional backgrounds | Vendors of AEC/O software used to represent form, function, or behaviour of buildings |
| (Receiver) | (Architects, Engineers, Contractors, Public Bodies) | (AEC/O software vendors) |
| Authoring Environment | BIM tools are software packages that are used for modelling and/ or are integrated design environment | Information Modelling software that enables specification of data structures with relationships |
| (Encoder) | ArchiCAD, REVIT, Allplan, TEKLA,,) | (EDM modeler, STEP tools) |
| Modeling Constructs | Parametric 3D elements and components that are digital equivalents of their real-world (physical) counterparts | High level ontological constructs such as abstract entities, types, properties , parity relations, etc |
| (Code) | (types of building elements and components) | (entities, datatypes, relationship) |
| Modeling Result | 3D representation of actual building that represents simplified physical properties of building | Non-linguistic data structures describing abstractions /generalizations of information states |
| (Message) | (model views, elements with a cross-section, materials) | (types of building elements and components) |
| Message Formatting | Each BIM modelling tool has its native format, but the external exchange depends on the tool | The most common format is ISO STEPS EXPRESS: other encodings are possible XML, Owl, OCL |
| (Encoding) | (native/open model formats: rvt,pln,ifc,cis,exml,pdf) | (open schema formats exp,owl,xsd) |

**Figure 203: Comparisons of the Viewpoints of BIM construct[228]**

[228] Source: Adopted and Modified from Cerovsek, T. (2011). A review and outlook for `Building Information Model`: A multi-Standpoint Framework for a technological development. Advanced Engineering Informatics 25, 224-244.

### 4.3. Collaboration

They say, in a networked world, you have either to collaborate or to perish (Bratton & Tumin, 2012).It is the world of collaboration and not corporation or coordination. Collaboration consists of high trust and dense interdependence, while cooperation is not and coordination is more of work based trust with medium connections (Keast & Mandell, 2016). BIM facilitates *collaboration* between participants during tendering. It becomes easier for the bidder to visualize the construction technology necessary for the preparation of time schedule and statement methods. Clients can be able to get the picture of the items and suggest the requirements instantly. The teamwork stays cohesive and communicative.

In 5DBIMBOQ, the assumptions and querry sheets are attached, to improve the *liability* between participants. It gives the project team an enhanced cohesion. Collaboration is key in BIM. Not because individuals are able to clearly view the model and details, but because participants are put in position to react quickly and openly to the obligations. Such a system gives a room for a more productive discussion and problem solving argument. Individuals were found to be aware of the importance, although many of them were not so sure on how to achieve it. For instance (Respondent 1[229]) indicated that collaboration is difficult to quantify but it is very important. Lacking collaboration causes inefficiency in many other areas of execution. A participant with self-initiative BIM effort needs collaboration to impart it to the team.

Through the request of duration to critical activities, 5DBIMBOQ model may improve collaboration between consultants and contractors. It motivates all other participants to set their activities to the critical durations, which at large it opens a room for a productive communication between participating units. To prepare a schedule a contractor needs enough rate breakdown and instruction on time. In (Eastman, Teicholz, Sacks, & Liston, 2011), consultants have not facilitated contractors adequately with CADs details. This is probably, because the detail level of information depends on the function. So if the contractors fills the incomplete information detailed by designers, it becomes difficulty to programme the schedule of activities.

With 5DBIMBOQ, the function of the model is set ahead giving the contractor an opportunity to bargain on the level of information that matters with designers and estimators, and so the contractor may be in a position to decide on the detail level necessary. This enhances the collaboration because

[229] Respondent 1: "One thing that cannot be measured but it is very important is COLLABORATION, it is something that you cannot quantify. Now COLLABORATION is NOT smooth in Tanzania. There are projects where MISSING ceiling is identified in the site. If it were possible, to indicate in the drawings items like ceiling, skirting and the like, it cannot be forgotten easily as it is. For example, in ARCHCAD BIM has a chat system, so this could help to improve Collaboration"

assurance of the information is higher than otherwise. BIM can be used to create material ordering, fabrication, and delivery schedules for all building components (Azhar, Nadeem, Mok, & Leung, 2008). Measuring items as a component and giving references to manufacturers increases an opportunity for the bidders to quickly *visualize* the item measured and hence pricing more *accurately*.

Nevertheless, 5DBIMBOQ empowers contractors to the total costs management through exposure of breakdown of rates and life cycle costing contents, which are important items in both time and cost management to the participants. Giving a contractor an influence to drive the cost information is giving the whole team a cost goal focus. In (Hardin, 2009), the construction manager at risk or CM-at-Risk and Design and Build (DB) were argued the best procurement deliveries in utilizing BIM efficiency. In these methods, the key factors supporting this argument include the fact that they go beyond *sharing* information, by introducing *liability* to the cost information for the benefit of the client. This is what collaboration is all about. IPD was claimed to relatively lack this client focus compared to CM-at-Risk. In fact, even traditional method or Design-Bid-Build (DBB), is in a position to utilize 5DBIMBOQ, because no one is left unquestionable by the *budget* or *cost* information, even the client of the project. Respondents (3[230], 6[231] and 10[232] indicated the same concern. The *no-one-fault-problem*, which at last the client carries the burden unknowingly. It may be argued that, the solution lies not on delivery method, but rather on the information liabilities, which as shown here the focusing liability on the *cost information* may work best because it leaves no one unquestionable. Probably that is why ((Matipa, 2008) and (RICS, 2014) insisted on the use of cost experts as the focal point in BIM implementation.

## 4.4. Transparency

5DBIMBOQ Model gives a detailed breakdown of the rate, which enhances the *transparency in cost estimates* and project delivery at large. Clients are more likely to understand the price of the item (materials, labour or plants) than the rate because the rate is a technical figure comprising of many variables. Such Information need to be open if BOQ is to perform optimally.

[230] Respondent 3:"PC Sum, Contingencies and Provisional sum is where we are benefiting (tunatoka vitambi huko) .So if we sweep I do not know. But I agree BIM, is going to help to improve information completeness in our BOQs"

[231] Respondent 6: "QS is only used for take-off instead of advising on the cost implications to what designers has given them. Usually Hard Copy is given, or at least today, you may give the soft copy. As a result, the accuracy of quantities and the information is problematic.BIM will even command the way we practice here in Tanzania. People now are demanding to clients a separate appointment. They believe it is good for their fees"

[232] Respondent 10: "To do this, QS must go and calculate manually. When the client want, we have no way other than doing.BOQ is very helpful in monitoring COST of the projects, as it consists of specs as well. The only challenge I see, is that contractor do cheat, and so it need strong team to supervise. It is very important to have close relationship with contractors. Sometime PC Sums is just laziness of incompetent QS, for example one project, had PC Sum of Doors. CAD is what I use, these modelling are about engineers.

*"Construction Sector Transparency Initiatives (CoST) is about increasing transparency. Enhanced transparency in the construction sector has two main benefits. First, corruption is reduced since persons intending illegality would perceive a greater risk of getting caught thus modifying their behaviour; and second, management would improve since slack practices would come to light and more care would be taken. Corruption and bad management both lead to poor quality construction and inappropriate structures that are unsafe and unsustainable". (Tanzania Civil Engineering Contractors Association (TACECA), 2008)*

The above perception on transparency should not be ignored. However the transparency in BIM have much more to add than this likely reduction in corruption. Collaboration for instance, may be enhanced because individuals have a chance to explore and understand the documents. Contractors are mostly reluctant to expose the rate components because of the fear to expose their overhead and profit margin to the clients, which they prefer to be confidential (Greenhalgh & Squires, 2011).

Lack of transparency, hinders creativity, prosperity, productivity and above all it motivates irresponsibility in the project delivery process. In order to collaborate productively, participants need to *understand* and *trust* each other. Information is worthless if it is not understood and trusted, actually it has not been well communicated. BIM is not about data management, it is about information management[233] in ensuring right decisions are attained rightly within right time. Collaborative and Communicative decisions need no information to pass unnoticed, unclear, untimely or doubtfully. Being transparent refer to easily seen, understood, detected and the like, as well as being able to transmit light so that the object behind or beyond can be clearly seen (TheFreeDictionary, 2014). It is the best path in ensuring nothing goes unseen in public undertakings, and enhancing trust for the betterment of our future (Transparency International, 2013). 5DBIMBOQ model improves transparency through detailed breakdown of measured quantities, rates and descriptions. Additional columns in the BOQ enhances clarity of the items measured to other participants while it gives room for the costs expert to question the designers. Likewise, the introduction of Life Cycle Costing items gives an opportunity facility managers to suggest on the designing stages and uncover the likely future difficulties.

Transparency is about openness in undertaking in the sense that information communication between participants is absolutely productive. If for instance, right information is communicated late or by relatively complicated signs (terminologies), it may be considered non transparent. It may equally

[233] Lecturer by Univ-Prof.Dr. Ing Mike Gralla (03 June 2015, Dortmund): " BIM is more of building Information Management than Building Information modelling.

result to the delay in decision making. In construction, some professionals differ significantly in signs, languages and standards. For instance, the use of the word *DITTO* in BOQ, which intends to refer to the ***as just previous*** item or description. It has a good intention of reducing bulkiness of descriptions and saving time, and yet it may lead to lack of transparency. The same applies to items like provisional sums, day-works and preliminaries where a given amount may be set aside technically. If they are not well addressed, they may turn into house of non-transparent information.

> *"In public administration,* **integrity** *refers to "***honesty***" or "trustworthiness" in the discharge of official duties, serving as an antithesis to "corruption" or "the abuse of office."* ***Transparency*** *refers to unfettered access by the public to timely and reliable information on decisions and performance in the public sector.* ***Accountability*** *refers to the obligation on the part of public officials to report on the usage of public resources and answerability for failing to meet stated performance objectives".* (Armstrong, 2005)

### 4.5. Life Cycle Costing, Sustainability and Green building

*Life Cycle Costing* is one of the key element that BIM is expected to introduce in any construction industry. Controlled whole-life costs and data is possible through BIM (Azhar, Nadeem, Mok, & Leung, 2008). The capabilities of BIM ensures visualization and prediction of future alternative designs of the construction projects than ever before. However the calculations of specific life cycle costing are not so direct, which makes BIM technologies less desirable to the estimators. In their works ((Kehily, McAuley, & Hore, 2012) and (Kehily, Woods, & McDonnell, 2013)) showed the possibility and the need for cost estimators (QSs) to merge the 5DBIM models strengths into spread sheets,which can facilitate the life cycle costing in the construction projects. It was stressed that, BIM technologies have not well addressed the calculation of the whole life cycle costing. In (Kehily, McAuley, & Hore, 2012), BIM tools are well approved for take-off and pricing functions, in respect to construction costs, but the tools are very unreliable in gaining a Whole Life Cycle Costing perspective.Even countries with a far better stage in BIM implementation, are yet to fully document life cycle costing in the construction. As a result, it may even become difficulty to distinguish contractual documentation of 2D professionals from 5D practicing professionals as (Jacob, 2015)[234] saw in Germany

[234] Source: Lecturer presentation from Dr. Mathias Jacob: "On his lecture, said most professionals are still thinking in terms of 2D. 5DBIM is almost an imagination in Germany. Although it has already been practiced and has improved accuracy, timely delivery, alternative design and transparency, yet there is no notable contractual documentation from 5DBIM directly".

*"A feature which is inherent in some of the leading 5D estimating applications such as CostX, CostOS and Buildsoft is a customisation feature which provides users with the ability to add columns and functions to the applications default workbooks and settings. In these applications users can customise cost data to include adjustments for the additional variables of life cycle costing that cannot be extracted from the model" (Kehily, Woods, & McDonnell, 2013)*

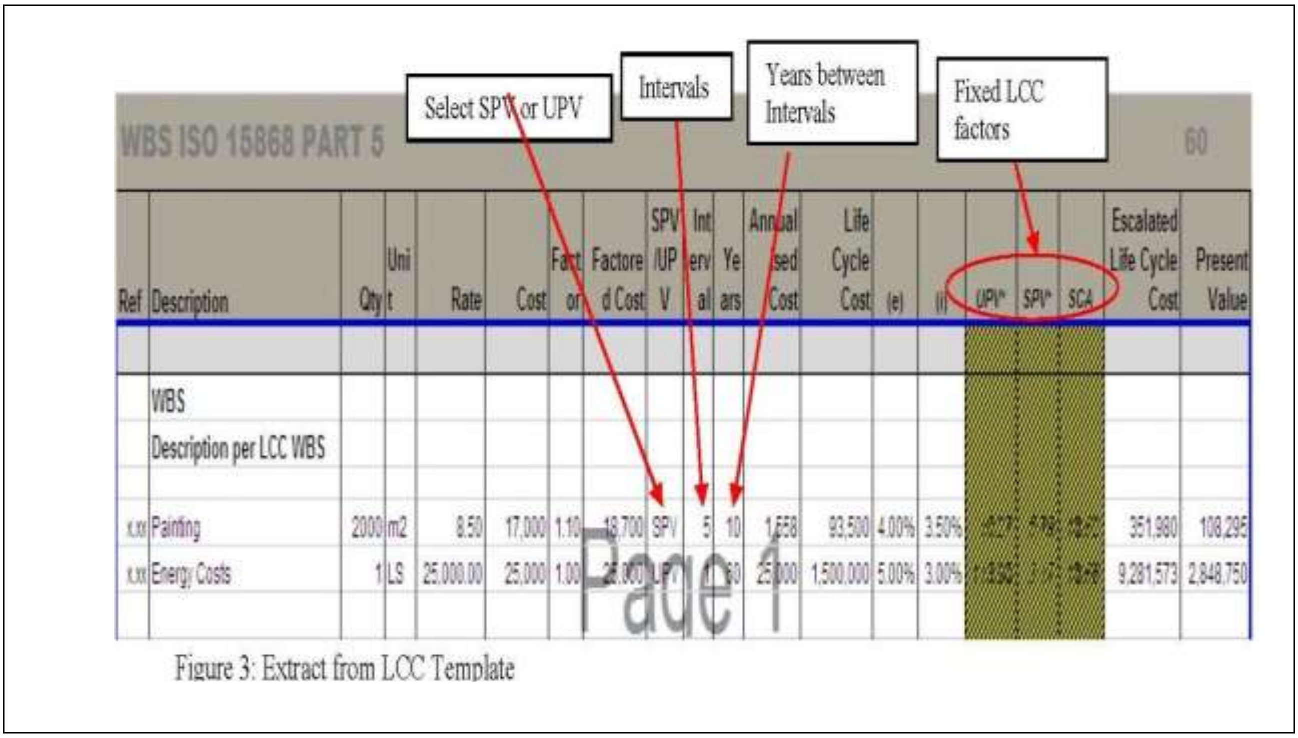


**Figure 204: Efforts to use Excel in calculating the Life Cycle Costing in the BOQ[235]**

According to (Smith & Tardif, 2009),on page 62, excel spreadsheet of spatial data is a building information model. It is a common misconception that professionals are thinking more on the geometrical 3D BIM than the "I", information in BIM.Most of the data in BIM consists of words and numbers (alphanumerical).

*"Whenever information is organized into something as simple as a table, with column headings that define the type of content contained in each cell in that column, the information can be described as "Structured", and can be manipulated "Intelligently" by simple algorithms designed to qualitatively distinguish the values in one column from the values in other." (Smith & Tardif, 2009)*

[235] Source: Kehily, D., McAuley, B., & Hore, A. V. (2012), Page 19-20

The 5DBIMBOQ model is the structured information integration mentioned above.It is a BIM and a BOQ is a BIM too, and so it is not wrong calling 5DBOQ instead of 5DBIM. The life cycle costing inserted and manipulated gives a high chance of improving the productivity effect of BOQ in the whole life Total Cost Management (TCM). It give a chance to improve collaboration between the design team and facility management team. According to (Vanlande, Nicolle, & Cruz, 2008) the two parts are usually dissociated in the processes of building management. It was viewed that "*teams which are concerned with the processes of facility management are rarely those that have participated in the conception and the construction of the building".*Respondents (2[236] and 19[237] ) showed that life cycle consideration is not common in Tanzania and very likely that the designers are not very much involved in advising on the activities like maintenance.

Transfering information from the designing team and construction to the facility managers is a challenge (Smith & Tardif, 2009). As such building owners try to find their own alternatives including the insist on the as built drawings and models.There is a great chance that designers and facility managers have no documentation linkage (See Respondent 16[238] and 17[239]). The introduction of the life cycle to the 5DBIM BOQ model may improve the *life cycle cost thinking* among the construction project participants, as (Respondent 21[240]) has indicated. That the concentration of the professionals is on the BOQ, and they are not thinking of the life cycle costing. At large this is a step toward a real sustainable construction. LCC is closely related to Life Cycle Assessment (LCA),which improves ***sustainability*** in the construction industry throughout all stages of the building life cycle, as given by (Ortiz, Castells, & Sonnemann, 2009).Likewise, in (Kibert, 2008) the first mentioned financial barrier to sustainability was lack of life cycle costing analysis and use. Others include the separation of budget between capital and operating costs.

[236] Respondent 2: "About Cost in Use, our Bills of Quantities (BOQ) does not show directly. It is only within design, because during the design stage, we normally advise the Architect on the selection of materials specified. We normally advise in all element, BUT we do not show in the BOQ, actually even the format of the BOQ has no allowance for that. When you go to the maintenance stage, the project is far over. So it is difficult for them to know what the designers thought. However, there very few projects where the designers are required to produce as built drawings and operational manuals."

[237] Respondent 19: "Life cycle costing is not included in BOQ. We normally do consider in our calculation but not writing in the BOQ.Expert are doing their profession by following the market or the requirements of clients and fees the client can pay. It is difficulty to prepare alternative designs or LCC assessment. We have never involved facility managers in the design and clients believe that is not part of designing team. The culture of maintenance is there and plan is usually there, but it is usually done for the sake of getting approval of certain proposals. To the clients, maintenance is just painting. Board is now making follow up the projects of maintenance. That helps a lot."

[238] Respondent 16: "What we do is to first build basing on our terms of references. Then we call a tender for Property Managers. We have our Property Managers, although they are not directly involved in designing phases of our new buildings, but we have ways of handling the challenges, say some time to communicate them the designers. To me if we can get that, it is where we want to go".

[239] Respondent 17: "Life Cycle Costing is just theoretical item; we do not have it in the practice or contractual documentation".

[240] Respondent 21: "We do not have life cycle costing thinking at all. Our mentality is only on the Bills Of Quantities"

Nevertheless, the items like waste, which are usually lesser considered but of high impact can now be dealt. In (Koskela, Lean Production in Construction, 2007), waste is any non-value adding activity that produces cost to the project directly or indirectly. Wastes of materials, unnecessary movements, re-works, errors of additional spaces, delays abnormal wear and tear of the equipment and loss of labour were among the mentioned examples of wastes in the construction projects. Respondent 1[241] showed concern about the effect of collaboration, irresponsibility and the wastes costs caused in the construction projects.The principles of sustainability as given by (Kibert, 2008), include ***reduction of resource consumption,reuse of the resources,recycling resources,protecting nature,eliminating toxics, applying life cycle costing and focusing on quality***.In essence, 5DBIMBOQ model covers most of the items relative to sustainable construction. Wastes, life cycle costs, rates breakdown and use of references and assumptions revolves around ensuring healthy and satisfactory building is commissioned.

Talking about sustainable construction is related to green builiding with exception of time dimension.Green building view things in short term, for example using non toxic materials in the construction or maintaining them on time. On the other hand, sustainability views the use of those materials relative to the future betterment. A man using using hardwood instead of plywood in door, may be green builder in terms of costs efficiency, but may not be sustainble if that hardwood is irreplaceable. Green building refers to healthy facilities designed and built in a resource-efficient manner, using ecologically based principles (*ibid*).In addition, by introducing life cycle thinking, 5DBIMBOQ model is expected to enhance the commissioning practice. That is ensuring that the delivered project operates as intended

### 4.6. Duration

*Duration* item is all about *time.* Conceptually, quantities reflects the space of the constructed facility. When combined with resource consumptions, this space travels through duration. Therefore the 5DBIMBOQ is the *space-time model* of the facility. Although practically, individuals starts with costing and then they prepare the schedule, the internal reality is different, they almost go together,that is time and resource consumption, which is how much time does it take to do that? Pinning time to any undertaking may not be a waste at all. In (Jongeling & Olofsson, 2007), it was claimed that

[241] Respondent 1: "There are benefits provided by BIM that cannot be quantified, for example the RE-WORK, how can you quantify this ITEM……One thing that cannot be measured but it is very important is COLLABORATION, it is something that you cannot quantify…….This habit of specifying by saying this material or equivalent, gives the room to temper with it…….. The Contractor brought those Plants during Mobilisation, some of which the Consultant, up to now they have not managed to instruct where they are to be used. As a result, the plants remain in the Yard of The Contractor. This means, the contractor incurs the costs, which he is entitled to be recovered. This is a burden to the client, to make sure the cost of those plants is paid (kwa sababu wao wali-specify lakini)(because they (consultants) specified, but) who is supposed or going to pay now, Quantity Surveyor or Architect or Engineer? No, the client"

Activity-Based Scheduling methods are not very well-suited for construction projects because the large amounts of on-site fabrication, which involves continuous or repetitive work at different locations. It was supported that the characteristics of construction align more closely with location-based scheduling. Therefore, it was argued that the BOQ can be helpful in modeling schedule of time in 4D CAD, because it gives *locations.* This 5DBIMBOQ model intends to add duration as well,which may facilitate both, activity and location scheduling depending on the nature of the construction project.Respondent 20[242], was more conscious with this item than others, believing that it may improve accuracy of time estimate.

The effect of duration or scheduling in the model is crucial and vey well related to current effort of BIM. The end result of the clash detection is to reduce rework and improve scheduling.Softwares like VICO Office Constructibility Manager are there to help checking interference between models from different disciplines. Definition of clash detection is not very clear (Lei Wei & Xuru, 2011), but it stems from the fact that different models are integrated in a one unified model for much higher analysis. As such, the interfering between elements need to be resolved for the better analysis before going into field. 5DBIMBOQ model, is lesser concerned with provisional of the visualisation necessary to facilitate crash detecting. That is left to the participants. The model will only specify the level of information that the model is expected to provide. This is what the clash detecting experts will have to charge and provide. In a simple picture, it is the level of duration details that underpins the visualisation and clash detection. That is what BIM does. It gives a clash free information that results into timely constructibility. It ensures the integrity and reliable results of the model in energy analysis, structural analysis, cost estimating, 4D scheduling, multi- disciplinary coordination, and so on (Lei Wei & Xuru, 2011). In their book (Smith & Tardif, 2009) said

> *"Designers and construction industry professionals are often caught looking through the wrong end of telescope, focusing on improvements in the design and construction of buildings rather than on the impact that design and construction has on the total life cycle costs and operations of building, or the total environmental impact of design and construction decisions."*

The same, applies here. It is a wrong end of telescope for a BIM participants,especially the clients to concentrate on the technology side of BIM or clash detection and visualiazation. The right end of telescope is the *level of information integration* that the technology is likely to produce. In this case, clash detection software is expected to satisfactorily attain certain level of estimated duration

[242] Respondent 20: "Even the issue of TIME, we normally generalise. I am very impressed with the Idea of TIME to be included in the BOQ. So I think contractors must also enter in the BIM system"

schedule. This optimum level of duration is crucial for optimizing costs as well. According to (Turner, 2009), both higher and lower duration may be harmful (*See*

*Figure 205: Duration-Cost Optimization* Importance).

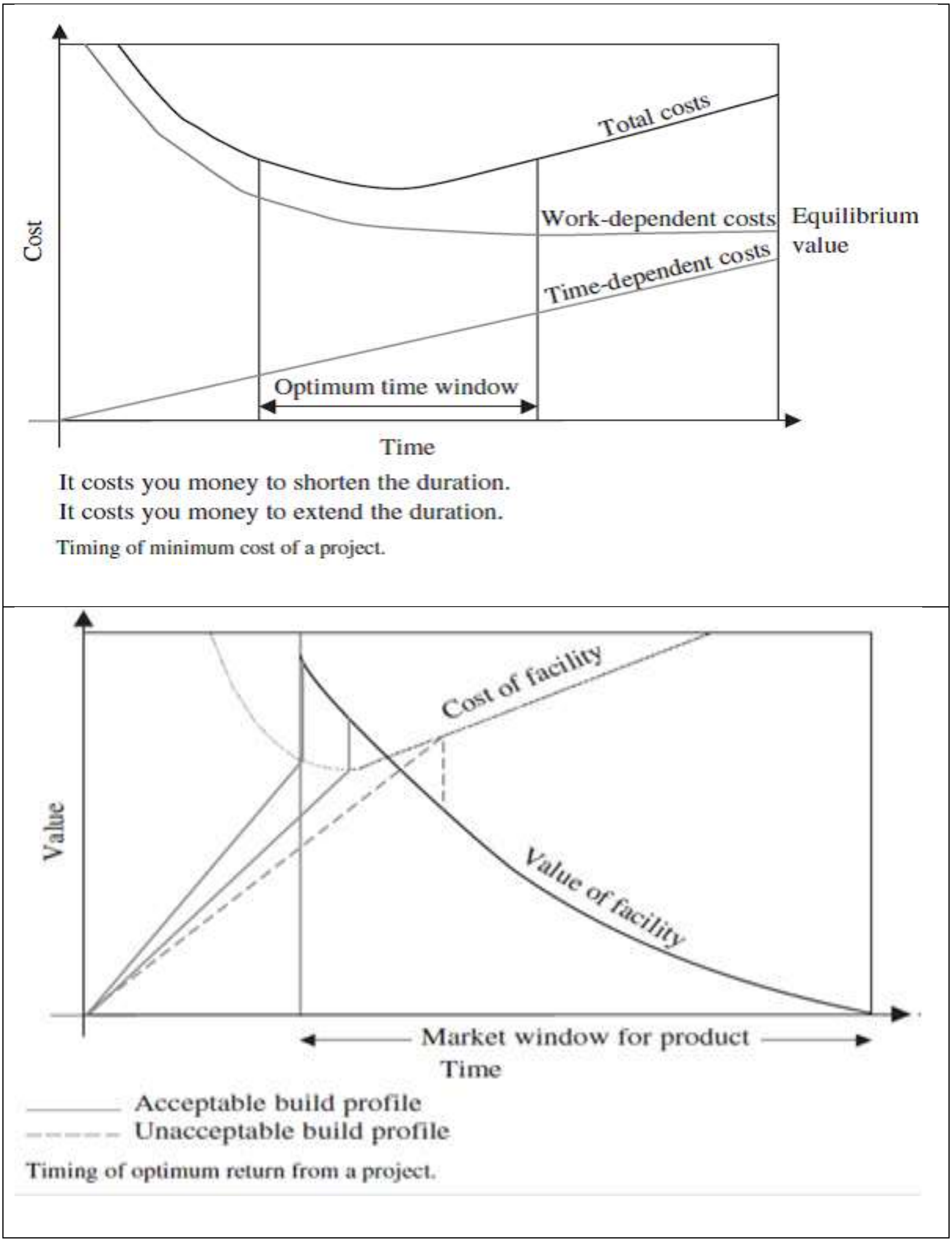


**Figure 205: Duration-Cost Optimization Importance[243]**

It was argued that, scheduling gives the project a timescale to justify the expenditure,to coordinate, control and predict the financial,efforts and resources required in order to achieve certain results. It is important to look at this undertaking careful. A formwork preparation depends on the work but the salary of foreman is time dependent item. The two has different behaviour. Unless the duration of an activity is given special priority, the deadlines may be helping very little compared to what it should be. The duration of the work is central to scheduling (ibid).Scholars support the need to improve the way time is modelled in construction.

> *"Moreover, although time is a factor of major importance in construction costs, traditional cost estimating methods do not offer any reliable guidance for assessing the impact of production duration on project costs" (Hanid, Koskela, & Siriwardena, 2010)*

## 4.7. Miscellaneous

In construction projects, there are also a number of things are more said than done. (Smith & Tardif, 2009), mentioned "as built records drawings" as one of the most contractually demanded and confirmed provided item but, without the real measurement criteria of performance . It was mentioned that rarely the contracts specifies what it means by as built record drawings and as a result the delivered documents are mostly impartial and are hardly used by the facility managers.Likewise, the question of time is common phenomena in any undertaking worldwide. In the Tanzanian construction projects, programmes are prepared,but mostly temporarily because of the low completeness of the information during design. This may lead to inefficiency because the deadlines dates, which are starting and finishing are likely to be unrealistic.The insertion of duration into activities in 5DBIMBOQ model may facilitate the efficiency in a given activity that has a complete information, be setting an individual binding deadline. The likely bid prices (Brandt & Franssen, 2007) due to deadline requirements may be worth exposed than being hiden, and probably being borne by the clients at the existing situation where delays of works are becoming standard performance. A seven construction company study in Sweden revealed that construction workers *completely waste* about 35% of work time (Jongeling & Olofsson, 2007). The commulative effect of delays to the overall project duration may be reduced using advanced binding deadlines of specific more manageable activities.In Germany, there may be a practice of binding deadlines (Brandt & Franssen, 2007) as it is well known by professionals

The 5DBIMBOQ model can give a way toward legal rights among participants. This is among the systematic hindrance in the implementation of BIM. In (Boldt, 2015)[244],argued that the inclusion of

[244] Source: Prof. Dr. Antje Boldt: Giving lecture on legal perspective on BIM.

BIM planning or design as special condition in HAOI is not enough from the legal perspective, because the BIM model ownership rights are still not clearly defined. A case in Kranhäuser-Rheinauhafen in Köln were given as example (*See Figure 206: Example of the Projects that was given as an example of patent* right ). In 5DBIMBOQ model,legal aspect worries are likely to be reduced from creativity of individuals to the information the owner need. The question is not on who provided the model, which requires handling of complex definitions of what is BIM, who contributes more and the like.The question turns into what information is supposed to be produced under this BIM Model level, which can relatively be answered easily using evidences from documentation. It may be relatively easier for the arbitrator to measure what BIM does (Attached Assumptions used in the Take-Off) than how or why BIM does (5DBIM facilitated taking Taking-Off).In other words, 5DBIMBOQ model may help to divert the thinking from understanding the meaning of BIM, which is relatively more subjective to a more objective way of defining BIM from the point view of the unique tangible outputs it produces. A participant to project is the basic owner of the creativity to the extent of the information that creativity produced to project.

Kranhäuser –Rheinauhafen in Köln

**KRANHÄUSER: URHEBERRECHT AM GEMEINSAMEN ENTWURF**

1. Sind auf den Vervielfältigungstücken eines erschienenen Werks order auf dem Original eines Werks der bildenden Künste mehrere Personen in der üblichen Weise als Urheber bezeichnet, werden sie gemäß § 10 Abs.1 UrhG - auch im Verhältnis zueinander – bis zum Beweis des Gegenteils als Miturheber des Werks angesehen
2. Bereits ein geringfügiger eigenschöpferischer Beitrag zu einem gemeinsam geschaffenen Werk, der sich nicht gesondert verwerten lässt, begründet nach § 8 Abs. 1 UrhG die Miturheberschaft

BGH, Urteil vom 26.02.2009 – I ZR 142/06

**Figure 206: Example of the Projects that was given as an example of patent right[245]**

[245] Source: Lecturer Notes From Boldt, A.(2015)

## 5. Conclusion

The low level of usage of Building Information Modelling (BIM) has positive relation to the low level of completeness in the Bills of Quantities (BOQ) in Tanzania. Use of BIM has been pioneered to have an influence on the increased information integration in the construction project procurement. Lack of BIM usage in the construction projects results into less collaborative, transparent, and life cycle delivery efficiency. It has been related to the inadequate automation, detailing, specification, exactitude and visualization in the documentation of construction project delivery. In Tanzania, BOQ is central to the pillars of delivery documentation efficiency in construction procurement. The incompleteness of BOQ has great consequences to the total cost management performance. Therefore, the low usage of BIM found in Tanzania, may be one of the reasons that the BOQ productivity in total cost management of the construction project is not adequate.

The hypothesis testing has shown that the existing relationship between low 5DBIM usage and BOQ completeness is not significant. This means, the null hypothesis that there is no significant relationship between BIM and BOQ completeness has not been rejected. On the other hand, it was found that in Tanzania BIM is lowly practiced and like in many countries, Germany being one of them, professionals have different perception on the meaning of BIM. Therefore, if a more refined unified definition of BIM is given and understood, then there is a great chance that more evidences can be clearer among practitioners during relevant BIM and non-BIM projects, which may give more evidences that the relationship between 5DBIM and BOQ completeness in Total Cost Management (TCM) is significant enough to reject the null hypothesis. Hence further development and testing of the suggested 5DBIMBOQ model or BIM for Tanzania may be worthwhile.

However, this study data collection were more confined in Tanzania which is a less developed country in construction technology and most likely a lowly BIM practicing context, which give a risk of generalizing the results as it lacks an adequate empirical comparison from best BIM practice environment. Consequently, this forms one of the future study, to vigorously re-test the hypothesis in known BIM practicing environment. Likewise, further areas of study open from this study include the contextual testing of the existing relationship between BIM and performance criteria in total delivery of Construction projects.

# X. Attachements and Appendices

## 1. Appendices

### 1.1. Study Schedule From March 2013 to 2016

| NO | ITEM OF THE TOPIC | | DURATION IN (MONTHS) FROM DECEMBER 2012-MARCH 2016 | | | | | | | | | | | | | | | | | | | REMARK |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 2012/2013--------------2013/2014---------------------2014/2015-------------2015/2016----- | | | | | | | | | | | | | | | | | | | |
| | | | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 | 26 | 28 | 30 | 32 | 36 | 38 | 40 | |
| 1 | LANGUAGE COURSE | 4 | | | | | | | | | | | | | | | | | | | | |
| A | Travelling | | | | | | | | | | | | | | | | | | | | | |
| B | Registration and other preparatory activities | | | | | | | | | | | | | | | | | | | | | |
| C | Course studying | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | |
| 2 | PROPOSAL (1ST AND 2ND STAGE) | 4 | | | | | | | | | | | | | | | | | | | | |
| A | Title restructuring | | | | | | | | | | | | | | | | | | | | | |
| B | Background formulation | | | | | | | | | | | | | | | | | | | | | |
| C | Problem restructuring | | | | | | | | | | | | | | | | | | | | | |
| D | Theoretical and Conceptual development | | | | | | | | | | | | | | | | | | | | | |
| E | Methodology and Methods selection | | | | | | | | | | | | | | | | | | | | | |
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| **3** | **INTRODUCTION** | **18** | | | | | | | | | | | | | | | | | | | | |
| **A** | **Title restructuring** | | | | | | | | | | | | | | | | | | | | | |
| **B** | **Research Gap identification** | | | | | | | | | | | | | | | | | | | | | |
| **C** | **Research Problem restructuring** | | | | | | | | | | | | | | | | | | | | | |
| **D** | **Theoretical and Conceptual development** | | | | | | | | | | | | | | | | | | | | | |
| **E** | **Methodology and Methods selection** | | | | | | | | | | | | | | | | | | | | | |
| **F** | **Contribution** | | | | | | | | | | | | | | | | | | | | | |
| **G** | **Research re-planning** | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | |
| **4** | **LITERATURE REVIEW** | **36** | | | | | | | | | | | | | | | | | | | | |
| **A** | **Resources soliciting and reading** | | | | | | | | | | | | | | | | | | | | | |
| **B** | **Studying the Germany industry** | | | | | | | | | | | | | | | | | | | | | |
| **C** | **Comparing professional training in** | | | | | | | | | | | | | | | | | | | | | |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Germany and Tanzania** | | | | | | | | | | | | | | | | | | | | | |
| **D** | **What is BIM** | | | | | | | | | | | | | | | | | | | | | |
| **E** | **Why BIM** | | | | | | | | | | | | | | | | | | | | | |
| **F** | **For Whom is BIM** | | | | | | | | | | | | | | | | | | | | | |
| **G** | **Technology adoption theory** | | | | | | | | | | | | | | | | | | | | | |
| **H** | **Other related** | | | | | | | | | | | | | | | | | | | | | |
| **I** | **Compiling the relevant materials** | | | | | | | | | | | | | | | | | | | | | |
| **J** | **BIM related Paper writing** | | | | | | | | | | | | | | | | | | | | | |
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| **5** | **METHODOLOGY** | **18** | | | | | | | | | | | | | | | | | | | | |
| **A** | **Philosophical Review** | | | | | | | | | | | | | | | | | | | | | |
| **B** | **Scientific research review** | | | | | | | | | | | | | | | | | | | | | |
| **C** | **Research Design and Strategies** | | | | | | | | | | | | | | | | | | | | | |
| **D** | **Theoretical and Conceptual development** | | | | | | | | | | | | | | | | | | | | | |
| **E** | **Methods, Techniques and Data Collection** | | | | | | | | | | | | | | | | | | | | | |
| **F** | **Sampling strategies** | | | | | | | | | | | | | | | | | | | | | |

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| **H** | **Measurement** | | | | | | | | | | | | | | | | | | | | | |
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| **6** | **DATA COLLECTION** | | | | | | | | | | | | | | | | | | | | | |
| **A** | **Data Collection Germany** | **6** | | | | | | | | | | | | | | | | | | | | |
| **A** | **Tools Formulation** | | | | | | | | | | | | | | | | | | | | | |
| **C** | **Data Collection in Germany** | | | | | | | | | | | | | | | | | | | | | |
| **D** | **Compilation** | | | | | | | | | | | | | | | | | | | | | |
| | **Theory Building** | | | | | | | | | | | | | | | | | | | | | |
| | **Model/Tool reformulation** | | | | | | | | | | | | | | | | | | | | | |
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| **B** | **Data Collection in Tanzania** | **8** | | | | | | | | | | | | | | | | | | | | |
| **A** | **Tools Formulation** | | | | | | | | | | | | | | | | | | | | | |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **B** | **Data Collection in Tanzania** | | | | | | | | | | | | | | | | | | | | | |
| **D** | **Discussion with academicians and experts** | | | | | | | | | | | | | | | | | | | | | |
| | **Data checking and recollecting** | | | | | | | | | | | | | | | | | | | | | |
| | **Paper presentation** | | | | | | | | | | | | | | | | | | | | | |
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| **7** | **DATA ANALYSIS** | **6** | | | | | | | | | | | | | | | | | | | | |
| **A** | **Tools selection and testing** | | | | | | | | | | | | | | | | | | | | | |
| **B** | **Data analysis and justification** | | | | | | | | | | | | | | | | | | | | | |
| **C** | **Presentation** | | | | | | | | | | | | | | | | | | | | | |
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| **8** | **FINAL CHAPTERS** | | | | | | | | | | | | | | | | | | | | | |
| **A** | **Interpretation** | | | | | | | | | | | | | | | | | | | | | |
| **B** | **Conclusion** | | | | | | | | | | | | | | | | | | | | | |
| **C** | **Recommendations** | | | | | | | | | | | | | | | | | | | | | |
| **D** | **Presentation** | | | | | | | | | | | | | | | | | | | | | |
| **9** | **Report writing** | | | | | | | | | | | | | | | | | | | | | |

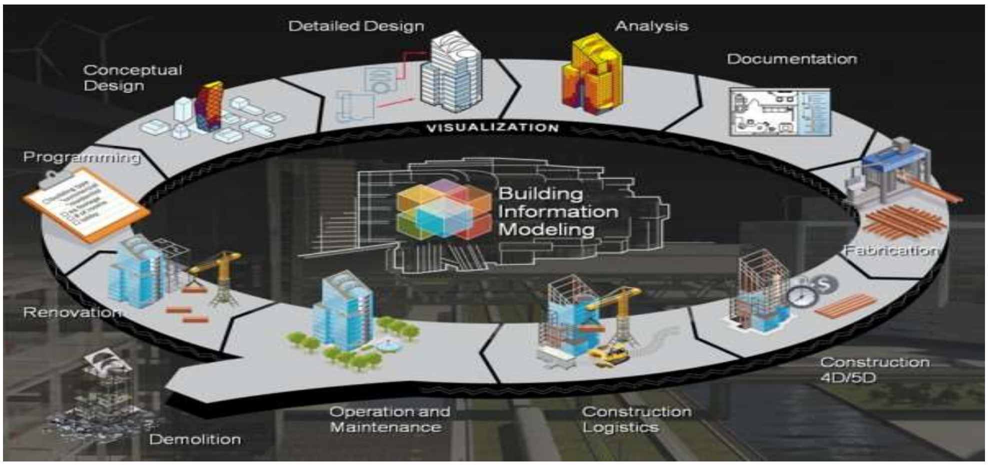
| | | | | | | |
|---|---|---|---|---|---|---|
| | **and Submissions** | | | | [redacted] | |

### 1.2. Questionnaires

**APPRAISING BUILDING INFORMATION MODELLING (BIM)**

**IN TANZANIA**

Building Information Modeling (BIM), is the raising technology of delivering projects worldwide. BIM is a tool and a process, where all participants use the same database to build the structure digitally before they do it in the construction site. The process can help the participants to simulate different characteristics of the Building in all stages, that is from designing, construction, operation, maintenance to demolition




The study, intends to develop a BIM model that can help in the effort of improving Total Cost Management in the construction industry. By filling this questionnaire, please help the researcher to investigate the status of ***Building Information Modeling***, especially in the ***process of Construction Cost Calculation***, ***Cost estimation and preparation of Bills of Quantities***. Stay assured that, confidentiality and other ethical matters are of first priority. The mode of answering is only marking in the appropriate boxes. Only 15 minutes will be enough to complete the whole questionnaire.

Thanks in advance for spending your precious helpful time in accomplishing this work.

**Researcher**: Juma Ahmed Mpangule

**Supervisor**: Univ.-Prof Dr.-Ing Mike Gralla

Technical University of Dortmund

## SECTION I:

**Please, Choose an appropriate match and mark as directed**

| | The Area of Profession | Mark (x) |
|---|---|---|
| | Quantity Surveying/ Building Economics | |
| | Construction Management/Project Management. | |
| | Building Surveying | |
| | What is the registration status of the Firm you are working with | |
| | Foreign Firm | |
| | Local Firm | |
| | What is your Profession Status | |
| | Full Registered Professional | |
| | Assistant Registered Professional | |
| | Graduate Registered Professional | |
| | Non Registered | |
| | Which of the following corresponds to your experience in Construction Projects | |
| | Less than 5 Years | |
| | Between 5 to 15 Years | |
| | Between 15-25 Years | |
| | More than 25 Years | |

## SECTION II:

**Please indicate your level of agreement by marking (x) in the appropriate box.**

**NOTE: 5 = Strongly Agree, 4 = Agree, 3= Not Sure, 2= Disagree, 1= Strongly Disagree**

| | In Public Building Contract; Bills Of Quantities works sections include | 5 | 4 | 3 | 2 | 1 |
|---|---|---|---|---|---|---|
| | Preliminary Costs Sections | | | | | |
| | Preambles Sections | | | | | |
| | Measured Works Section | | | | | |
| | Provisional Works Section | | | | | |
| | Prime Costs Sections | | | | | |
| | Day works Section | | | | | |

| | In Public Building projects, Bills Of Quantities comprises of | 5 | 4 | 3 | 2 | 1 |
|---|---|---|---|---|---|---|
| | Provisional Quantities, to be re-measured. | | | | | |
| | Standard Descriptions. Example Ditto and As Per Drawings | | | | | |
| | Duration Estimate of the Critical Elements. | | | | | |
| | Provisional Sums Costs for Special works. | | | | | |
| | International Standard Measurement Reference. Example ISO | | | | | |
| | Local Standard Measurement Reference. Example East Africa SMM | | | | | |
| | Attached questions and answers from the Designers (Query Sheet used in Take-Off) | | | | | |
| | Outlines of assumptions used in Take Off quantities. | | | | | |

**NOTE: 5 = Strongly Agree, 4 = Agree, 3= Not Sure, 2= Disagree, 1= Strongly Disagree**

| | In Public Projects Bills Of Quantities, Standard information include | | | | | |
|---|---|---|---|---|---|---|

| | | | | | | |
|---|---|---|---|---|---|---|
| | Serial Number of measured Items | | | | | |
| | Descriptions of the item measured | | | | | |
| | Quantity measured | | | | | |
| | Estimated Duration for each measured Activities. | | | | | |
| | Measurement Unit. Example Kg, LM and SM | | | | | |
| | Rate or Price for the item. | | | | | |
| | Total Amount of the measured item | | | | | |
| | Materials, Labour and Plant Costs included in the RATE | | | | | |
| | Waste, Subcontractor or Taxes Costs estimate included in the RATE | | | | | |
| | Suppliers or Manufacturers Description references | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| | In Public Construction Projects Contract Documentations; Designers Facilitates preparation of the Bills of Quantities through the following | 5 | 4 | 3 | 2 | 1 |
| | Providing DETAILED SCHEDULES of Building COMPONENTS Example: Bolts, Nails, Windows, Doors, WCs, Electrical appliances | | | | | |
| | Providing DETAILED SCHEDULE of critical elements .Example: Bar bending Schedule, Breakdown of Truss and Perspective view of Plumbing and Electrical Installation | | | | | |
| | Providing more Realistic Dimensions and Images of the External works Elements. Example: Fence,Pavement,kerbstones,Gates and the like | | | | | |
| | Providing digital drawings that gives automatic quantities. Example: Use of Digital Computer Aided Design tools, | | | | | |
| | Providing Manual Instruction through Query Sheet and Instruction Books | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| | In Public Construction Projects Documentation; Bills Of Quantities Document include the following information | 5 | 4 | 3 | 2 | 1 |
| | Future REPLACEMENT Costs for Fixtures and Fittings. Example is WCs | | | | | |
| | References or Clauses of International Standard Organisation (ISO) example (ISO 16739,15926 and 15686) | | | | | |
| | Future MAINTENANCE Costs for different Building Components. Example is Doors, Electrical appliances and Ceiling Boards. | | | | | |
| | Estimated future DISPOSAL Costs for various Building Components. Example is Roof Covering, Floor Finishes and Light Fittings. | | | | | |
| | ALTERNATIVE Suppliers of Building COMPONENTS like, Windows, Doors, WCs and Electrical appliances | | | | | |
| | Warranty/Life Span of Materials and Building components. E, g Doors, Hinges and floor finishes. | | | | | |
| | Preliminaries Costs Break down. Example: Time Based or Progress Based | | | | | |
| | Breakdown of the Items used to build up RATE. Example: Materials, Labour, Plants, Waste, Depreciation, Taxes and like | | | | | |

**NOTE: 5 = Strongly Agree, 4 = Agree, 3= Not Sure, 2= Disagree, 1= Strongly Disagree**

| | | | | | | |
|---|---|---|---|---|---|---|
| | Use of Computer Technologies in Preparation of Bills Of Quantities in Public Projects facilitates | 5 | 4 | 3 | 2 | 1 |
| | Elimination provisional sums | | | | | |
| | Inclusion of Estimated Duration of Activities of the project | | | | | |
| | Elimination of OVER Measured quantities | | | | | |
| | Elimination of UNDER Measured quantities | | | | | |
| | Elimination of Aggregate units like “ITEM” and “SUM”. | | | | | |
| | Inclusion of Maintenance Costs | | | | | |
| | | | | | | |
| | In Public Building Project BOQ, Computer Technologies helps in | 5 | 4 | 3 | 2 | 1 |
| | Including maintenance Costs for different Components. Example is WCs | | | | | |
| | Calculating the costs of Materials, Labour and Plant in building the rate | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Calculating Wastage Costs | | | | | |
| | Retrieving Warranty/life span of Materials and Building components. E, g Doors, Hinges and floor finishes. | | | | | |
| | Obtaining information of a RATE. Eg. Materials, Labour, Plants, Waste, Depreciation, Taxes and like, used to build it. | | | | | |
| | Estimate of Preliminaries Costs e.g. Cranes, Scaffolds to be Used | | | | | |
| | | | | | | |
| | | | | | | |
| | In Civil Works Project BOQ, Computer Technologies helps in | 5 | 4 | 3 | 2 | 1 |
| | Including Maintenance Costs for different Components. | | | | | |
| | Calculating Materials, Labour and Plant Costs | | | | | |
| | Calculating Wastage Costs | | | | | |
| | Including Replacement Costs | | | | | |
| | Including Warranty/life span of Materials and components used | | | | | |
| | Identifying more information about the Rates Eg. Materials, Labour, Plants, Waste, Depreciation, Taxes and like, used to build it. | | | | | |

| | In Construction Project Documentation, which of these groups is closer to technology used | 5 | 4 | 3 | 2 | 1 |
|---|---|---|---|---|---|---|
| | 2D CAD and 3D Computer Aided Design | | | | | |
| | 3D Building Information Modelling or Parametric dimension of BIM | | | | | |
| | 4D Building Information Modelling or Time Dimension inclusive BIM | | | | | |
| | 5D Building Information Modelling or Cost Dimension inclusive BIM | | | | | |
| | Nth D Building Information Modelling | | | | | |
| | Graph iSOFT MEP, ECOTEC Analysis, CISCO IT and COBie | | | | | |
| | MasterSeries ,Auto CAD MEP e.t.c | | | | | |
| | Auto Desk Revit, Vector works and Allplan Nemetschek | | | | | |
| | Autodesk QTO, Vico,iTWO RIB, DProfiler, BIM Measure from Causeway | | | | | |
| | Microsoft Excel | | | | | |

PLEASE READ THIS PHRASE BEFORE ANSWERING THE FOLLOWING PART:
Building Information Modelling (BIM) being a digital database of parametric building project information (all drawings, specifications, building images, analysis, time schedule, costs estimation, quantities, materials pricing, and the like) shared by all participants during the whole delivery process from inception to demolition of the building.

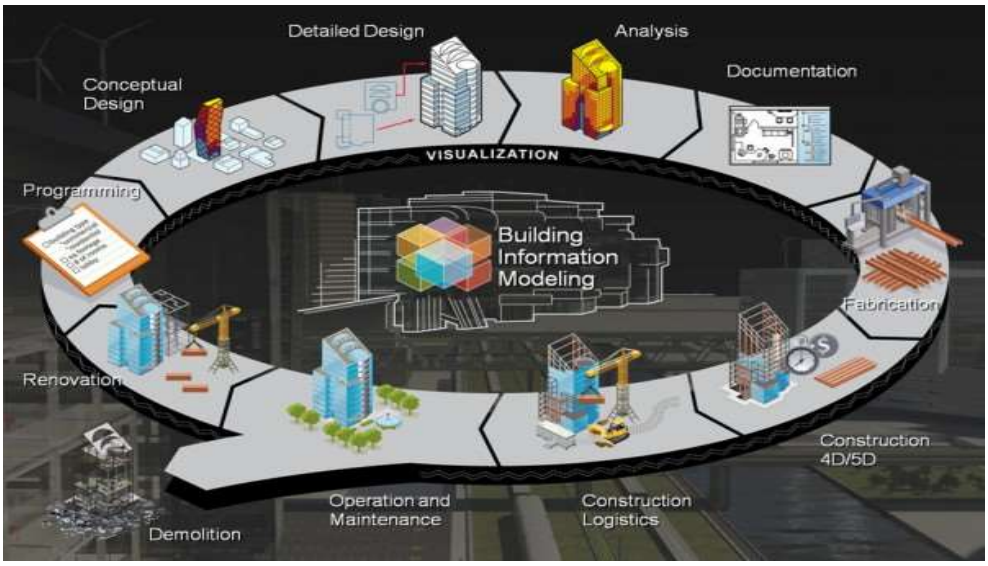
| | In Tanzanian Public Construction projects Documentations, BIM is likely to result into | 5 | 4 | 3 | 2 | 1 |
|---|---|---|---|---|---|---|
| | More Complete Detailed Drawings in Designing stage | | | | | |
| | More Clear Works Description and Specification | | | | | |
| | More Accurate Quantity Take-Off of the works | | | | | |
| | More Accurate Pricing of the works | | | | | |
| | More Timely Costing of Design Change Orders | | | | | |
| | Lesser Changes in Designing during Construction phase | | | | | |
| | Lesser Provisional Quantities in the Bills of Quantities | | | | | |
| | Lesser Provisional Sum in the Bills of Quantities | | | | | |
| | Lesser Final Contract Sum Increase from the Initial Contract Sum | | | | | |
| | Lesser Time Extension from the Planned Completion Time | | | | | |
| | Better Estimate of Maintenance Costs | | | | | |
| | Better Estimate of Future Building Components Demolition Costs | | | | | |
| | Estimate of Building Operation Costs using Bills Of Quantities | | | | | |
| | Estimate of Construction Wastage Costs using Bills Of Quantities | | | | | |
| | Estimate of Detailed Activities Duration Using Bills of Quantities | | | | | |

### 1.3. Architectural firm Questionnaire

**APPRAISING BUILDING INFORMATION MODELLING (BIM)**

**IN TANZANIA**

Building Information Modeling (BIM), is the raising technology of delivering projects worldwide. BIM is a tool and a process, where all participants use the same database to build the structure digitally before they do it in the construction site. The process can help the participants to simulate different characteristics of the Building in all stages that is from designing, construction, operation, maintenance to demolition.




The study, intends to develop a BIM model that can help in the effort of improving Total Cost Management in the construction industry. By filling this questionnaire, please help the researcher to investigate the status of ***Building Information Modeling***, especially in the ***process of Cost Calculation***, ***Cost estimation and preparation of Bills of Quantities***. Stay assured that, confidentiality and other ethical matters are of first priority. The mode of answering is only marking in the appropriate boxes. Only 15 minutes will be enough to complete the whole questionnaire.

Thanks in advance for spending your precious helpful time in accomplishing this work.

**Researcher**: Juma Ahmed Mpangule

**Supervisor**: Univ.-Prof Dr.-Ing Mike Gralla

Technical University of Dortmund

**SECTION I:**

**Please mark (x) in the appropriate box.**

| Item | Guiding Description | Mark (x) |
|---|---|---|
| | | |
| 1 | **The Area of Profession** | |
| | Architecture | |
| | Architectural Technology | |
| | | |
| 2 | **What is the registration status of the Firm you are working with** | |
| | Foreign Firm | |
| | Local Firm | |
| | | |
| 3 | **What is your Profession Status** | |
| | Full Registered Professional | |
| | Assistant Registered Professional | |
| | Graduate Registered Professional | |
| | Non Registered | |
| | | |
| 4 | **Which of the following corresponds to your experience in Construction Projects** | |
| | Less than 5 Years | |
| | Between 5 to 15 Years | |
| | Between 15-25 Years | |
| | More than 25 Years | |

**<u>PLEASE READ THIS PHRASE BEFORE ANSWERING THE FOLLOWING PART:</u>**

**Bills of Quantities (BOQ),** here refers to formal and standardised document that is used in the construction project as a part of contract document containing cost and financial matters with regard to the **delivery of the project.**

**SECTION II:**

**Please indicate your level of agreement by marking (x) in the appropriate box to indicate a YES or NO answer to the question**
**NOTE: Y = Yes and N= No**

| | | | |
|---|---|---|---|
| | In Bidding/Tendering, Bills Of Quantities consists of Item, Description, Unit, Rate and Amount filled in columns. Which of the following is submitted together as additional information to the rate/price. | Y | N |
| | Materials Costs | | |
| | Labour Costs | | |
| | Wastage Costs | | |
| | Subcontractor´s Costs | | |
| | Plants Costs | | |
| | Overhead costs | | |

| | | | |
|---|---|---|---|
| | In Construction Contract; Bills Of Quantities works sections include | Y | N |
| | Preliminary Costs Sections | | |
| | Preambles Sections | | |
| | Measured Works Section | | |
| | Provisional Works Section | | |
| | Prime Costs Sections | | |
| | Day works Section | | |
| | | | |
| | In Construction Projects, Bills Of Quantities comprises of | Y | N |
| | Provisional Quantities, to be re-measured. | | |
| | Duration Estimate of the Critical Elements. | | |
| | Provisional Sums Costs for Special works. | | |
| | Calculations Breakdown used in Quantities Take-Off. | | |
| | | | |
| | In Construction Projects Bills Of Quantities, Standard information include | Y | N |
| | Serial Number of measured Items | | |
| | Descriptions of the item measured | | |
| | Quantity measured | | |
| | Estimated Duration for each measured Activities. | | |
| | Measurement Unit. Example Kg, LM and SM | | |
| | Rate or Price for the item. | | |
| | Total Amount of the measured item | | |
| | Materials, Labour and Plant Costs included in the RATE | | |
| | Waste, Subcontractor or Taxes Costs estimate included in the RATE | | |
| | Suppliers or Manufacturers Description references | | |
| | | | |
| | In Construction Projects Contract Documentations; Designers Facilitates preparation of the Bills of Quantities through the following | Y | N |
| | Providing Automatic Detailed Schedules of building components example: bolts, nails, windows, doors, wcs, electrical appliances | | |
| | Providing Automatic Detailed Schedule in critical elements .Example: Bar bending Schedule and Perspective view of Slabs, Beams and Plumbing and Electrical Installation | | |
| | Providing DIGITAL DRAWINGS that GIVES AUTOMATIC QUANTITIES. Example: Use of Digital Computer Aided Design tools, | | |
| | | | |
| | In Construction Projects Documentation; Standard Cost Document or Bills Of Quantities (BOQ) include the following information | Y | N |
| | Future REPLACEMENT Costs for Fixtures and Fittings. Example is WCs | | |
| | Future MAINTENANCE Costs for different Building Components. Example is Doors | | |
| | Estimated future DISPOSAL Costs for Building Components. Example is Roof Covering | | |

| | | | |
|---|---|---|---|
| | Warranty/Life Span of Materials and Building components. E, g Doors, Hinges and floor finishes. | | |
| | Breakdown of the Items used to build up RATE. Example: Materials, Labour, Plants, Waste, Depreciation, Taxes and like | | |
| | | | |
| | In Construction Documentation, which of the following groups is closer to technology you are using | Y | N |
| | 2D CAD and 3D Computer Aided Design | | |
| | 3D Building Information Modelling or Parametric dimension of BIM | | |
| | 4D Building Information Modelling or Time Dimension inclusive BIM | | |
| | 5D Building Information Modelling or Cost Dimension inclusive BIM | | |
| | Nth D Building Information Modelling | | |
| | Graph iSOFT MEP, ECOTEC Analysis, CISCO IT and COBie | | |
| | MasterSeries ,Auto CAD MEP e.t.c | | |
| | Auto Desk Revit, Vector works and Allplan Nemetschek | | |
| | Vico, i TWO RIB, etc. | | |
| | Microsoft Excel | | |

**SECTION III:**
**Please indicate your level of agreement by marking (x) in the appropriate box.**
**NOTE: 5 = Strongly Agree, 4 = Agree, 3= Not Sure, 2= Disagree, 1= Strongly Disagree**

| | | | | | | |
|---|---|---|---|---|---|---|
| | These are benefits accruing to BIM projects over Non BIM projects in the preparation of Bills of Quantities (BOQ) | 5 | 4 | 3 | 2 | 1 |
| | Elimination provisional sums | | | | | |
| | Inclusion of Estimated Duration of Activities of the project | | | | | |
| | Elimination of OVER Measured quantities | | | | | |
| | Elimination of UNDER Measured quantities | | | | | |
| | Elimination of Aggregate units like “ITEM” and “SUM”. | | | | | |
| | Inclusion of Maintenance Costs | | | | | |
| | | | | | | |
| | In Building Project cost calculation, BIM facilitates | 5 | 4 | 3 | 2 | 1 |
| | Including MAINTENANCE Costs for different Components. Example is WCs | | | | | |
| | Calculating the costs of Materials, Labour and Plant in building the rate | | | | | |
| | Calculating Wastage Costs | | | | | |
| | Retrieving Warranty/life span of Materials and Building components. E, g Doors, Hinges and floor finishes. | | | | | |
| | Obtaining information of a RATE. Eg. Materials, Labour, Plants, Waste, Depreciation, Taxes and like, used to build it. | | | | | |
| | Estimate of Preliminaries Costs e.g. Cranes, Scaffolds to be Used | | | | | |
| | | | | | | |
| | In Civil Works Project cost calculation, BIM facilitates | 5 | 4 | 3 | 2 | 1 |
| | Including Maintenance Costs for different Components | | | | | |
| | Calculating Materials, Labour , Plant Costs | | | | | |
| | Calculating Wastage Costs | | | | | |
| | Identifying more information about the Rates Eg. Materials, Labour, Plants, Waste, Depreciation, Taxes and like, used to build it. | | | | | |

PLEASE READ THIS PHRASE BEFORE ANSWERING THE FOLLOWING PART:

**Building Information Modelling (BIM)** being a *digital database* of *parametric* building project *information* (all drawings, specifications, building images, analysis, time schedule, costs estimation, quantities, materials pricing, and the like) shared by *all participants* during the whole *delivery process* from *inception to demolition* of the building.

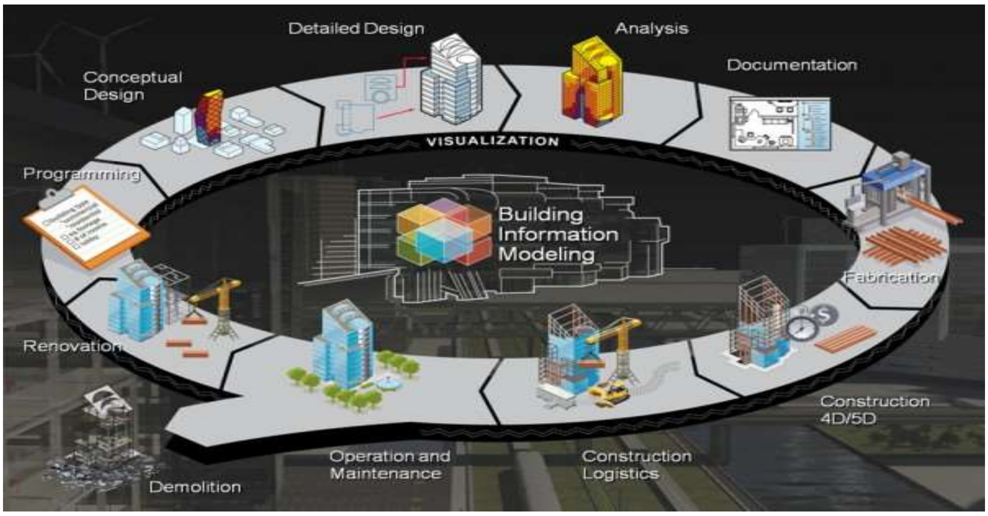
| | **In Construction Projects Documentations, BIM is likely to r**esult into | 5 | 4 | 3 | 2 | 1 |
|---|---|---|---|---|---|---|
| 5. | More Complete Detailed Drawings in Designing stage | | | | | |
| 6. | More Clear Works Description and Specification | | | | | |
| 7. | More Accurate Quantity Take-Off of the works | | | | | |
| 8. | More Accurate Pricing of the works | | | | | |
| 9. | More Timely Costing of Design Change Orders | | | | | |
| 10. | Lesser Changes in Designing during Construction phase | | | | | |
| 11. | Lesser Provisional Quantities in the Bills of Quantities | | | | | |
| 12. | Lesser Provisional Sum in the Bills of Quantities | | | | | |
| 13. | Lesser Final Contract Sum Increase from the Initial Contract Sum | | | | | |
| 14. | Lesser Time Extension from the Planned Completion Time | | | | | |
| 15. | Better Estimate of Maintenance Costs | | | | | |
| 16. | Better Estimate of Future Building Components Demolition Costs | | | | | |
| 17. | Estimate of Building Operation Costs using Bills Of Quantities | | | | | |
| 18. | Estimate of Construction Wastage Costs using Bills Of Quantities | | | | | |
| 19. | Estimate of Detailed Activities Duration Using Bills of Quantities | | | | | |

### 1.4. Semi Structured Interview Guide

**APPRAISING BUILDING INFORMATION MODELLING (BIM)**

**IN TANZANIA**

Building Information Modeling (BIM), is the raising technology of delivering projects worldwide. BIM is a tool and a process, where all participants use the same database to build the structure digitally before they do it in the construction site. The process can help the participants to simulate different characteristics of the Building in all stages, that is from designing, construction, operation, maintenance to demolition




The study, intends to develop a BIM model that can help in the effort of improving Total Cost Management in the construction industry. By filling this questionnaire, please help the researcher to investigate the status of ***Building Information Modeling***, especially in the ***process of Construction Cost Calculation***, ***Cost estimation and preparation of Bills of Quantities***. Stay assured that, confidentiality and other ethical matters are of first priority. The mode of answering is only marking in the appropriate boxes. Only 15 minutes will be enough to complete the whole questionnaire.

Thanks in advance for spending your precious helpful time in accomplishing this work.

**Researcher**: Juma Ahmed Mpangule

**Supervisor**: Univ.-Prof Dr.-Ing Mike Gralla

Technical University of Dortmund

**KEY**

**DEFINITION OF NUMBERS**

**5:** Items mentioned by the Respondent-**Equivalent to Strongly Agreed**

**4:** Items closely related to the sentence of the Respondent**- Equivalent to Agreed**

**3:** Items never mentioned by a Respondent **- Equivalent to Not Sure**

**2:** Items that are indirectly explained by the Respondent**- Equivalent to Disagreed**

**1:** Items directly Disagreed by the Respondent-**Equivalent to Strongly Disagreed**

**BOQ**

**Bills of Quantities (BOQ),** here refers to formal and standardised document that is used in the construction project as a part of contract document containing cost and financial matters with regard to the delivery **of the project.**

**BIM**

**Building Information Modelling (BIM)** being a *digital database* of *parametric* building project *information* (all drawings, specifications, building images, analysis, time schedule, costs estimation, quantities, materials pricing, and the like) shared by *all participants* during the whole *delivery process* from *inception to demolition* of the building.

| | The Respondent Background | Mark (x) |
|---|---|---|
| | Architecture | |
| | Quantity Surveying | |
| | Group, inclusive of a Quantity Surveyor/Architect or Structural Engineer | |
| | Other Profession | |
| | | |
| | Nature of the Organisation | |
| | Consultancy | |
| | Main Contractor | |
| | Construction Subcontractor | |
| | Private Client | |
| | Public Client | |
| | | |
| | Nature of the Firm Registration | |
| | Foreign Firm | |
| | Local Firm | |
| | | |
| | Experience of the Firm in Construction Projects | |
| | Less than 5 Years | |
| | Between 5 to 15 Years | |
| | Between 15-25 Years | |
| | More than 25 Years | |
| | | |
| | Nature of the Construction Projects the Firm is mostly involved | |
| | Civil Works | |

| | | |
|---|---|---|
| | Building Works | |
| | All of the Above | |

| | | | | | | |
|---|---|---|---|---|---|---|
| | On BIM Level | 5 | 4 | 3 | 2 | 1 |
| | Manual, 2D CAD and 3D Computer Aided Design | | | | | |
| | 3D Building Information Modelling or Parametric dimension of BIM | | | | | |
| | 4D Building Information Modelling or Time Dimension inclusive BIM | | | | | |
| | 5D Building Information Modelling or Cost Dimension inclusive BIM | | | | | |
| | Nth D Building Information Modelling | | | | | |
| | | | | | | |
| | On Bills Of Quantities Information Completeness | 5 | 4 | 3 | 2 | 1 |
| | Presence of Provisional Quantities, to be re-measured. | | | | | |
| | Presence of Standard General Descriptions. Example is As Per Drawings or As per Instructions | | | | | |
| | Presence of Provisional Sums Costs for Special works. | | | | | |
| | Presence of Aggregated Units like SUM or ITEM or | | | | | |
| | Lack of Attached questions and answers from the Designers (Query Sheet used in Take-Off) | | | | | |
| | Lack of Attached Outlines of assumptions used in Take-Off calculations | | | | | |
| | Lack of Internationals Organisation Standards (ISO) references | | | | | |
| | Lack of Attachment of Materials, Labour and Plant Costs included in the RATE | | | | | |
| | Lack of Attachment of Breakdown of components like Waste, Subcontractor or Taxes Costs estimate included in the RATE. | | | | | |
| | Lack of Life Cycle Costing Components like Maintenance Costs | | | | | |
| | Lack of Duration Estimate of Activities Measured in BOQ | | | | | |
| | | | | | | |
| | ADDITIONS | | | | | |
| | Public Construction Projects Characteristics | 5 | 4 | 3 | 2 | 1 |
| | Extension of Completion Time due to Instructions | | | | | |
| | Increased Contract Sum due to Variation Order | | | | | |
| | Reasonably Completed in Time and Within Budgets | | | | | |
| | | | | | | |
| | Common Practice of Project Procurement | 5 | 4 | 3 | 2 | 1 |
| | Design-Bid-Build | | | | | |
| | Design and Build | | | | | |
| | Integrated Project Delivery | | | | | |
| | Other Methods | | | | | |
| | | | | | | |
| | BIM can easily be implemented in | 5 | 4 | 3 | 2 | 1 |
| | Roads Works | | | | | |
| | Building Works | | | | | |
| | | | | | | |
| | BIM can best be initiated by | 5 | 4 | 3 | 2 | 1 |
| | Clients | | | | | |
| | Professionals | | | | | |
| | | | | | | |
| | In Tanzanian Public Construction projects BIM is likely to improve | 5 | 4 | 3 | 2 | 1 |
| | Transparency | | | | | |
| | Collaboration | | | | | |
| | Time Management | | | | | |
| | Costs Management | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Quality Management | | | | | |
| | Sustainable Design | | | | | |
| | | | | | | |
| | In Tanzania ,likely challenges to BIM implementation include | 5 | 4 | 3 | 2 | 1 |
| | Lack of Awareness among Participants | | | | | |
| | In-built difficulties in the Bureaucracy of the construction system | | | | | |
| | Lack Local Construction Industry common Standards | | | | | |
| | Fear of the effects Technological Change | | | | | |
| | Lack of Capital necessary to invest in BIM by Participants | | | | | |

### 1.5. Example of Interview Summary

**RESPONDENT NUMBER 1- RES 1**

**CHARACTERISTICS OF RESPONDENT**

i. Housing Corporation with a number of public building projects and in-house experts in construction projects and facility management. Experience of more than 25 years in the local market

ii. Key functions includes designing, construction and property management.

iii. Respondents were Representative Engineer, Architects and Quantity Surveyor

**SUMMARY OF INTERVIEW**

**PRESENCE OF BIM**

iv. We have BIM but at the very **basic level**, of computer aided design

v. In our team of experts, Architects are leading the practicing of this lower level of CAD or BIM, and Quantity Surveyor are far from it:

vi. We need BIM, and it will improve our way of designing our works

vii. Our level of BIM here is CAD and REVIT. It is costly to buy example GRAPHISOFT and use BIM while the execution of the projects in our country can only be done by CAD. It is important that the Government make it as a law. ***May be if the GRAPHISOFT will say these are software for Africa hahahahahahaha!***

viii. The laws or rule relative to BIM should be directed to different levels or capital of projects and participants respectively.

ix. In Tanzania, the trend of multi-storey building is high! It is better for you to focus your dissertation in only Class 1-3, where we need BIM in building project. Looking in project pyramid, many projects are small. Only few projects Huge, and that is where the Government loses money, as I have told you. Because all these, mostly are under the Government. And actually, the smarter the contractor the more the client/government loses money. Refer the example in OTHERS section

**COMPLETENESS OF THE INFORMATION**

i. ***"Kuna vitu ambavyo huwezi kuviquantify",*** THAT IS there are things that you cannot quantify. ***"There are benefits provided by BIM that cannot be quantified, for example the REWORK, how can you quantify this ITEM".***

ii. There is a challenge of specification, some specified materials are not easily found, unless otherwise we need standard. For example, all re-measured works put into BIM system and provisional sums should have specific page

iii. Another thing is the awareness of the Quantity Surveyor with the updated materials specification in some works. For example Quantity Surveyor depend mostly on the service experts, this can cause *copy and paste* of the information from the service experts to Bills Of Quantities, that is why in that particular Area, most of the BOQ are coming with the Provisional Sums. It is difficult to find a Quantity Surveyors who can quantify services competitively.

iv. We need BIM, and it will improve our way of designing our works.

v. VARIATIONs in our projects is almost standard, ***"every project must have significant VARIATIONS"***. If we could even manage to attain the increase of costs due to variation not to exceed 10%, it would be a success project. Of course, we cannot avoid but 4% would be reasonable.

vi. Source of variations are introduction of new works, lack of building standard like in South Africa, they have developed their own road standard. We Tanzanian have copied the UK thing, which is not environment friendly; it does not have reflection of the local materials.

vii. Bills Of Quantities usually lack enough information necessary for the cost management

**LIFE CYCLE COSTING ASSESSMENT**

x. We have a big problem in this Area of Life Cost r life Span of the Structure, every expert comes with his or her own specification. So only the warranty from the product manufacturer, gives us hope that the structure will last longer. This is not enough, because the warranty of one component does not guarantee the EFFECT OF INTERCONNECTION, of joined component, because warranty is only on small part. Say, warranty on roofing sheets without warranty on timber, will not guarantee the life span of roof structure, or say you have warranty on reinforcements but you do not have the warranty of the mix design of the concrete. Take an example of **Germany or Scandinavian Countries**, there are Building Codes that tells you HOW A STRUCTURE SHOULD BE CONSTRUCTED, we are lacking that. There are also Project

Seminars where experts sit together to design and specify from the STANDARDS.

xi. This habit of specifying by saying this material or equivalent, gives the room to temper with it.

**COLLABORATION**

xii. One thing that cannot be measured but it is very important is COLLABORATION, it is something that you cannot quantify.

xiii. At the moment COLLABORATION is NOT smooth in Tanzania. There are projects where MISSING ceiling is identified in the site. If it were possible, to indicate in the drawings items like ceiling, skirting and the like, it cannot be forgotten easily as it is. For example, in ARCHCAD BIM has a chat system, so this could help to improve Collaboration.

xiv. Example, World Bank or United Nations projects, (hawataki Kubahatisha) they do not want to GUESS, they make sure Architects and other designers make enough details, and then a Quantity Surveyor does his Job keenly, BUT yet there are VARIATIONS, because there is no ENOUGH SHARING OF INFORMATION among the involved experts ***(They are still doing in the same platform of "hapa nipe nikupe")***. So it would be better the WORLD BANK or UN to COMAND that the project be done under BIM environment, because with BIM, even the length of wires

xv. Another reason for Variation, is SHORTAGE OF TIME due to the low ratio of the expert vs number of projects. You may find one expert say an Architect is having five works per TIME. *Me as an engineer, having many project, I will at most deal will the most urgent projects, and as a result you are going in the site meeting without even knowing what was in the last site meeting* .We are NOT doing **Partnering** like, in Europe. Here we are just starting collaborating, by DESIGN AND BUILD. Which actually all the projects we have tried to use Design and Build have failed, in S-M, as an example, and was done by foreign contractor.

xvi. The reason behind failure of design and build project we did, was this lack of enough time in designing. Imagine tender document, almost 3 months, tender board approval is almost 1 month, and then the contractor MUST fill the document within 30-45 days. This time is not enough for the contractor to come up with productive idea to the project. Working breakdown structure of the projects requires allocation of the whole resources like man power, time, materials and the like necessary for the establishment of the time for the execution of the project. But in this one month is only enough for the contractor to imagine the projects.

**OTHERS**

xvii. We need legal system that recognize BIM. We do not have standards.

xviii. Relevant Board that can help to promote BIM

xix. BIM is needed the same way drawing board was swept by Computer, CAD and the like will be swept, we are doing our works manually in essence, compared to what BIM what. ***"tunafanya vitu manual, ninakupa mchoro, mimi natumia AUTOCAD hard copy, wewe unatumia ARCH CAD, mnakuja kukuta Colums zinapishana mm kadhaa"***. No question, we need BIM.

xx. We need BIM, and it will improve our way of designing our works.

xxi. It is much easier to use BIM in civil Works than in Building Works. In civil work has easier standards than in building. Take an example with our project with one foreign based company BSGT. This company managed to bring the Equipment/Plants Listed in The Bills Of Quantities during tendering. The Contractor brought those Plants during Mobilisation, some of which the Consultant, up to now they have not managed to instruct where they are to be used. *As a result, the plants remains in the Yard of The Contractor, meaning the contractor incurs the costs, which he is entitled to be recovered*, this is a burden to the client, to make sure the cost of those plants is paid "***kwa sababu wao wali-specify lakini who is supposed or going to pay now"***, Quantity Surveyor or Architect or Engineer? No, the client.

xxii. Hindrance include Cost of Software. If the clients are failing to finish the professional fees, do you think they can buy a software?

xxiii. THIS THESIS, is a very viable project but please limit your scope. So that you can have good recommendation. Just say, this is a technological thing, class 7-4 most cannot use this. Most contractors from class 1-3 can afford this, buying plants. This is developing country, Most of the government projects are being given to those firms, and Most of the scandals are in those type of projects. Management and human resources in those firms is wide and good, while from class 4-7 it is common to have 1 person in the firm. And so, it is easier for the government to give a statement that from class 1-3 must use BIM.

xxiv. Civil Work, is interesting, The Bills Of Quantities, has very few pages but hold Billions of money. Actually we need a BIM debate.

xxv. Me as an engineer,

## 1.6. Related Study Report

**ONE PAGE REPORT**

**SUBJECT: Seminar and Exhibitions Attendance**

**STUDENT: Juma Ahmed Mpangule** ***DATE : 27th February 2014***

### INTRODUCTION

This is a brief report on the few seminar/exhibitions attended to strengthen understanding of the Building Information Modeling relative to my research with the title of Appraising BIM in Tanzania the case of Public Related construction Projects. The first was in Muenster, second in Essen and third in Berlin. Despite of the various experience and benefits acquired, the following few are worth pointed out.

### OBSERVATION 1

There are many providers of BIM platforms among others, ArchiCAD 17 GraphiSOFT, RIB iTWO, BENTLEY, VECTORS, NEMENSCHEK AND REVIT AUTOCAD. All of these demonstrates the possibility of BIM within construction projects. The difference is on the category of BIM. Some ends up to 3D like ArchiCAD while other provide 5D BIM services like RIB. This means currently there are many levels of BIM and related providers.

### OBSERVATION 2

As usual, Academicians gave the science behind BIM before professionals conclude by giving practical part of BIM. It was made clear that BIM is like hitting the **BULL'S EYE IN DARTS** (Prof Dip-Ing Hans Georg Oltmanns). Another key issue prevailing is the preposition that BIM can strengthen some clauses in (Verdingungsordnung fur Bauleistungen (VOB)), *PART A* which refers to General Provisions on the Awarding of Contracts for Construction Work ( Dr. Klaus Schiller)in construction projects procurement in Germany.

### OBSERVATION 3

BIM is more than a software. It is the database of desired solution for construction projects in a digital form in separate or united format. BIM does not refer to designing using 3 dimensional drawings, which is a mere 3D CAD. In BIM different Software perform some functions to complete what BIM does. It is possible to use a 3D BIM model from another company and execute a project using the 5D BIM related software (iTWO RIB or VICO) to manage the project more efficiently. BIM levels ranges from 3D to NthD BIM, the basic being 3D BIM model. Depending on the usefulness, participants have number of choice in terms of BIM and providers as well.

**LESSON LEARNT**

Up now, I believe there is possibility to assess the BIM relative to contract Documentation. There seem to exist a very close relationship between 5D BIM and Total Cost Management improvement in the construction projects. For the developing countries, to quickly benefit from BIM, it is very important that, the existing system of procurement are maintained and BIM usage involve integration of BIM to the already existing CAD technology.

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I, Juma Ahmed Mpangule, hereby declare that my thesis is original and all endeavours went into preparing the dissertation was performed by me. The views expressed in here, are from my investigations except where reference or acknowledgements are made. This has not been presented and will not be presented to any other university for a similar or any other award.

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