BUILDING INFORMATION MODELING (BIM)
Principles, Usage, Benefits and Challenges
for its application in the Kingdom of Saudi Arabia (KSA)

مبادئ واستخدامات وفوائد وتحديات تطبيق

الـ BIM (تمثيل معلومات المباني)

في المملكة العربية السعودية

by

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ABSTRACT:

This study probes deep into the stratums of the subject of construction management, to potentiate BIM in the light of legal and economic landscape of Kingdom of Saudi Arabia. Previous research and empirical analyses are critically analyzed using descriptive correlations which are then assessed through the utilized primary data in form of survey findings. The study aims at distilling the predicaments presented in the previous research in order to distill the hypothesis and construct the relevant premises for the study. The trends in the literature are extrapolated using both deductive and inductive approaches; which are further cross matched and analyzed to support the presented predicament in this research study. The constructed hypotheses in this chapter are deductively analyzed using descriptive analysis by focusing on both the primary data at hand and the case studies, interpreting the use of BIM in KSA.

The collected primary data from the survey questionnaire is analyzed in great detail using exploratory data analysis where different statistical techniques are employed using IBM SPSS statistical software to make important insights and analyze the hypothesis. T-Test is used to test the final hypothesis using SPSS. Case study approach is also used to demonstrate the facts regarding the BIM usage for mega projects and support the predicaments made in the study.

The research aims at assisting the KSA's AEC industry in demystifying the stereo types related to BIM usability and application and construct a case for the potentials and benefits of BIM adaptation for the KSA's AEC industry. It further demonstrates the advantages of BIM applications and usage over traditional building methods and distills the major challenges and constraints the AEC industry can face in the adaptation of BIM specific to KSA and suggesting important steps for their mitigation.

Keywords: Building information Modeling BIM, AEC Industry, BIM benefits, BIM challenges, BIM implementation, BIM drivers, BIM in KSA

ملخص

إن الهدف من هذه الدراسة هو التعمق في قطاع إدارة التشييد وفهم مدى إمكانية تطبيق نظام (تمثيل معلومات المباني) والمعروف بـ BIM في المملكة العربية السعودية من الناحية النظامية والاقتصادية.

وقد تم اجراء عمليات جمع وتحليل البيانات من خلال استبيان بحثي، كما تم دراسة البحوث المماثلة السابقة، ومن ثم القيام بتطبيق العديد من الاختبارات الإحصائية.

ومن خلال الاستفادة من البحوث السابقة فقد تم بناء الفرضيات ومقومات الدراسة البحثية، ومن ثم تم استخدام المنهجيات المناسبة لتحليل ما تم جمعه من بيانات وما تم دراسته من البحوث والدراسات المتعلقة، وحيث أن البيانات الأساسية التي تم جمعها باستخدام استبيان الكتروني من 66 من المختصين في المجال والعاملين في المملكة العربية السعودية ، فقد تم استخدام عدة أنواع من التحليل الاحصائي الرقمي من خلال برنامج SPSS المختص بهذا الغرض ومنها T-Test وأيضا ANOVA. ومن ثم تم فحص النتائج من خلال دراسة حالة بخصوص استخدام BIM في بناء جامعة الملك عبد العزيز في المملكة العربية السعودية.

كما يهدف البحث إلى مساعدة قطاع الانشاءات في المملكة العربية السعودية لفهم الفوائد المؤثرة في تطبيق BIM وكذلك أبرز المعوقات الرئيسية لتطبيق BIM في مشاريع التشييد والانشاءات في المملكة ، ومن ثم وضع مقترحات وخطوات مهمة لقطاع الانشاءات وللجهات الحكومية المعنية للاستفادة من تطبيق BIM في المشاريع المستقبلية.

Dedication

I dedicate this dissertation

To my beloved mother who was behind all my life successes and for this master degree as well, she is the one who deserves to hold this degree with her patience and encouragement to me despite all the struggles I went through during my studies.

To the soul of my son Ahmad (2004 – 2014), whom I learned from him during his two years of bravely, fighting brain cancer that we should do our best despite the difficulties we face and then Allah will choose the best for us.

To my mother who was my main supporter during my journey in life and study.
To my family for their patience with me when I was busy with the dissertation.

To Professor Abdel Halim Boussabaine, for his great guidance, advice and support.

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Thank you all

Ibrahim Awad

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CHAPTER 1: INTRODUCTION

The Architecture, Engineering and Construction (AEC) industry is being transformed through a tectonic shifting in the methods used for building projects. This revolution is characterized by the complete integration and virtualization of the building process through the recently introduced Building Information Modeling (BIM) concept. The scope and complexity of the issues with the adaptation of the BIM for the AEC industry in Kingdom of Saudi Arabia (KSA) is both complicated and complex given that many factors come into play. In order to smooth out the transitional phase and distill all the stereo types regarding BIM in the industry for its proper understanding this research study digs deep down into the literature and uses primary data to support the predicaments constructed through literature regarding the efficacy and usability of BIM for the AEC industry in KSA. In order to construct a convincing case for the adaptation of BIM, which requires tremendous changes to be induced, it is important to demonstrate a clear benefit in the long term for the transition by deconstructing the potentials and benefits associated with its usage. Consequently to fully demystify the underlying factors stopping the shift in the AEC industry towards BIM it is also detrimental to probe into the challenges and limitations of BIM. Hence, the study first capitalizes on the literature to identify both benefits and challenges specifically for the KSA's economic environment and then utilizes multiple approaches to analyze the constructed hypothesis using the collected primary data in the form of survey and case study.

BIM apparently present comprehensive, efficient, and effective solution to all the problems faced by the AEC industry, it inherits maximum capability of the virtual computing along with the connected infrastructure, which enables complete interoperability and smooth data sharing during each phase of the construction project. However, side by side the integration of the new system with the traditional approaches to construction poses many transitional challenges. The system in its entirety gets fragile due to acute interconnectivity and dependence on virtual environment alone. In addition a lack of statistical proof of the ability of BIM to decrease costs and increase efficiency poses an impediment to its adaptation.

Given that the deployment of software and its complete usage requires changes at all levels of organization along with the costs of implementation and its operations, the AEC companies working in KSA report to have more challenges than benefits to the adaptation of BIM. The situation is increased due to absence of support and appropriate legal and economic infrastructure deployed by the governmental authorities. However, as the economy is progressing into new era companies are finding incentives in investing in new systems which have the ability to reduce costs, increase productivity and enable sustainability along with other factors. In that regard BIM is the ultimate solution to the prospective problems of the AEC industry (Beheiry, 2012).

The inability to coordinate and integrate plans, work schedule, 2D drawings and other aspects can create problems in ensuring that standards are maintained in the project. Some of these problems with coordination of plans exist because the construction industry is different from the other sectors (Seokho Chi Et Al. 2015).The differences are in relation to issues of customisation, on-site assembly, and planning of tasks. It is also a worry for many people that most construction sites are under planned and under resourced. Further, it is important to consider that the collaboration and utilisation of staff is important for the effectiveness and safety of the site. Any tool that can ease tasks is also helpful in reducing wastage and errors (Al-Jenaibi 2015). This often leads to improved processes and better workflows.

When meticulous planning is ensured from the beginning of the project, it becomes possible to keep conforming to safety practice and introducing other practices as may be required as the construction proceeds.

1.1 RATIONALE:

BIM has the potential to solve the complexities involved with construction project management and the anticipated benefits are tremendous for the industry which provide a bottom line of excessive cost cutting and efficiency. With the excessive use of data analysis and virtual platforms in every industry, the world is making a shift into an age of information where the cyber physical interactions can be the most appropriate method for achieving maximum efficiency and effectiveness. In the domain of building management the technological shift provide a huge opportunity for communication, interoperability and virtual modeling at multiple phases in a construction project. Hence, BIM provides a comprehensive hub in which all the technological advancements are utilized for better management and planning of construction projects; the platform has multifaceted capabilities which makes it at the same time a Modeling tool, Information tool, Facilities management tool and communication tool. The five dimensions based comprehensive model for building projects allows for data driven decision making with complete transparency of information at all levels of the projects.

Regardless of the potentials and benefits promised by the BIM the AEC industry specially in KSA has been very slow in keeping pace with the technically advanced techniques, rather a stringent behavior is present among the professional which hinders them from making the required shift. There is an acute requirement for demystifying the stereotypes surrounding the new technology and present a convincing case for the companies working in KSA to adapt to the BIM methodology. One important loop hole in the literature is the lack of documented ground realities for the usage and applications of BIM in construction projects which can justify the initial costs an organization has to bear for its adaption. There is also a lack of case studies dedicated to present the benefits associated with the BIM usage in the short and long run. It can be extrapolated from rends in multiple industries that economic factors play an instrumental role in deriving any such revolution, in which companies make the shift to advanced ways and leave their traditional ways of working. Hence, it is very important to demonstrate a case for cost cutting and effectiveness through well documented assumptions and facts associated with BIM usage, such that the concerns of the construction companies can be clarified.

With the recent shift in the KSA's strategy towards economic transformation the government has undertaken some gigantic steps to boost its economy and huge investments are being made into the construction of some mega projects; which are too complex to be handled with traditional methods of construction project management. It is estimated that the Saudi government intends to spend a tremendous amount of $1 trillion on building projects and infrastructure. The projects in pipeline culminate vast array of sectors: residential (30%), healthcare (20%), education (10%), and infrastructure (50%).

Hence, there is a requirement for the professionals to understand the concepts of BIM and its potentials if they want to stay competitive in a booming AEC industry. At these lines this research study aims at catering the and resolving the ambiguities and stereotypes for the professionals regarding the efficacy of BIM in KSA, while at the same time identifying the perceptions and believes of the professionals regarding BIM application. The study also fills the gap for the regulatory authorities by identifying the challenges faced by the industry in order to embrace the transformation and suggesting ways for the regulatory authorities to cater the problems to enable smooth transition.

1.2 RESEARCH AIM:

The research aims at assisting the KSA's AEC industry in demystifying the stereo types related to BIM usability and application and construct a case for the potentials and benefits of BIM adaptation for the KSA's AEC industry. It further demonstrates the advantages of BIM applications and usage over traditional building methods and distills the major challenges and constraints the AEC industry can face in the adaptation of BIM specific to KSA and suggesting important steps for their mitigation.

1.3 RESEARCH OBJECTIVES:

- To probe into the benefits and potentials of BIM for the KSA's AEC industry using the literature and the perception of the professionals working in the industry.

- To elaborate the challenges and constraints associated with the adaptation of BIM in KSA's AEC industry through the use of both literature and primary data acquired through survey presented to professionals.
- To identify the major driving factors that can enable the transition in the KSA's AEC industry and suggest important steps regulatory authorities can take to support the transition.
- To construct a strong case for the adaptation of BIM for the AEC industry professional by using proof from case study and response of professionals who are currently using BIM in their companies.

1.4 RESEARCH HYPOTHESIS:

1. The benefits and potential of adapting BIM for construction companies working in KSA surpass the challenges and constraints associated with the adaptation.
2. The regulatory authorities have not taken appropriate steps to enable smooth transition of the AEC industry towards BIM.
3. The perception of professionals is effected by the type of company they work for and their prior BIM usage experience.

1.5 RESEARCH STRATEGY:

The research study uses both primary and secondary data to achieve the constructed aims and to probe deeply into the predicaments constructed for the research. A combination of both deductive and inductive approach is utilized throughout the analysis, where the already identified hypothesis are justified and alongside important insights and inferences are constructed through the analyzed data from both literature and the survey analysis conducted. Furthermore a case study is used to document grass root level implementation and consider facts for the efficacy of BIM usage in mega projects in KSA. The literature is probed deeply to demonstrate the documented application and usage advantageous for the KSA AEC industry. The literature review is also utilized for defining the benefits and challenges of BIM both generalized and specific to KSA. The collected primary data from the survey questionnaire is analyzed in great detail using exploratory data analysis where different statistical techniques are employed using IBM SPSS statistical software to make important insights and analyze the hypothesis. T-Test is used to test the final hypothesis using SPSS. Case study approach is also used to demonstrate the facts regarding the BIM usage for mega projects and support the predicaments made in the study.

1.6 RESEARCH STRUCTURE:

Chapter 1 provides an overview of the whole research and constructs the important research objectives, aims and hypothesis for the study to follow.

Chapter 2 gives a detailed analysis of the literature on the subject, by probing into applications, benefits, challenges and drivers of BIM in KSA.

Chapter 3 delineates the methodology employed for the research and explains the intended procedures to complete the research objectives and test the hypothesis.

Chapter 4 demonstrates the complete results and analyzes them by alongside discussing their efficacy in fulfilling the aims and objectives of the research.

Chapter 5 gives the concluding words on the findings and uses triangulation of key findings to construct the outcomes from the study. It also provides with the important recommendations for the regulatory authorities.

CHAPTER 2: LITERATURE REVIEW

INTRODUCTION

This chapter probes deep into the stratums of the subject of construction management, to potentiate BIM in the light of legal and economic landscape of Kingdom of Saudi Arabia. Previous research and empirical analyses are critically analyzed using descriptive correlations. The chapter aims at distilling the predicaments presented in the previous research in order to distill the hypothesis and construct the relevant premises for the study. The trends in the literature are extrapolated using both deductive and inductive approaches; which are further cross matched and analyzed to support the presented predicament in this research study. The constructed hypotheses in this chapter are deductively analyzed using descriptive analysis by focusing on both the primary data at hand and the case studies, interpreting the use of BIM in KSA.

The review utilizes the desk based study approach in which peer reviewed articles and industrial journals are utilized to define the appropriateness and effectiveness of BIM in construction management in KSA. Multiple areas of construction management and their regulatory frameworks are exploited to compare traditional ways of construction with BIM; the effectiveness of BIM in those areas are further established using secondary data. BIM is the state of art mechanism for construction project management which provides the facility of planning, designing, integrating and managing the essentials of a construction project virtually through 3D, 4D and 5D CAD modeling. Vast quantities of research studies have been inked to validate its efficiency and effectiveness for construction industry, which capitalizes on its premium planning and management abilities.

2.1 BIM: ITS PRINCIPLES AND USAGE

BIM is the ultimate solution for the misunderstood problems of the construction industry; and as an interactive tool, it tends to bridge the gap of understanding between professionals from multiple disciplines working on a project (Forsythe et al. 2015).

According to Forsythe et al. 2015, BIM utilizes intelligent algorithms along with Computer Aided Design (CAD) modelling in a robust virtual environment that allows efficient simulation of devised plans before the start of the construction project; which allows for effective operations planning for the construction phases to follow. Furthermore, according to Kang et al. (2016) BIM software are aided with self-altering and machine learning algorithms which aids the engineers and designers to eradicates any mistakes beforehand. According to the research study, vast libraries backing BIM software enables object oriented designing, which constantly execute the proposed design and pinpoints any anomalies, which are missed in traditional ways of planning and design. Such intelligent algorithms tremendously reduce the probability of onsite mistakes and injuries, which translates into lower construction wastes and hence higher profits (kang et al., 2016).

The Concept of BIM is entailed in different ways by different users, depending upon its extent of utilization in a construction project. There are multifaceted ways to capture the usage and importance of BIM, which are exploited from the literature. One of the major facets of BIM is its ability to virtually construct and specify the design of a building project before the physical work gets under way; this concept of virtual design and construction (VDC) was elaborated in details by Kunz and Gillian (2007). An increasing trend in use of BIM in every aspect of construction project processes was concluded, it is the ability of BIM software to efficiently and collaboratively manage every aspect of the construction process, virtually under a single umbrella (Kunz and Gillian, 2007). Kunz and Gillian (2007) further elaborated that the most critical project phase for BIM application is the planning phase before the initiation of construction, where BIM potentiates speedy conceptual design and support for documentation in a Computer Aided Design (CAD) environment. BIM allows the designers and engineers to validate risk control measures before construction, which greatly reduces construction waste and allows for effective waste management practices. It further accentuates the resource capability by allowing for strategic management (engaging experts from various disciplines) and efficient control mechanisms.

A comprehensive quantitative outlook was presented by Dean (2007) to validate the need for the addition of BIM in the curriculum for construction management degrees and training programs. Dean (2007) formulated a questionnaire survey for the professionals working in the construction industry to precipitate the extent of importance given by the AEC industry as a whole to BIM. It was demonstrated that BIM holds immense importance among the industry professionals and contractors and it shall be added to the construction management curriculum for all programs (Dean, 2007).

Khemlani (2007) precipitated multiple pre-requisites for enabling full BIM operability for a construction project. The study aids AEC industry professionals to understand the skillset required for proper integration of BIM for project planning and implementation; ten most important requirements are enunciated in the paper, prominent ones include: Compatibility of Industry Foundation Classes (IFC), skill set to manage large projects, library object handling and formation, integration of efficient tools and ability to conduct multiple CAD analysis on the virtual design. BIM, according to the construction industry professionals, tremendously aids in the modeling through intelligent algorithm to validate designs and plans. However, there is a real need for the proper understanding of the processes involved in BIM calibration, and for trained professionals working in the field (Khmlani, 2007).

2.1.1 BIM Applications:

BIM has many areas that are commonly used for, such as Clash Detection, Material Take-off, Cost estimation, Onsite construction management and monitoring, Build-in code specifications and libraries, Health and Safety Management planning and Facility management

2.1.2 Visualisation

According to Saleeb (2015), BIM is great tool for visualization. The scholar argues that it can provide a building's 3D virtual representation. He adds that during the project's bidding phase, manager of the construction can offer renderings, walkthrough as well as sequencing of building's model to communicate better BIM concept in three dimensions.

According to him, visualization gives better comprehension of the way final product should look like. It eliminates thought processes of bringing various views of traditional 2D together to obtain the view in 3D of a building's detail. Moreover, virtual mock-ups, for example, laboratories and/or building envelope are given to designer as well as the owner (Saleeb 2015. This helps in visualising, better understanding, and making decisions on aesthetics as well as the space's functionality. Virtual mock-ups may be utilised in reviewing three dimensional shop-drawing of building envelope (Saleeb 2015). He adds that these virtual mock-ups help in communicating and collaborating among project participants. Visualisation improves planning as well as sequencing of construction of curtain wall (Saleeb 2015). According to him, even though virtual mock-up is cost-efficient when compared to physical mock up, physical mock up can still be needed in case members such as casework drawers or assembly of building like curtain walls require going through physical tests series (Saleeb 2015). Hence, virtual mock ups can become good standard of initiating such mock-up processes and actual mock up is, in most cases, necessary after virtual mock-up gets approved.

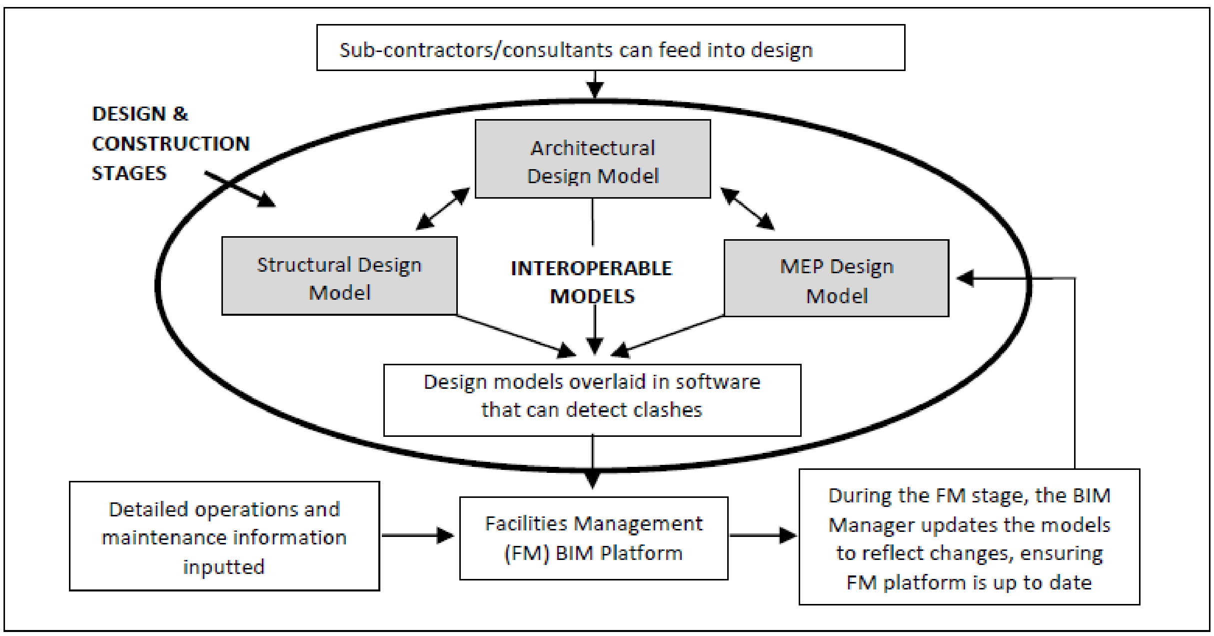

Figure 1: Interoperable BIM process (Thurairajah, N. & Goucher, D., 2013)

2.1.3 3D Coordination

It is recognised that construction team's collaboration with architect and engineer as well as the owner is often preferred to begin during the early stages of the design phase. According to Melson, Krause & Bared (2015), during that time, BIM shall be implemented immediately. If architect has 2D drawings only, the manager of the construction need to convert those 2D drawings into three dimensional intelligent models. Mooney (2015) adds that in case specialty contractors, particularly MEP contractors as well as steel fabricators get involved in the construction they should spatially coordinate each of their work. The three dimensional coordination is began right after model has been created in order to make sure that hard clash and/or soft clash conflicts get resolved. In general, the construction manager's advance coordination efforts in construction aids in reducing tremendously design errors and enhancing understanding in good time of the work that is needed.

2.1.4 Pre-fabrication

Prefabrication helps in reducing cost of field labour as well as time and increasing accuracy in better quality construction. According to Park, Park & Oh (2015), there are more tools as well as options that are readily available within controlled-environment of jobsite so as to carry out tasks more precisely, with fewer costs and in shorter time period. Prefabrication needs design as well as field accuracy. It can be noted that building information model (BIM) produces such level of accuracy through including specification, sequence and finishes as well as the three dimensional visual for every component. However, Seokho Chi et al. (2015) argue, each team involved in construction has to ensure that BIM become interoperable with software utilised by fabricators. In this manner contractors may use BIM and create details for product in their fabricating software. Additionally, construction managers have to administer schedule of procurement of such products. In general, these prefabricated products have to be delivered to construction site at the right time (Shrestha et al. 2015).

Moreover, according to Jrade & Jalaei (2016), the BIM helps in timely modifications of designs in order to eliminate and/or reduce utilisation of the beam penetrations which may be as a result of MEP conflicts. Few penetrations of beam can be inevitable for a complex project (Jrade & Jalaei 2016). According to them good coordination of the penetrations with the technology of BIM advocates determination of locations of beam penetration and prefabricates offsite. They agree that beam penetration which is prefabricated can save time, money as well as effort tremendously as compared to the onsite beam penetration. Furthermore, as the scholars put it, roof penetrations in the case of concrete rooftops need to be sleeved before concrete pour at roof level. Steel that supplements each penetration should also be available (Shin et al. 2016). BIM coordinates these penetrations when specialty contractors get on board.

Building information modelling can be utilised in enhancing information exchange of products between the participations. Moreover, it is applied in virtual coordination of the location as well as routing of products. Based on such information, product can get detailed with fabrication software (Wang 2015). Once material gets prefabricated as well as arrives on the site, foreman of specialty trade needs to coordinate with construction manager to make sure that they are making that virtual design as well as construction reality.

2.1.5 Planning as well as Monitoring

Construction planning demands the model's scheduling as well as sequencing to coordinate the virtual construction within the time available and space. Schedule of anticipated progress of construction gets integrated into virtual construction. The scheduling usage introduces the time as fourth dimension (4D) (Zhang et al. 2015). There exist two common methods of scheduling which can be utilised in creating 4D BIM. They include the critical-path method (CPM) as well as line of balance.

2.1.6 Critical Path Method

In CPM, every activity gets listed, linked to each other, as well as assigned durations. Zhang et al (2016) add that activity's interdependency gets added as predecessors and/or successors to the other activities. Furthermore, duration of activities is also entered. According to Zhang et al (2016), the longest path gets defined to be the most critical on the basis of dependency as well as duration of activities. Such activities may not contain any float. If the activities do not get completed in the anticipated duration, total time taken for these projects will be pushed out further. In general, critical path method (CPM) is the often used technique which helps projects in staying within schedule.

2.1.7 Line of Balance

The technique known as Line of Balance utilises locations as basis of scheduling. The method is often referred to as alternate to critical path method (CPM). It becomes advantageous for the tasks which are repetitive to increase the productivity of labour. In such a method, the durations of activities get based on available size of crew and sequence of location (Zhang et al

(2016). They also argue that the labour force productivity can get altered as required to depict accurately construction schedule. This approach places focus on locations which are being completed by trade before another trade comes in. It, therefore, reduces amount of mobilisations as well as resources. Line of balance is good method of scheduling that helps in planning and monitoring the repetitive tasks as construction progresses.

Planning by utilising building information model improves site utilization and space coordination as well as product information (Zabukovec & Jakli 2015).

2.1.8 4D BIM

According to Sampaio & Simes (2015), 4D models can include site-logistics plan and/or tools, for example, SMARTBOARD above virtual construction are used in visually depicting space usage of job site. This model has to include the temporary components like cranes, trucks and fencing among others. It can also include access routes of traffic for the trucks, cranes and lifts as well as excavators. All these should be incorporated within building information model as part of logistics planning.

Furthermore, site utilisation comprises lay-down areas, progress of site work, as well as trailers location and equipments including hoist assembly (Sampaio & Simes 2015). In the same manner, when building gets closed in, space coordination has to be managed well for roughing and the eventual finishing activities.

According to Sweis et al. (2015), there are many acquisition systems of field data which can be utilised with 4D BIM model in order to track the construction’s progress. The Radio Frequency Identification (RFDI) as well as 3D laser-scanning RFID can also be applied in tracking the delivery status of materials (Sweis et al. 2015).

2.1.9 Radio Frequency Identifications

The RFID utilisation is good for a project's prefabricated components such as the precast concrete-panels (Sweis et al. 2015). Radio Frequency Identifications are linked to BIM and shows when elements are in their correct location. For example, tagged projector may be linked into the type property of the element in BIM (Sweis et al. 2015). The integration of BIM as well as RFID helps in keeping track of location of projector and indicates when materials get into designed locations once they are installed (Sweis et al. 2015).

Planning as well as monitoring is extremely significant part of construction (Gürcanli, Baradan & Uzun 2015). Construction managers can apply different 4D BIM-enabled tools to enhancing process of quality control. Baker et al. (2015) also contend that construction planning as well as monitoring using 4D building information model is a great process of building a facility according to the designed model.

2.2 ADVANTAGES OF BIM FOR THE KSA AEC INDUSTRY:

2.2.1 Current Prospects for BIM usage in KSA:

It is evident that the Saudi government intends to spend a tremendous amount money on building projects and infrastructure, as part of the National Transformation Project which is one key program towards achieving the KSA Vision 2030. The projects in pipeline culminate vast array of sectors: residential (30%), healthcare (20%), education (10%), and infrastructure (50%). Al Qwasmi, General Manager Tekla for KSA region stated at the Saudi Build 2014 exhibition:

"From mixed use mega developments to sports stadiums, the Kingdom is attracting the world's top architects, who are designing increasingly complex projects that require the latest 3D Building Information Modeling (BIM) software,"

Tekla tends to be the market leader in construction projects, specifically integrating BIM at its fullest. Tekla initially opened its exclusive operations in Dammam and Riyadh, focusing on its specialized software: Tekla BIMsight. Many prominent projects in the country have been fully designed and constructed using such BIM software from Tekla, such as: Capital Market Authority Headquarters, King Abdullah Financial District, and the King Abdulaziz Center For World Culture. It is predicted that the global BIM market will grow to a whopping $8.6 billion in 2020.

"Tekla's technology was used in 10 of the 12 stadiums at the 2014 FIFA World Cup Brazil, including the Arena Amazônia, where the construction company Martifer Construções improved

*productivity by 20 per cent and efficiency by 30 per cent," (*Al Qwasmi, General Manager Tekla for KSA).

According to the National Transformation Program 2020 announced in May 2016, the Kingdom of Saudi Arabia needs to deliver above 1 million homes in the coming years, mainly through Public Private Partnership projects. KSA tends to be the leader in the GCC region for the allocation of construction projects for development, as shown in figure 2.

The Deloitte GCC Powers of construction 2014 report states that the critical issue undermining the large scale construction projects in KSA is the reality of input cost inflation and the possibility of project delays. Such discrepancies mainly culminate due to lack of immaculate designs and use of traditional ways of construction. For such humongous construction projects according to the report it is detrimental to use the BIM software at each stage and utilize virtual designs and plans completely.

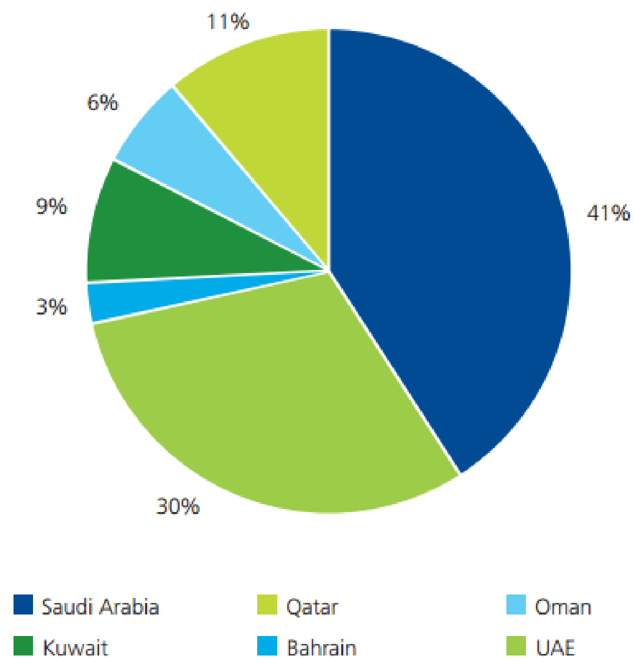

Figure 2: Development activity across the GCC (Powers of construction, 2014).

Most literature mentions BIM as construction software, but it lacks to link BIM to improvement of regulatory framework in Saudi Arabia for AEC industry; it is one of areas this research wants to address. To achieve seamless integration of standard practices, the new tools must integrate these practices from the beginning. Literature has also established that the Saudi Construction sector is subject to many laws and regulations especially in the wake of the 2015 crane accident in the Holy Mosque in Makkah. To ensure that construction projects adhere to all the rules, it is clearly important to consider these rules from the beginning of the project. This ensures that all the rules and regulations are executed when each stage is reached in the construction phase (Shen et al. 2015).

BIM creates a new platform where all control and safety planning tasks can be integrated in the design and construction stages within the project. The resulting situation is where firms have the ability to remain more consistent to safety and health regulations (Li et al. 2015). Even though this technology is still not fully adopted by all the firms or practitioners in the construction sector, those who have used the technology can attest to its capabilities in the compliance to standard practices in the country. With all the mandatory practices that are noted above, there is need for a platform that can automate processes in the construction sector to incorporate those (Zhang et al. 2015). Therefore, the main agenda of this study is to evaluate how BIM has helped practitioners in this sector to adhere to rules and regulations related to legal requirements of a country.

Making this determination is important so that one can understand how BIM generally impacts the construction sector. With automation through BIM, it is possible for practitioners to integrate standard requirements from the beginning of the project so that no processes are forgotten or overlooked at one point in the construction sector.

According to the Middle-East BIM Report 2011, the respondents from the KSA AEC industry are well aware of the potential benefits of using BIM in construction projects. The reports entail the perceived benefits for both users and non-users. It was found that BIM is considered to be the best solution to the key problems of construction industry.

2.2.2 Construction Project Delays in KSA: BIM as a solution

The delay in construction projects regulated by the Saudi government tends to be the biggest issue in hindering accelerated growth in the AEC industry of KSA; a speedy solution is the need of the hour given that the government has intended to spend huge sums on construction projects (Public and government sector) in the coming years (Al-Kharashi and Skitmore 2008). BIM has the ability to act as the problem solver in the construction delays for the industry, given its state of the art CAD tools which aid the engineers to immaculately design systems throughout the project cycle, without any hidden obstacles. The integrated libraries and the virtual simulation environment give an opportunity to the project teams to collaborate in order to define lean and efficient processes, with risk management, which can eradicate all the issues which lead to construction delays (Bryde et al. 2013).

Literature is rich with surveys and case studies which postulate the severity of project delay issues in KSA. According to a survey conducted by Falqi (2004), a comprehensive report was constituted in which 2,379 construction projects were analyzed. Falqi (2004) reported 952 construction projects that were delayed in KSA which accounts for a staggering 40% of the total projects implemented (Al-Kharashi and Skitmore 2008). It was further concluded by Falqi (2004) that the delays in construction projects in KSA, at an average, ranges between 129% to above 190%. According to a study conducted by Sadi Assaf and Al-Hejji (2006), average time delays experienced by professionals working in KSA AEC industry ranges from 10% to 30% of the total allocated time to the construction project. It was further demonstrated that the average overrun time can extend up to 50% in particular types of construction projects.

In a questionnaire survey conducted by Al-Kharashi and Skitmore (2008), all the possible causes for construction delays in governmental and public sector projects were precipitated. The researchers concluded that the major causes account from five reasons: slow decision making, suspension of construction process due to unforeseen reasons, ineffective scheduling, and conflicts between parties pertaining due to information gaps, and payment delays from authorities. In addition the researchers noted that the inability of project teams to deal with technical requirements and delay in design reviews also cause hindrances in construction processes (Al-Kharashi and Skitmore, 2008).

To avoid such catastrophic delays which are prevalent on almost regular basis in KSA, a great solution is the use of BIM along with Integrated Project Delivery (IPD) systems for construction project management as recommended by The American Institute of Architects. It shall be noted that BIM provides a perfect technical infrastructure to handle delay issues effectively and provide platform for project teams to make effective schedules with minimum delay risk capitalizing on the technical aid provided by the design and scheduling tools with integrated libraries.

2.2.3 BIM as A platform for enhanced collaboration and integration:

The coordination and collaboration facilities of BIM's virtual platforms allow the stakeholders working on the projects to effectively interact with each other and make informed and efficient decisions at each stage of the project; thereby reducing the friction of integration and consequently wastages incurred due to late design changes (Arayici et al. 2011; Jernigan 2014; Azhar et al. 2012; Eastman et al. 2011; Bryde et al. 2013).

According to the literature, lack of collaboration and availability of efficient decision making mechanism for the stakeholders in traditional construction management systems, accounts for severe wastages in the later stages of a construction project.

"*Inefficiency and waste account almost 30% of the capital costs of construction and much of this could be avoided through integrated team work; such fragmented team work inhibits performance improvement and prevents continuity of teams that are essential for efficiency*" (Egan, 1998). Given that the KSA government intends to invest billions of dollars for their KSA vision 2030, mitigation of waste cost incurred due to lack of collaboration can save millions of dollars; which can be accomplished by the effective use of BIM for the projects.

BIM aids the project managers to promulgate a sense of trust through the project teams' hierarchy by enabling easy accessibility to the virtual BIM platform (Hardin 2009; Grilo& Jardim-Goncalves 2010). Planning and design can be shared through the BIM model which utilizes advanced communication software systems in order to enable smooth flow of information (Elmualim & Gilder 2011; Carmona & Irwin 2007). It further allows involvement of stakeholders from all fields in early decision making in the construction project; this phenomenon tends to align the stakeholders and they exactly get to know where the project is heading.

The mechanism of collaboration and information sharing in BIM can be demonstrated by the figure below, which is enabled by the openly accessible virtual environment provided by BIM to the multiple project teams for collaborative decision making and sharing of information.

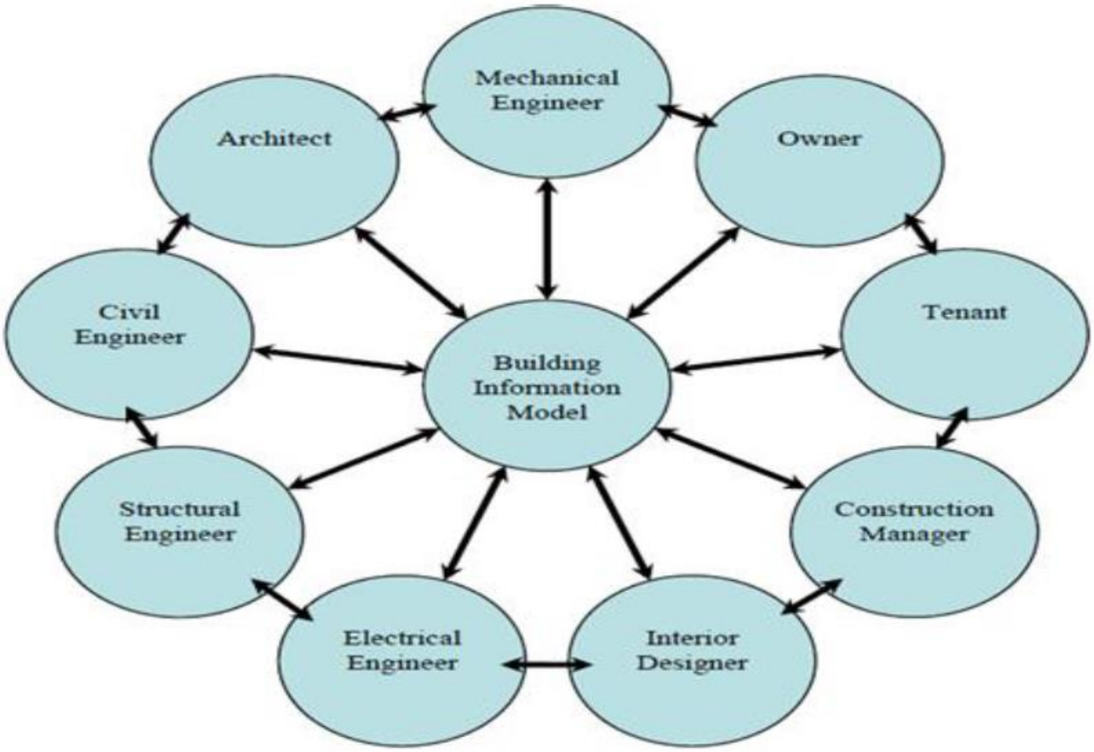

Figure 3: The web of information sharing across project teams; Source: Holder Construction, Atlanta, Georgia, USA.

2.2.4 BIM as an enabler for sustainable designs:

The Saudi government has stressed upon making sustainable construction buildings, which considers the safety of the environment through green construction processes (Krygiel & Nies, 2014). This essential need is brought to the top in the list of priorities by the regulatory authorities due to the rapid change in the environment and the potential of such mega construction projects to cause smog and other long term environmental problems for the public. In addition, better sustainability plans can provide energy efficient designs for the buildings; hence, the construction processes as well as the buildings consume lesser energy in the project cycle. Furthermore, the government officials have stressed upon making the buildings as energy efficient and environmental friendly as possible, such that, the sustainability of the projects can be increased.

The current practices prevalent among the AEC industry experts in KSA tend to be divergent from the sustainability principles. Globally building operations consume a staggering 42% of the total energy resources of the world, which potentiates the threats of global warming and energy depletion (Schueter & Thessling 2008). Hence, it is detrimental for the government officials to mandate sustainable and green building designs; which shall be done by enhancements in designs and construction plans from pre-planning to demolition phase of the project (Park et al. 2012).

The traditional 2D design methodology holds many drawbacks when it comes to planning for sustainability for the building project lifecycle, which is mainly due to its limiting ability for the designers to fully comprehend and deduce sustainability issues in the planning phases of the project. Lack of visualisation and collaboration of the stakeholders in the conceptual design phase makes it difficult for the engineers to constitute sustainable building designs (Azhar 2012).

BIM postulates a perfect solution to the problem, with its tools for visualisation and ability to integrate libraries, aiding engineers to visualize and assess the sustainability of building designs. Designers and engineers can collaborate to evaluate and analyse the sustainability of a building design in the planning phase using BIM simulations and visualization tools (such as LEED and BREEAM) in order to make calculated decisions to ensure sustainability (Eastman et al. 2011). In addition to building sustainability, BIM allows the engineers to conceptualize and design operations management strategies for the construction phase deemed at reducing construction wastage and pollution in form of noise, air and water; hence enabling environmental friendly construction (Moreno et al. 2013). BIM capitalizes on wide array of interactive tools to make a building as green as possible; the energy consumption can be saved by augmenting the designs based on calculations for appropriate sun direction, building envelope, air circulation etc. (Abbasnejad & Moud 2013; Arayici et al. 2011; Hardin 2009). BIM further allows the engineers and designers to induce appropriate level of flexibility into the designs for the later stages focusing on possible sustainability concerns (Osapuolet, 2012).

2.2.5 BIM for Better Safety Management:

The Saudi government has paid a special consideration to the Safety management strategies for the upcoming construction project, due to the unfortunate event that took place in the Holly mosque in 2015, when cranes fell due to wind storms, taking many lives of pilgrims. BIM gives unique solution by providing integrated tools for Health and Safety management which can be used in parallel throughout the project planning phase and the construction phase in order to ensure effective safety management technique congruent with the building designs and construction processes. Bhat and Gowda (2013) proclaimed in their study that each year almost 1.2 million deaths occur in construction industry due to ineffective H&S planning. Poor H&S planning causes, at an average, a total loss of 15% of the project budget (Hallowell, 2011).

BIM offers tools and simulations techniques for the stakeholders to analyse a design for safety performance and possibilities of safety risks in construction activities. Safety engineers can constitute safety assessment plans, exactly aligned with the construction processes and building designs, through the use of 6D visualization tools (Moreno et al 2013; Zang & Hu 2011). Safety planning comes with an additional advantage of saving additional costs and man hours, as when a safety risk is mitigated the construction process becomes leaner and smoother, and there are no costs incurred for accidents (Bhat & Gowda, 2013). Literature shows that using BIM has allowed the safety engineers to completely eliminate risks of accidents during construction and as low as zero cases of accidents are administered in construction projects which utilized BIM tools for safety management (Moreno et al. 2013).

2.2.6 Reduction in Time and Cost with Increased Design Quality and Building Performance:

Researchers have demonstrated through the use of survey, interviews and case studies that implementation of BIM for a construction project radically increases the efficiency and effectiveness of teams working on the project and in addition reduces the costs incurred in many forms (Bryde et al. 2012; Sebastian 2011). The easy accessibility of the BIM model allows the teams to collaborate in order to make best design decisions, which tend to improve the quality of final building design. The interactive nature and real time update feature of BIM allows the teams to share information and design changes instantly, without having to go through approvals of different parties, such a feature of BIM saves tremendous amount of time and energy and can eradicate the sources of project delays (Bryde et al. 2012; Osapuolet 2012; Sebastian 2011; Jernigan 2014; Arayici et al. 2011; Barlish et al. 2012; Karna et al. 2009).

BIM is an effective way to induce risk mitigation strategies at all stages of the project life cycle, which eliminates the tendencies of contingency such as schedule clashes among teams, during construction phases which saves tremendous amount of cost and time, in addition ensures good quality of designs and enhance the building performance till its demolition (Barlish & Sullivan 2012; Sinopol 2010; Jernigan 2014; Hardin 2009; Porwal et al. 2013).

The tools of BIM software such as the integration of value engineering through utilization of 4D scheduling aided with the 5D cost and materials takeoff estimations, which are then combined into a collective whole through 3D simulations, allows all the stakeholders to understand and align their respective plans for construction beforehand; hence giving a kick start in the construction phase with savings of time, money and efforts (Osapuolet 2012; Howard et al. 2008; Jernigan 2014; Hardin 2009).

Researchers also demonstrated quantitative analyses for the cost and time savings enabled by the BIM technology utilization in multiple mega projects around the globe. Clash detection tool of BIM was found to increase the project value by up to 10% while at the same time decrease time incurred up to 7% (Liu et al., 2010; Kunz and Gillian, 2007). Jernigan (2014) concluded that utilization of BIM reduces project cost in the range of 8-15%; the figure was established after considering many case studies from U.S. BIM comes with a flexibility of working with cost estimation and materials takeoff tools, which are widely available in the market which can be utilized to accurately predict the total cost of the project; hence the big problem of payment delays due to unpredictable costs of the projects can be solved effectively (Koskela 2003; Schade et al. 2011; Liker 2003; Abbasnejad &Moud 2013).

2.3 THE DRIVERS OF BIM APPLICATION FOR KSA:

The Middle-East BIM report 2011, collected vast amount of data in the region to demonstrate the possible drivers for the adoption of BIM in KSA. According to the report the industry professionals believe that having a clear mandate for using BIM in a project can be considered as the biggest driver of the BIM transition; a clear mandate translates into a defined guideline from the government on legal grounds requiring companies to use BIM for the construction projects. At the second place, the availability of industry standards was considered to be a crucial driving force for BIM adoption. Availability of skilled professionals was viewed as the third major driver for BIM adoption, given that there is an acute shortage of industry professionals who can fully understand and use BIM. It shall be noted that a lack of accreditation process also feeds into the obstacles of BIM adoption and hence a defined accreditation process in placed by government officials can drive the BIM adoption.

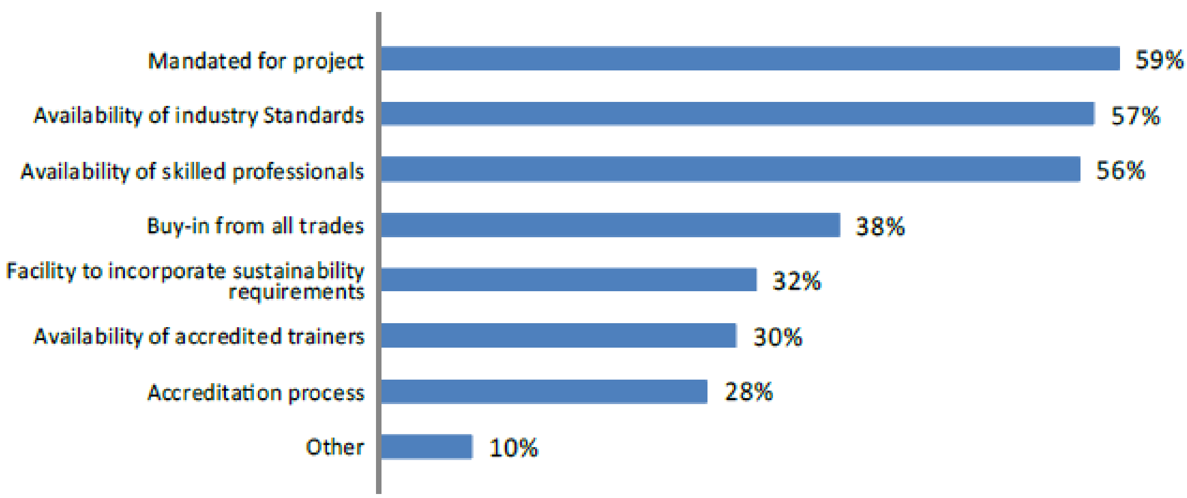

Figure 4: Drivers of BIM in KSA region (Middle-East BIM report 2011).

2.3.1 Government Pressure

Drivers of BIM are referred to as factors that drive its usage. One of such drivers is pressure from the government (Yoon et al. 2015). Most construction companies currently utilise BIM because governments favour its usage. Yoon et al. (2015) agree that most governments have published policies with regard to BIM application in order to ensure safe practice in construction. Even though Saudi Arabia is also applying sufficient pressure on construction companies encouraging them to use BIM more frequently, it has not yet matched the current. For instance, the government of the United Kingdom has made the BIM of Level 2 mandatory on all projects that are publicly funded. Dubai government has also announced a policy for mandating BIM in the construction of mega projects.

Yoon et al. (2015) add that even in Australia the government has adopted similar approach as well. They intend to utilise BIM for all the construction projects within the public sector. Currently there are some national BIM deployments in USA, and Far East. This is a key drive in using BIM and can apply efficiently to Saudi Arabia. According to Yoon et al. (2015), most governments have placed a policy requirement there are certain projects for which construction companies must demonstrate BIM abilities before they are awarded. Governments are putting this pressure because of BIM’s ability to improve H&S (Mohseni et al. 2015).

2.3.2 Customer or competitive pressure

Sara & Nouf (2015) argue that construction industry has appeared very competitive in the recent past. The clients have also come to learn the benefits of using BIM. Therefore, in this regard, clients request contractors not only to demonstrate capability of offering BIM but also describe that capacity with track record of projects of BIM they have managed successfully. Since customers need such deep knowledge in BIM application, strategic managers have started implementing it. Sara & Nouf (2015) add that the customers of Saudi Arabia can put such a pressure as well given what the BIM brings along as a package of benefits.

2.3.3 Desire to Remain Competitive in Technology

Companies that have adapted to BIM have been reported to be seen as visionaries and leaders in innovation. It allows the BIM using companies to show that they can lead the market and ensure long term benefits for their clients by investing into their infrastructure and methods of working. Hence, this competitive edge gives the companies both an actual boost in their effectiveness and efficiency and a psychological edge over their competitors. Early adapters of new technology have been seen to evolve as the market leaders in any industry (Kang et a., 2015). In addition to in the wake of governmental authorities encouraging the transformation hence, any government funded projects in Saudi Arabia are more likely to be given to the BIM adapters. These firms are seen as trying to accomplish business targets and not the technological ones. This drive highlights the connection of RIBA to BIM and H&S. The desire for RIBA to be techno-savvy ahead of others forces them to use BIM most of the time (Kang et al. 2015).

BIM is helpful in carrying tasks of the Royal Institute of British Architects (RIBA) stages. BIM is applicable to the seven RIBA stages. RIBA is viewed as a document that the architects and the construction industry use to provide shared framework in building projects' organisation as well as management (Kang et al. 2015). It is utilised as process map as well as management tool (Kang et al. 2015). At stage 0, strategic definition is done which involves appraising the project coming up. In stage 1,design brief is formed. Stage 2 involves mapping the design concept. In stage 3, the developed can now be marched with the cost information. Stage 4 is the technical design stage which involves the design teams answering the design queries. Stage 5 is the construction phase. Stage 6 involves doing the post construction work. It includes closing out and handing out. Stage 7 is the period of the usage of the constructed building. At stage 7, evaluation is done to assess whether the project is successful and also what can be added that was not included. The stage involves even post occupancy activities (Kang et al. 2015).In all the stages the BIM is very useful since it provides the virtual representation of every stage before it is reached. It enables visibility of the RIBA stages and eliminates gambling or trial and error (Sampaio & Simes 2015). In this way, RIBA gives workers prior understanding of their work before they even starts. RIBA gives significant work phase reference points applicable in many contractual as well as appointment documents including practice guidance.

2.4 OBSTACLES TO THE ADOPTION OF BIM:

Forsythe et al. (2015) clearly argues that part of the reason adopting BIM technology in Saudi Arabia has remained low at only twenty present is lack of expertise. This is a delicate and complex technology and is used in complex construction processes, and which requires efficient training before implementing (Forsythe et al. 2015). It is, therefore, necessary that Saudi Arabia will have to train workers first on how to apply this BIM technology before it can widely be adopted. Another challenge touted by many scholars is lack of enough customer demand. People cannot use what they do not need, and according to Mohseni et al. (2015), many construction workers in Saudi Arabia have not in the recent past been eager to use the BIM technology. Mohseni et al. (2015) attribute this to lack of awareness creation. It is felt by a number of scholars that most people in Saudi Arabia still consider BIM a new technology even though it has been in existence for some time now.

Cost is at the forefront of the challenges experienced in applying BIM software. Apart from the expertise which may also be expensive, there are other costs such as updating the software, maintaining internet costs, paying hosts and also replenishing hardware among others (Haapasalo, Halttula & Herva 2015). Many governments, Saudi Arabia included, have, therefore, been very cautious in giving to their citizens a technology that may be cumbersome implementing. In that regard, some analysts argue that BIM has not been very popular with the small projects in Saudi Arabia. It suits much larger projects that only government and other few individuals can manage (Haapasalo, Halttula & Herva 2015). According to Haapasalo, Halttula & Herva (2015), BIM can be used even in small projects given the company is willing.

According to the Middle-East BIM report 2011, surveys in the region of KSA demonstrate that the biggest obstacle to the BIM implementation is the non-availability of skilled staff to fully integrate BIM facilities to a construction project. The cost of software usage and integration comes in at the second number. According to the report the Saudi Government shall play a major role in helping the transition in the AEC industry. The report states that simply mandating the BIM usage at the official level will not produce amiable results; however, the government needs to step in to give incentives and covers financial costs of the transition. There is a demand for the appropriate Information Technology infrastructure to be mechanised for smooth transition.

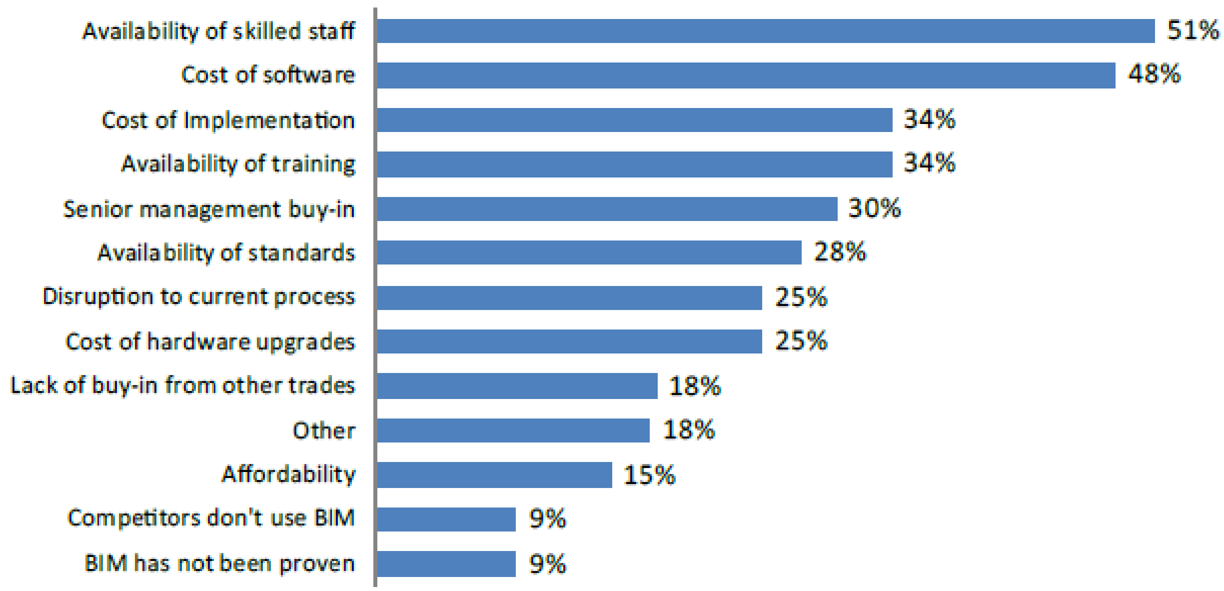

Figure 5: Obstacles to the adoption of BIM (Middle-East BIM report, 2011).

Industry standards in KSA still need proper shape and implementation to facilitate better BIM practices. The reports state that the KSA government is eager to fully adopt BIM practices however; there is a lack of a definitive plan to invest in human resource capabilities, such as a schedule for training programmes.

Literature provides a basis for the identification of four categories of challenges and obstacle that hinder the implementation of BIM in KSA's AEC industry:

- Technical Challenges

- Financial Challenges
- Legal challenges
- Industry environment challenges

2.4.1 Technical Challenges:

2.4.1.1 Use of Incompatible mediums for interoperability:

A construction project is handled through a complex collaborative environment in which professionals from multiple fields have to work under an umbrella to ensure that the designs and plans align into a single whole; some of the technical teams include: Suppliers, Contractors, Clients, architects, MEP experts, structural designers, subcontractors, FM experts etc. There is a possibility that all these parties might have different CAD standards and software platforms to complete their tasks, which might not be compatible with each other to be integrated under a single BIM platform (Hardin, 2009). Hence, the use of multiple software hinders the compilation of a comprehensive BIM model (Bryde et al., 2013; Chien et al. 2014). Such an issue of interoperability undermines the basic motto of a BIM model which is to provide a shared platform for the exchange of information from multiple fields throughout the project lifecycle (Wikforss et al. 2007; Eastman et al. 2011).

Interoperability is regarded as the biggest hurdle to the implementation of BIM to mega projects in KSA, given that it requires professionals from all the fields to switch from their fortes to new CAD platforms, which comes with huge transitional costs (Smith and Tardif, 2009).

However, with the advent of mechanisms such as “interoperability of BIM” a system is proposed by multiple researchers to provide the ability of exchange of details for the BIM model by extraction from multiple software systems. Hence, professionals shall be trained and equipped with knowledge of different softwares so that they can extract information and formulate a comprehensive BIM model (Azhar et al., 2012). In the wake of such problem an effective solution has been proposed in the form of Industry foundation Classes (IFC) as a solution to the interoperability problems: an international public standard scheme developed by the vendors of BIM (Ku &Taiebat 2011; Liu et al. 2010; Thein 2011). IFC provides a mechanism allowing the importing of data from multiple applications into BIM model.

2.4.1.2 Unavailability of Experts to handle complexities of BIM software:

As demonstrated in figure 5 above, the unavailability of skilled labour equipped with expertise to handle complexities of BIM software, demonstrate the biggest obstacle to the professionals working in the Middle East area. According to the BIM-Middle East report (2011), 51% of the professional who participated in the wide scale survey reported the absence of skilled labour for BIM as an obstacle to the adoption of BIM architecture.

According to a study conducted by Arayici et al. (2009), the demand of BIM implementation is rising at a tremendous rate, however the supply of skilled labour is lacking behind hence creating a huge gap. The major reason for slow development of skilled labour in the BIM software is its complexity and delicacy of handling which requires extended training and experience in usage before any individual can become an expert (Liu et al., 2010; Eadie et al., 2013).

It is suggested by several researchers that it is the job of government in KSA to step in and define clear criteria’s and certification programs for AEC students and labs enabling student to experience BIM platform shall be included in the university curriculum. Furthermore, professional training programs under a single umbrella housing universal standards must be developed by the BIM vendors, which might enable trainees to get maximum knowledge in the minimal amount of time (Hore e al., 2011; Gu and London, 2010; Chan, 2014).

2.4.1.3 BIM model management issues:

BIM model provides a one stop transparent platform for all the project teams to share information and communicate to understand design specifications throughout the project lifecycle. The teams are empowered to conduct changes in real time and update the BIM model version for all others to see and extract information from (Eastman et al., 2011; Azhar et al., 2012). Hence, the BIM model shall be managed immaculately with coordination managers and backup maintenance for any contingencies (Gu and London, 2010; Chien et al., 2014).

The BIM model manager shall be equipped in knowledge of a vast array of disciplines being utilized in the BIM software architecture, to perform the duties of management and risk mitigation at all stages of project cycle, which include: skills in BIM software, understanding of construction standards, Information and communication technology (ICT) expertise, and general communication management (Impro, 2009). One crucial issue to be handled is that of clash detection when inducing information from different softwares into BIM model and then translating the information into an understandable chunk of information for other teams (Brewer et al., 2012; Hardin, 2009).

Hence a lot of responsibility is to be handled by the BIM model manager and a very crucial hurdle in the start of project is to assign appropriate model manager who is well versed in all the required skills. It is noted by the researchers that there is acute shortage of such individuals in the field especially in the regions such as KSA, who are still in the transitional phases. Moreno et al. (2013) noted this shortage of BIM model managers as one of the biggest obstacle to BIM utilization.

2.4.2 Financial Challenges:

2.4.2.1 Transitional costs for BIM implementation:

BIM implementation comes with a package of huge sums of initial investment in the form of the purchase of software and required hardware along with licences to use the components of the system. In addition to the costs of infrastructure, companies have to endorse to long term training programs and hire highly skilled workers, which further adds to the overall cost of implementation (Bryde et al. 2013; Eadie et al 2014; Thompson & Miner 2010).

Companies have to deploy huge budgets into hiring experts on adhoc basis, as consultants and experts in BIM, for different fields, given that there is an acute shortage of skilled workers and construction companies in KSA does not have enough skilled labour to handle the complexities of BIM software (Azhar et al., 2012). The interoperability issues are to be dealt with additional consultancy services, along with the hiring of special BIM model managers for ensuring adequacy of plans and designs (Love et al., 2013; Ku and Taiebat, 2011).

Researchers have further noted that the internal structure of organisation and its ability of adaptability plays a huge role in deciding the costs of transition towards BIM; in addition financial standing of the organisation which allows it to invest in the future also demonstrates the readiness for change (Kouider et al. 2007; Ruikar et al. 2005). So according to extensive research, transitional costs for BIM implementation are similar to hedging for construction companies, as they spend huge amounts and energy to hedge on the future rate of returns (Won et al., 2013; Yan and Damian, 2008; Azhar et al., 2012).

2.4.3 Legal and Contractual challenges:

2.4.3.1 The Issue of Intellectual Property Rights (IPR):

BIM model interoperability and tendency of providing collaborative environment with real time access and update ability comes with a price of unprotected intellectual property; given that throughout the project lifecycle transparent systems and designs are to be accessed by multiple parties working on the project. The BIM final model with all the data regarding delicate designs and control measures is to be used by the Facility Management teams after project completion as it is which further aggravates the situation of security against intellectual property (Porwal & Hewage 2013; Lewis et al., 2010).

The entitlement of ownership to the intellectual property of designs and plans for construction also poses an issue of concern, given that there are no defined standards and IPR legal frameworks for BIM addressed by the governmental authorities of KSA. Researchers have considered the matter in great details and have argued intently on the matters of IPR: they claim that the rights of BIM final model belong to the client with the condition that if the client has employed the designers and engineers to constitute the model. This claim has been revoked by designers and engineers working partially and full time in the construction field, who argue that the IPR of BIM models belong to them because of their individual input (Oluwole 2012; Eadie et al. 2010; Eastman et al. 2011). Despite of the efforts of researchers worldwide to construct a framework for IPR of BIM models there is a general fear among the professionals and companies regarding the ownership of BIM models (Liu et al., 2010). The problem mainly persists due to lack of governmental and regulatory authorities' involvements in the matter as there are no defined contractual frameworks and standard protocols for BIM implementation (Migilinskas et al. 2013; Elmualim & Gilder 2014; Ku & Taiebat 2011).

Liability of the BIM model is another issue of concern which has been widely debated upon among the industry professionals. According to Chao-Duivis (2009), BIM model provides the facility to trace back the design input from multiple individual who can be separately liable for different components of the BIM model. His study concluded that the building outline shall be owned by the architect and he shall be liable for all the consequences; similarly electrical design engineer shall be liable for the electric design in the BIM model and so on (Chao-Duivis, 2009). Thompson (2001) argued that if BIM is to be embraced in its entirety industrial standards shall be devised to completely eradicate all such frictions such as IPR and an open source environment shall be created. Another recommended procedure to handle the IPR issue is through designing a framework for a contract in which all disputes shall be resolved while endorsing any parties to work to the project in collaboration (Osapuolet 2012; Rosenberg 2007).

Bryde et al. (2013) came up with a much easier solution which could be deployed in the KSA landscape, in which standard protocols are not required and parties tend to give out licenses for their intellectual property which are royalty free.

2.4.3.2 Lack of legal infrastructure for Procurement and regulatory monitoring:

AEC industry in KSA faces an acute issue regarding procurement strategies which tend to induce fragmentation in the project leading to undefined risk sharing and profits. The traditional procurement strategies lead to conflicts between the clients and the technical parties involved in managing the construction project, due to haphazard structure of risk and reward sharing in the industry (Ling et al., 2014; Dulaimi, 2010; Sebastian, 2011).

According to Porwal and Hewage (2013), the current AEC industry lacks a comprehensive project delivery system which can be used as a blueprint for the BIM model.

Researchers have proposed different procurement methods to be utilized for BIM models, along with their benefits and drawbacks. According to Migilinskas et al. (2013) and Moreno et al. (2013), industry shall utilize the most integrated procurement procedures for BIM, given that collaboration is the prise of BIM technology; they rated Design and Build (DB) and Construction management at risk (CM@R) as the utmost appropriate methods. Hardin (2009) proclaimed that the Design-Bid-Build (DBB) is the unhealthiest method for procurement to be utilized in BIM.

As defined before the best method for construction project procurement is by far the IPD method as proposed by the American Institute of Architects (AIA). According to multiple researchers IPD stands as the single most comprehensive method to be utilized with BIM given it has similar features and is based upon similar principles of collaboration and efficiency (Glick & Guggemos 2009; AIA 2007; Moreno et al. 2013).

2.4.4 Economic Environment Challenges:

2.4.4.1 Lack of BIM demand from government:

One of the biggest hindrance to the implementation of BIM for projects is the failure of government and clients to understand the long term worth of utilization of BIM which results into reservations against paying higher costs for the mandate of BIM software (Eadie et al., 2013; Chan, 2014). Due to the reason of increased initial investments and lack of examples to be examined for the effective utilization of BIM technology and increased time and cost saving pertaining from BIM based projects, the government and clients tend to be insecure about the initial investment and they prefer to be last in the competition to embrace the BIM revolution (Eastmanet al., 2011). Researchers claimed that in such hostile environment and lack of willingness to invest in the future, government shall step in and demonstrate a model for BIM implementation which can serve as an example for the whole industry (Chan, 2014; Lu and Li, 2011; Hardin 2009).

Dubai municipality can serve as an example for KSA governmental authorities to follow, given that their aggressive jump to use BIM in mega projects and demonstrate its fruitful impact on the end results.

Several researchers and veteran professionals claimed that, the largest impediment to use BIM in AEC projects is the lack of demand from the governments/clients to use BIM as a compulsory requirement (Kunz & Gilligan 2007; Brewer & Gajendran 2010; Eadie et al. 2013; Won et al. 2013; Chan 2014). It is obvious from the recognized benefits of BIM that, the client is the most beneficiary from the implementation of BIM (Olofsson & Eastman 2008; Eadie et al. 2013). That means governments and clients can play an active role to rapidly mandate BIM in the AEC industry. (Dubai Municipality Circular 196, 2013).

2.4.4.2 Lack of stakeholder experience and usage of BIM:

BIM technology delves upon the strategy of stakeholder collaboration and integration for efficient and effective decision making under a single umbrella, however, this property of BIM makes it difficult to implement given that there are teams from wide array of fields involved in a single project and all of them are not ready to embrace BIM replacing their traditional methods. Hence, the exchange of information and collaborative decision making in the BIM is halted if any party involved in project does not uses BIM (Linderoth 2010; Liu et al. 2010; Elmualim & Gilder 2014). Stakeholders with small companies face a bigger problem to come upto the standards of other parties as huge initial costs are required for the transition, which makes the market landscape uneven for the construction industry if BIM is fully embraced and mandated for all projects (Migilinskas et al. 2013; Kouider et al. 2007; Eastman et al. 2011).

CONCLUSION:

BIM is the ultimate solution to the problems construction industry has faced from years and as the momentum is shifting towards mega structures in KSA, use of BIM to eradicate discrepancies in design and planning, as well as increasing productivity is detrimental. The literature review demonstrates various quantitative and qualitative studies carried out in the past to demonstrate the efficacy of BIM usage in the AEC industry. The research studies analyzed also validate the premise that there is a dire need for the KSA government to regulate the use of BIM and support the transition by financially supporting public and private construction firms. The studies further quantitatively demonstrate that there is an acute shortage of skilled workers in the construction industry who can fully integrate the project phases in the BIM environment.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 RESEARCH METHODS

The study focuses on utilizing different aspects of research methodologies in order to devise a comprehensive framework through qualitative and quantitative assessment for the implementation of BIM in the KSA AEC industry. The research utilizes both inductive and deductive approaches to both, test the hypothetical assumptions made through the literature review and to precipitate unique challenges and advantages to the AEC industry and KSA.

The methodology tends to assess and enhance the conceptual framework established through the study of literature for the implementation of BIM in the KSA AEC industry.

The research methodology revolves around a three tier approach: Firstly, a detailed Survey Questionnaire is compiled which is made available online and the links are sent via email to professionals working in KSA AEC industry, which tends to precipitate both quantitative and qualitative factors associated with the implementation of BIM in the AEC industry. The survey questions are devised in order to test the constructed hypothesis through the extensive study of literature. Secondly, a case study from the KSA AEC industry is selected and analysed to demonstrate the efficacy and advantages of BIM for the industry through data analysis. Project case is selected on the basis of origin and the extent of BIM utilization to delve upon the perceived advantages of BIM for a construction project.

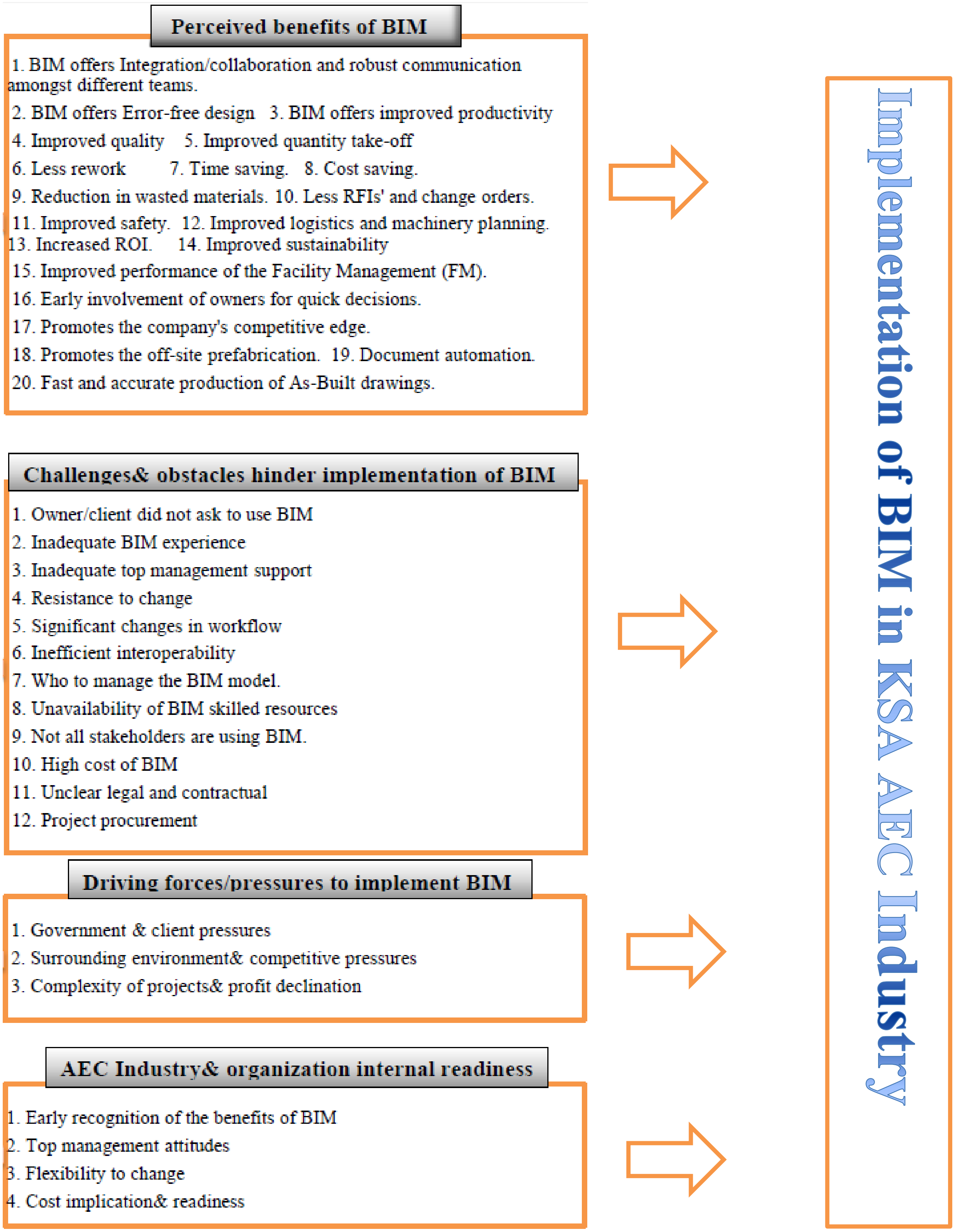

Figure 6: Conceptual framework for methodology

The study utilizes both deductive and inductive approaches for the extrapolation of trends from the collected data both in the form of survey and literature review. One important benefit of using deductive approach is that it allows the researcher to focus on the most crucial issues and greater amount of focused data can be analysed (Saunders, Lewis & Thornhill 2009).

The research questions and objectives are answered using the qualitative methods of data collection such as questions being asked from the professionals through online surveys and content analysis for case study and review of literature; surveys are used as a structured tool to acquire essential qualitative data. We use the approach for survey as structured tools for answering the research questions outlined by Wilson and Santoro (2015). Hence the study accumulates both primary and secondary data for the triangulation of key findings and justifying the predicaments created for the research.

In qualitative methods, techniques such as literature review, observation, and others are applied to collect data for answering research questions. By definition, quantitative methods use structured tools such as questionnaires are relied upon to collect the necessary data for analysis. Wilson & Santoro (2015) also state that these are structured tools that have specific questions for the respondents. In this study, the researcher shall rely on primary data and secondary data. Secondary data can be defined as that data that is collected from already existing sources while primary data is fresh data collected through structured tools. The researcher shall rely on secondary data from recent publications to gain the necessary ideas, concepts, data, and insights related to the research questions. The research will also collect data from questionnaires. Since the application of technology and automation in the construction sector is a relatively new area of study, there are several researchers who have focussed on the area. They have made some publications that this research can rely on to make conclusions. Therefore, recent publications such as journals, books, conference papers, periodicals, and internet sources will be probed in relation to the research questions. The cleansed data is further analysed for the extrapolation of major trends and correlations in the identified variables, aimed at fulfilling the research objectives.

The nature of data required from these sources includes theoretical insights and data analysed to make conclusions. Especially for papers that have completed data collection in this area, it is important to evaluate the types of data collected and the significance of the data (Kratina et al. 2015. It is also important to understand the conclusions made by those authors after the collection of data. While it is important to understand that no one single study resembles another, it is critical for this paper to only consider high-quality papers. This ensures that the data used in answering the research questions is of good quality. Therefore, it is justifiable for the researcher to first collect the articles that need to be used and then classify them or rate them according to their quality (Kratina et al. 2015). This ensures that papers aren't selected randomly leading to the compromise of quality standards in this paper.

There are several advantages connected to using multiple methods of data collection. First, the amount of time required for data collection is highly reduced because secondary data is used to lay a foundation for the study. The other advantage of this approach is that it makes it possible for the research to check studies beforehand and determine their quality before they are used in the study (Gligorijević & PržUlji 2015; Bajwa 2015; Kuiper et al. 2015; WANG et al. 2015). This method is also advantageous since primary data collection introduces fresh insights that can either support secondary data or refute some claims (Gligorijević & PržUlj 2015). According to them, this introduces clarity, accuracy and originality in the research. The disadvantage of using literature review is that it can make one discriminate papers on the basis of the information contained (Gligorijević & PržUlji 2015). They argue that it is possible that highly technical studies are avoided. The researcher takes note of this and due consideration will be given to all papers.

Primary data, however, is expected to give first-hand information in the experience one gets from using BIM. Secondary data will give the theoretical background and other relevant literature on the use of BIM. Primary data is expected to give first-hand experience which construction workers and managers have with using BIM. The workers and managers will respond if indeed BIM has practically increased efficiency and performance of construction projects. The target population for the primary data will be managers, engineers, employees, and government officials. This research uses descriptive and quantitative statistics. The research employs correlational statistical tests. According to Ghosh (2016), correlational statistical test looks for association that exists between variables.

3.2 RESEARCH PHILOSOPHY

This research is based on positivism because of the researcher's belief that the problems in the construction sector in Saudi Arabia can may be solved scientifically using BIM. The argument of this research study is that careful and correct application of a product of science called BIM can improve the efficiency of construction in KSA given that it is a good method to handle construction projects. The researches aims at assessing the current construction industry landscape in KSA and evaluate its readiness for the transition towards BIM utilization. However, the researcher also intends to get the rated opinions from the professionals who have been in the construction industry and may have been dealing with the BIM in order to make objective deductions, and therefore, bases the research on positivism.

3.3 SAMPLE AND SAMPLING TECHNIQUE

3.3.1 Sampling Technique

The process of answering the research questions will be carried out using the purposeful sampling technique, and the target audience will be chosen in accordance with the relevance and their ability to contribute effectively to the research aims and objectives. The audience basically shall be a sample representing all sorts of professionals working in the field of CAE industry of KSA such that a generalized perception of the industry and professionals of KSA can be developed regarding BIM and they can be used to make important insights and suggest appropriate changes to the regulatory authorities.

3.3.2 Sample Size

The researcher will provide questionnaires to more than 200 candidates who are working in the construction industry. The target number was to get around 100 responses which is a number determined by the researcher and is not based on any probabilistic calculation. The sample as it is, is feasible in this research. The responses from questionnaires will be complemented with the collected secondary data. The small sample size is due to the given constraints such as researcher time, industry specific limited population, availability and interest of questionnaire respondents. The small sample size also enables the researcher to complete the research in due time since it does not consume a lot of time during data collection (Cameron, Sankaran & Scales 2015).

3.4 DATA COLLECTION

The data collection will be done through online Questionnaire, which will be in five parts: (1) Demographical information, (2) questions related to drivers facilitating successful adoption of BIM, (3) questions related to barriers that may hinder BIM adoption including (process and technology), (4) questions related to readiness assessment in four areas (people, process, technology and management), and (5) questions related to current level of BIM usage and knowledge.

The sample will be collected from professionals (Architects, Engineers, project managers, and others) working in AEC industry organizations in KSA, these organizations will include:

- Architecture Firms
- Engineering Firms
- Construction Firms
- Building Clients/Owners

3.4.1 Data Collection Procedure

Data collection is described as the process of gathering raw information either from the field or from secondary sources (Pepe & Catania, 2015; Kalenga 2015). Data collection on the other hand, refers to the method by which that information gets collected (Pepe & Catania 2015; Ray 2015). As aforementioned, this research will use more than one procedure to collect data. First, there are two types of data to be collected as has been mentioned above. There is primary data and also secondary data. Both of them have been adequately described.

3.4.2 Collecting Secondary Data

Two techniques are used for the collection of secondary data: desk based research and content analysis approach. The target is the published reports and papers in peer reviewed journals and also the content published online regarding the usage, benefits and challenges of BIM in the KSA AEC industry. For the secondary data collection the approaches outlined by Ray (2015) are utilized and all sorts of online available material are also considered as supporting data to the analysed literature. The utilization of internet sources and online libraries for data collection allows the researcher to save time and concentrate on other essential features of the study.

3.4.3 Collecting Primary Data

The method deploys an approach to gather first hand data and direct information from the potential audience working in the field of study rather than relying on second hand nformation from other sources. This method is deployed to fill the gaps in the literature and to fully construct the cases around the defined research objectives from every angle. The researcher will send the questionnaire links to the target sample. The researcher will send follow up emails, reminders and calls to ensure that the questionnaire recipients respond in a timely manner. The aim of this follow up is to save time during data collection.

3.5 DATA COLLECTION INSTRUMENT

Data collection instruments are research tools used for gathering information. As described earlier given its efficiency and efficacy the researcher will rely upon online libraries of dependable peer reviewed journals for secondary data collection, in addition to that the websites of the companies working in the KSA and the websites of the regulatory authorities will be sued to collect important information which is not given in the research papers. The content will be then cleansed and analysed in order to distil the insights to be made. Questionnaires, as aforementioned, are instruments of data collection that contain structured questions whether open-ended or closed-ended, and which respondents are supposed to answer. Online surveys are preferred by most researchers over interviews given that the participants feel comfortable and can demonstrate their actual view point without the need to fabricate any assumptions (Bajwa 2015). This is because they fill questionnaires on their own and they do not have to mention who they are. This, the researchers have realised, enables them to give answers honestly without hiding information for being shy or for fear and favour ((Bajwa 2015). Questionnaires also give researchers easy time because after distributing them to the respondents they let the respondents fill them on their own. Therefore, the questionnaires help them in saving time since they use that time to accomplish other aspects of the research. However, major setback for using questionnaires has always been the fact that questionnaires demand high levels of literacy. For most researches, it is not enough just knowing how to read and write for respondents to use questionnaires effectively, one must be able to interpret and comprehend the questions inside the given questionnaire.

3.6 DATA ANALYSIS

The raw information collected from multiple sources is first cleansed and distilled to concentrate on the targeted data in alignment with the constructed research questions. The information collected through the secondary data will first be categorised and distilled to justify the constructed research objectives which will be presented in a categorical manner (Nakanishi, 2015). The secondary data will form the base for the collection and insights to be made from the primary data. This shall allow the researcher to make appropriate association and analyse the primary data in an effective way to fully justify the hypothesis. Quality and relevance will be used as benchmarks for the classification of secondary data and association of information collected from different resources will be made in the light of the research objectives.

The primary data is then classified and accumulated on the basis of the premises constructed from the secondary data. The collected answers from the survey analysis are first cleansed and appropriate weightage is given to every selection to make the responses qualitatively and quantitatively relevant to each other, Data is then analysed and distilled for anomalies and all the responses which seem to be the outliers are closely analysed for their efficacy. After the cleansing of data the demographics of the participants are visualized through different statistical techniques to give a demonstration of the sample background and its relevance with the constructed research objectives.

Different constructed variables are then analysed using the exploratory analysis approach where graphical presentation is used to explain the responses and their efficacy in accordance with the research questions.

The research tends to attempt to make correlations between different qualitative responses on the basis of the professional background of the respondent and their experiences with BIM. Furthermore one way ANOVA test is used to test the hypothesis to analyse the influence of certain variables over the others in the data.

CHAPTER 4: RESULTS ANALYSIS AND DISCUSSIONS

The aim of the chapter is to orchestrate the research findings conducted on the lines of the previously established premise. An empirical and constructive approach is used by illustrating data from survey and a case study. The findings first are directed to demonstrate a need of BIM application in the construction industry on the lines of value it can bring for the companies involved in the process. By accentuating this awareness the research findings establishes a concrete case to demonstrate that BIM is extremely beneficial for construction industries in terms of their own benefits. The findings are then directed towards instigating the governmental agencies to mandate a legal framework which can ensure proper implementation of the BIM practices in construction industry of KSA.

The survey was targeted at a wide range of professionals linked with the construction industry to get a holistic view of the current perceptions, ground realities and future prospects of BIM in KSA. The focus was laid on assessing the readiness of the industry to adapt to the BIM revolution and probe the obstacles to its adoption along with distilling its potentials for the industry. The survey responses also demonstrate the intervention of governmental authorities in supporting the transition of the construction industry and focus is on precipitating the loop holes in the regulatory framework which can limit the acceptance of BIM.

The survey was distributed to more than 200 potential participants with a diverse company background. The samples include responses from private, international and public government organisation hence; a generalized response may be expected. Due to limited amount of time 66 professionals responded to the request and delivered their responses. There is an acceptable range of representation from the three types of AEC companies.

An attempt will be made to make correlations among different variables in the survey through an inductive approach to highlight the impact of one variable on the other. The survey was conducted using online platform.

The survey findings are divided into the following sections:

- Participant's professional Background
- Adaptation and application of BIM in KSA
- Perceived benefits of BIM adaptation
- Challenges to adaptation
- Drivers of BIM adaptation
- The role played by regulatory authorities

4.1 PARTICIPANT'S PROFESSIONAL BACKGROUND:

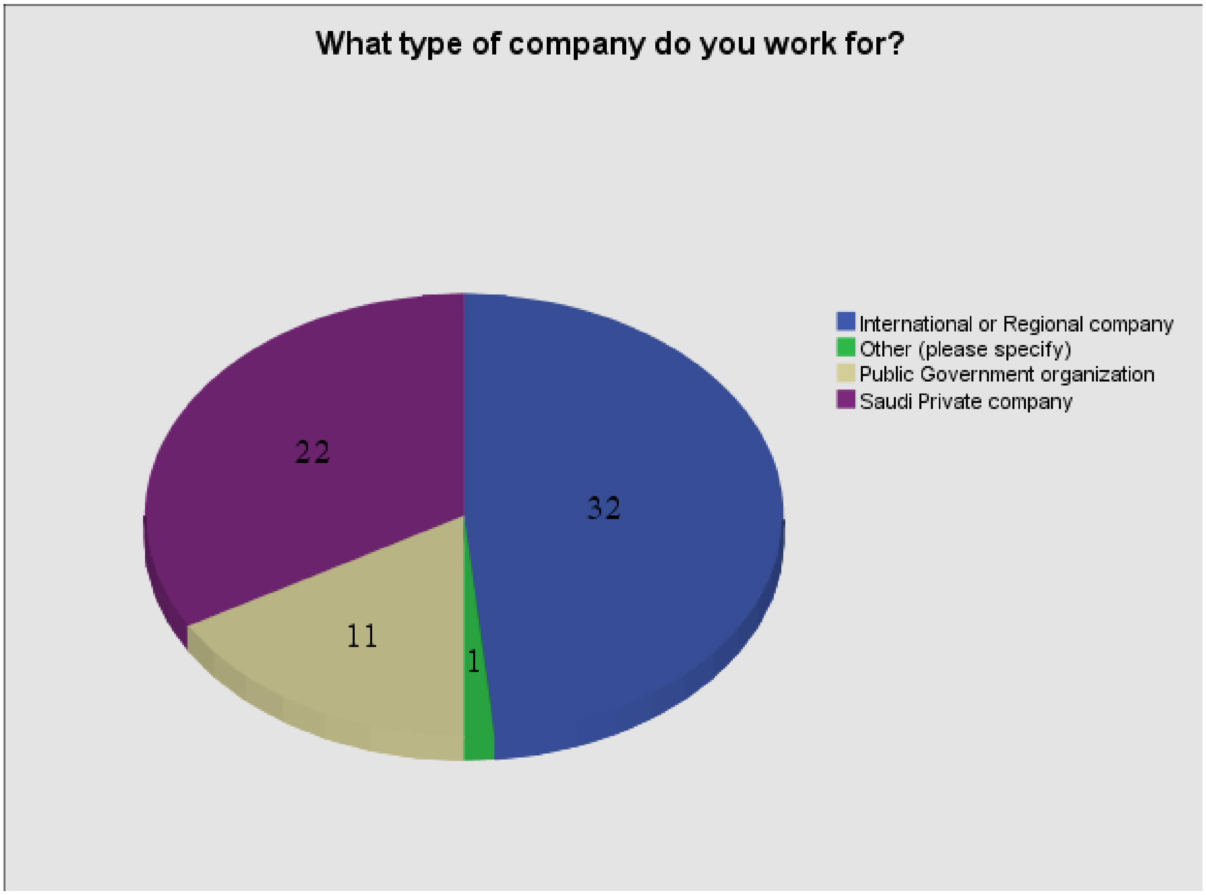

Figure 1: The response regarding the type of company of the participants.

The sample of data acquired through the survey responses demonstrates that a majority of participants were from three sectors of the AEC industry: Public Government Organisation, Saudi Private Company and International or Regional Company. As shown in the pie chart above the highest number of participants worked in a regional or international company, almost 50%, while at the second spot in terms of quantity of representation in the sample was Saudi Private Company which is followed by the Public government organisation. This breakdown of the sectors is pretty reasonable given that it encapsulates all kinds of stakeholders and can provide a comprehensive perspective regarding BIM usage and implications for KSA.

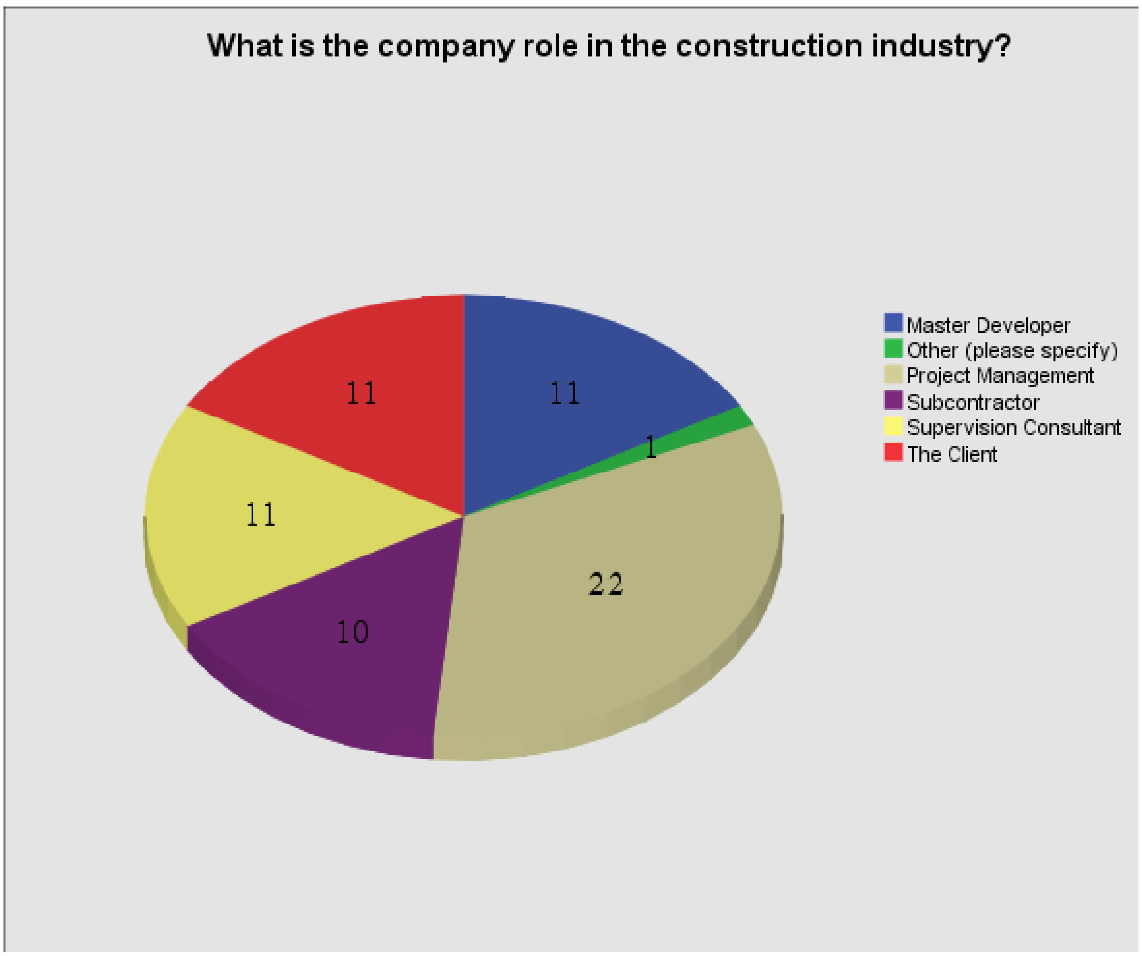

Figure 2: Role of participant's company in the construction industry.

The figure above demonstrates a pie chart summarizing the role in construction industry of the participant's company. It was established after analysing the responses from the participants from the type of company and role of company, that all of the Saudi Private companies are involved in Project management activities, while on the other had the Public government organisations are involved as clients in the construction industry. On the other hand the Regional or International Companies play multifaceted roles in the construction industry of KSA, which include: Master Developer, Subcontractor, and Supervisor Consultant. However, the greatest share in the respondents as shown in figure above was that of Project management, 22 in total; while all other roles had an equal share in the sample.

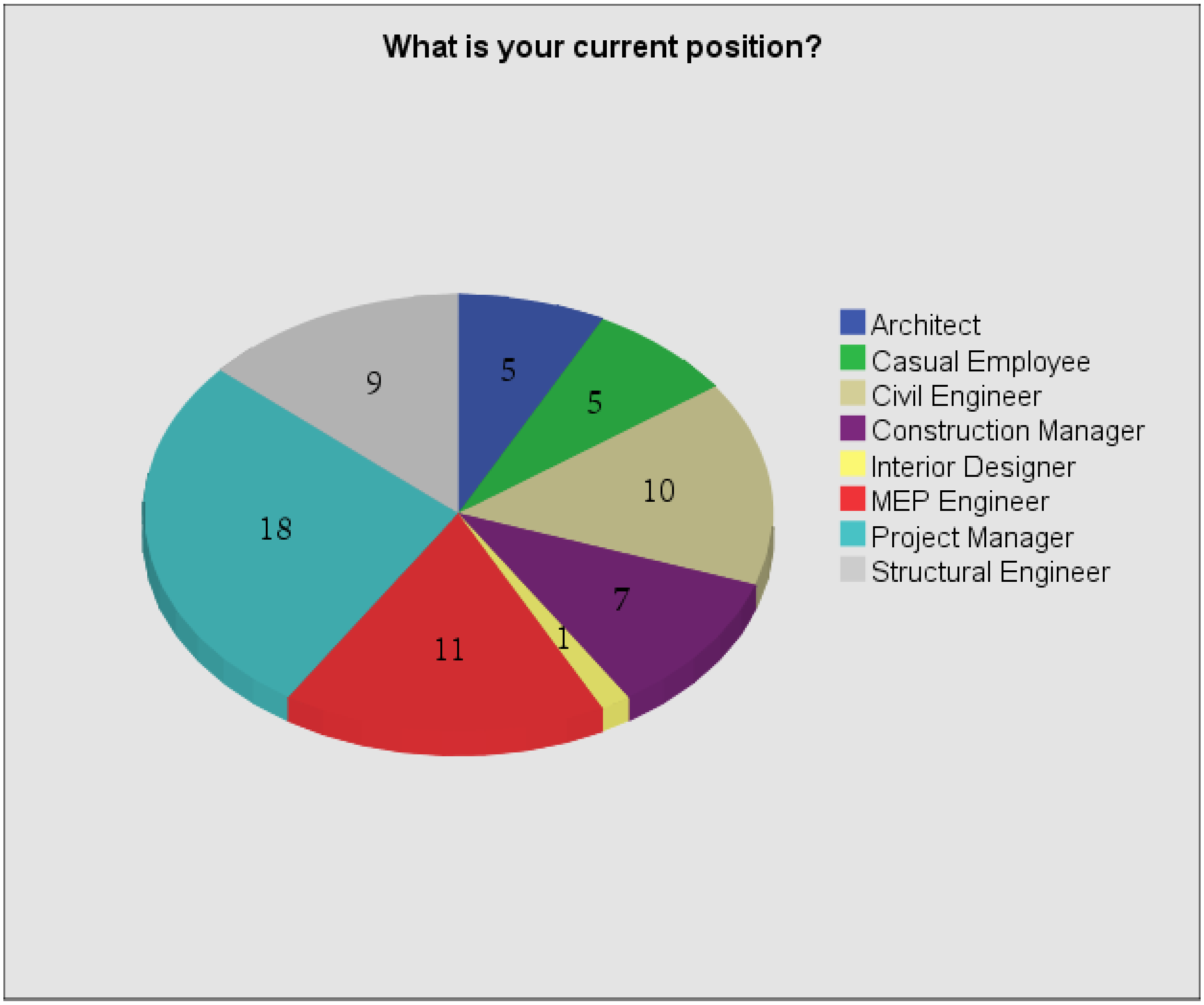

Figure 3: The current position of the participant in the company.

The participants were further requested to report their current position in the company which shall denote their role. The figure above demonstrates that a majority of the participants are project managers (18 participants) with their primary role to manage construction projects in the company. After project managers the greatest share in the sample was that of MEP engineers (11) followed by Civil Engineers (10) and Structural Engineers (9). The sample is further divided into participants holding four different positions with a comparatively smaller representation:

Construction Manager (7), Architect (5), Casual Employee (5) and Interior Designer (1). Hence, the sample contains a very versatile set of professional which can ensure a considerable representation of all professionals working in the construction industry of KSA.

4.2 BIM USAGE AND UNDERSTANDING:

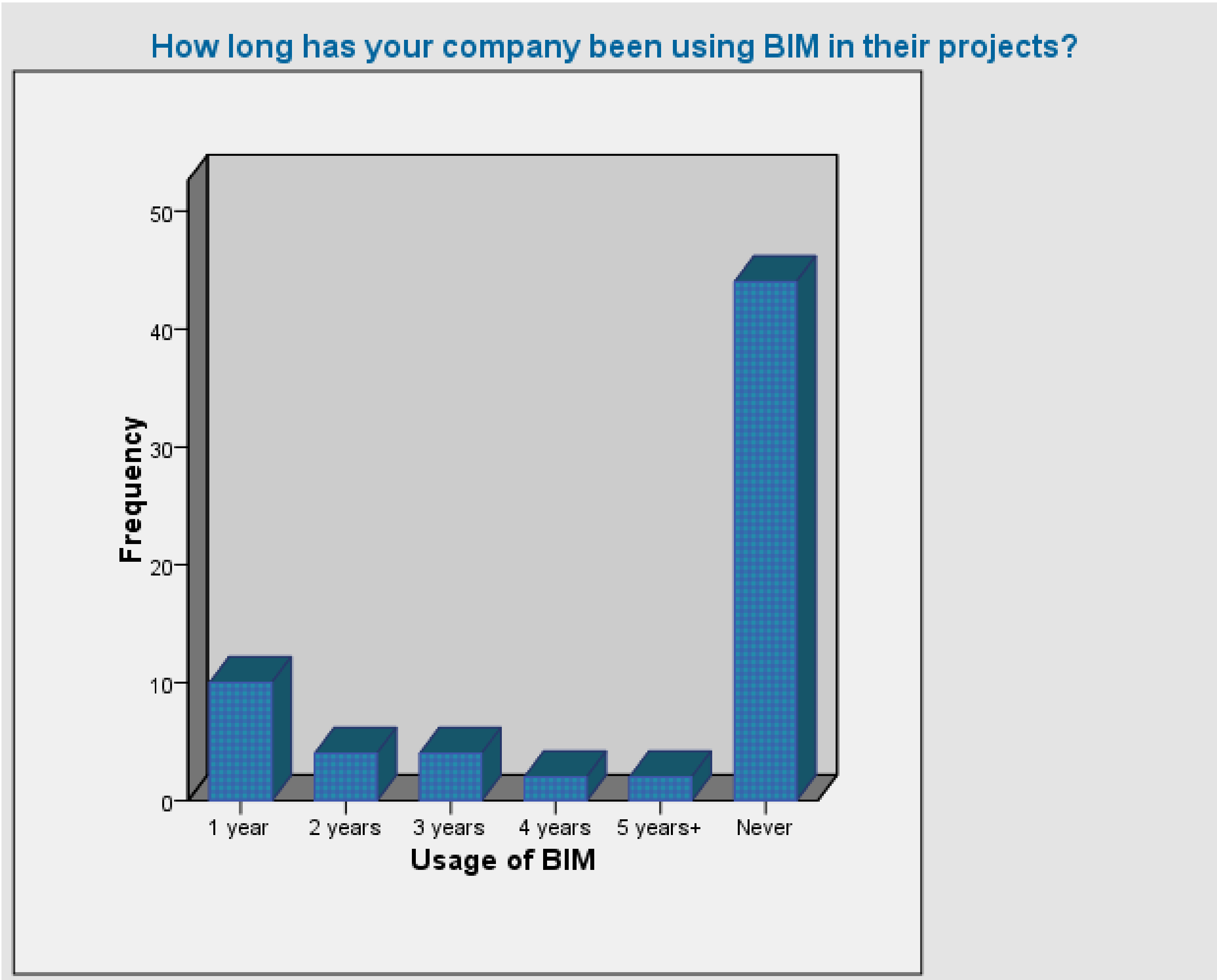

Figure 4: The time of BIM usage in the company.

The figure above allows the visualiztion of the usage of BIM software by the participants. It shall be noted that regardless of its perceived benefits and efforts made by the governmnet in the recent years to encourage its usage; the usage of BIM software is limited to specific sectors in the industry. It can be extrapolated from the data using exploratory analysis that Project Managers are reluctant to the BIM software usage. Although, as developed in the literature review, that BIM encapsulates all sorts of tools and standard protocols which are extremely beneficial for managers to aptly manage and orchestrate the teams working on the construction projects. Hence, it can be declared that the project management companies working in KSA are not aware fo the potential of BIM in their scope of work. The overall results as shown in the bar chart above show that there is an acute lack of experience in the usage and application of BIM software in the construction industry of KSA; given that above 50% of the participants reported to have never been used BIM software before in their work.

After a closer analysis of the trends shown in the responses it is extrapolated that the Project managers have never used BIM in their job, the same is the case with the Subcontractors who also reprted to have never been exposed to BIM software before. Supervisor consultnts also reported to have never used BIM software before. However almost all of the Master Developers and clients in the construction industry reported to have experience in BIM software usage.

The master developers with experience in the BIM software are associated with the regional or International construction companies while the clients are solely associated with the Public governmnet organisation.

It can be further established that the Saudi Private organisations do not really use BIM for their construction managemnet purposes, which demonstrates the lack of regulatory supervision of such activities and propoer resurcefulness of the employees to use BIM software in their jobs.

It is further noted through the combined analysis of the survey responses that Regional or International companies utilize a greater level of BIM capabilities, as most of their employees reported their company usage of BIM to be Level1; while the usage of Saudi Private companies’ employees reported a usage of Level0. The Public Governmnet organisations' employees did not showed much information regarding the usage of BIM software in their company however, two of them reported a Level2 & Level3 usage of BIM.

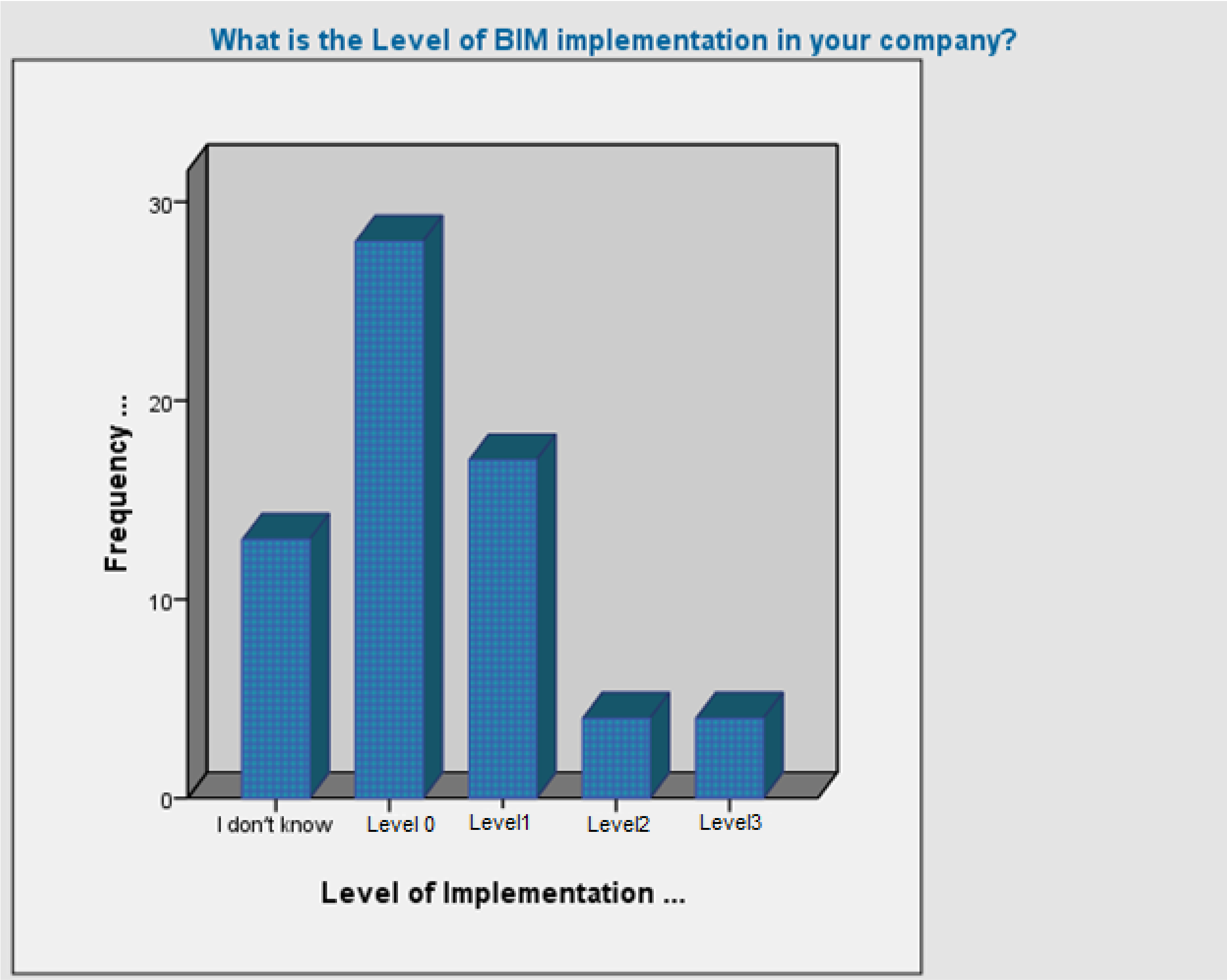

Figure 5: Level of implementation of BIM in the company.

The results are further demonstrated in the bar chart above. It can be extrapolated that the survey responses show that companies in Saudi Arabia use minimal amount of BIM in their construction activities, as out of 66 participants around 28 reported the use of BIM software of their company to be at a level 0, while around 15 participants had no idea of the adaptation level of BIM by their company. Level 1 of implementation was reported by around 18 participants while Level 2 and Level 3 was reported by 2 participants each.

The overall resulst from the survey demonstrate a clear lack of knowledge of the BIM capabilities, which is due to very limited usage of software in the industry. The Saudi Private companies specifically seem to have ignored the BIM revlution and are not mandated by the regulatory authorities or the clients to use the software. The results show that there is a clear need for a shift in paradigm in the construction industry through the use of multiple propagation instruments by the regulatory authorities such that companies can understand the benefits of BIM usage and can invest in their infrastructure for a better future.

The inferences above can firther be backed by the reported knowledge and understanding of the particiants of the BIM software. The bar chart below demonstrates that a majority of the participants (n=34) reported to have heard of BIM but have never used it for professional purposes. However, another important inference can be made from the question that almost all of the participants reported to atleast have heard about the BIM capabilities, which shows that the recent attempts of the regulatory authroitities in Saudi Arabia has made some effect to propagate the BIM technology but have lacked the ability to convince the companies to adapt to its usage.

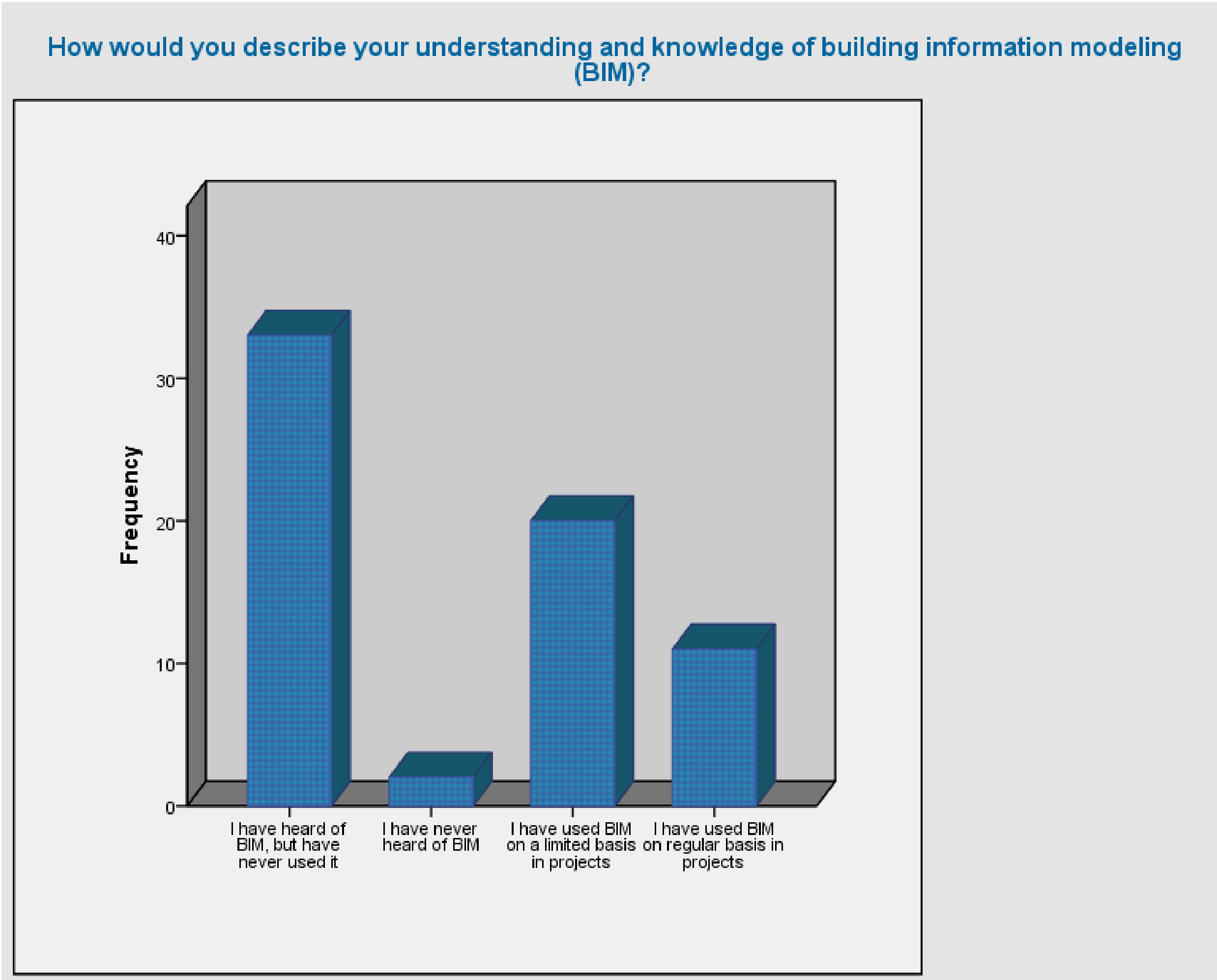

Figure 6:The description of understanding and knowledge of BIM of the participants.

Among the participants in minority who reported to have used BIM in their jobs before reported a frequent usage of development of 3D/4D models of BIM from 2D designs. The second most frequently used activity of BIM was reported to be the addition of specification requiremnets to graphic visuals in BIM, while a few of the participants reported the use of BIM for operations managemnet and quantification of buildings purposes.

Hence, it can be extrapolated from the results that there is a clear lapse in the knowledge and usage of BIM software, given that the construction companies use BIM for very limited applications if they use it at all. The results demonstrates that the higher managemnet of the companies are not fully aware of the long terms benfits and potentials associated with the BIM usage, in addition to that the results show a failure of reglatory authorities to support the BIM transition.

Although, as it is reported in the literature review, Saudi governmnet has undertaken many mega project in the wake of the 2030 Saudi vision for the usage of BIM software in those projects; however, it seems that the governmnet has not really done much effort to encourage BIM usage in the private companies working in the construction industry and the usage and appliacation is limited to the public companies and a few international organisations.

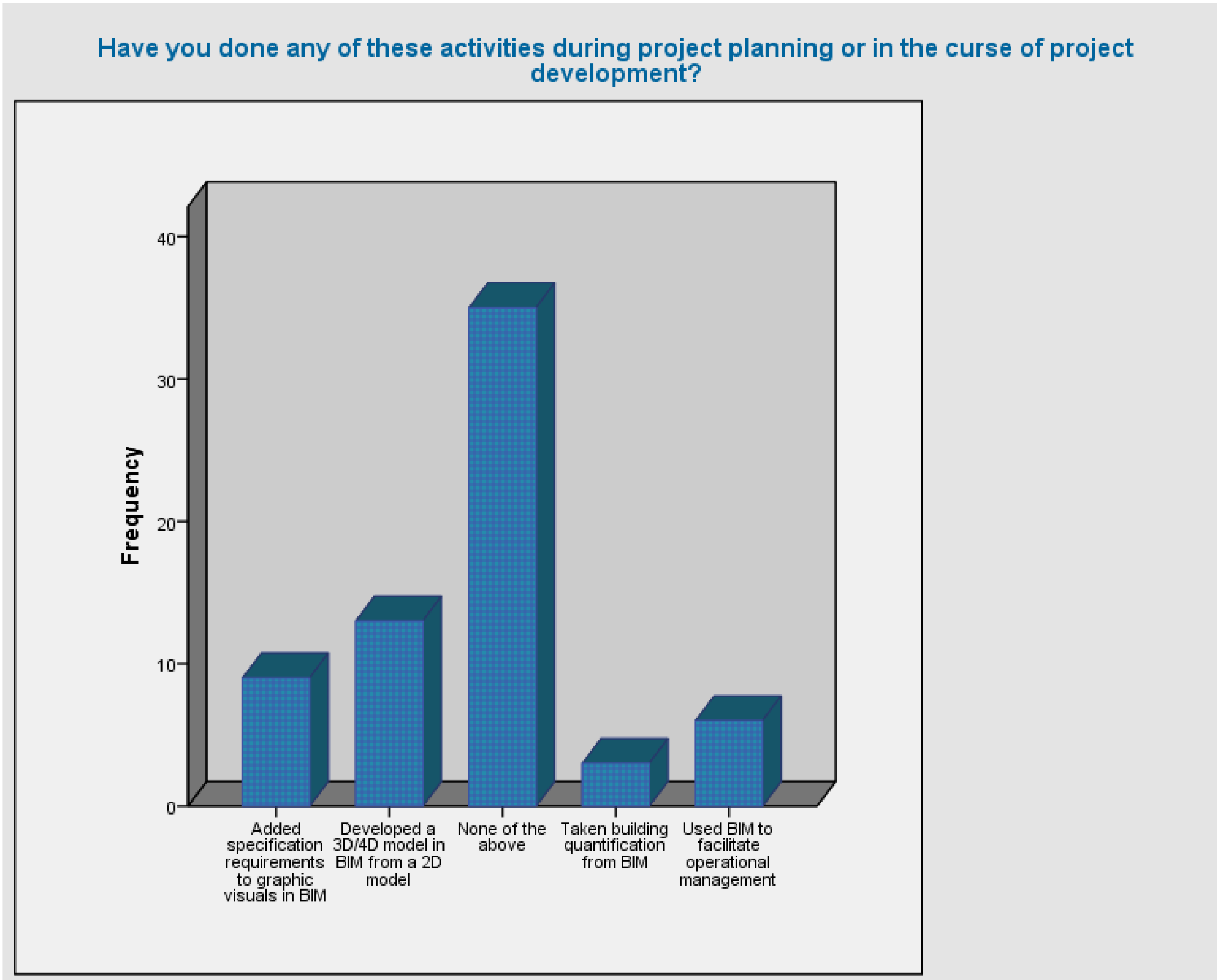

Figure 7: The conduct of activities relating to BIM in the past.

4.3 THE PERCEIVED BENEFITS:

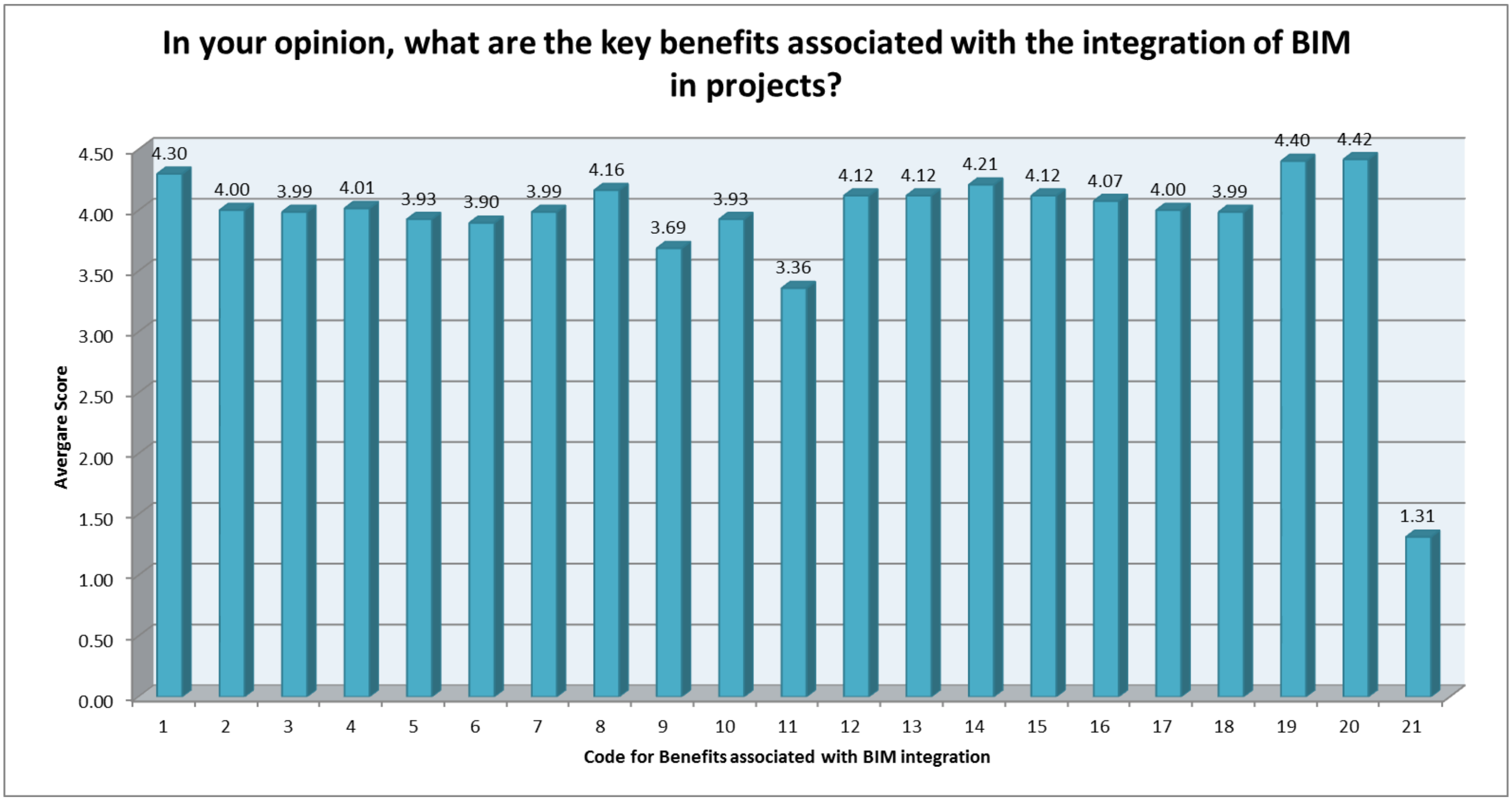

Figure 8: Degree of agreement (average scores) on the level of benefits associated with BIM integration.

The list of benefits associated by the BIM integration used in the survey:

1. BIM offers Integration/collaboration and robust communication amongst different teams
2. BIM offers error-free design
3. BIM offers improved productivity
4. Improved Quality
5. Improved quantity take-off
6. Less rework

7. Minimizes the time spent on a project / Time Saving
8. Minimizes expenditure / Cost Saving
9. Reduction in wasted materials
10. Less change orders
11. Improved Safety
12. Improved logistics and machinery planning
13. Increased ROI
14. Improved sustainability
15. Improved Facility Management
16. Early involvement of owners for better and quicker decision making
17. Promotes the company’s competitive edge
18. Promotes the off-site prefabrication
19. Better document automation
20. Fast and accurate production of As-Built drawings
21. No benefits for BIM

The survey was used to probe the perceived advantages of almost all the benefits associated with the BIM software integration. Likert scale from 1 to 5 was used to give the liberty to the participants to fully interpret their degree of acceptance and rejection of a specific benefit associated with the BIM integration; where a score of 1 demonstrates a strong disagreement while on the other extreme of the scale a score of 5 denotes a strong agreement with the statement presented to the participants. Consequently for each potential benefit participants were asked to show their degree of agreement for its efficacy.

The bar chart above demonstrates the average scores for each of the 21 benefits of BIM presented to the 66 participants in the survey, as rated by them on the degree of agreement with the efficacy of each benefit. As it can be seen that a majority of average scores are above 4 on the scale which shows that majority of participants agreed with the efficacy of almost all of the benefits associated with integration of BIM software in their construction activities.

The average score for the benefits can be categorised into three sections: the first section represents the benefits that are strongly agreed upon by the participants with scores above 4.2; the second section represents benefits with average score above 4 and below 4.2; and the final section represents benefits with average scores below 4. The following list provides the ranking of the benefits of the integration BIM in terms of the average scores from the 66 responses, from highest to lowest:

1. Fast and accurate production of As-Built drawings
2. Better document automation
3. BIM offers Integration/collaboration and robust communication amongst different teams
4. Improved sustainability
5. Minimizes expenditure / Cost Saving
6. Improved logistics and machinery planning
7. Increased ROI
8. Improved Facility Management
9. Early involvement of owners for better and quicker decision making

10. Improved Quality
11. BIM offers error-free design
12. Promotes the company’s competitive edge
13. BIM offers improved productivity
14. Minimizes the time spent on a project / Time Saving
15. Promotes the off-site prefabrication
16. Improved quantity take-off
17. Less change orders
18. Less rework
19. Reduction in wasted materials
20. Improved Safety

The first three positions (scores above 4.2) in terms of the average scores registered in the survey constitutes of Fast and accurate production of As-Built drawings, Better document automation and BIM offers Integration/collaboration and robust communication amongst different teams. The production of drawings as documented in the literature reviews traditionally poses tremendous amount of challenges among the design engineers and due to lack of standard protocols the build drawings are difficult to understand for other teams working on the construction project. In addition to its difficulty in production and understanding, producing drawings by hands is an arduous and time taking process which consumes considerable ratio of time for the whole project. BIM provides the virtualization of designs through computer generated algorithms which facilitate the design engineers to quickly conceptualize a design and check its feasibility in the complete entirety. In this sense BIM solves a huge problems in the design phases of the construction project. Given that the designs are generated through computer aided drawings on standard protocols, it is easy for the project managers to understand them and present it to multiple teams at the same time.

Another huge problem in working on large construction projects is that of keeping up with production of documents encapsulating the details of any decisions made by the stakeholders during the project life cycle. BIM offers a comprehensive solution to the problem by allowing automatic generation of documentation for every step in the construction project. The software allows the teams to generate reports for multiple purposes at different stages of the project which incredibly reduces the hassle of manually produce documentation which is both arduous and time consuming.

The question ranked third investigates the benefits associated with the BIM in terms of its capability to enable collaboration integration, and smooth communication among the teams working in the planning and operational phases. The responses show that almost all of the participants agreed with the statement and there was no reported disagreement neither was there a single neutral stance taken by any participant. An average score of 4.30 demonstrates that many participants showed a strong agreement with the statement however, the majority chose only the agreement.

As elaborated in the literature review BIM has the capability to enable very smooth data flows and real time communication among the teams from design to the construction phases of the project. Given that the 4D designs can be shared through virtually shared platforms, the engineers can interact with the designers and managers at the same time and delegate tasks to the teams with ease. BIM allows for the visualization of complex designs which can bring all the stakeholders on the same page enabling complete collaboration and smooth communication.

At the fourth rank in terms of the average scores is the benefit of BIM in improving sustainability of the buildings. BIM software use multiple applications that support the designers to integrate the elements of construction practices that can ensure sustainable designs of the buildings and allows the engineers to plan for the safety of the building before the actual construction starts. The BIM software can also be used to simulate the effects of certain parameters on the buildings in the planning phases of the project.

Given that BIM allows for the test of the feasibility of designs and plans before the actual start of the construction project any ambiguities or discrepancies can be dealt with timely such that the losses use to design changes during the construction can be minimized. In addition to this the BIM software predicts the best utilization of raw materials for the engineers and has the capability to propose efficient usage of equipment before the start of construction. Both these factors aid the engineers in cutting the costs of construction and considerably reduce any losses associated with design changes after construction emanating due to faults in the initial plans.

BIM further improves the management and planning for logistics and machinery and allows the engineers to enable the most efficient usage of equipment for the construction activities before the construction starts. This benefit is selected to be as the sixth best among the 20, which shows that professionals perceive this advantage to considerable add to the attraction of using BIM for their projects.

Early involvement of owners and stakeholders for better and quicker decision making is another important benefit which is perceived to be among the higher ranks by the professionals in Saudi

Arabia. BIM has the capability to enable visually interactive designs which are easily understood by all the stakeholders alike, hence it allows the owners and major stakeholders to collaborate with the engineers and express their thoughts fully regarding any component of the design quickly and easily.

The quality of designs is improved with the usage of BIM and the professionals in Saudi construction companies improve considerably. BIM allows for standardized designs based on templates for each component in the building which reduces probability of errors in the designs and increases the overall quality of plans and designs conducted before starting the construction. Many professionals align with the predicament that the integration of BIM into the company's activity is beneficial for the company's reputation among its partners and industry. This can potentially give a competitive edge to the company given that the reliability of the clients can increase and government mandate can be easily acquired for multiple purposes.

Many of the participants agreed to the benefit of BIM integration that it integration allows for better productivity which is due to the capability of BIM to provide elaborate plans for each phase of the project which can be adjusted in relation with the time acquired for each module, so as to ensure maximum efficiency during construction for the utilization of human labour and equipment.

Although regarded as one of the most important benefits of BIM worldwide, the quantity take-off capability of BIM lies behind in the rank for average scores. However, majority of participants agreed with its benefits. Quantity take-off allows the design engineers to quickly estimate the quantity of materials or equipment required in the construction phases of the project which allows them to communicate accurate costing predictions to the owners or other stakeholders. Such capability also allows the engineers to efficiently deal with the suppliers by pre-ordering much of the materials and goods required during the construction which can considerably reduce delays.

Among the lowest ranked benefits of the BIM stands Less rework, reduction in wasted materials and improved safety; although all three of them are shown in the literature review to be one of the biggest positive benefits of integrating BIM. However, it shall be noted that even though the average scores for the benefits are comparatively lower than other benefits but majority of the participants agreed with their efficacy. Less rework is reported in detail in the literature review, which is due to tested and accurate designs allowed by the visualization and collaborative capabilities of the BIM. Given that major decisions can be taken in the planning phases through the involvement of all key stakeholders, hence in the construction phase minimum rework is required and construction activities can be carried out smoothly.

BIM further allows for the estimation for the production of waste material during the construction which allows the design engineers to firstly develop designs which can produce lowest waste and secondly define criterion for the management of the waste materials beforehand.

Lastly, improved safety is now a days considered as one of the biggest advantages of BIM, given that many integrated additional applications can be used with basic BIM software which can allow for the proper handling and management of construction workers and define zones that are unsafe during construction phases. For KSA’s government one of the biggest factor that is enabling the emergence and mandate of BIM is its capability to improve safety during construction which is being implemented in the wake of the crane incident occurred recently in the holly mosque.

4.4 CHALLENGES AND BARRIERS:

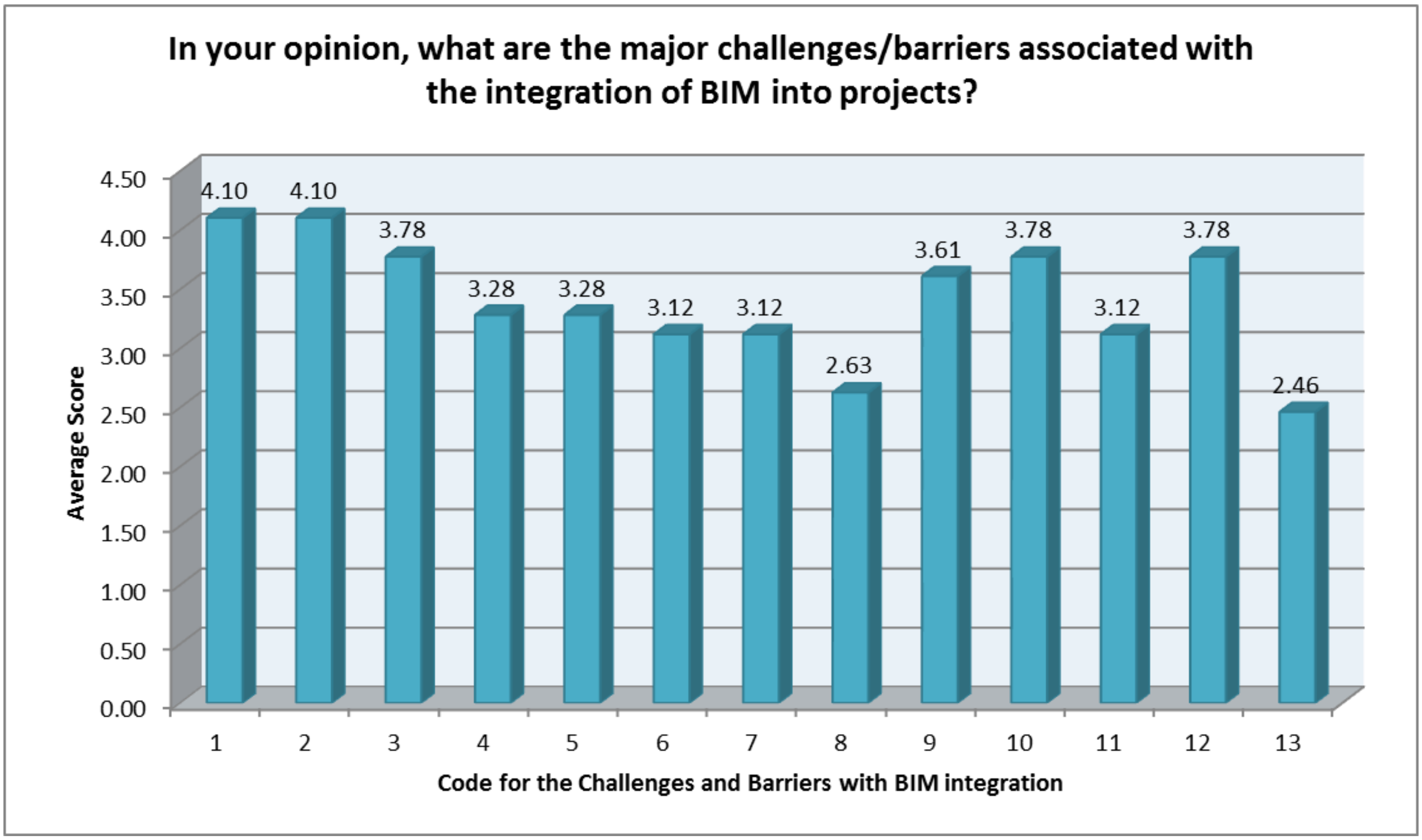

Figure 9: Agreement (average scores) regarding the challenges in the integration of BIM.

1. BIM is not requested by the Owner/client
2. Lack of knowledge/information regarding BIM

3. Top management support is not sufficient
4. Significant changes in standard workflow
5. Inefficient interoperability
6. Disagreement on who should manage/own the BIM
7. Insufficient IT infrastructure and resources
8. High cost of BIM software and implementation
9. Social and habitual resistance to change
10. Lack of case study evidence of the financial benefits associated with BIM
11. Issues of intellectual property rights
12. Current legal and procurement procedures does not support BIM
13. There is no significant challenge

Given that the previous analysis of the application and usage of BIM in Saudi Arabia shows very limited understanding and usage of BIM in the Saudi construction sector; the reported challenges in the survey holds great importance to understand the reasons for lower implementation and present solutions for its adaptation in the future. In the figure above a higher score demonstrate a greater average agreement of the participant with the efficacy of the presented challenge to the BIM adaptation. The following list depicts the rank of the challenges based on the average scores of each challenge and barrier as perceived by the participants, based on higher to lower average scores:

1. BIM is not requested by the Owner/client
2. Lack of knowledge/information regarding BIM

3. Top management support is not sufficient
4. Current legal and procurement procedures does not support BIM
5. Lack of case study evidence of the financial benefits associated with BIM
6. Social and habitual resistance to change
7. Significant changes in standard workflow
8. Inefficient interoperability
9. Disagreement on who should manage/own the BIM
10. Insufficient IT infrastructure and resources
11. Issues of intellectual property rights
12. High cost of BIM software and implementation

According to the acquired responses from the 66 participants working in the Saudi construction industry the biggest impediments are listed to be the lack of requirement of BIM by the clients and the owner of the projects and the lack of knowledge and information regarding BIM. The first challenge is associated with the second challenge given that a lack of awareness among the clients and owners directly effects their decision of not requesting the usage of BIM for their construction projects. As it was established in the application and usage section of the analysis, the usage of BIM is very limited all of these issues originate from the issue of lack of awareness among the professionals in Saudi Arabia regarding the importance and benefits of BIM.
After that comes the issue of lack of support and encouragement from the top management for the integration of BIM which points towards a lack of awareness of BIM as well.

One extremely important issue in the integration of BIM as depicted by the responses is the is the incoherence of the current legal and procurement procedures mandated by the government in Saudi Arabia. This challenge can be considered the biggest impediment to the integration of BIM in the industry given that the companies see a threat in adapting to the protocols established in BIM software which are not supported by the legal infrastructure in the country.

Another important challenge is the lack of evidence from case studies showing the financial advantages accrued by the companies in the country from any specific construction projects. Keeping in view this loophole the current study also documents a case study based on a mega project conducted in KSA which completely integrated the BIM software.

The organisational resistance to change is also considered one of the biggest challenges to the adaptation of the BIM practices in the industry. Given that the construction industry has been following the traditional ways of design and documentation from several years the experienced employees does not show willingness to move on from their expert domains, such employees are also among the top management and have considerable power in decision making; hence, they exercise their power to resist the change towards the BIM adaptation.

Among the lowest ranked challenges are a few important ones but due to lack of depth in the knowledge regarding the BIM capabilities in the participants they have been given a lower average score. Among such challenges are insufficient IT infrastructure and resources and the issues of intellectual property rights. The BIM software requires efficient and advanced IT infrastructure for complete implementation and smooth communication among the teams involved, hence a lack of IT infrastructure may pose an insurmountable challenge for the adaptability of the software and utilizing its full potential. The issue of intellectual property rights is one of the major issues with the usage of BIM worldwide, given that there are many reported disputes among the stakeholders of the construction projects as to who owns the rights of the designs, The issue further complicates when complete designs have to be shared to all the teams working on the project and due to their digital nature the designs can be easily copied and reproduced.

The bar chart above shows results from the specific challenges associated with one of the most important capability of BIM which is the cost estimation capability. The responses from the survey demonstrate that most of the professional perceive the updating and coordinating of other professionals regarding cost estimation to be the biggest challenge which is followed but the process of quantification and then the handling of prototype case modelling.

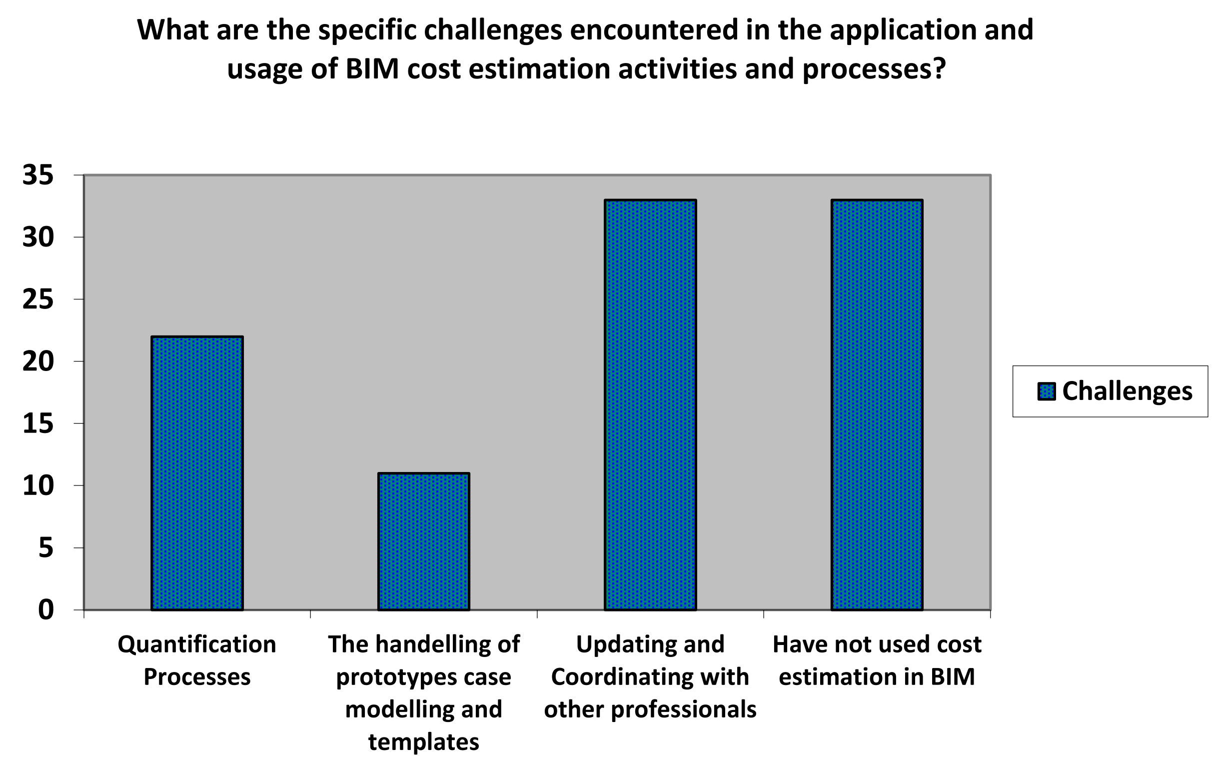

Figure 10: Challenges associated with cost estimation in BIM.

4.5 KEY DRIVERS:

What are the key drivers that you believe will increase the BIM usage in KSA?

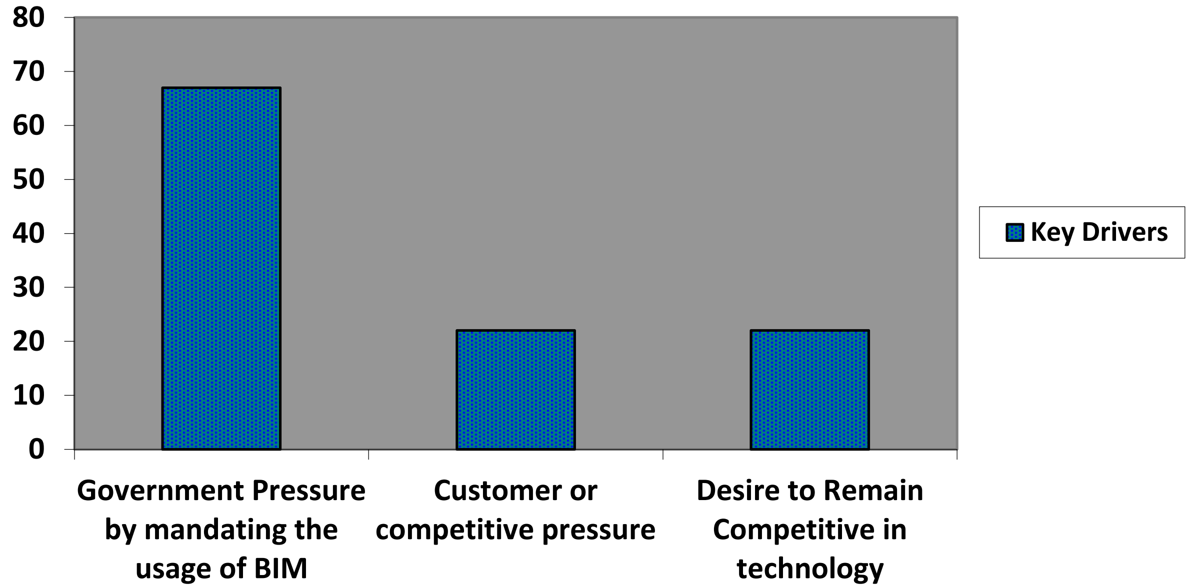

Figure 11: Key drivers of BIM in the KSA AEC industry.

There are three key drivers which were inquired about which were perceived by the participants to be most beneficial for enabling the BIM transition in the construction industry of KSA. The participants were asked to choose the drivers which according to them were most important for the transition. The bar chart above demonstrates the results of responses from 66 participants. As it can be seen almost all the participants chose Government pressure by mandating the usage of BIM to be an important driver for the BIM usage in KSA, while an equal number of participants chose customer or competitive pressure and desire to remain competitive in the industry.

The results clearly point that there is a lack of pressure by the government through the mandating of BIM usage which is regarded as the most important factor in the industry for the adaptation of any change. Given that it was established in the previous sections that a limited number of companies use BIM hence, a clear mandate from the government can push the transition towards BIM. The current role played by the regulatory authorities in KSA is further probed in the next section.

4.6 THE ROLE PLAYED BY REGULATORY AUTHORITIES:

Has the KSA construction industry set clear standards and guidance for BIM management, including modelling, implementation, monitoring the performance?

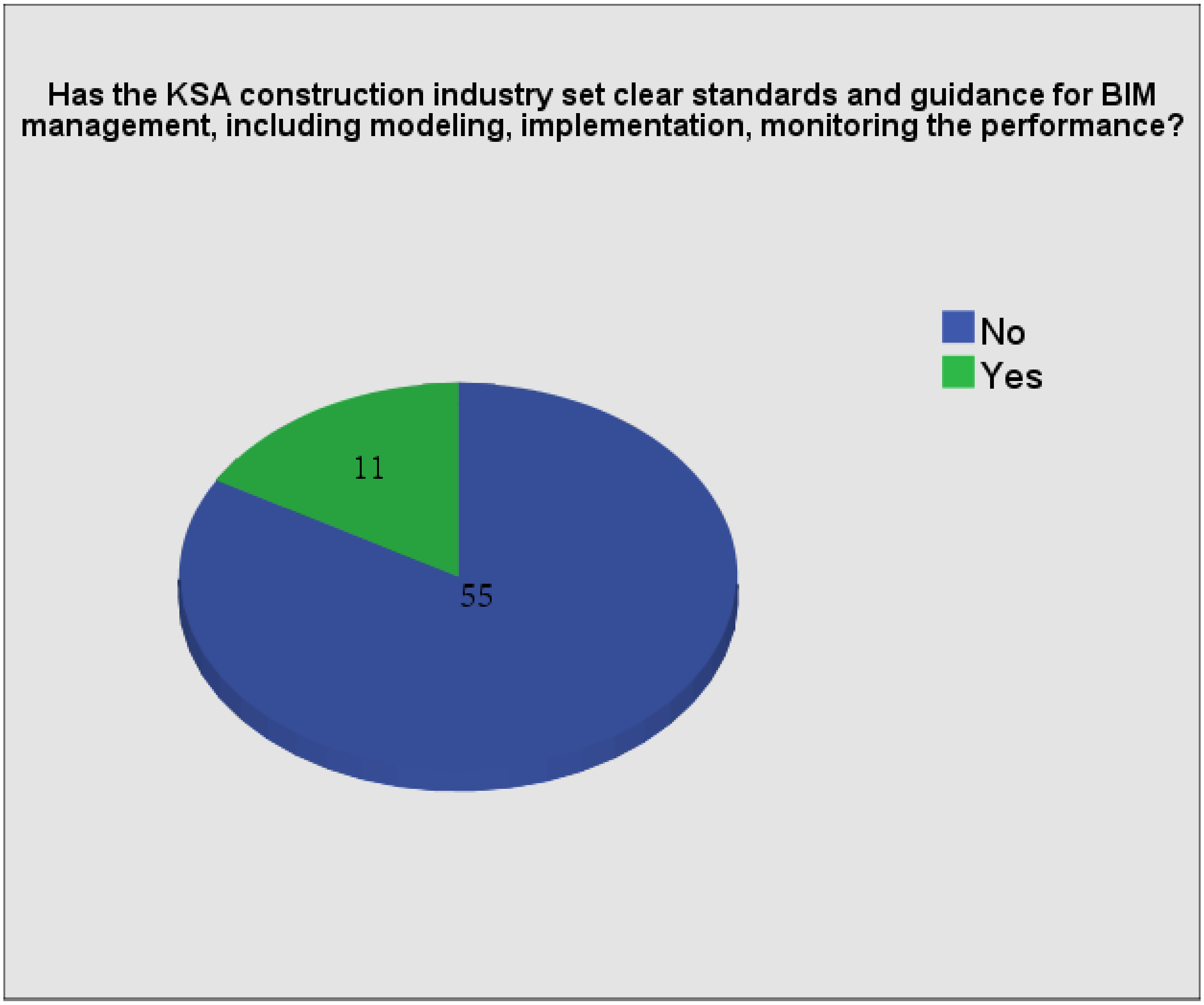

Figure 12: The agreement with the setting of clear standards from regulatory authorities.

According to the response of the participants regarding the exstence of clear standards and guidance by the industry, it can be established that the authorities have failed to set clear standards and protocols for integrated usage of BIM. Out of 66 participants an overwhelming majority of 55 chose ‘No’ as an answer to the question regarding the clear standards set by the construction industry while only 11 of the 66 chose ‘Yes’ for an answer. It clearly depicts that regulatory authorities have not provided the required breeding ground for BIM usage and have not supported the companies in enabling the transition.

The participants were further asked to give their opinion regarding the allocation of responsibility of mandate for BIM to the governmnetal authorities and were asked to choose between Minsitry of Municipal and Rural areas and Minsitry of planning. The bar chart below demonstrate the results of the responses. As it can be extrapolated that the majority of participants chose Minsitry of Municipal and Rural areas to be given the responsibility for setting the mandate for BIM usage while a considerably smaller number of participants chose the second option.

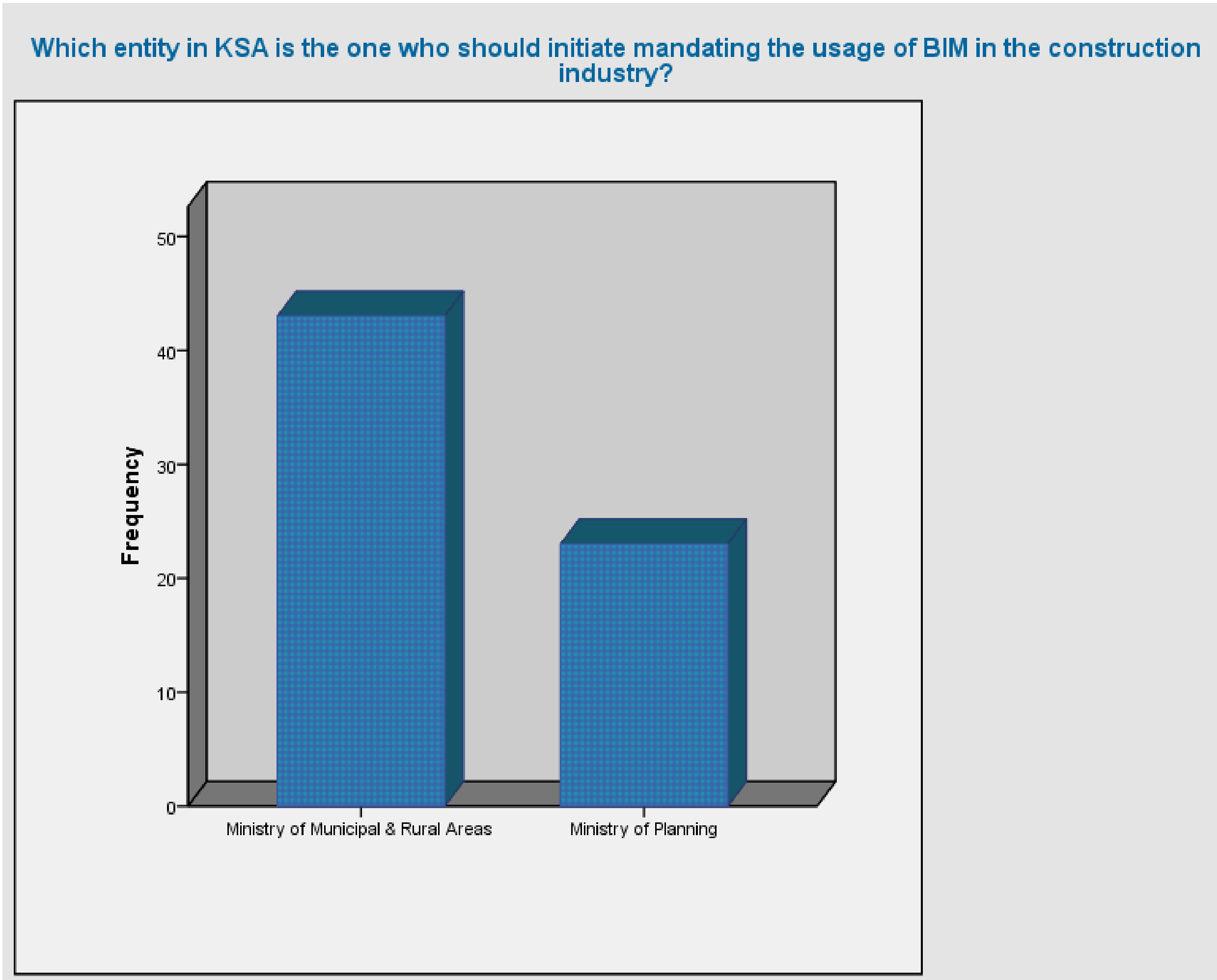

Figure 13: The selection of authorities for the mandate of BIM usage.

4.7 T-TEST & ANOVA TEST:

T-Test & ANOVA TEST TO CHECK IF THE TYPE OF COMPANY OF THE PARTICIPANT INFLUENCES THE PARTICIPANT'S PERCEPTION OF BENEFITS OF ITS INTEGRATION

The One way ANOVA test is conducted in SPSS to investigate if the type of company of the participants has a significant effect on their degree of agreement for the benefits associated with the integration of BIM. The NULL hypothesis suggests that there is no significant influence of company type of the participants on their degree of agreement with the benefits associated with the integration of BIM.

Some very important inferences can be made by extracting values for individual averages of scores of benefits from each company type. The Descriptive table show that the means for the three groups for almost all the listed benefits are different however the statistical significance of the difference in the variance can be judged using the ANOVA test results in the second table.

Before the assessment of the results it shall be noted that the participants representing the Saudi Private Companies do not have any experience with the BIM usage hence their selection is purely based on perception. On the other hand the participants belonging to the Public Government Organisation have considerable amount of experience in BIM usage, hence their responses will be based on real world implementation; while the participants from the regional or international organisation include both kinds of selection, perception based and experience based for the implementation of BIM. Keeping in view these facts we shall consider the selection of participants from Public Government organisation to be the most valid while the responses from the participants from Saudi Private Organisation to be the least valid ones.

Hence, from the inferences of the individual means for each group it can be extrapolated that the actual experience with the usage of BIM impacts the agreement of the participants of its benefits given that for Public Government Organisation group the mean score for each question is much higher to that of other inexperienced company groups.

Now, in order to check the statistical significance of the inference made from Descriptive tables we shall check the ANOVA results. As it can be seen in the table the significance for the difference in variance between groups is below 0.05 (5% significance) for each benefit, hence the NULL hypothesis can be rejected and it can be concluded that the experience in BIM considerably changes the perception of its benefits in a positive way.

One important result is that for the question regarding the increase in safety due to BIM usage, which suggests that almost all of the participants who have actual experience in BIM usage strongly agreed with the statement while those participants who did not had experience in BIM usage disagreed with the statement.

Table 1: Descriptive (SPSS)

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
In your opinion, what are the key benefits associated with the integration of BIM in projects? - Improved quantity take-off	Saudi Private company	22	4.09	.294	.063	3.96	4.22	4	5
	Regional or International Company	32	3.69	.471	.083	3.52	3.86	3	4
	Public Government organisation	11	4.64	.505	.152	4.30	4.98	4	5
	Total	65	3.98	.545	.068	3.85	4.12	3	5
In your opinion, what are the key benefits associated with the integration of BIM in projects? - Less rework	Saudi Private company	22	3.36	.790	.168	3.01	3.71	3	5
	Regional or International Company	32	4.03	.822	.145	3.73	4.33	3	5
	Public Government organisation	11	4.91	.302	.091	4.71	5.11	4	5
	Total	65	3.95	.909	.113	3.73	4.18	3	5
In your opinion, what are the key benefits associated with the integration of BIM in projects? - Minimizes the time spent on a project / Time Saving	Saudi Private company	22	4.18	.395	.084	4.01	4.36	4	5
	Regional or International Company	32	3.72	.958	.169	3.37	4.06	3	5
	Public Government organisation	11	4.82	.405	.122	4.55	5.09	4	5
	Total	65	4.06	.827	.103	3.86	4.27	3	5
In your opinion, what are the key benefits associated with the integration of BIM in projects? -	Saudi Private company	22	4.09	.294	.063	3.96	4.22	4	5
	Regional or International Company	32	4.16	.723	.128	3.90	4.42	3	5

Minimizes expenditure / Cost Saving	Public Government organisation	11	4.73	.467	.141	4.41	5.04	4	5
	Total	65	4.23	.606	.075	4.08	4.38	3	5
In your opinion, what are the key benefits associated with the integration of BIM in projects? - Reduction in wasted materials	Saudi Private company	22	2.55	.912	.194	2.14	2.95	2	4
	Regional or International Company	32	4.22	.659	.117	3.98	4.46	3	5
	Public Government organisation	11	4.73	.467	.141	4.41	5.04	4	5
	Total	65	3.74	1.136	.141	3.46	4.02	2	5
In your opinion, what are the key benefits associated with the integration of BIM in projects? - Less change orders	Saudi Private company	22	4.09	.294	.063	3.96	4.22	4	5
	Regional or International Company	32	3.72	.772	.136	3.44	4.00	2	5
	Public Government organisation	11	4.55	.522	.157	4.19	4.90	4	5
	Total	65	3.98	.673	.083	3.82	4.15	2	5
In your opinion, what are the key benefits associated with the integration of BIM in projects? - Improved logistics and machinery planning	Saudi Private company	22	4.18	.395	.084	4.01	4.36	4	5
	Regional or International Company	32	3.94	.435	.077	3.78	4.09	3	5
	Public Government organisation	11	4.91	.302	.091	4.71	5.11	4	5
	Total	65	4.18	.527	.065	4.05	4.32	3	5
In your opinion, what are the key benefits associated with the integration of BIM in projects? - Improved Safety	Saudi Private company	22	2.00	.000	.000	2.00	2.00	2	2
	Regional or International Company	32	3.81	.535	.095	3.62	4.01	3	5
	Public Government organisation	11	5.00	.000	.000	5.00	5.00	5	5
	Total	65	3.40	1.157	.143	3.11	3.69	2	5

Table 2: ANOVA (SPSS)

		Sum of Squares	df	Mean Square	F	Sig.
In your opinion, what are the key benefits associated with the integration of BIM in projects? - Improved quantity take-off	Between Groups	7.746	2	3.873	21.366	.000
	Within Groups	11.239	62	.181		
	Total	18.985	64			
In your opinion, what are the key benefits associated with the integration of BIM in projects? - Less rework	Between Groups	17.893	2	8.946	15.862	.000
	Within Groups	34.969	62	.564		
	Total	52.862	64			
In your opinion, what are the key benefits associated with the integration of BIM in projects? - Minimizes the time spent on a project / Time Saving	Between Groups	10.376	2	5.188	9.637	.000
	Within Groups	33.378	62	.538		
	Total	43.754	64			
In your opinion, what are the key benefits associated with the integration of BIM in projects? - Minimizes expenditure / Cost Saving	Between Groups	3.320	2	1.660	5.090	.009
	Within Groups	20.219	62	.326		
	Total	23.538	64			
In your opinion, what are the key benefits associated with the integration of BIM in projects? - Reduction in wasted materials	Between Groups	49.449	2	24.724	46.304	.000
	Within Groups	33.105	62	.534		
	Total	82.554	64			
In your opinion, what are the key benefits associated with the	Between Groups	5.970	2	2.985	8.042	.001
	Within Groups	23.014	62	.371		

integration of BIM in projects? - Less change orders	Total	28.985	64			
In your opinion, what are the key benefits associated with the integration of BIM in projects? - Improved logistics and machinery planning	Between Groups Within Groups Total	7.728 10.057 17.785	2 62 64	3.864 .162	23.821	.000
In your opinion, what are the key benefits associated with the integration of BIM in projects? - Improved Safety	Between Groups Within Groups Total	76.725 8.875 85.600	2 62 64	38.363 .143	267.997	.000

4.8 CASE STUDY: KING ABDEL AZIZ UNIVERSITY

The selected case study regarding the construction of King Abdel Azizi University presents a case of implementation of BIM at all levels of the construction project. The basic aim of the stakeholders to implement BIM in its entirety was to enhance the performance of construction teams and to increase cost effectiveness by removing damages due to failure in the construction phases. King AbdelAzizi University construction was a humungous project first of its sort for which BIM was used in its entirety in the Middle East area. The King AbdelAzizi University covers an area of 12 million square feet, which houses a complete commercial mall along with residential and office floors, furthermore, the university encapsulates many multi purpose facilities which are designed to fascinate the general public and create a landmark for KSA's economy (Sharif, 2016). The construction project had a total budget of $1.3 Billion.

4.8.1 Project Outcomes:

According to Porwal and Hewage (2013, p.5), use of BIM for the construction of King AbdelAzizi University greatly enhanced the construction productivity and proclaimed many diverse advantages throughout the project lifecycle. Due to the width and extensive scope of the project it was noted by many professionals that in the planning phases it was impossible enunciate the requirements in form of required resources, capital and quantity takeoffs, in addition there was no estimate possible for human resource management through traditional ways (Bhata, 2016). Moreover, the increased number of physical document to be produced demonstrated a threat for vast number of human errors, which can result into humungous wastages in the construction phase (Lu et al., 2015). The planning and management of Quantifications, operations, H&S and collaborative practices presented a huge impediment as well, given that vast number of activities and worker skills were required in different phases of the construction. The limitations regarding the traditional 2D designs and documented unstructured reports gave way to the use of BIM for the efficiency enhancement, cost savings and effective planning and management. As a result the enunciated facts demonstrate the project was highly successful in terms of achieving increased speed, enhanced coordination, reduced costs and reduced accident cases.

Lu et al. (2015) demonstrated that the integration of technology and BIM in construction projects greatly enhances the speed f construction as the issues are already dealt with in the planning phase and there are less registered design failures administered in the construction phase. This is enabled due to the ability of BIM to construct 3D, 4D and 5D plans, which can be demonstrated virtually at any time to the engineers and contractors for effective and accurate implementation. The use of BIM allowed the designers and quantity surveyors to accurately predict possible problems in the construction phases and the software in turn helped them in troubleshooting the problems. This led to increased efficiency and the King AbdelAzizi University was completed well before the date expected from tradition construction practices (Sharif, 2016).

The use of BIM for the King AbdelAzizi University project was instrumental in the improved coordination and collaboration of all stakeholders, starting from the planning phases to the project completion. BIM allowed the designers to virtually interact with the contractors and operations managers' teams to collaboratively design for minimum design issues and update the stakeholders aptly through online resources. The onsite coordination was also increased as the workers could understand the overall progress of the project and the safety precautions that shall be taken. The management of onsite equipment was hence made more efficient and less costly as design issues were spotted in the planning phases and designers and engineers collaborated to mitigate all such discrepancies that might be a source of wastages and time consuming for construction workers.

The enhanced planning and coordination led to reduced costs for the construction phases. In addition to the enhanced planning, the special consideration given to standardized design and operations management practices, reduced damages during the construction phases (Lu et al., 2015).

It was established by the director that minimal wastage or design discrepancy issues were reported throughout the project due to the use of advanced planning, design and management tools fully integrated with BIM software for each planning phase. Where engineers and operations managers alike were given a platform to do safety risk analysis and in turn take precautions beforehand for each phase of the project. The tools provided standard protocols to be implemented for each level in the hierarchy of workers and mandated a necessity for conduct of good practices among the stakeholders.

The facts demonstrated that for the King AbdelAzizi University project, BIM was used to aid contractors in performing job-hazard analysis (JHA) as well as developing safe methods of work. For example, in excavation work as well as equipment planning (Fukushi 2015). Excavation has been touted as one of the dangerous operations in construction. Possible hazards are lack of protective system, soil placement is unsafe, and equipment operation is near excavation as well as unsafe access. BIM is then used in conducting job hazard analysis of such project that involves mass excavation (Fukushi 2015). Construction team uses BIM in visualising the project and better recommendations that can ensure H&S of workers are made. For instance, it can be recommended that the condition of the slope is checked frequently throughout the excavation period and also check on the slopes. These recommendations are done after proper analysis and are aimed at ensuring that injuries are avoided.

In addition, BIM is also utilised in mapping on-site flow of equipment. For example, a project may require extensive dump trucks' use for transporting materials from excavation pits. Gravel ramp could be a good solution for trucks as they enter as well as exit excavation area (Adamu, Soetanto & Emmitt 2015). Locating correctly this ramp, in relation to the other activities of construction, is crucial for the proper access of trucks and in avoiding congestion or trade stacking. BIM helps simulate ramp so that it confirms that no conflict exists with other activities in the construction (Adamu, Soetanto & Emmitt 2015).

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

The analysis and the discussions on the collected data illustrate deep insights into the positives and negatives associated with the adaptation of BIM which are specific to the legal and economic environment of KSA. It can be extrapolated from the key findings that although there are many benefits associated with the adaptation of BIM, at the same time its adaptation has to face many challenges which is the reason that there is still resistance in the AEC industry towards this technological shift. The study first gives a detailed view of the literature regarding the integration of BIM in the KSA construction industry. The literature review covers in depth the principles and usage of BIM, where its important features and capabilities for the construction industry are highlighted. Further the potential of BIM for the KSA AEC industry are highlighted. All the benefits inherent with BIM usage for the construction industry are elaborated in the light of literature. Furthermore, the literature reviews provides a comprehensive coverage of the potential drivers of BIM usage for the KSA AEC industry which can enable the BIM revolution. Lastly the challenges and obstacles associated with the adaptation of BIM are discussed in the light of the literature which is divided among three major portions: Financial Challenges, Legal and contractual Challenges and Economic Environment challenges.

The findings of the literature review are further probed using survey questionnaire presented to construction industry professionals working in KSA. The survey responses are analyzed in the light of the established literature and inferences are made accordingly. The participants are divided into three major groups depending on the kinds of company they work for and the influence of the three groups on the usage and perception of BIM is investigated. Exploratory analysis is used with an inductive approach to derive the major insights from the collected data.

Advanced data analysis technique such as the ANOVA test is utilized using SPSS statistical software to test the established hypothesis regarding the impact of experience in BIM usage on the perception of benefits of BIM integration.

It was established through the analysis of the survey that one of the biggest obstacles to the BIM usage in KSA AEC industry is the lack of case studies defining financial advantages associated with the integration BIM in construction projects. In order to fulfill the gap identified this study analyzes a construction project case study in which BIM was integrated and used in its entirety and positive results were accomplished in all the project phases.

It is established that in order to avoid such catastrophic delays which are prevalent on almost regular basis in KSA, a perfect solution is the use of BIM along with Integrated Project Delivery (IPD) systems for construction project management as recommended by The American Institute of Architects. It shall be noted that BIM provides a perfect technical infrastructure to handle delay issues effectively and provide platform for project teams to make effective schedules with minimum delay risk capitalizing on the technical aid provided by the design and scheduling tools with integrated libraries. It was further constructed that BIM aids the project managers to promulgate a sense of trust through the project teams' hierarchy by enabling easy accessibility to the virtual BIM platform (Hardin 2009; Grilo & Jardim-Goncalves 2010). Planning and design can be shared through the BIM model which utilizes advanced communication software systems in order to enable smooth flow of information (Elmualim & Gilder 2011; Carmona & Irwin 2007). BIM further allows the engineers and designers to induce appropriate level of flexibility into the designs for the later stages focusing on possible sustainability concerns (Osapuolet, 2012). BIM comes with a flexibility of working with cost estimation and materials take off tools, which are widely available in the market which can be utilized to accurately predict the total cost of the project; hence the big problem of payment delays sue to unpredictable costs of the projects can be solved effectively (Koskela 2003; Schade et al. 2011; Liker 2003; Abbasnejad &Moud 2013).

BIM is the ultimate solution to the problems construction industry has faced from years and as the momentum is shifting towards mega structures in KSA, use of BIM to eradicate discrepancies in design and planning, as well as increasing productivity is detrimental. The literature review demonstrates various quantitative and qualitative studies carried out in the past to demonstrate the efficacy of BIM usage in the AEC industry. The research studies analyzed also validate the premise that there is a dire need for the KSA government to regulate the use of BIM and support the transition by financially supporting public and private construction firms. The studies further quantitatively demonstrate that there is an acute shortage of skilled workers in the construction industry who can fully integrate the project phases in the BIM environment. Specific studies are used to validate the constructed hypothesis in the first chapter and construct the premises investigated in this study.

Hence it can be concluded that after the triangulation of key findings abstracted from both primary and secondary data in conjunction with the case study, that the NULL hypothesis 1 can be rejected and the benefits of adapting BIM for AEC industry of KSA surpass the challenges and constraints associated with them.

Consequently it was constructed through the statistical analysis of the survey findings that the regulatory authorities have not played an appropriate role in supporting the BIM transition as a majority of participants pointed to a lack of legal and economic infrastructure provisioned by the government on those lines the NULL hypothesis 2 can also be rejected and it can be concluded that there is a requirement for the regulatory authorities to take appropriate steps for enabling the transformation to BIM.

The third hypothesis was tested through the conducted T-Test and was analyzed in great detail. It can be concluded that NULL hypothesis 3 can also be rejected and the participant's background significantly impacts their perception of BIM.

5.1 RECOMMENDATIONS:

Building from the triangulation of key findings as defined through the abstraction of insights from multiple data sources, there are many steps that can be taken by both regulatory authorities and the companies to adapt to BIM. First and foremost is the realization that the benefits of BIM both in the short and long term are much more impactful than the challenges at hand of its adaption. The companies shall try to induce this feeling of association with the new technology in its employees by investing the educational activities related to BIM and working in collaboration with other companies which have experience in its usage and learning from their transformation.

5.1.1 Regulatory authorities shall intervene to facilitate the transition:

One of the biggest hindrances to the implementation of BIM for projects is the failure of government and clients to understand the long term worth of utilization of BIM which results into reservations against paying higher costs for the mandate of BIM software (Eadie et al., 2013; Chan, 2014). Due to the reason of increased initial investments and lack of examples to be examined for the effective utilization of BIM technology and increased time and cost saving pertaining from BIM based projects, the government and clients tend to be insecure about the initial investment and they prefer to be last in the competition to embrace the BIM revolution (Eastmanet al., 2011). Researchers claimed that in such hostile environment and lack of willingness to invest in the future, government shall step in and demonstrate a model for BIM implementation which can serve as an example for the whole industry (Chan, 2014; Lu and Li, 2011; Hardin 2009). Hence, the governmental authorities shall take the responsibility of funding and streamlining the processes involved with the transition of BIM. The authorities shall realize that it is in the mutual benefit of the industry and the society that the companies shall follow the standard protocols and utilize the capabilities of BIM in construction project management.

5.1.2 Provide rules for the issues of IPR:

BIM model interoperability and tendency of providing collaborative environment with real time access and update ability comes with a price of unprotected intellectual property; given that throughout the project lifecycle transparent systems and designs are to be accessed by multiple arties working on the project. The BIM final model with all the data regarding delicate designs and control measures is to be used by the FM teams after project completion as it is which further aggravates the situation of security against intellectual property (Porwal & Hewage 2013; Lewis et al., 2010).Hence, it is the responsibility of the regulatory authorities to provide the appropriate infrastructure for the handling of the IPR issues and allowing the companies to work in collaboration with each other without the threat of being treated unfairly for their contribution.

5.1.3 Skill Development of employees:

The unavailability of skilled labor equipped with expertise to handle complexities of BIM software demonstrate the biggest obstacle to the professionals working in the Middle East area. According to the BIM-Middle East report (2011), 51% of the professional who participated in the wide scale survey reported the absence of skilled labour for BIM as an obstacle to the adoption of BIM architecture. Hence, there is a need for the authorities to invest in the training and educational programs to enable the next generation to handle the complexities of the BIM appropriately. The companies shall collaborate with the authorities to invest in the skill development of their employees for the proper management of the BIM model.

5.1.4 Define categorical roles of managers in managing the BIM Model:

BIM model provides a one stop transparent platform for all the project teams to share information and communicate to understand design specifications throughout the project lifecycle. The teams are empowered to conduct changes in real time and update the BIM model version for all others to see and extract information from (Eastman et al., 2011; Azhar et al., 2012). Hence, the BIM model shall be managed immaculately with coordination managers and backup maintenance for any contingencies (Gu and London, 2010; Chien et al., 2014). Management of BIM is one of the biggest issues and there are many ambiguities in the industry as to who should be liable and manager of the BIM model. The industry shall come up with criteria for job description for the management of the BIM model and define categorically the roles of different kinds of managers in facilitating the working environment for different teams collaborating through the virtual platform.

APPENDIX A

COVERING LETTER

Dear Sir/Madam,

I am a student at British University in Dubai (BUiD) pursuing a Master Degree in Project Management. I am carrying out a research on "The potential of BIM for AEC industry in Kingdom of Saudi Arabia and the challenges to its adoption". I am focussing on the construction sector only. This is not an examination and, therefore, there are no correct or wrong answers. All answers or responses will be useful for the study.

All responses will be treated as confidential and the results will be reported in terms of entire population only. In order to maximise confidentiality, your names are not requested and does not need to be provided. You are kindly requested to respond to all the items in the questionnaire. In case of any question, the researcher's cell phone number and email address are indicated below.

Your positive response will be highly appreciated.

Thank you,

Yours faithfully,

Ibrahim Awad

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Building Information Modeling Survey Questionnaire

Instructions

This survey will take approximately 5 minutes to be completed. You are kindly requested to answer as many questions as possible. As you respond to the questions, please be informed that:

- No answer will be regarded as wrong or right
- Answer the questions honestly and precisely
- Some of the questions may seem repetitive. However, they were designed to meet the objectives of the study
- You are not compelled to answer any question which you do not know

Questions

1. What type of company do you work for?

a. Saudi Private company
b. Public Government organization
c. International or regional company
d. Other, please specify:________________________

2. What is the company role in the construction industry?

a. Master Developer
b. Contractor
c. Design Consultant
d. Supervision Consultant

e. Project Management

f. Financing

g. Subcontractor

h. Supplier

i. The Client

j. Government Regulator

k. Other, please specify:______________________

3. How long has your company been using BIM in their projects?

a. Never

b. 1 year

c. 2 years

d. 3 years

e. 4 years

f. 5 years+

4. What is the level of BIM implementation in your company?

a. Level 0

b. Level 1

c. Level 2

d. Level 3

e. Not applicable

f. I don’t know

5. What is your current position?

a. Construction Manager

b. BIM Manager

c. Project Manager

d. Civil Engineer

e. Structural Engineer

f. MEP Engineer

g. Architect

h. Interior Designer

i. Casual Employee

j. Other, please specify:_______________________

6. How would you describe your understanding and knowledge of building information modeling (BIM)?

a. I have never heard of BIM

b. I have heard of BIM, but have never used it

c. I have used BIM on a limited basis in projects

d. I have used BIM on regular basis in projects

7. **Have you done any of these activities during project planning or in the course of project development?**

a. Taken building quantification from BIM

b. Used BIM to facilitate operational management

c. Developed a 3D/4D model in BIM from a 2D model

d. Added specification requirements to graphic visuals in BIM

e. None of the above

8. What are the specific challenges you have encountered in the application and usage of BIM cost estimation activities and processes in your projects.

a. Quantification processes

b. Updating and coordinating with other professionals

c. The handling of prototypes, case modeling and templates

d. Have not used BIM cost estimation activities and processes

e. Other (please specify)

9. **What are the key drivers that you believe will increase the BIM usage in KSA?**

a. Government pressure by mandating the usage of BIM

b. Customer or competitive pressure

c. Desire to remain competitive in technology

d. Others, please state ……..

10. Has the KSA construction industry set clear standards and guidance for BIM management, including modeling, implementation, monitoring the performance?

a. No

b. Yes

11. Which entity in KSA is the one who should initiate mandating the usage of BIM in the construction industry?

a. Ministry of Municipal & Rural Areas

b. Ministry of Housing
c. Ministry of Transportation
d. Counsel of Economic Development Affairs
e. Ministry of Planning
f. Others, please state ……………..

12. In your opinion, what are the key benefits associated with the integration of BIM in projects? For each option state your opinion from 1 to 5 or select 6 if not applicable (1=Strongly 2=Agree, 3=Neutral, 4=Disagree, 5=Strongly Disagree, 6=NA)

a. BIM offers Integration/collaboration and robust communication amongst different teams
b. BIM offers error-free design
c. BIM offers improved productivity
d. Improved Quality
e. Improved quantity take-off
f. Less rework
g. Minimizes the time spent on a project / Time Saving
h. Minimizes expenditure / Cost Saving
i. Reduction in wasted materials
j. Less change orders
k. Improved Safety
l. Improved logistics and machinery planning
m. Increased ROI
n. Improved sustainability

o. Improved Facility Management
p. Early involvement of owners for better and quicker decision making
q. Promotes the company's competitive edge
r. Promotes the off-site prefabrication
s. Better document automation
t. Fast and accurate production of As-Built drawings
u. No benefits for BIM

13. In your opinion, what are the major challenges/barriers associated with the integration of BIM into projects? For each option state your opinion from 1 to 5 or select 6 if not applicable (1=Strongly 2=Agree, 3=Neutral, 4=Disagree, 5=Strongly Disagree, 6=NA)

a. BIM is not requested by the Owner/client
b. Lack of knowledge/information regarding BIM
c. Top management support is not sufficient
d. Significant changes in standard workflow
e. Inefficient interoperability
f. Disagreement on who should manage/own the BIM
g. Insufficient IT infrastructure and resources
h. High cost of BIM software and implementation
i. Social and habitual resistance to change
j. Lack of case study evidence of the financial benefits associated with BIM
k. Issues of intellectual property rights
l. Current legal and procurement procedures does not support BIM

m. There is no significant challenge

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