# Empirical Investigation into Development of a curricular Framework to Embed Building Information Modelling with Undergraduate Architectural Programmes within Saudi Arabia

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# Abstract

The demand for BIM implementation within the AEC industry has recently increased. BIM has therefore, becomes one of the significant methods for solving and preventing issues within the AEC industry. This has motivated governments and owners to require BIM within their projects, such as the UK and the USA. As the result, many construction companies and architectural firms have taken the initiative to implement BIM within their systems. However, there are some barriers that organisations face in terms of the implementation of BIM such as the lack of experts in BIM, resources, hardware and software and so on. Many scholars believe that BIM must be embedded within the AEC education sector to help close the gap between AEC education and AEC industry. Hence, several AEC schools have introduced BIM within their curriculum. Also, there are two BIM frameworks (BIM Academic Forum BAF initial Framework and IMAC framework) to embed BIM within the AEC education. However, none of these two have been evaluated yet and both of them are very general to use for Undergraduate Architecture Programmes. To dates, academics have not reached a consensus in how BIM should be taught within undergraduate architectural programmes.

In term of The Kingdom of Saudi Arabia (KSA), the vision is unclear for BIM within the AEC industry and AEC education. There is some evidence that reveal the need for BIM in KSA such as the number of BIM jobs required and some other non-academic resources calling for the need of BIM to be implemented within Saudi projects. However, the number, size, cost and complexity of projects in KSA which have suffered from many issues such as payment plans, delays, lack of Saudi experts and discontinued projects is worthy for motivating the Saudi Government and construction companies to implement BIM.

Therefore, the aim of this study is to propose a strategic approach for embedding BIM within undergraduate architectural programmes in KSA. This aim is achieved through the development and understanding of the current teaching strategy of BIM within AEC education sectors and the industry perspectives in relation to BIM implementation. To achieve this aim quantitative and qualitative methods of data collection were adopted in

order to asset the level of utilization of BIM within the AEC industry and education sector in KSA. As well as identifying educational gaps for utilizing BIM in architectural programmes in KSA. Misunderstanding BIM, the lack of development within architecture education sector in KSA and unacceptable output for AEC industry are three of the most significant findings from the quantitative data analysis. The qualitative data helped to outline the method of how BIM should be embedded. Most interviewees had realised the benefits of collaboration using BIM, and indicated their preface to introducing BIM to Integrated Design Studio with high support from other modules. The proposed BIM framework was validated by academics and professionals within KSA using semi-structured interview whereby, most comments were focusing on developing the level of awareness of BIM amongs academics. This study proposed a number of recommendations for AEC industry in KSA, academics who are interesting in integrating BIM within the curricula and researchers with an interest in BIM within AEC industry.

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# List of publications

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Almutiri, Y. (2016). *BIM initial Framework to embed BIM within Undergraduate Architecture Programme in KSA*. The 9th Saudi Students Conference, United Kingdom, Birmingham 13th Feb – 14th Feb

# List of Abbreviations

| | |
|---|---|
| **AIA** | American Institute Of Architects |
| **APs** | Architecture Programmes |
| **AS** | Architecture Schools |
| **AEC** | Architecture, Engineering and Construction |
| **AEC-ES** | Architecture, Engineering and Construction-Education Sector |
| **BAF** | BIM Academic Forum |
| **BIM** | Building Information Modelling |
| **CDA** | Collaborative Design Approach |
| **CodeBIM** | Collaborative Design Education using BIM |
| **CAD** | Computer Aided Design/Draft |
| **COBie** | Construction to Operations Building information exchange |
| **FM** | Facility Management |
| **MLDS** | Multilevel Design Studio |
| **SABC** | Stand-Alone BIM Classes |
| **NATSPEC** | The Association of National Specialist Colleges |
| **KSA** | The Kingdom of Saudi Arabia |
| **NCARB** | The National Council of Architectural Registration Boards |
| **UGAP** | Undergraduate Architecture Programmes |
| **VDS** | Vertical Design Studio |
| **ROI** | The Return of Investment |

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# Chapter 1. Research Introduction

This chapter provides background information to understand the need for this PhD research. The research rationale, need of the research and research aim and objectives are discussed. It starts with the motivation of the research, then the research questions. This is followed by identifying the aim of the research and its objectives. Also, the chapter presents the significance of the research, its scope and methods applied in this research. Finally, the chapter presents the thesis structure with brief information about each chapter.

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## 1.1 Introduction

Currently, the AEC Industry around the world is growing dramatically and projects are becoming more complicated and difficult to be designed and managed by a single designer. Moreover, building data flows are becoming more complex with increasingly intricate project requirements. Over the last 100 years, a vast number of building systems e.g. telecommunication, security, underground parking, air-conditioning and sustainability, have been added to the process of designing a building project (Krygiel & Nies, 2008). Therefore, these data and teams should have an environment where they can work together and share data with no issues; which will help to achieve a better result and quality, with a reasonable cost.

Although, traditional methods have to some extent been successful in addressing design issues, projects have suffered from poor efficiency and productivity. The lack of collaboration and sharing data which have been caused by the use of the traditional method have caused losing data, misunderstanding, omissions, increasing costs (Azhar, Khalfan, & Maqsood, 2012). It is important that number of experts work together to have a well-

designed project which is not hindered by the complexity of the buildings (Grilo & Jardim-Goncalves, 2010).

As a solution to some of the aforementioned problems, in recent years, there is an increasing uptake of Building Information Modelling (BIM) within construction companies particularly in developed countries, such as the United States, the United Kingdom and Australia (BIM Academic Fourm, 2013; BIM Industry Working Group, 2011; Brewer, Gajendran, & Goff, 2012; Dicker & Snyder, 2008; Hardin, 2009). Adopting BIM within AEC Industry has a significant impact on projects and environment. Moreover, increasing uptake of BIM was stimulated by a number of factors including the need for integrated data management, drive towards whole project lifecycle data management and political pressures calling for effective collaboration between different stakeholders to enhance the quality of the construction industry and cost reduction (McGraw-Hill, 2014; Sabol, 2008; Shahrin, Johansen, Lockley, & Udeaja, 2010; H. Yan & Damian, 2008).

Currently there is lack of understanding within AEC education sector on approaches to embed BIM within existing curricula. To foster collaboration between disciplines in the AEC Industry, BIM has been introduced within Architecture, Engineering and Construction (AEC) programmes in many ways (Barison & Santos, 2010a). However, the BIM teaching methods could be classified into two stands; Stand-Alone BIM Classes and Integrated Design Studio using BIM(Hyatt, 2011; Poerschke, Holland, Messner, & Pihlak, 2010; Singh, Gu, & Wang, 2011). The changing for these programmes has faced some issues and challenges because of moving from a mono-disciplinary education system towards a multi-disciplinary education system. Rest of the discussion is organised as illustrated in Fig 1-1.

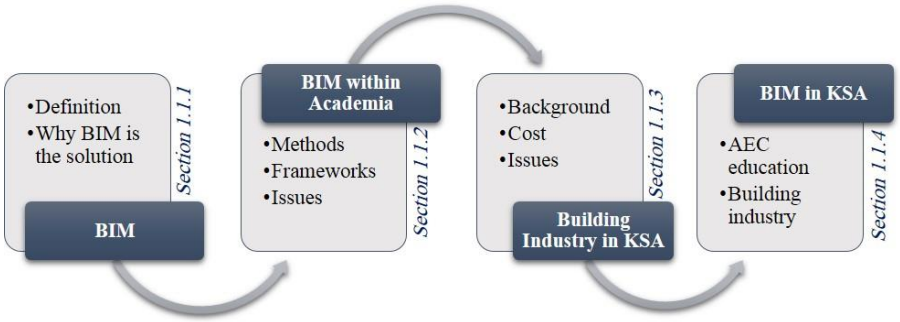


*Fig 1-1: The introduction's outline*

### 1.1.1 *Introduction to BIM*

Over the last decade, BIM, as an integrated design and delivery approach, has become a solution for major issues in the AEC Industry and the call for projects to use BIM has come from both the owners and the government (McGraw-Hill, 2012). In the United States, for example, a survey conducted by McGraw (2012), shows that the percentage of owners who insist on having their projects presented using BIM has increased from 58% in 2009 to 67% in 2012 (McGraw-Hill, 2012). In the United Kingdom, the use of Building Information Modelling has been made mandatory on major Government construction projects by 2016 (BIM Task Group, 2013). That demand and the benefits behind using BIM have led to an increase in the number of firms adopting BIM in their systems. For example, in the United States, the percentage of AEC Industry firms who have adopted BIM has dramatically increased from 28% in 2007 to 71% in 2012 (McGraw-Hill, 2012). In Europe, BIM implementation gradually increased from 2007 to 2010, but after 2010 the percentage surged and the implementation of BIM was higher than that in the United States (McGraw-Hill, 2010). BIM is increasing dramatically and it has been required to be used in some of the developed countries.

This movement towards the BIM implementation has been driven by the benefits of BIM for owners, teams, projects and firms. There is a wide accepted benefits for AEC industry such as design accuracy, real time analysis for design justification, better service, building performance and design process and delivery. These benefits have saved time in drawing and editing projects, improve the quality of the project and save money (Eastman, Teicholz, Sacks, & Liston, 2011; Hardin, 2009).

However, there are some barriers that may affect the implementation within AEC Industry. such as interoperability, cost of hardware and software, and lack of BIM expertise (Eastman et al., 2011; Hardin, 2009). Most of these barriers can be improved by software developers or changing the mechanism of projects' process within construction companies and firms (Eastman et al., 2011). One of the most important barriers is the lack of BIM users within the AEC Industry (McGraw-Hill, 2012). Moreover, according to Becerik-Gerber and Rice (2010), training employees is a critical issues for successfully implementing BIM (Becerik-

Gerber & Rice, 2010). Hence, some of scholars have stated that the AEC educational sector involve to help in graduate AEC professionals well-known about BIM process and technology (Aly, 2014; Vinšová, Matějovská, & Achten, 2014; Woo, 2006).

### 1.1.2 *BIM in academia*

There is a significant movement towards BIM implementation within AEC industry (Australian of Institute of Architects, 2013; BIM Task Group, 2013; Porwal & Hewage, 2013). Although, this movement is transforming the global industry from applying the traditional method within projects to implementing BIM method, there is a need to revise architecture curricula in light of these developments (Kocaturk & Kiviniemi, 2013).

BIM has been introduced in many AEC educational sector around the world, for example, by the end of 2010, 56% of AEC schools in the United State of America have introduced BIM (Gerber, Gerber, & Ku, 2011). Moreover, several universities in Australia such as The University of South Australia and The University of New South Wales have started to teach BIM within their curricula (BIM Education Working Group, 2012; UNSW, n.d). In the United Kingdom, BIM has been taught in several universities mostly in level 7 (master level) and with few cases at undergraduate level (Kocaturk & Kiviniemi, 2013; Mandhar & Mandhar, 2013). Moreover, BIM Academic Forum (BAF) in UK has established an initial BIM framework to embed BIM within AEC schools in the UK (BIM Academic Fourm, 2013). In Australia, Macdonald (2012) has developed a conceptual framework to teach BIM within AEC schools in Australia (Macdonald, 2012).

Although, that shows BIM has been already introduced in AEC education sector and there are some efforts to embed it within architectural curricula, there is no consensus in what, when and how to introduce BIM to AEC students (Association of Collegiate Schools of Architecture, 2010-11; Barison & Santos, 2010a, 2010b; BIM Industry Working Group, 2011; Kocaturk & Kiviniemi, 2013; Peterson, Hartmann, Fruchter, & Fischer, 2011). However, the following explores the different methods and techniques used to teach BIM to AEC students.

- **Teaching possibilities**

Teaching BIM within AEC education sector could be divided into two stands; Stand-Alone BIM Classes and Integrated Design Studio. First, the general characteristic of the Stand-Alone BIM Classes method is teaching BIM as 3D modelling software; which could be verified by the BIM modules' name e.g. "Advanced CAD - 3D Visualization - Computer Applications for Professional Practice - Architectural Representation" (Association of Collegiate Schools of Architecture, 2010-11). This method has been started in mid-90s by two USA universities, Georgia Institute of Technology and The Texas A&M University (Barison & Santos, 2010a, 2010b; Ibrahim, 2007); and still been used (Brewer et al., 2012).

On the other hand, the concept of Integrated Design Studio has been introduced in 2006 through an Integrated Design Studio in Penn-State University (Barison & Santos, 2010a, 2010b; Mandhar & Mandhar, 2013; Onur, 2009). Since then, three new terms have been created; interdisciplinary, multi-disciplinary and trans-disciplinary, in order to encourage students to work cross-disciplinary. In general, using these methods could improve the knowledge of cross-disciplinary collaboration for students (Wu & Issa, 2013). However, both methods Stand-Alone BIM Classes and Integrated Design Studio could be used to teach students. Kocaturk & Kiviniemi (2013), recommended that BIM should be introduced to architecture students from the first year of their academic level in UK through two classes and an Integrated Design Studio (Kocaturk & Kiviniemi, 2013). The two methods can solve some issues better than if using one of them.

- **BIM within academic Levels**

BIM, technology or process, has been introduced differently within the AEC education sector for freshman year to post-graduate levels (Gerber et al., 2011; Mandhar & Mandhar, 2013; Wu & Issa, 2013). However, in USA, the junior and the senior level have more focused classes on BIM than other levels (Gerber et al., 2011). According to the same resource, architectural programmes have the highest number of BIM classes introduced on the master level compared with other majors and the undergraduate architectural programmes (Gerber et al., 2011). Introducing BIM at an early stage architectural programmes has been seen by

some educators as a threat to creativity (Gerber et al., 2011). However, teaching BIM should be focusing on the learning outcomes for each level and its requirements.

- **Teaching BIM via architectural issues**

In term of Architectural Programmes outcomes, students should acquire knowledge, skills and competence within each level to achieve responsible practice. Teaching BIM supposed to be integrated with the curriculum using a matrix manner without having a negative impact on these principles. However, each school has its own way to integrate BIM within the curricula to achieve their aims. A survey conducted in USA by Gerber et al. (2011) presents that the majority of architectural programmes have taught BIM for design and visualisation followed by sustainability, digital fabrication and constructability (Gerber et al., 2011).

- ***Challenges and Difficulties for embedding BIM within Architectural education***

Based on the literature review (Chapter 2), challenges and difficulties in teaching BIM within AEC education sector can be divided into two areas, academic environment and technology. In term of academic environment, several challenges have been raised by academics to justify non-inclusion of BIM within their curricula. Some architectural schools have a packed curricula and adding a new module including BIM will raise an issue for them (Kocaturk & Kiviniemi, 2013). In addition, Clevenger et al. (2010) has stated that there is a lack of support given by educators and BIM resources as two of the most pressing challenges facing the embedding of BIM within the architectural schools (C. M. Clevenger, Ozbek, Glick, & Porter, 2010; Sabongi, 2009). Other academics have concerns about how diverse the group will be in the Integrated Design Studio using BIM and individual issues in relation to the learning objectives for each member within the group (Poerschke et al., 2010).

Moreover, teaching AEC students in a mono-educational system, where each AEC programme has its own method without having any classes across-disciplines, using BIM will have a negative impact on Integrated Design Studio (R. Sacks, Kaner, Eastman, & Jeong, 2010). The concept of teaching the Integrated Design Studio has to be introduced through a multi-educational system. In addition, BIM has been taught in the AEC schools in many ways, yet there is still a lack of understanding of the concept of Collaborative Design Approach. A survey conducted by Wu and Issa (2013) in The US reveals that the lack of

understanding of the Collaborative Design Approach using BIM is one of the most noticeable weaknesses for AEC schools. In general, most of the defects which have been highlighted by the survey are related to the lack of Collaborative Design Approach across-disciplines, a lack of understanding of BIM work-sharing and lack of strategic BIM implementation within projects (Wu & Issa, 2013).

The demand for Collaborative Design Approach using BIM in AEC Industry has increased and employers are looking for BIM skills when recruiting new workers (Aly, 2014). Hence, AEC schools need to look at how they can embed BIM within their programmes using Integrated Design Studio to enhance the Collaborative Design Approach in order to achieve the AEC Industry needs.

The complexity of BIM software, on the other hand, has become one of the barriers to embed BIM with AEC education sector. BIM computer applications could be complicated for those lacking experience (Taylor, Liu, & Hein, 2007; Woo, 2006), it needs time for educators to understand the tools and for students to master it (Taylor et al., 2007). Moreover, there is assumption that the BIM tools may have a negative impact on the creativity of students (Peterson et al., 2011). However, educators will gain a proper level of understanding in how students will learn about designing and building construction using 3D environment model; and students will gain a great level of understanding in how building works (Vinšová et al., 2014).

Aforementioned challenges and difficulties for BIM education have been recorded from different case-studies around the world; and those points have been evaluated differently depending on the academic levels, countries and experiences. Hence, this research explores and ranks those challenges from Saudis AEC Industry and AEC education perspectives.

- **The need of BIM framework for embedding BIM with Undergraduate Architecture Programmes**

The need to design a roadmap to embed BIM with Undergraduate Architecture Programmes is increasing as no consensus in how to embed it (BIM Academic Fourm, 2013; Kocaturk & Kiviniemi, 2013; Succar, 2009). The BIM roadmap will help students to fill the needs of AEC Industry. There are some examples of how AEC Industry and AEC education work

together to develop BIM roadmap. For example, in US, the National BIM Standard-United States™ (NBIMS) is trying, with AEC education sector, to reach a consensus level in how BIM should be embedded within AEC-ES (Rodriguez, 2014). In UK, on the other hand, the BIM Academic Forum (BAF) has started an initiating roadmap to teach BIM within their AEC education sector (BIM Academic Fourm, 2013). Moreover, Macdonald (2012), has developed a BIM framework for AEC education sector for Australian Universities which has not been evaluated yet (Macdonald, 2012).

In term of BIM in architecture programmes, there are limited resources about whether BIM framework has been developed to be embedded within undergraduate architecture programmes. However, most of the architecture schools have taught BIM within an Integrated Design Studio (Joannides, Olbina, & Issa, 2012; Kocaturk & Kiviniemi, 2013; Stivers, 2012). It has been stated that teaching BIM via an Integrated Design Studio is safe option in the introduction of BIM (Boeykens, De Somer, Klein, & Saey, 2013). However, Kocaturk and Kiviniemi (2013) have proposed a method in how architecture schools in UK should embed BIM (Kocaturk & Kiviniemi, 2013). They have suggested that the concept of BIM should be taught gradually, and it has to connect with other modules within the curricula (Kocaturk & Kiviniemi, 2013). Their proposal is still very general and proposed to architecture programmes in UK only.

### 1.1.3 *AEC Industry in the Kingdom of Saudi Arabia (KSA)*

The Kingdom of Saudi Arabia is one of the biggest and leading countries in the Middle East and has one of the largest and rapidly growing construction sector, the value of its projects is more than one trillion US Dollars (Deloitte, 2014). They have instructed to build more than two million houses, develop the infrastructure including airports and train stations, and build 11 stadiums with a capacity of 45,000 fans (Al-Arabiya-News, 2014).

Scholars have drawn similarities between existing environments within which current KSA AEC industry operates to situation in existence prior to 1980. As highlighted by Alhowaish (2015), the situation, the financial flow and the size of the projects assigned were similar to currently prevailing situation (Alhowaish, 2015). The revenues from oil has brought remarkable financial support to the Saudi AEC Industry (Ikediashi, Ogunlana, & Alotaibi,

2014). It has been stated that more than 75% of construction projects were funded by the KSA Government (CDS, 1994). The 1980s economic boom did not last too long, with dropping oil prices, which had a negative impact on KSA government funded projects (Alhowaish, 2015; Ikediashi et al., 2014). The KSA Government had to decide either to abandon projects or renegotiate the payment (Ikediashi et al., 2014). In other cases, according to Al-Sedairy (2001), the Government relied on local construction companies who have no experience in constructing a complex project to finish their complex projects (Al-Sedairy, 2001).

Most of the challenges currently faced by the KSA AEC industry are similar to those faced the KSA AEC industry in 1980s. There has been a significant growth within the KSA construction sector which appears to be the second economic boom (Alhowaish, 2015). To a large extent, this growth is triggered by a number of mega-projects started by Saudi Government within housing, transportation and utilities sector, with project value exceeding one trillion dollar (Deloitte, 2014). This includes projects such as construction of 11 new sports stadiums, with a capacity of 45,000 fans (Al-Arabiya-News, 2014). In both periods, the KSA government has spent more money in their projects, sometime ten times of the estimated cost (Alhowaish, 2015). That shows the issue of the financial flow in KSA and the effect of the oil price on the construction sector in KSA.

In addition to construction sector issues, it has been stated that most of the local construction companies have a lack of knowledge, management and experience in the project lifecycle (Jannadi, 1997). Moreover, there is a need to develop capacity of Saudi workforce, as it has been stated that the Saudi AEC Industry has a lack of Saudi Architects and Engineers (Almsheeti, 2014). Because of that and the complexity and scale of KSA Government's projects, many foreign construction companies were attracted to work in KSA construction sector. Those foreign construction companies have to partner with local construction companies and firms. Their aim is to finish projects with a high standard level and to improve the knowledge of the local construction companies in how to construct project in a high standard level.

Anecdotal evidence suggests that many foreign construction consulting and contracting firms are using BIM based technologies and processes to support major construction works in KSA. For example, the 11 stadiums have been considered to be designed and constructed using BIM (saudi-gazette, 2014). However, there is limited drive on BIM uptake from the public sector owners. In KSA, the needs of BIM expertise has increased significantly because of international construction companies working in KSA (Construction Week, 2013). That shows in the number of jobs' advertisement; the internationals companies are seeking more than 60 BIM position to be filled up by Saudis employees (glassdoor, n.d).

Moreover, there is anecdotal evidence suggesting an increase of interest among workers within construction sector in KSA in BIM. There are few websites were organised by workers in KSA to discuss BIM and its implementation. For example, Linked-In website, there is a small group called "BIM Users in Saudi Arabia" has been created to share and discuss matters in content of BIM and KSA (Manago, 2013). Noticeably, the group creator and most of the members are non-Saudis. Also, another group in Facebook which been created by Saudi and has bigger number than the one in Linked-In (Facebook, 2012).

### 1.1.4 *Application of BIM in KSA*

The AEC Industry in KSA has a massive investment in the infrastructure sector exceeding of one trillion US dollars. This has forced some construction companies to adopt BIM for their projects such as the 11 stadiums (saudi-gazette, 2014). Moreover, construction companies in KSA: local and international, are seeking BIM expertise to work in KSA (glassdoor, n.d). Despite the increasing demand of BIM skills and aggressive construction development in KSA, the development of Undergraduate Architecture Programmes is still far behind and their graduated students have not reached the AEC Industry expectations (Jannadi, 1997; Medallah, 2015). Architecture schools should teach theoretical aspects and existing knowledge in the context of raising the efficiency of the architecture students and filling the AEC Industry needs (Tzonis, 2014).

There are only limited examples of BIM implementation within the AEC Industry and AEC education in KSA. In general, there is almost no evidence to show that BIM has been implemented within AEC Industry in Middle East There are some activities toward BIM

implementation in Middle East countries (Mandhar & Mandhar, 2013). For example, in Dubai the use of BIM has become mandatory (Constrcution Work team, 2014). Moreover, there are some BIM projects that are designed and constructed in Abu Dhabi (iTech, 2014). In KSA, because of the lack of academics resources, it seems that BIM have not yet implemented yet been within AEC Industry. However, the massive construction in KSA and the huge budget spends on Saudi projects are the key triggers to motivate the Saudi government and construction companies to implement BIM.

In term of embedding BIM within AEC education in Middle East countries, it has been stated that there are only two universities where BIM has been introduced; University of Al-Shajah in the UAE and Aim-Sham University in Egypt (Mandhar & Mandhar, 2013). According to the same source, these two universities have taught BIM as a technology only (Mandhar & Mandhar, 2013). In KSA, the lack of information in relation of BIM implementation within AEC education sector affected the lack of clarity in either BIM has been taught or not. Hence, the lack of academic resources has raised some questions about the current situation, the future strategies of BIM implementation within the AEC Industry and AEC education in KSA.

- **Challenges and Difficulties for BIM education within architecture programmes in KSA**

In general, the lack of academic resources about BIM within AEC education in KSA has caused some issues in identifying challenges and difficulties for BIM education within AEC education sector in KSA. However, there are some issues about where architecture programmes have been taught in KSA Universities. Based on KSA Universities' websites, Architecture Programmers have been taught either in Engineering, Environmental Design or Architecture and Planning Faculties (AlBaha-University, n.d; KAU, n.d). This has created a small difference between the outputs of each faculty.

Moreover, before 2004, there were seven universities and five of them have architecture programmes (HESC, 2014). Now, there are more than 25 universities, 16 of them are having an architecture programmes (HESC, 2014). There is no accreditation bodies designed for architecture programmes in KSA. Based on universities' websites, most of universities quote

their programmes from international universities (AlBaha-University, n.d; KAU, n.d). Although, there are more than 25 universities and 16 architecture programmes, there is still a lack of Saudi Architects and Engineers within AEC Industry in KSA beside their lack of knowledge (Almsheeti, 2014).

These differences and difficulties constitute a challenge to embed BIM within Undergraduate Architecture Programmes in KSA. Along with the lack of academic resources, teaching BIM within Undergraduate Architecture Programmes could face some challenges. Although, these were some issues identified from few scholars and non-academic resources, embedding BIM within Undergraduate Architecture Programmes in KSA may face other challenges similar to other architecture schools around the world. Hence, the lack of academic resources has raised some questions about the current situation of architecture curricula and the future of development based on the AEC Industry needs. Moreover, with the lack of Saudi workers, identify the level of satisfaction of the AEC Industry professions in KSA about the output of Saudi universities.

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## 1.2 Research Questions

There are two main concerns facing this PhD research. First, the state-of art of how BIM has been taught within Undergraduate Architecture Programmes. It can be argued that it is unclear how BIM should be taught in AEC education sector. Although, there are some initiation frameworks from some organisation (e.g. BAF), these frameworks have not been evaluated yet and it may not meet the Saudi AEC Industry needs. Second, BIM, current situation and the future within KSA. The massive construction in KSA can be the only motivation to enhance BIM implementation in KSA. However, to develop a framework to embed BIM within Undergraduate Architecture Programmes in KSA, the following questions need to be answered:

1. What are current strategic and tactical methods in embedding BIM within AEC Education Sector?
2. What are key challenges and the current level of BIM maturity within AEC Industry and AEC Education Sector in KSA?
3. How could BIM be embedded effectively within the Undergraduate Architecture Programmes in KSA?

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## 1.3 Aim and Objectives

There are several issues in relation to embed BIM within Undergraduate Architecture Programmes in KSA such as the lack of academic resources, the academic system in KSA and the AEC Industry needs. Moreover, it was found that there is a major gap of knowledge regarding pragmatic and consistent research for evaluating the effectiveness of the existing methods used for integrating BIM in education. Therefore, the aim of this research is to develop a curricular framework to support embedding BIM within Undergraduate Architecture Programmes in the Kingdom of Saudi Arabia Universities. The research aims to achieve the following objectives:

**Objective 1:** To critically review the current strategies and attempts to embed BIM within the architectural educations.

**Objective 2:** To investigate the current approaches of BIM deployment within architectural education and the AEC Industry in KSA

**Objective 3:** To develop a curricular framework to embed BIM effectively within Undergraduate Architecture Programmes in KSA.

**Objective 4:** To validate the framework by examining the professional opinions of academics within architecture departments and professionals to refine it based on feedback.

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## 1.4 Significance of the Research

A key beneficiary of this research effort is Architectural students. Embedding BIM within Undergraduate Architecture Programmes will improve their knowledge, skills and communication (Gregory, Herrmann, Miller, & Moss, 2013; Holland, Wing, & Goldberg, 2013; Macdonald, 2012; Stivers, 2012). They will start to understand the model in 3D environment and how should they work with other disciplines. Moreover, using BIM technology and understanding BIM process will help them to find a better job (Wu & Issa, 2013).

In term of AEC Industry in KSA, the output of the BIM framework will help to fill the gap within the AEC Industry. As the demand for BIM users and trainers has rapidly increased in KSA, graduated architects with BIM skills will help construction companies and firms to implement BIM within their projects. However, the experience of AEC professionals in adopting BIM can be one of the main factors which can help to embed BIM within Undergraduate Architecture Programmes in KSA.

Finally, embedding BIM within curricular framework is a relatively new area of research which needs to be explored and developed much further. This project aims to contribute to the existing research on the embedding of BIM within the Undergraduate Architecture Programmes and will be one of the first research projects focusing specifically in KSA context.

| 1.1 | 1.2 | 1.3 | 1.4 | 1.5 | 1.6 |
|---|---|---|---|---|---|
| Introduction | Research questions | Aim and objectives | Significant of the research | Research Scope | Thesis Structure |

## 1.5 Research scope and the research method outline

After considering the researcher's resources and timescale, the scope of this PhD research has been determined by a number of different factors. For example, this research has not been funded and there are no other monetary resources available. Based on the literature review, the data obtained was based on academic articles and some related case studies on teaching BIM within AEC education sector context. However, this data has no direct link to BIM implementation within AEC Industry and Undergraduate Architecture Programmes in KSA. Nevertheless, based on the literature, there is some evidence to show an increase in the demand for BIM users in KSA, namely from job advertisements and the number of construction projects in KSA. To build on the data from the literature review, data for this project will be divided into three stages.

The first stage is the preliminary study aiming: 1) to gain an overview of the understanding of BIM in both an academic and professional field within KSA, and 2) to define BIM education challenges in KSA. A multi-method quantitative technique will be used to achieve these aims of this stage. A designed questionnaire will be sent to professionals and academics, and a structured interview will be done with a chosen expert in this field. The results of this data will help to give a summary of the current situation of BIM in KSA and help to design the second phase of the data collection.

In the second phase of the data collection, a semi-structured interview will be used to interview academics from architecture departments within KSA Universities. The aim of this phase is to explore the issues and the chance of embedding BIM within Undergraduate Architecture Programmes. Then a conceptual framework will be developed based on the literature review and the two phases of the data collection to embed BIM within the Undergraduate Architecture Programmes in KSA. Finally, the conceptual framework will

be validated by academics from architecture departments and AEC professionals within AEC Industry in KSA using a semi-structured interview.

| 1.1 | 1.2 | 1.3 | 1.4 | 1.5 | 1.6 |
|---|---|---|---|---|---|
| Introduction | Research questions | Aim and objectives | Significant of the research | Research Scope | Thesis Structure |

## 1.6 Thesis Structure

The thesis contains eight chapters, as shown in Fig 1-1. Each chapter starts with an introduction that outlining the aim and the scope of the chapter.

- **Chapter One (Research Introduction)**

This chapter explains the motivation for this research. It starts with a brief background about the AEC Industry in KSA, the increasing demand of BIM and its benefits, the method of teaching BIM within academia, and BIM within KSA. This is followed by the research questions which reflect problems facing this thesis. Then, identifying the aim and the objectives of this research followed by the significant of the research and the research scope (Table 1-1).

*Table 1-1: Chapter One (Research Introduction)*

| 1.1 | 1.2 | 1.3 | 1.4 | 1.5 | 1.6 |
|---|---|---|---|---|---|
| Introduction | Research questions | Aim and objectives | Significant of the research | Research Scope | Thesis Structure |

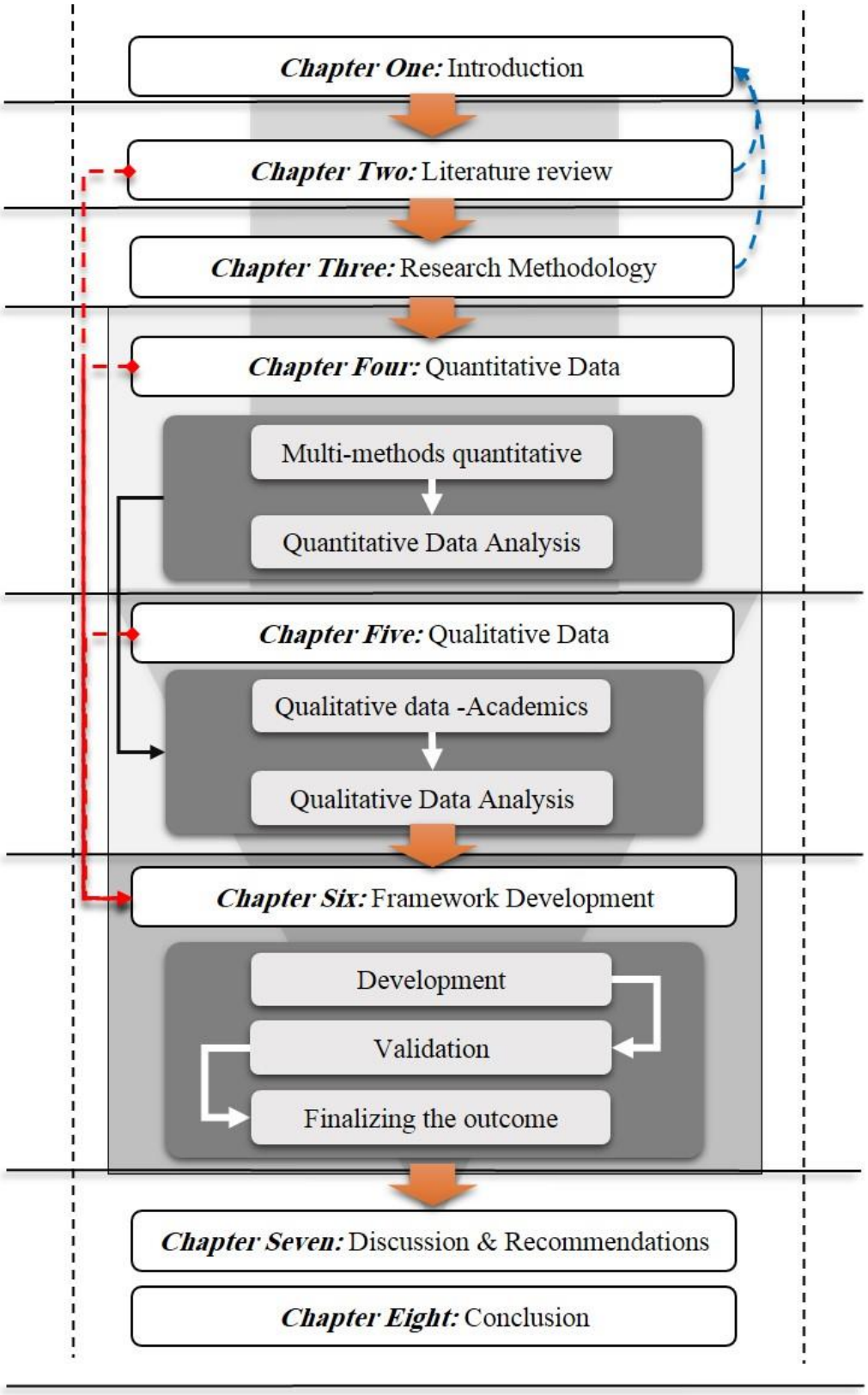



*Fig 1-2: Thesis Structure*

- **Chapter Two (BIM within AEC education sector: Literature Review)**

The chapter presents the current literature review about BIM within AEC Industry and education sector. It starts with a brief background about BIM and its definition. Then, the increasing demand of BIM within AEC Industry and the benefits of adopting BIM within projects. This is followed by identifying some of the BIM barriers and challenges facing the BIM implementation. After that, the chapter gives a deep understanding of how BIM has been taught within AEC education. Finally, explaining the situation of BIM within AEC Industry and education in KSA, and the situation of architecture programmes in KSA (Table 1-2).

*Table 1-2: Chapter Two (BIM within AEC education sector: Literature Review)*

| 2.1 | 2.2 | 2.3 | 2.4 | 2.5 | 2.6 |
|---|---|---|---|---|---|
| BIM | BIM within AEC Industry | BIM in Academia | BIM Framework | BIM in KSA | Summary |

- **Chapter Three (Research Strategies and Methodology)**

This chapter explains the research philosophy and the research design in this thesis. Moreover, it describes the rationale of the section of the methodological choices. The chapter also explains the technique used to collect data and the choice of the sample size. Finally, it identifies how the outcome of the data will be analysed (Table 1-3).

*Table 1-3: Chapter Three (Research Strategies and Methodology)*

| 3.1 | 3.2 | 3.3 | 3.4 | 3.5 | 3.6 |
|---|---|---|---|---|---|
| Research Process | Research Philosophy | Research Design | Method of Data Collection | Data Collection Designs | Summary |

- **Chapter Four (Quantitative Data: The Current Situation of BIM adoption in KSA)**

Chapter four presents the results of the first phase of the data collection. The aim of this chapter is to understand the current situation of BIM and the architecture programmes in KSA. It starts with an explanation of the sample size and the response rate. This is followed

by a description of the survey and the method used to distribute the questionnaire. After that, the findings of the BIM maturity level and the use of BIM technology in KSA will be presented through this chapter. Finally, this chapter presents the results of the question related to architecture programmes in KSA (Table 1-4).

*Table 1-4: Chapter Four (Quantitative Data: The Current Situation of BIM in KSA)*

| 4.1 | 4.2 | 4.3 | 4.4 | 4.5 | 4.6 |
|---|---|---|---|---|---|
| Total response rate | Survey Description | BIM Maturity Level | BIM Technology | Architecture Programmes in KSA | Summary |

- **Chapter Five (Qualitative Data: Semi-Structured Interview)**

This chapter presents the structure of the semi-structured interview and its outcomes. The chapter includes a description of the interview and the findings. The interviews were with 11 academics and a focus students group.

*Table 1-5: Chapter Five (Qualitative Data: Semi-Structured Interview)*

| 5.1 | 5.2 | 5.3 | 5.4 | 5.5 | 5.6 |
|---|---|---|---|---|---|
| Interview Description | Interview Method and Analysis | Interview Findings | BIM within Their Modules | Teaching BIM | Summary |

- **Chapter Six (The Development of BIM Framework)**

This chapter presents the development of the BIM framework as part of this research. The framework was developed from the two conceptual frameworks were presented in (Chapter Two), resulting from analysis of key literature in the area. The presented framework was further refined based on inputs gathered from Quantitative data (Chapter Four) and Qualitative data (Chapter Five). This chapter is divided into three parts, first, describing the findings of the three aforementioned chapters (Two, Four and Five), second, describing the initial framework to embed BIM within Undergraduate Architecture Programme in KSA. Finally, the chapter presents the validation of the framework.

*Table 1-6: Chapter Six (The Development of BIM Framework)*

| 6.1 | 6.2 | 6.3 | 6.4 | 6.5 |
|---|---|---|---|---|
| Introduction | Key Findings | Initial BIM Framework | Validation | Summary |

- **Chapter Seven (Discussion, Conclusion and Recommendation)**

The chapter presents how the thesis has achieved the aim and the objectives of the PhD thesis. It has divided into four sections; introduction, achievement of the research, contribution to knowledge and recommendation

*Table 1-7: Chapter Seven (Discussion, Conclusion and Recommendation)*

| 7.1 | 7.2 | 7.3 | 7.4 |
|---|---|---|---|
| Introduction | Achievement of Research | Contribution to Knowledge | Recommendation |

# CHAPTER 2

BIM within AEC education sector: Literature Review

Sections

| | | | | | | |
|---|---|---|---|---|---|---|
| 2.1 | 2.2 | 2.3 | 2.4 | 2.5 | 2.6 | 2.7 |
| BIM | BIM professional | BIM benefits | BIM barriers | BIM education | BIM in KSA | Summary |

# Chapter 2. BIM within AEC education sector: Literature Review

This chapter gives a theoretical perspective of Building Information Modelling (BIM) implementation in The AEC Industry and AEC education sector. It is divided into four areas. First, it starts with defining BIM and the increasing demand on BIM within AEC Industry. Then, this is followed by the BIM benefits and barriers facing the implementation. After that, the Chapter introduces the methods of how BIM has been taught within AEC education sector. This includes the timeline of embedding BIM within AEC education sector and the BIM teaching possibilities. Then, it covers some of the challenges and difficulties facing the embedding of BIM within AEC education sector. The final section in this chapter focuses on the situation of AEC Industry and AEC education sector in KSA. It covers the situation of BIM within each sector and the increasing demand on BIM within Saudi AEC Industry. Moreover, the section explains the current situation and the future of architecture programmes in KSA.

| 2.1 | 2.2 | 2.3 | 2.4 | 2.5 | 2.6 |
|---|---|---|---|---|---|
| BIM | BIM within AEC Industry | BIM in Academia | BIM Framework | BIM in KSA | Summary |

## 2.1 Building Information Modelling (BIM) - A Technology Review

Building Information Modelling (BIM) has been defined in various ways due to the area of expertise or to serve the definer's aim. The majority of researchers agreed that Building Information Modelling is an integrated design and delivery approach. BIM technology, method or both. Professionals and educators have played the main role in defining BIM. The following presents some perspectives related to the BIM definition:

From the AEC industry perspective, BIM has been explained by the USA Mortenson Company as "an intelligent simulation of architecture" (Campbell & AIA, 2006; Eastman, Teicholz, Sacks, & Liston, 2008). A simulation brings the real-world in a 3D environmental program in order to predict issues earlier than the traditional CAD method. On the other

hand, Sabol (2008) presented BIM as a sophisticated software tool that helps to record information and to assist with its components (Sabol, 2008). These two attempts by industry professionals, to define BIM, show how it can differ, depending on the person defining it and their focus.

Two of the most well-known books in the BIM field The BIM Handbook 1& 2 – BIM and Building construction have defined BIM in accordance with the aim of their books. The writers of The BIM Handbook 1&2 have presented BIM as "A modelling technology and associated set of processes to produce, communicate, and analyse building models" (Eastman et al., 2008, 2011). This definition is very general which means it can be used by any expert to suit any field.

On the other hand, Hardin (2009) in his book BIM and Building construction has focused on the construction part rather than the project lifecycle. He described BIM as a virtual construction of a facility where intelligent objects play the main roles in helping team members to share during a project, in order to enhance the communication and collaboration between a multidisciplinary team (Hardin, 2009). It can be argued that the different focuses of both writers has generated two different definitions but the concept of BIM is unchanged. In contrast, as Sabol (2008) has defined BIM as a technology, Ambrose (2007) claims that BIM is a way of thinking, a conceptual position, and not a tool (Ambrose, 2007). Professionals and educators have seen BIM from different perspectives, as either technology, a process or both. Most of them agree that the use of BIM has great benefits but there is no consensus on how to implement BIM and this is where many of the issues surrounding BIM have arisen.

| 2.1 | 2.2 | 2.3 | 2.4 | 2.5 | 2.6 |
|---|---|---|---|---|---|
| BIM | BIM within AEC Industry | BIM in Academia | BIM Framework | BIM in KSA | Summary |

## 2.2 BIM Usage within AEC Industry

BIM has recently been widely adopted within AEC Industry and it is a new term which has helped in reducing issues during the design process, operation and management of building

projects, increasing the performance of projects and the productivity of a team (McGraw-Hill, 2014). BIM is not only a new tool but a new method of working and with its advanced computer programmes; it has played a major role in helping construction companies to find more effective solutions for projects and improved work in a 3D modelling environment. Projects usually described by a softcopy or hardcopy 2D drawings such as plans, sections and schedules has not yet changed but how we coordinate and collaborate to understand the project is an improvement on the traditional CAD method. For example, co-workers in one project can work with fewer errors and more involvement. Furthermore, it will help architect's offices to manage the quality, budget and time spent on their project, especially when their projects have a variety of specialized workers dealing with one project. The BIM benefits can cover the entire project lifecycle; and consequently, there are examples where BIM has been of benefit to AEC. Architects for example, usually use BIM to model their projects. On the Sydney Opera House, BIM was used to aid facility management (Sabol, 2008). There are several definitions for BIM from the professionals and academics but, most of them agree that BIM is a new process and tools.

### 2.2.1 *BIM Benefit*

The switch from the transition method to the BIM method demands some changes for the architectural firms. Processes, software and culture have to be changed to gain BIM benefits. Fig 2-1 shows the comparison between the traditional method process in designing and constructing projects and the main concept of the BIM process. With the traditional method, the significant impact on the project occurs in the construction documentation stage where several issues arise, such as an increase in the overall cost of the project and a time delay. However, the BIM process brings such issues to light at an early stage. As long as the project is still in the design process and has not yet been constructed, money and time can be saved. In order to achieve this, there needs to be a change in designing and constructing.

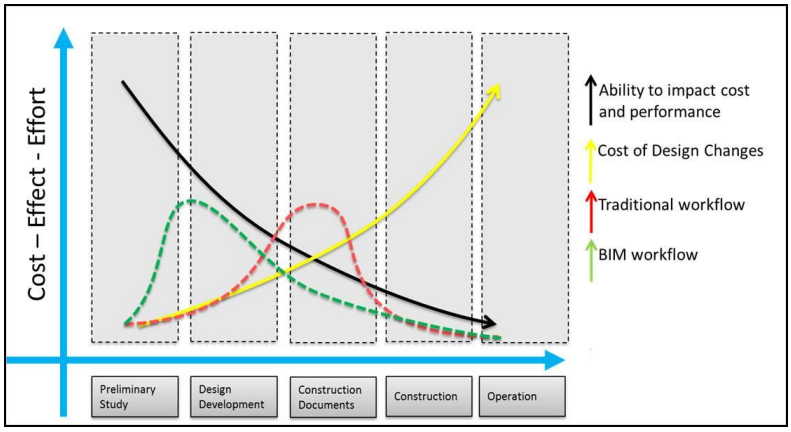



*Fig 2-1: The value of BIM for the design process*

Some arguments state that changing from the traditional method to BIM method is a waste of time and will invariably increase costs, particularly since staff will need to be trained. In fact, investment in BIM and the training of employees is actually cost-effective; in other words, the return on investment (ROI) is significantly noticeable with BIM adoption within architecture firms and construction companies (McGraw-Hill, 2014; Poirier, Staub-French, & Forgues, 2015). Although, according to Poirier et al. (2015), there are two frameworks to evaluate the ROI, it seems that measuring the ROI cannot be done for underdeveloped BIM use within construction companies. BIM, with its method and technology, has improved three areas: Collaboration, Visualization (the object-oriented) and how it connected (Krygiel & Nies, 2008; Kymmell, 2008; R. Sacks et al., 2010; Succar, 2009). All the values behind adopting BIM should be ramified from these three areas. BIM has positively affected the value of AEC Industry businesses, projects and professionals working on the project. The report divides the benefits into three areas:

- **The benefit of BIM to businesses:**

Integrating BIM with the architectural firms' systems leads to a great number of advantages for their business. One of the most important advantages in using BIM, which most professionals agree on, is how cost effective it is. However, the value of BIM could be evaluated differently, especially as beginners are less experienced in evaluating the benefits of BIM to their businesses, compared with experts (McGraw-Hill, 2009). Moreover, in term of ROI, more than 75% of architecture firms and construction companies have reported a

positive ROI on investing in BIM (Eadie, Browne, Odeyinka, McKeown, & McNiff, 2013). However, AEC industry can clearly benefits from the implementation of BIM when they set a clear guidance and methodology to implement it within their projects (Arayici et al., 2011). The BIM value for the business is uncountable, especially with the different perspectives from the AEC professionals. However, according to the McGraw (2012) survey, the AEC professionals have seen the biggest value of BIM; and the top five benefits as mentioned in the report are (McGraw-Hill, 2012):

1. Marketing a new business to new clients: as mentioned before in this research, there are many owners and governments asking to deliver their project using BIM, which could be an opportunity to capture this business. Moreover, presenting projects using BIM for owners who do not require a BIM could help in winning the challenges with other competitors.
2. Overall better construction project outcomes: Using BIM has reduced a number of problems which are usually presented by firms using the traditional method. 48% of owners see a highly positive impact on the overall project outcome when BIM plays the main role (McGraw-Hill, 2012). In order to get a better project outcome, the AEC team has pointed out that reducing problems, increasing the client relationship with the project and gaining personal satisfaction from the project will lead to a great outcome (McGraw-Hill, 2012) and using BIM can guarantee this.
3. Reducing errors and omissions in construction documents: Most BIM users agree that using BIM for designing and construction projects will allow for problems to be identified early, before the building construction stage.
4. Offering a new service: Most AEC firms have noted that using BIM has added to their framework a new business opportunity. According to a report by McGraw (2012), the percentage of architects who have introduced BIM has increased from 41% in 2009 to 48% in 2012 (McGraw-Hill, 2012).
5. Reducing rework: with the traditional method, rework was one of the issues which resulted in a loss of money and time. BIM, on the other hand, has helped co-workers to collaborate and visualize in an effective way, to fix problems before the construction stage.

These top five benefits, according to McGraw (2009), have been ranked by the AEC professionals and show the range of benefits that BIM has for businesses. It is important in this PhD project to present the benefits of BIM to the projects and professionals working on these projects, especially the architects, as the PhD research focus in embedding BIM within Undergraduate Architecture Programme.

- **The benefit of BIM to projects:**

Each project has a design process which is divided into five stages: Preliminary Design, Design Development, Construction Documents, Construction and Operation. These five stages form a well-known process which is well established. Indeed, the traditional method has solved certain issues and speed up the process of designing buildings but there are still a number of problems. Lack of understanding, poor communication and the loss of data are some of the unresolved issues with the traditional method, which is linked to problems in the sharing of information and the collaboration between team members (Fig 2-2)

1. Sharing information: The huge amount of data flow to projects is difficult to monitor, especially with the complexity of the buildings. Most of the data provided could be edited by participants, which makes data security and control extremely important. Transporting data between co-workers during the design process using printed papers and CDs has led to several issues such as losing data, rework, miscommunication and increasing man-hours. However, the BIM method and its technology have improved the sharing of information, making it much more accessible by using parametric software, where the data is linked with its model.

   This method has had a significantly impact on reducing errors and omissions in spatial coordination and geometry, which was a common problem with the traditional method (Eastman et al., 2008). Additionally, reducing these issues will have a direct correlation with the project cost and construction time. In other words, reducing errors and omissions in the design process will lead to a reduction in the cost and the time of building the project.

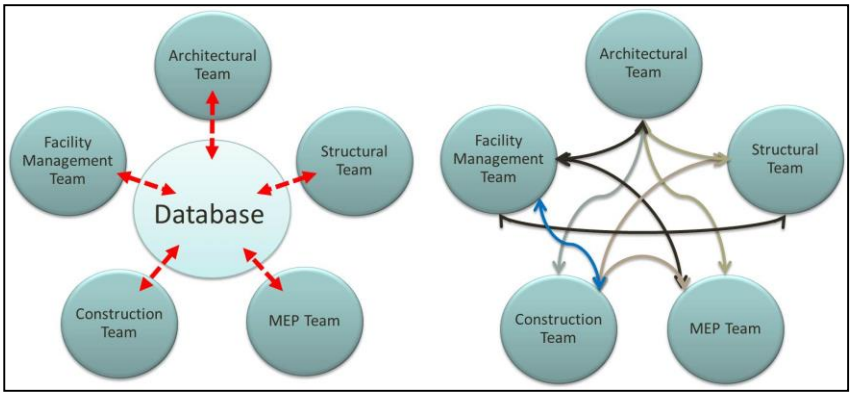



*Fig 2-2: The difference between BIM and traditional method in sharing data (Ryan, 2013)*

2. Collaboration: each stage of the design process has its multidisciplinary team and the team is divided into several groups. For example, the design development stage has a design team which includes architects, MEP professionals and civil engineers. This shows the amount of different professionals involved at a particular stage of the project. With the traditional method, each stage had to be done individually and then data will be sent to the next group. The lack of communication between these groups has caused misunderstanding of project requirements, leading to many errors and omissions. However, BIM has presented a new method where all participants in the project will be able to communicate, to see the overall design process and to contribute. Projects have gained a number of benefits by adopting this method, such as reducing design time, improving the level of understanding among team members and reducing the time spent on construction drawings (Eastman et al., 2008).

Overall, the visualization improvement in BIM has enhanced the quality of presenting the project and improved performance and efficiency in comparison with the traditional method. Moreover, the method of sharing data and its visualization has presented opportunities for possible improvements in earlier stages and more accurate cost estimates. At the same time, the benefits of BIM on the project lifecycle are threefold and exemplified in collaboration, visualization and linking information.

- **The benefit of BIM for team collaboration:**

Having a project with almost zero errors shows the professionalism of the team who are involved in the project. In general, the collaboration and visualization in BIM has improved personal productivity, the teams' understanding of the project requirements and led to faster responses to design changes (Eastman et al., 2008). Each participator can see the benefits of BIM from different points of view. For example, architects see the benefits of BIM in these three areas: efficiency, presentation and teamwork (McGraw-Hill, 2012). According to Coates et al. (2010), adopting a multidisciplinary BIM approach can led to major benefits for architecture firms and construction companies (Coates et al., 2010)

BIM has improved the coordination of documents and drawings which has increased the efficiency of projects. As a result, this has saved time and reduced errors and omissions, which has given the opportunity for architects to focus on increasing building performance and to be more creative, simultaneously improving their personal productivity. In fact, architects should be spending time on creativity and the building performance rather than fixing coordination. Designing and constructing project using BIM tools will lead by default to fix coordination. Software such as Autodesk Revit could help in sharing the architectural model cross-disciplinary. Then, using Autodesk Navisworks will help to link all the models in one file, which helps to identify clashes cross-disciplinary; see Fig 2-3. Hence, the team could organise these clashes and sort them by discipline who will fix these clashes and up-data the file.

In terms of visualization, architects marketing their ideas through effective presentation help in delivering the ideas to other professionals involved in the project. Adopting BIM in architectural firms has benefited architects in the multiparty communication required to understand the overall needs of the project. Firstly, the visualizations and communication in BIM, whereby data is linked with geometry and shared in a 3D modelling environment, has significantly improved communication between team members and improved the level of understanding. According to McGraw (2009), architects have ranked it as highly important, among other benefits (McGraw-Hill, 2009). Secondly, BIM visualization has improved collective understanding of the intended design which has been rated by architects as the second most important benefit of BIM (McGraw-Hill, 2009).

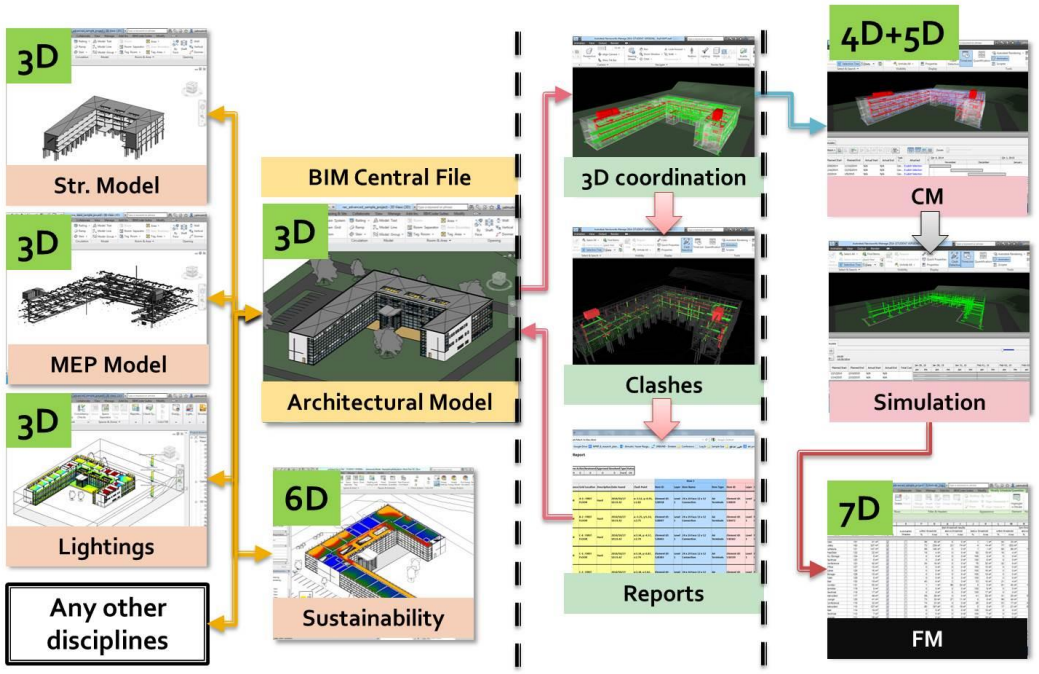



*Fig 2-3: Sharing Architectural file cross-disciplinary and linking that using BIM tools*

Benefits of BIM across project lifecycle and for various professional teams have been well established. Although the benefits and their importance vary depending on the firms, the more BIM is implemented, the more benefits firms are likely to see. These benefits extent throughout the project lifecycle for all stakeholders. Each team member involved in the project has a different opinion and means of evaluating the benefits of BIM for them.

### 2.2.2 *Barriers to BIM Implementation*

Moving away from the traditional 2D CAD program and the paper-based practices to BIM and the method of sharing a 3D environmental design has huge benefits. However, this will inevitably lead to significant changes on how projects will be undertaken and how the different professionals working on the project will be involved. It has been noted that the following three points are the most challenging factors which AEC Industry firms face: 1) getting seniors to adopt the new methods 2) changing the organisation of staff to suit particular skills (Eastman et al., 2008, 2011) 3) cost of implementation (software and training) 4) lack of senior management support 5) scale of culture change required 6) lack of supply chain buy-in 7) staff resistance and ICT literacy and 8) legal uncertainties (Eadie, Odeyinka, Browne, McKeown, & Yohanis, 2014; Eastman et al., 2008, 2011). However,

BIM users would rank these barriers differently than who have not adopted yet (Eadie, Odeyinka, et al., 2014; Harty & Laing, 2010) Although, these factors represent some of the challenges that implementing BIM is likely to have for building firms, this could be improved by changing the cultural attitude within the industry and dealing with BIM as both a practice and technology (Eastman et al., 2008, 2011; Harty & Laing, 2010).

There are other challenges that need to be addressed if BIM is to gain increasing credit and recognition in the AEC Industry. One of these challenges is concerned with the interoperability between computer applications. This is one of the major aspects of the industry that requires consideration and improvement and has been rated as a top priority for development by AEC Industry professionals. The McGraw reports (2009, 2012) found that to increase the benefits of BIM, it needs to look specifically at improving interoperability to show the functionality of BIM software applications. In addition, AEC Industry companies have rated three other challenges which BIM faces: 1) BIM deliverables need to be more clearly defined between parties 2) more internal staff are required with BIM skills 3) encouraging more owners to use BIM (McGraw-Hill, 2009). Noticeably, in the second report from McGraw (2012), the ranking of these challenges changed depending on the firms' experience. The first three; interoperability, functionality and more clearly defined BIM deliverables between parties were still ranked as the top three areas requiring development. However, there was a slight increase in the number of owners asking for BIM, moving from fifth place to fourth place in the list of challenges which BIM faces. The importance of having more internal staff with BIM skills saw a decrease in its ranking but was still within the top seven issues. One of the more recent challenges is the need for 3D building product manufacturer content which was ranked in fifth position on the list (McGraw-Hill, 2012).

- **Barriers facing firms to adopt BIM**

The benefits of adopting BIM has encouraged most developed countries such as (UK, USA, Singapore, Norway, Denmark, Finland, Hong Kong, South Korea, Netherlands) to make or in process of making use of BIM mandatory as part of public procurement process (Zeiss, 2013). Although, the demand for BIM users and finalizing projects using BIM are increasing, some arguments claim that implementing BIM may cause several problems. For example, preparing employees and the cost of adopting BIM are some of the problems which

shareholders face (Eadie, Odeyinka, et al., 2014; Harty & Laing, 2010; McGraw-Hill, 2012). There are some of non-BIM users who have pointed out several issues in implementing BIM within AEC Industry firms (Anthony, 2014; McGraw-Hill, 2012): 1) There is not enough demand from clients 2) There hasn't been sufficient time to evaluate BIM 3) Software and hardware upgrades are too expensive 4) Functionality does not apply very well to what we do 5) There is insufficient BIM-compatible content available for industry needs. Indeed, these issues could have a negative impact on the implementation of BIM within the AEC Industry. However, some of these issues could be addressed by vendors developing specific computer applications tailored to the BIM approach, but this process is likely to take time. Despite the challenges that BIM faces and the issues that have been highlighted in its use construction companies have seen considerable benefits in adopting BIM within their system.

### 2.2.3 *The future of BIM adoption*

The Influence of BIM drove some of the governments to require the use of BIM within their projects. For example, In UK the government has announced that all their projects in 2016 have to be handled in BIM format (BIM Task Group, 2013). That would help them in reducing the cost and the carbon dioxide which caused by construction and operation process (BIM Task Group, 2013). With the same reason, the Australian government has encouraged construction companies to adopt BIM (buildingSMARTAustralasia, 2012). Adopting BIM will help in reducing errors; as it mentioned in the BIM benefits, by using some tactics such as using the clash-detection tool in Autodesk Navisworks. Such tool could identify clashes between different objectives; mechanical vs. electrical vs. pluming vs. architecture model. Then, the team could note that by saving a picture for the clash and write down how it should be fixed and who should be involved.

In USA, all projects; which have been managed and maintained by the General Services Administration GSA, are encouraged to deploy mature 3D, 4D and BIM for all their projects (U.S.GeneralServicesAdministration, 2007; Yori, 2011). The GSA is an organization which manages and maintains over 8500 public buildings across the USA, and has more than 170 new project (U.S.GeneralServicesAdministration, 2007). Dealing with these buildings and

its assets need to have information explicit, the main concept of BIM is to make the data explicit and reachable.

The positive impact behind adopting BIM within the design, construction and operation processes has a significant influence on encouraging construction companies and governments around the world to adopt BIM within their systems. A report from McGraw (2014) presents that the construction companies in ten developed countries have highly adopted BIM within their system (McGraw-Hill, 2014). This report even presents the future for the implementation of BIM within the same countries. Fig 2-4, shows an increasing number of companies who will fully adopt BIM (McGraw-Hill, 2014).

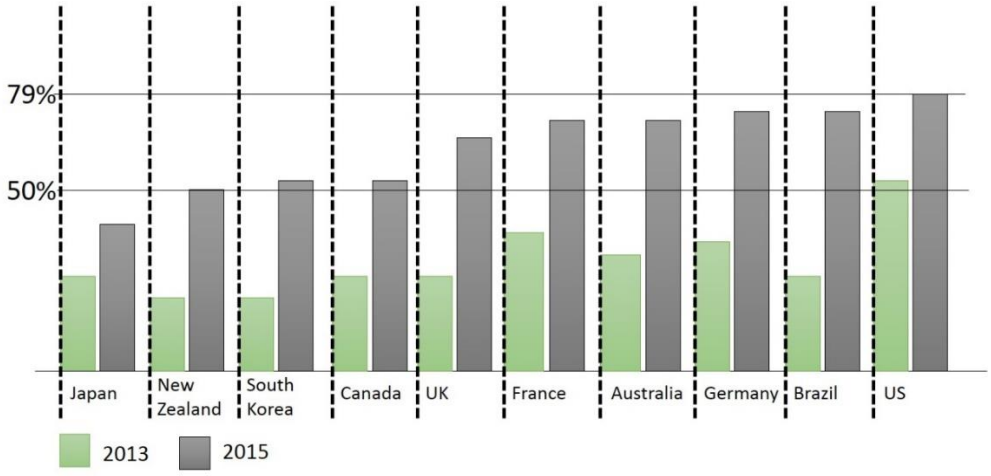



*Fig 2-4: High/Very High BIM Implementation Levels (By Country) (McGraw-Hill, 2014)*

Any stage of the design and construction phases is about input and output of data certain. The BIM is based on having a central database for all the project lifecycle with an easy access. Additionally, when it comes to facility management the value of these data becomes uncountable. Therefore, making a significant decision for the future has to have a great knowledge of the past and understanding of the current situation. Hence, BIM adopters should develop a roadmap for BIM adoption; it has to include the past, present and the future. The continuing in adopting BIM and its development will lead to dissimilar levels of BIM maturity. The roadmap would help to identify level of maturity in using BIM and a guidance to open data exchange in the future. In UK, The Department of Business Innovations and Skills (BIS) has a significant effort in developing their BIM roadmap, Fig 2-5 (BIM Industry

Working Group, 2011). Their roadmap has helped to classify the mature level of each UK companies and outline what they need to reach the government aim by 2016 and think about BIM future. At this stage, according to Porwal and Hewage (2013), most of the UK construction companies are located in level 1 and the best in class are experience a significant benefits in level 2 (Porwal & Hewage, 2013). By using the BIM resources, clients could have great benefits in reducing cost with a high quality production. Moreover, these resources will help in reducing the level of carbon dioxide and waste.

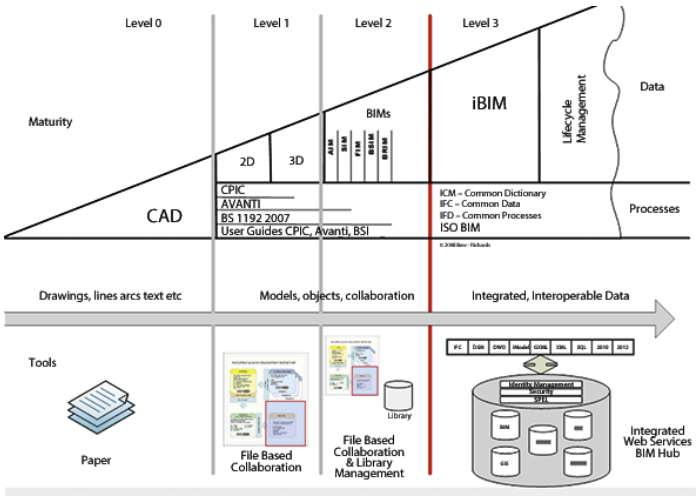



*Fig 2-5: BIM maturity levels in UK (BIS, 2011)*

The BIM task group has presented in their BIM2050 report that these data could be used, for example, to a self-assembly 3D printer; which will be in level 5 after 2030 (BIM2050group, 2014). The BIM roadmap it has to be design not from the AEC Industry perspective, AEC educations has to be part of this. Educators have to provide what the AEC Industry needs.

| 2.1 | 2.2 | 2.3 | 2.4 | 2.5 | 2.6 |
|---|---|---|---|---|---|
| BIM | BIM within AEC Industry | BIM in Academia | BIM Framework | BIM in KSA | Summary |

## 2.3 BIM in Academia

The increasing demand for implementing BIM in the AEC Industry's projects has encouraged AEC educators to start thinking about embedding BIM within their curriculum.

Despite the noticeable growth in BIM users, the industry has some issues regarding the implementation of BIM. One of the concerns is the cost of training potential employees in BIM and, alongside other issues which have previously been highlighted, firms are nervous about adopting the new approach. However, overcoming these obstacles is not solely the responsibility of employers but the educators who will work with potential recruits and prepare them for the industry. In fact, the AEC syllabuses should respond and reflect the market need.

A number of arguments arise about the use of digital tools in AEC institutes. Questions about when and how to adopt the new technology is complicated by a lack of qualified teachers. The technology (e.g. Emails, Microsoft office and digital devises such as Mobiles and tablets) has become a part of the real life, although, teaching new technology to architectural students become challengeable for AEC educators (Mandhar & Mandhar, 2013). Moreover, in many cases the AEC institutes usually have a single professional in computer aided-design/drawings who are capable of teaching students and dealing with any technical issues within the institutes (Mandhar & Mandhar, 2013). In term of teaching BIM, Hartmann and Fischer (2008) state that, one of the major reasons for not teaching BIM for students is the lack of teaching experience.

However, the increasing demand for BIM is inevitable and there are many cases where AEC-ES has already introduced BIM into their programmes. There are more than 103 universities around the world have taught BIM within their curriculum (Barison & Santos, 2010b). Moreover, The Association of Collegiate Schools of Architecture ACSA in USA with Autodesk are working together to embed BIM within architectural programmes (Gregory et al., 2013). However, there is significant impact on architectural programmes by embedding BIM within their curriculum. The 3D modelling environment using BIM tools has aided students in "a greater understanding of building systems integration" (Livingston, 2008). Creativity, understanding project drawings, project management, cost estimating, quantity take-off and scheduling are just some of the areas that architectural students are expected to learn. Peterson et al. (2011) state that teaching architectural students by using BIM tools will lead them to learn how to manage projects and understanding the relationship between project scope, time and cost (Peterson et al., 2011).

### 2.3.1 *Evaluation of BIM implementation in academia*

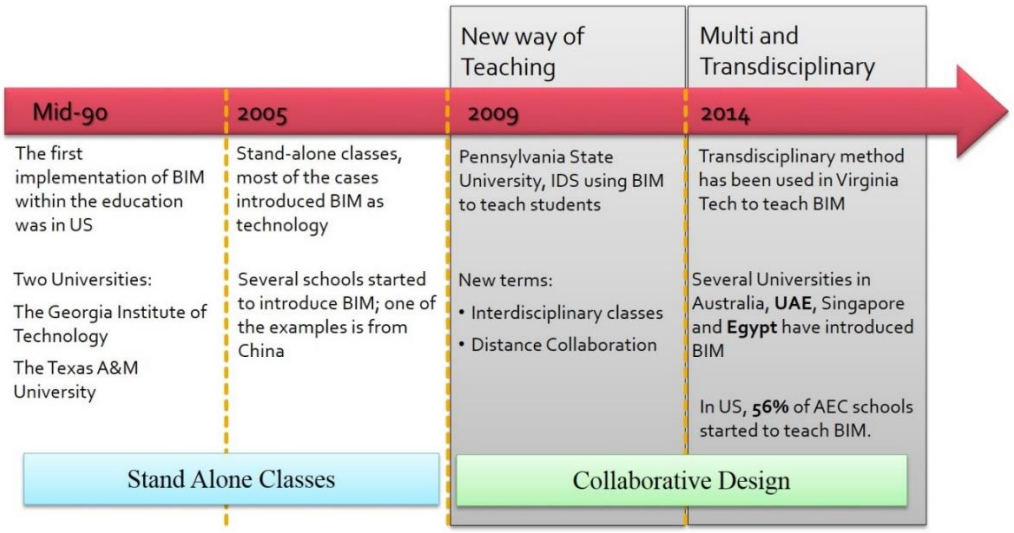



*Fig 2-6: The Timeline of the BIM teaching development within AEC Schools*

There are many schools who have taught BIM based on technology or process within their systems by using different methods (Barison & Santos, 2010a, 2010b; Gerber et al., 2011; Mandhar & Mandhar, 2013). It has been found that 103 AEC schools have already adopted BIM (Barison & Santos, 2010b) and the majority were from United States. As Becerik-Gerber et al. (2011) report, there is a significant growth in teaching BIM within the AEC schools in the United States. It states that 56% of surveyed universities in the United States have adopted BIM (Gerber et al., 2011). Noticeably, the architectural programmes have led other programmes in adopting BIM with their curricula (Barison & Santos, 2010b; C. M. Clevenger et al., 2010). A breakdown of BIM classes provided within undergraduate AEC programmes in USA, shows engineering to have the biggest share with 57% followed by architecture with 50% and construction with 36% (Gerber et al., 2011). Moreover, a survey by Gerber et al. (2011) indicates that each programme has different strategies in when BIM should be taught. For example, BIM has been taught at sophomore, junior and senior levels. Where most architect programmes have introduced it at senior and masters levels, it has been seen as a threat to creativity (Gerber et al., 2011). Hence, each programme has its own perspective on how and when BIM should be incorporated within the curricula. The PhD project explores the history of implementing BIM within the AEC Education and then highlights some of the strategies used to introduce BIM.

The implementation of BIM within an AEC-ES started in the mid-90s, where The Georgia Institute of Technology and The Texas A&M University both used BIM 3D modelling applications to teach their students, see Fig 2-6 (Barison & Santos, 2010a, 2010b; Ibrahim, 2007). In 2003, the University of Minnesota introduced BIM through teaching Revit Architecture Software (Barison & Santos, 2010a; Mandhar & Mandhar, 2013). After four years of teaching Revit Architecture to students in the Architecture School at the University of Minnesota, the head of the Architecture School, Dr. Cheng, said that, "we understand better now its strengths and weaknesses, and, after seeing the results in the first studio, we have a great deal of confidence that by introducing it early in the curriculum, we will produce highly skilled, critical-thinking architects" (Autodesk, 2007b).

At the beginning of the 20th century, several schools started to teach BIM but it was introduced as a stand-alone BIM course (BIM course module), not within an existing class. In 2003, for example, Madison Area Technical College in the United States introduced architectural third party applications by using Autodesk software (Barison & Santos, 2010a; Mandhar & Mandhar, 2013). From the college's website, the college has provided for their students three BIM computer applications from Autodesk, in stand-alone classes, namely "Intro to Revit – Revit MEP – Advance Revit"(MadisonCollege, n.d). A year after that, California State University at Chico adopted BIM within the Building construction programme using a stand-alone BIM course method (Barison & Santos, 2010b; C. M. Clevenger et al., 2010; Gier, 2008; Mandhar & Mandhar, 2013). They have used BIM tools to help students to understand how to extract the estimated cost and the quantity take-off (C. M. Clevenger et al., 2010; Gier, 2008).

In 2006, the concept of integrating BIM within Architecture Programmes reached a peak and several ideas have been put forward about how BIM can be introduced within the curriculum. The idea of integrated Design Studio (IDS) was introduced by Pennsylvania State University to teach multi-disciplinary groups using BIM (Barison & Santos, 2010a, 2010b; Mandhar & Mandhar, 2013; Onur, 2009; R Sacks & Barak, 2009). Their system of introducing BIM to students has been awarded by the National Council of Architectural Registration Boards (NCARB, 2011). According to the NCARB's jury, the given project provides a real-world experience for their students from different backgrounds: 1)

architectural engineering–construction, 2) architectural engineering–mechanical, 3) architectural engineering–construction, 4) architectural engineering–lighting/electrical, 5) architectural engineering–structural, 6) architecture; and teaching assistant: architectural engineering–construction by giving them a real scenario in designing a building with a specific programme, existing site conditions and actual budget (NCARB, 2011; PennStateUniversity, 2012).

After 2006, AEC Industry, in USA, has raised the need of BIM collaboration skills. According to Wu and Issa report (2013), the lack of collaboration cross-disciplinary, the lack of understanding of BIM work-sharing and strategic BIM implementation have got the highest concern in USA AEC Industry (Wu & Issa, 2013). On the other hand, the AEC educators have no consensus in how BIM should be taught within the curricula. The differences in how they taught BIM could be seen in Fig 2-6. However, Moving from Stand-Alone Classes to multi-disciplinary method could be the Cornerstone for a new era of BIM teaching method. Several techniques have involved such as "Inter-disciplinary - Multi-disciplinary – Trans-disciplinary" (Barison & Santos, 2010a; Macdonald, 2012; Repko, 2012). At this stage, the research divided into three categories based on when, which and how BIM taught; teaching possibilities, levels of education and its relationship to teaching BIM and BIM topics target within architectural field.

Several scholars have suggested that BIM is about people, processes and technology which needs to be taught through a collaborative and integrated design approach. Ngo (2012) suggests that in order to achieve a better understanding of BIM, it needs to be embedded within civil engineering programmes in UK (Ngo, 2012). Moreover, it will help students to understand how projects work and the needs of the AEC industry which can help them to find better jobs (Ngo, 2012).

### 2.3.2 *Pedagogical Issues in BIM Teaching*

Teaching BIM within a stimulating programme has raised some concerns about the teaching methods and techniques. There is no commonly accepted method in how BIM should be taught within the AEC programmes. However, teaching BIM within AEC programmes could be divided into two methods; stand-alone classes and IDS, which each one of them having

several techniques. Furthermore, BIM has been taught within undergraduate and post-graduate architectural programmes to help in covering and understanding some aspects within the building lifecycle. According to Gerber et al. (2011) report, most of architectural programmes offered BIM classes are focus on design, visualization and constructability activities using BIM (Gerber et al., 2011); and in the future most of them they will be focus on sustainability, model-based estimating and site planning (Gerber et al., 2011; Joannides et al., 2012). These methods and techniques covered in this PhD research from two different perspectives; how BIM taught within AEC programmes and how it has been seen from BIM forums.

- **Teaching BIM within AEC education**

1. Stand-alone BIM Classes

The general characteristic of the stand-alone classes method is teaching BIM as 3D modelling software (Association of Collegiate Schools of Architecture, 2010-11). This method started in mid-90s by two USA universities, Georgia Institute of Technology and The Texas A&M University (Barison & Santos, 2010a, 2010b; Ibrahim, 2007); and still been used in most universities (Brewer et al., 2012). From the findings of the Association of Collegiate Schools of Architecture (Association of Collegiate Schools of Architecture) report (2010-2011), a number of classes are named "Advanced CAD - 3D Visualization - Computer Applications for Professional Practice - Architectural Representation" (Association of Collegiate Schools of Architecture, 2010-11). In Australia, NSW university have introduced BIM through these three modules: 1) Computer Aided Design 2) Building Information Modelling and 3) Advanced Techniques using BIM (Brewer et al., 2012; Wong, Wong, & Nadeem, 2011). From the description of these syllabuses, the Advance Techniques using BIM is more of a collaborative class than the others (UNSW, n.d).

Moreover, The percentage of BIM compulsory classes is higher than elective classes within the undergraduate architectural programmes in USA (Gerber et al., 2011). In comparison with the post-graduate architecture programmes, the elective classes are much higher than the required classes. Teaching BIM as a computer graphic design may help students to gain modelling skills and to be a master in using BIM tools, but students may not have a suitable

level of IDS experience which has been identified by professionals as one of the most important areas for improvements in the AEC-ES (Wu & Issa, 2013). In addition, the main concept of BIM is to work in a multi-disciplinary environment; hence, having stand-alone BIM classes by itself will not achieve the desired level of collaboration. The stand-alone BIM classes should continue as a method to deliver BIM tools for architecture students, but it cannot be relied on this method without embedding it with the design studio.

2. Integrated Design Studio using BIM

This method will help students from several disciplines to understand the workflow and give them a holistic understanding of the AEC Industry (Ambrose, 2012; Becerik-Gerber & Rice, 2010; Peterson et al., 2011). In addition, This method will help to increase the knowledge of IDS cross-disciplinary (Wu & Issa, 2013). The concept of IDS has introduced in 2006 through an Integrated Design Studio IDS in Penn-State University (Barison & Santos, 2010a, 2010b; Mandhar & Mandhar, 2013; Onur, 2009). Their method has helped AEC students to gain significant knowledge in how project will be done in real-life; which has led to be awarded by the National Council of Architectural Registration Boards (NCARB, 2011). Moreover, many universities in the United States started to teach BIM within their taught programs through the IDS. Several of them have awarded by the American Institute of Architects AIA because of embedding BIM within a IDS; such as Oklahoma University and Stanford University (AIA, 2008).

The concept of embedding BIM within an IDS in AEC programmes has not reached a mature level yet (Ambrose, 2012). To embed BIM within an IDS, universities have used several techniques; interdisciplinary, multi-disciplinary, trans-disciplinary and distance-collaboration, to help students to encourage working in a collaborative environment. The first three terms; interdisciplinary, multi-disciplinary, trans-disciplinary are nearly identical, but it could be distinguish by clarifying the role of each disciplinary and the host (Barison & Santos, 2010a, 2010b; Repko, 2012). First, the different between the inter-disciplinary and multi-disciplinary is how the problem will be introduced. In inter-disciplinary case, a design issue will be introduce to the entire team within the design studio; in contrast with multi-disciplinary, the design issue will be introduced first to one of the discipline (in this

case the architectural students) who will discuss it with the team (Aarts, Chalker, & Weiner, 2014; Barison & Santos, 2010a, 2010b; Education, 2010; Repko, 2012). In term of Trans-disciplinary Fig 2-7, professionals or/and students from upper-level will engage with the team in either the inter-disciplinary or the multi-disciplinary techniques to solve the problem by advising or working with them (Barison & Santos, 2010b; Repko, 2012).

The role of each discipline will be slightly affected by the AEC institute decision in which techniques they will be used to embed BIM in an IDS. However, using any of them will lead to improve significantly the level of knowledge, skills and collaboration for AEC students. Simulation of the real-time process of a project-lifecycle using BIM tools has increased significantly the knowledge of students cross-disciplinary; but to achieve the level of collaboration, students need to have a mature level in understanding BIM technology and process. As it mentioned, there is no consensus in how BIM will be embedded within the architectural programmes and who should be involved.

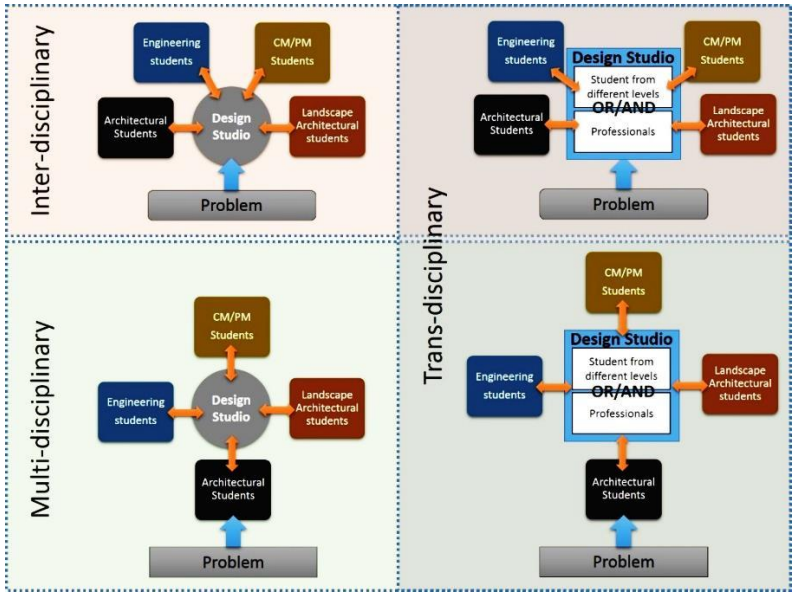



*Fig 2-7: The differences between the collaboration method techniques*

The diversity of a collaborative team is dependent on the AEC schools; the maximum number which has been found from the literature review is six students from different departments in each group. This case was found in the Penn-State University where six students; 1) architectural, 2) landscape architecture, 3) construction, 4) lighting/electrical

engineering, 5) structural and 6) mechanical have to work in one project (NCARB, 2011; PennStateUniversity, 2012; Poerschke et al., 2010). The task is based in real situation where the project being designed based on a specific programme, existing site conditions and actual budget (NCARB, 2011; PennStateUniversity, 2012; Poerschke et al., 2010). On other case, The California Polytechnic State University has introduced BIM in their Building Design course whereby students of architecture, engineering, building construction and their teachers, who have an experience of professional practice, are working together on integrated projects (Barison & Santos, 2010a).

However, both methods; the stand-alone BIM classes and the IDS should be taught within the architectural programmes. Architectural students need first to utilize BIM software then start to design and develop their works. In Auburn University, the school of architecture started by introducing BIM in one week tutorials and then students start from a simple and basic building. Teachers have reported that students from the small projects have gained invaluable experience in understanding the scope and complexity of the project (Barison & Santos, 2010b; Mandhar & Mandhar, 2013; Taylor et al., 2007). After that, they moved to more complex and much bigger project; they used a commercial building project of 20,000 – 30,000 SF to increase the knowledge of their students (Barison & Santos, 2010b).

In addition, in the Georgia Institute of Technology, students have been given a short introduction within a stand-alone BIM class and are then expected to present their design studio work through BIM tools, based on the introduction (Ibrahim, 2007). Furthermore, Kocaturk & Kiviniemi (2013), recommended that in order to have a direct impact, BIM should be introduced for the undergraduate architectural programmes from the first year architecture programme in UK through two classes and an integrated design studio (Kocaturk & Kiviniemi, 2013). They indicate that students should learn first how to model and represent their work; then how to build their building information and share it through design studio (Kocaturk & Kiviniemi, 2013). In addition, teachers and students need to have an access to 3D visualization and associated property databases (i.e., size, material properties, cost, etc.) that create a solid foundation for teaching BIM (C. Clevenger, Glick, & del Puerto, 2012).

- **Teaching BIM through the Academic levels**

Generally, each one of the AEC educations has a number of BIM classes, but with differences in the teaching methods, number of modules provided and when BIM has to be introduced. BIM has taught from the freshman level to the graduation level and most of the cases show that the graduation level and the level before are the most targeted level to teach BIM (Gerber et al., 2011; Joannides et al., 2012) (see Fig 2-8 and 2-9). However, embedding BIM with the undergraduate architectural programmes has concernedly become an issue, especially, when educators have to get answers for when BIM should be introduced, how we teach it and at what is the value of BIM for architecture students (Mandhar & Mandhar, 2013).

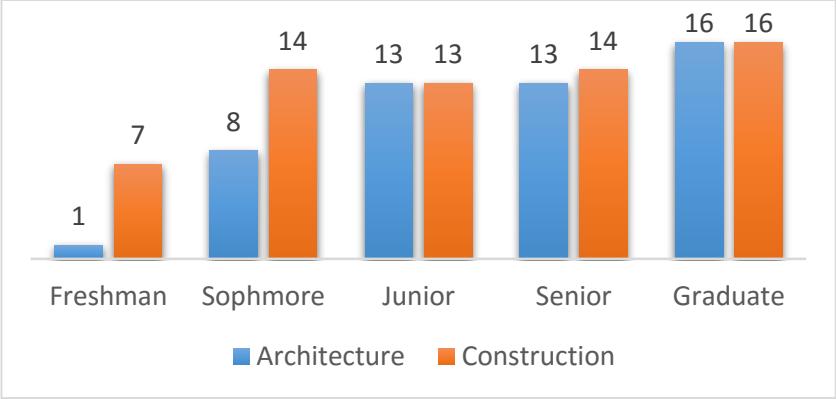



*Fig 2-8: Number of BIM classes offered in academic levels (Joannides et al., 2012)*

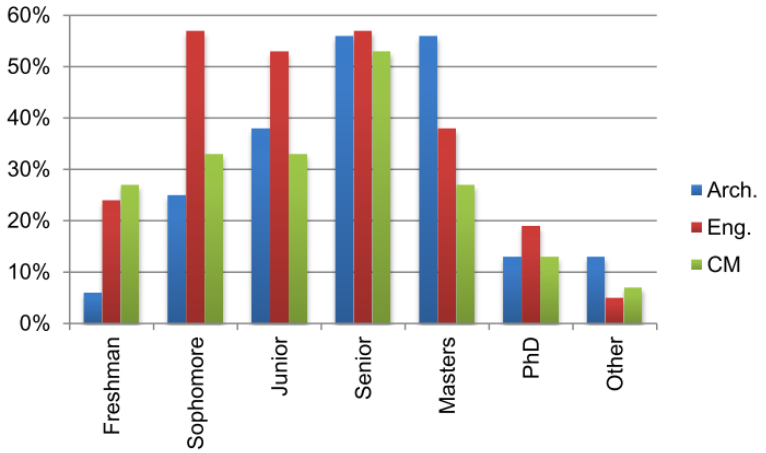



*Fig 2-9: Comparison between Architecture, engineering and building construction in the number of BIM classes (Gerber et al., 2011)*

BIM, technology or process, has taught for all levels within the AEC programmes including post-graduate levels (Gerber et al., 2011; Joannides et al., 2012; Mandhar & Mandhar, 2013). In USA, the number of BIM classes is increasing significantly after the junior level; which has been presented in both surveys (Gerber et al., 2011; Joannides et al., 2012). Moreover, according to the same resource, architectural programmes in USA have the highest number of BIM classes introduced on the master level comparing with other majors and the undergraduate architectural programmes (Gerber et al., 2011). Introducing BIM in early stage architectural programmes has been seen by some educators as a threat to creativity (Gerber et al., 2011). However, teaching BIM should be focusing on the learning outcomes for each level and its requirements.

- **Teaching BIM through architectural issues**

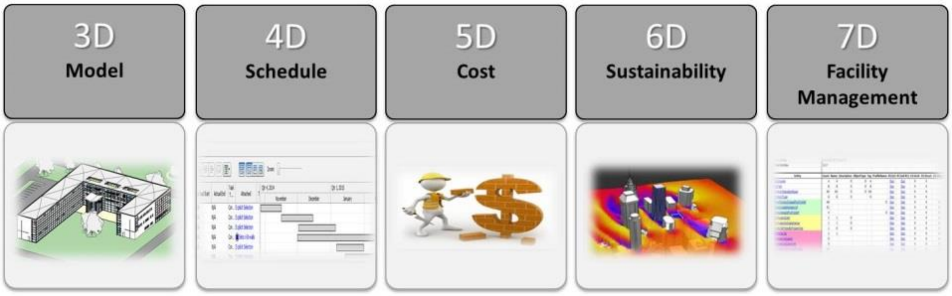



*Fig 2-10: BIM nD Process and Technology*

In term of Architecture Programmes outcomes, students should acquire knowledge and skills to reach a competence level to be responsible. Teaching BIM is supposed to be embedded within Undergraduate Architecture Programme using a matrix manner without having a negative impact on other principles' aims. However, BIM focusing topics within Undergraduate Architecture Programme could present in BIM nD terminology '3D, 4D, 5D, 6D and 7D' see Fig 2-10. These terminologies have helped AEC students to understand some aspects within the building lifecycle. However, not all the AEC-ES has embedded all of these BIM terminologies; each school has different opinion in which they should teach to their students. For example, from the Gerber et al. (2011) report, the surveyed universities in the United States were asked where BIM is taught or where BIM is planning to be taught in the future. Universities who offered BIM classes have used BIM for design, visualization and constructability activities (Gerber et al., 2011) (see Fig 2-11).

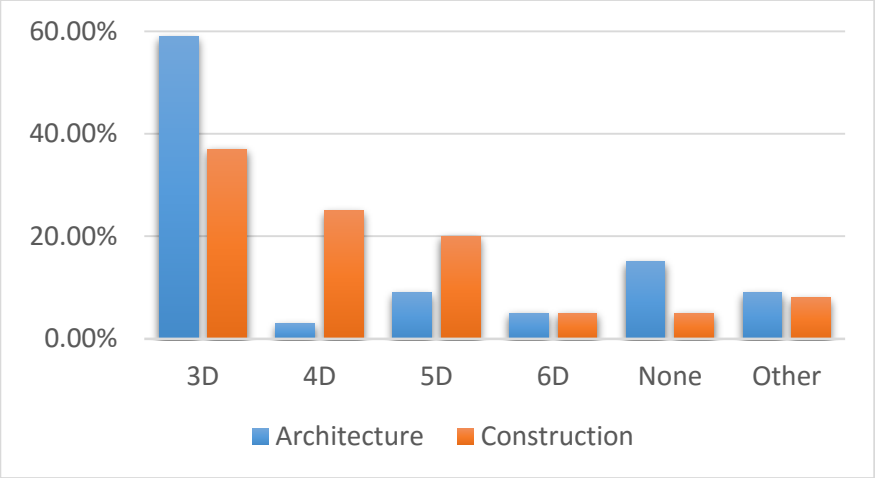



*Fig 2-11: BIM topics are taught in US universities (Joannides et al., 2012)*

On the other hand, universities who are planning to teach BIM prefer to expand BIM's applications in teaching the concept of sustainability, model-based estimating and site planning (Gerber et al., 2011; Joannides et al., 2012). Moreover, from the same report, each program has different opinions in what should be taught. Architectural programs have rated the design and visualization as a main priority followed by sustainability, digital fabrication and constructability. On the other hand, engineering programmes considered the design to be most important followed by visualization and constructability. For Building construction programmes, constructability, 4D scheduling and model-based estimation were given priority, followed by the design, visualization and sustainability and cost control (Gerber et al., 2011). In many cases, universities have taught some of these terminologies using IDS. Although, embedding all BIM terminologies is time consuming, (Mandhar & Mandhar, 2013) it will benefit AEC students and prepare them to the real-life (Pihlak et al., 2011).

- **BIM Technology within academia**

In term of Computer Aided Design/Draft CAD, the most popular software has been introduced to architecture students is AutoCAD. The majority of AEC introduce AutoCAD at an early stage in undergraduate studios and computer labs (KAPP, 2009). AutoCAD represents geometric features with lines, surfaces and solids but does not understand the role of the feature. This programme may help architects with their projects but it does not provide specialized software for architect drawings. These results in the use of many kinds of

unspecialized software and so schools of architecture and architects' offices find it difficult to decide what software they should teach and use.

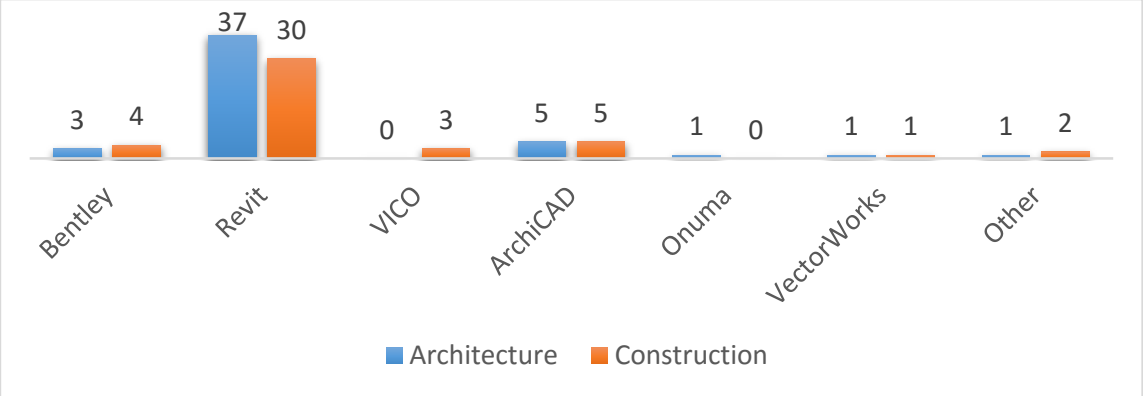



*Fig 2-12: BIM Technology taught in US universities (Joannides et al., 2012)*

As BIM is process and technology, the PhD project covered some of the aspects related to BIM technology. There are many BIM tools have used by the industry and being taught by AEC education sector such as 'Revit package – Tekla – ArchiCAD – Solibri'. In the AEC education sector field, the choice of the BIM computer programme should be built on what is the best for their students. In addition, the ability in utilizing some of BIM tools could assist students seeking employment (Rodriguez, 2014). However, the AEC Industry can have a direct impact on what computer application should be chosen. For example, the New Jersey Institute of Technology, College of Architecture and Design has taught their upper undergraduate architectural students BIM through individual classes (Barison & Santos, 2010a; Mandhar & Mandhar, 2013). Demand of architectural firms for qualified junior architects in BIM and the use of Revit Architecture has led NJIT to teach it within the curricula (NJIT, n.d). In 2007, The University was awarded 'Revit BIM Experience Award' by the Autodesk Inc. for Creation of Fully Digital Approach to Architecture Programmes (Autodesk, 2007a; Barison & Santos, 2010a; Rudesill, 2007). Embedding BIM into the curriculum in the New Jersey School of Architecture (NJSOA) has benefited students in making design decisions which consider issues beyond aesthetics, such as sustainability, cost and designing a constructible façade (Rudesill, 2007).

Generally, the Autodesk software "Revit Architecture" has been used widely within universities in the United States to teach Undergraduate Architecture Programme

(Alshanbari, Giel, & Issa, 2014; Aly, 2014; Joannides et al., 2012; Rodriguez, 2014; Sabongi, 2009) According to Joannideset al. (2012), more than 70% of the surveyed universities use Revit Architecture and the other 30% use one of six other software programmes including ArchiCAD and Bentley (Joannides et al., 2012) (see Fig 2-12). Moreover, more than half of the responded universities have taught Revit Architecture which almost similar to the number of universities who have taught AutoCAD, according to ACSA (Association of Collegiate Schools of Architecture, 2010-11). However, BIM is a new approach and technology used to design and construct projects and it is this new technology that should be introduced to students. In UK, more than 79% of CMC responses were adopted Revit (Architecture – Structure – MEP), and 45.6% of them were used Navisworks followed by 42.1% who used Sketch Up (Underwood et al., 2015)

### 2.3.3 *BIM Forums*

Recently, in some of the developed countries several BIM groups have been created; the National BIM Standard-United States™ NBIMS-USA, building SMART alliance™, The BIM Academic Forum-UK and BIM education-Australia. These forums have worked in tandem with AEC Industry and AEC-ES to improve the quality of buildings and to provide the AEC Industry with a qualified AEC juniors. Some of them have layout a framework to embed BIM within AEC education, such as BIM Academic Forum BAF in UK (Underwood et al., 2015)and BIM Education in Australia. On the other hand, the NBIMS-USA is trying with AEC colleges to reach a censuses level in how BIM should be embedding within AEC programmes; that presents on the aim of the latest conference the BIM Academic Education Symposium in 2014 (Rodriguez, 2014).

- **BAF initiation Framework**

The BIM Academic Forum BAF has developed a BIM learning outcomes framework (BIM Academic Fourm, 2013). They suggest that each university which is planning to embed BIM have to consider its own approach based on number of factors; they do not need to adopt the latest approach (BIM Academic Fourm, 2013). Moreover, the architectural undergraduate programmes in UK is a three level programme; level 4, 5, and 6. From a workshop session,

the BAF has described the potential learning outcomes based on UK HEI (BIM Academic Fourm, 2013).

*Table 2-1: Presentation of learning outcomes (BIM Academic Fourm, 2013)*

| Level | | Knowledge of understanding | Practical Skills | Transferable skills |
|---|---|---|---|---|
| Undergraduate | **4** | Improve of collaboration<br>The Business of BIM | Introduction to technology used across disciplines | BIM as Process/Technology/ People/policy |
| | **5** | BIM concept – construction processes<br>Stakeholders' business drivers<br>Supply chain integration | Use of visual representation<br>BIM tools and application<br>Attributes of a BIM system | Value, lifecycle and sustainability<br>'Software as service' platforms for projects<br>Collaborative working<br>Communication within inter-disciplinary teams |
| | **6** | BIM across the disciplines<br>Contractual and legal frameworks/regulation<br>People/change management | Technical know-how: Structures and materials<br>Sustainability | Process/Management<br>How to deliver projects using BIM<br>Information and data flows<br>BIM Protocols/EIR |

The key learning outcomes from each stage has divided into three levels based on the academic levels. Year one 'Level 4', students will gain an overall understanding of the current situation of AEC Industry and then the need of improvement. Moreover, they will be introduced to how the data has been prepared, issued and shared; and what is the role of BIM in that case. In year two 'Level 5', students will gain knowledge and understanding of the role of BIM within the business and collaborative work within an integrated supply chain. The last year 'level 6', students will be focusing more on building competence and knowledge relating to people, process and system based on BIM adoption (BIM Academic Fourm, 2013).

- **IMAC Framework**

In Australia, undergraduate students from AEC Australian Universities were provided with BIM presentation by The Association of National Specialist Colleges NATSPEC for the past 4 years (NATSPEC & Rooney, 2015). BIM education framework was developed by Jennifer Macdonald and CodeBIM; it called IMAC framework (CODEBIM, n.d; Macdonald, 2012)

(Fig 2-13). The IMAC BIM framework designed to help educators benchmark their courses in order to improve collaborative design within AEC-ES. It aims to redevelop an existing curricula from University of Technology Sydney UTS, University of South Australia UniSA and University of Newcastle UN. The IMAC framework is divided into four stages and different level of achievements; Illustration, Manipulation, Application and Collaboration. These stages were linked with the Bloom's taxonomy. The following describes each one of the four stages:

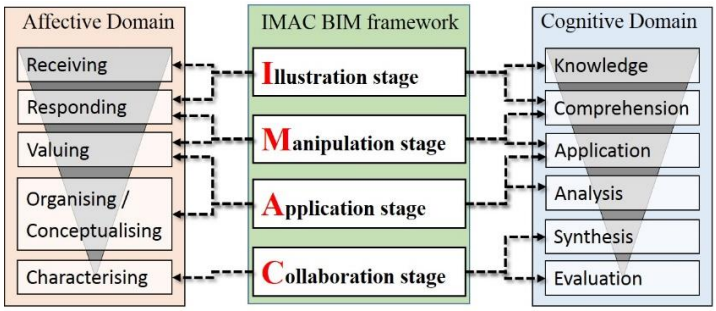



*Fig 2-13: The four stages of BIM framework linked with the Bloom's taxonomy (Macdonald, 2012); this graph developed by the researcher*

1. Illustration stage:

This stage aims to be an introductory stage where the concept of BIM will introduce to AEC students. Each department will use a well-developed BIM model to explore the building. The BIM model will help lectures/tutors to highlights some of BIM components/connections in order to help students to understand how buildings work.

2. Manipulation stage:

Students, in this stage, begin to use an existing BIM models. They will be asked to make few changes in the BIM model and/or create basic elements. Moreover, student will develop their skills in IT, teamwork.

3. Application stage:

Students have to have a basic theoretical knowledge about their major and understanding how to apply their knowledge to solve discipline-related problems. Architecture students

will build their BIM project from the beginning and develop their skills in setting the BIM model for the teamwork. Engineering students will learn how to analyse the BIM model by using BIM tools. Students in the construction department will develop 4D and 5D schedules along with materials take-off and site logistics using BIM model from other disciplines. All of them will be introduced to the value of engineering and sustainability; and how they could work with other disciplines and sharing data.

4. Collaboration stage:

In this stage, students' cross-disciplines will be work together in a shared project. Students will help each other to understand matters in relation to their majors in order to close the gap between AEC departments. A partly or finished BIM models could be an assignment for them to make some changes. Also, students will learn the different types of contract between teamwork.

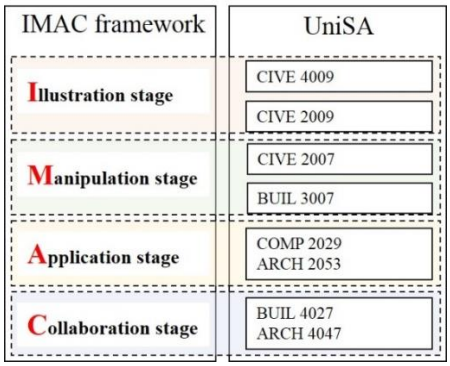



*Fig 2-14: Linking the IMAC framework with UniSA's modules*

The IMAC framework has helped to develop undergraduate AEC programmes in several Australian Universities. For example, students in UTS have taught BIM collaboration through IDP studio which is a multi-disciplinary studio (NATSPEC & Rooney, 2015). In UniSA, they have taught their students with similar approach. According to CodeBIM website (n.d.); the UniSA has linked their modules with the IMAC framework see Fig 2-14.

- **Comparison between IMAC and BAF framework**

Although, the BAF framework is an initiation framework, but the concept in how to embed BIM within curricula was seen from different perspective. The different between the IMAC

framework and the BAF initiation framework is that the four stages in the IMAC framework has not linked yet with the academic year (Macdonald, 2012; NATSPEC & Rooney, 2015), in comparison with BAF framework where its linked. The IMAC framework gives universities a choice in when they should to introduce BIM to their students. In this case, the framework may adopt differentially, and they will have different outputs. On the other hand, the BAF initiation framework gives a clear structure for what should be the output from each academic level. This can, in some level, unite the AEC-ES's output; but this framework is designed from a three years programmes.

Moreover, the first two levels in the IMAC framework aiming to give an overall concept about BIM by teaching students the concept of BIM then exploring a BIM model. After that, students start to use BIM tools based on their knowledge from the previous two levels. On the other hand, the BAF framework starts with BIM technology along with the concept of BIM, then students will learn the lifecycle of the project in the second academic year and collaboration in the third academic year.

### 2.3.4 *BIM Integrated Design Studios*

There are several examples in how BIM has been taught using Integrated Design Studios. If fact, the concept of teaching BIM using IDS has introduced in several countries such as US, Australia, UK, Finland (CODEBIM, n.d; NATSPEC & Rooney, 2015). Using BIM via a IDS has help to improve personal skills, knowledge and communication for students. Briscoe states that using BIM in Integrated Design Studio has not only help students to make their design decisions it has helped them to look to the beauty side of the buildings when they decide the materials (Pihlak et al., 2011). The following shows three interesting case-studies in how BIM has been integrated within an Integrated Design Studio.

- **The Penn State University Inter-disciplinary design studio:**

The concept of their studio was gathering students from six departments to work in an Integrated Design Studio (architectural engineering–construction, architectural engineering–mechanical, architectural engineering–construction, architectural engineering–lighting/electrical, architectural engineering–structural, architecture). (Barison & Santos, 2010a, 2010b; Mandhar & Mandhar, 2013; Onur, 2009; R Sacks & Barak, 2009). Their

programme has started in 2009 (Poerschke et al., 2010); and it has been awarded by NCARB (NCARB, 2011), ACSA (Association of Collegiate Schools of Architecture, 2010-11) and National AIA (Pihlak et al., 2011). However, the team within the BIM Integrated Design Studio has architecture and landscape architecture students from the fifth year, and students from different departments were from fourth year (Pihlak et al., 2011). Moreover, BIM has been taught within the six departments (Mandhar & Mandhar, 2013; Pihlak et al., 2011). That has help students cross-disciplinary to understand the concept of BIM and how to work with other groups.

Although, there was a concern about the influence of engineering students on the creativity of architecture and landscape architecture students, one of the most significant findings was stated by Professor Sam Hunter is that the teams who were able to manage conflicts lead to the most innovative building from all participants' perspectives (Pihlak et al., 2011). In addition to the benefits of teaching Integrated Design Studio using BIM, Dr. Hunter found that such method has developed the most creative learning environment because of the equality of expertise of each student (Mandhar & Mandhar, 2013; Pihlak et al., 2011).

- **Columbia University C-BIP**

The IDS in Columbia University is designed from the fourth semester of the master degree in architecture. In each year, the Columbia University C-BIP invites a group of consultant between five to eight professionals. This group consists of software consultant environmental engineers, and a few mechanical engineers who will help to run the IDS (Pihlak et al., 2011) Students asked to develop a building element from scratch and work with other disciplines; they work back and front to reach a well-develop element (Marble, 2012).

However, the effort added by other disciplines to the class was below than the expected level (Marble, 2012). They expectation was to have a real architecture firm with its consultants from other disciplines. The interviewee stated that they will improve that in the future. Moreover, They experience with and the dynamic of the IDS was fascination (Marble, 2012). He said, they have arranged the work on different buildings at different scales in different

ways (Marble, 2012). At this point, the architecture studio in the Columbia University has got a new identity by organizing an IDS with professionals.

- **Comprehensive Design Studio at Oklahoma State**

Students along with educators and practitioners have started to use BIM within their comprehensive design studio during the summer time in 2010. The students were selected from upper level of their academic level. According to Stivers (2012), the learning curve for the three groups in how to use BIM was very steep (Stivers, 2012). He has mentioned that the use of BIM has increase their proficiency (Stivers, 2012). However, the learning curve for students was affected by the amount of information and the new way of the design development and construction, and the course period (Stivers, 2012).

- **Observation**

The Penn-State University, Columbia University and Oklahoma University were three different examples in how BIM can be taught within IDS. Although, there is a lack of academic resource about evaluating those examples, the few resources reveal that teaching BIM using IDS can benefits students. The following are some highlighted points:

1- BIM can be introduced in early stage or in the upper level.
2- The team of IDS can be organised from students from different departments and/or practitioners and/or educators.
3- They may start with a small task “building element to be develop” then having a big task.

### 2.3.5 *Challenges and Difficulties for BIM Education*

BIM has been embedded within the AEC-ES in many ways. It has been taught in early stage of academic programme and/or in upper level only. There have been recoded that BIM technology and/or process introduced differentially; IDS “inter/multi/trans-disciplinary and distance learning”. In some cases, professionals and educators have played a significant role by participating in the IDS. The new ways of teaching have caused several challenges to embed BIM within AEC-ES. Each disciplines has different challengeable issues; these issues

could be summarized in difficulty with BIM computer applications, issues related to academic environment and issues related to students' learning curve.

First, modelling using BIM technology is not easy for students and educators who have lack of experience in BIM tools (Taylor et al., 2007; Woo, 2006; L. Yan & Shirong, 2013). For example, in Woo (2006) case study, students suffered from learning Revit as BIM based technology (Woo, 2006). They were struggling to understand the concept of having an element linked with its data. However, students will have a great level of understanding of how buildings work when they finished the BIM model (AIA, 2008; Repko, 2012). It has been stated by Peterson et al. (2011) that BIM technology may mislead students from the actual course content (Peterson et al., 2011). Also, teaching educators to use BIM tools is more challengeable, BIM becomes a problem for who have lake of IT skills (Gordon, Azambuja, & Werner, 2009).

Second, there are several issues that have been pointed out by academics in relation to academic environment. For example, it has been mentioned that the current curriculum has no room to teach BIM within the AEC-ES (Kocaturk & Kiviniemi, 2013; NATSPEC & Rooney, 2015). Moreover, the change of teaching habits which has been excited for decades to the new method (NATSPEC & Rooney, 2015). The lack of BIM materials and the support given by educators were indicated as BIM challenges in the AEC-ES (C. M. Clevenger et al., 2010; Sabongi, 2009; L. Yan & Shirong, 2013). The limited time to teach BIM where several scholars think that single semester is not enough to introduce such a new method (Holland et al., 2013; Stivers, 2012; Wu & Issa, 2013).

Third, managing students in IDS is more challengeable and difficult. When teaching BIM from a multiple disciplinary, educators need to be sure about the students background, level, learning objective, teaching responsibilities and curricula outline (Poerschke et al., 2010; Underwood et al., 2015). Some of these IDS may have more than 80 students which require a large studio (NATSPEC & Rooney, 2015). Also, students need to develop their time management skills, as it has been required to help students with the new method (Stivers, 2012). However, the outcome of teaching IDS using BIM is uncountable. These matters could be solved through developing the curriculum to achieve the objectives of each

disciplinary (Onur, 2009); and to have a multi experts in BIM, no one could cover all the aspects in BIM and building lifecycle (Woo, 2006).

Moreover, teaching AEC students in a mono-educational system using BIM will have a negative impact on IDS concept (R. Sacks et al., 2010). Although, BIM has been taught in the AEC-ES in many ways, there is still a lack of understanding the concept of Integrated Design Studio IDS. A survey conducted by Wu and Issa (2013) in US reveals that the lack of understanding of the IDS using BIM is one of the most noticeable weaknesses for AEC-ES. In general, most of the defects which have been highlighted by the survey are related to the lack of IDS cross-disciplines, a lack of understanding of BIM work-sharing and strategic BIM implementation (Wu & Issa, 2013). Generally, The demand for IDS using BIM in AEC Industry has increased and is sometime employers are looking for when recruiting new workers (Aly, 2014). Hence, AEC-ES needs to look at how they can embed BIM within their programmes using IDS to enhance the Collaborative Design Approach in order to achieve the AEC Industry needs. In comparison with the stand-alone classes, students will gain great benefits such as being more realistic and knowing how and when they need to use the tools of BIM (Mandhar & Mandhar, 2013). However, it may be difficult for students to problem solve if there are gaps in their knowledge (Mandhar & Mandhar, 2013). Moreover, such methods require more time so that teams and materials can be organized, which will affect the semester timeline (Mandhar & Mandhar, 2013).

In general, the design process within construction industry is transforming. The big data within the AEC Industry has caused this transforming which needs to change. These data such as; materials, assembly and construction management, analysis (environmental issues, circulations, loads) and new technology. To this end, most of the Architectural School are struggling to keep up with these changes in the AEC Industry. Along with this, architecture studio design which is the core of the architecture curricula is kept isolated from the rest of modules (Kocaturk & Kiviniemi, 2013). The architecture curriculum has been designed to support the architecture studio design; it should be a matrix connection.

| 2.1 | 2.2 | 2.3 | 2.4 | 2.5 | 2.6 |
|---|---|---|---|---|---|
| BIM | BIM within AEC Industry | BIM in Academia | BIM Framework | BIM in KSA | Summary |

## 2.4 The need of BIM framework for education

Although, these examples of how BIM has been introduced within the curricula have a significant impact on the output of the AEC education sector, most of scholars in the field of BIM education believe that teaching BIM within the AEC curricula will positively benefits students in the design communication and the design process (Holland et al., 2013; Stivers, 2012; Vinšová et al., 2014). Moreover, students will start to learn how to improve their project based on building performance (Holland et al., 2013; Mandhar & Mandhar, 2013). It is more likely that AEC students with BIM skills find a better job. It has been stated that teaching BIM for AEC students will help them to apply for better job (Azhar, Sattineni, & Hein, 2010; Salazar, Mokbel, & Aboulezz, 2006; Stivers, 2012; Wu & Issa, 2013).

However, there are some concerns about the level of effect in teaching BIM without strategic control within architecture programmes. Most of the case-studies show that BIM has been taught within a studio design or/and through stand-alone classes (Azhar et al., 2010; Barison & Santos, 2010b; Kocaturk & Kiviniemi, 2013; Liu, 2010). Although, these have helped to improve their knowledge, it may mislead students or limit the benefits of BIM for students (Stivers, 2012; Wu & Issa, 2013). For example, designing using BIM technology has helped architecture students to predict how building will be. However, students have spent more time in rendering rather than solving problem (Aly, 2014).

The need of BIM framework for education is increasing to produce qualified architects to work in the AEC Industry (BIM Academic Fourm, 2013; Eadie, Comiskey, & McKane, 2014; Gray, Gray, Teo, Chi, & Cheung, 2013; Mathews, 2013; Wu & Issa, 2013). Hence, to gain a significant benefits from teaching BIM within architecture programmes, Building Information Modelling (BIM) needs to be a gradually embedded within architecture programmes and linked with the rest of modules. Kocaturk and Kiviniemi (2013) suggest that to teach BIM, schools need to embedded it gradually instead of “add and stir” method

(Kocaturk & Kiviniemi, 2013). Moreover, they recommended that BIM has to have a connection with other subjects in the curriculum (Kocaturk & Kiviniemi, 2013).

| 2.1 | 2.2 | 2.3 | 2.4 | 2.5 | 2.6 |
|---|---|---|---|---|---|
| BIM | BIM within AEC Industry | BIM in Academia | BIM Framework | BIM in KSA | Summary |

## 2.5 BIM within the Kingdom of Saudi Arabia KSA

The Kingdom of Saudi Arabia is one of the biggest countries in the Middle East and has one of the largest and rapidly growing construction sector (Deloitte, 2014). The KSA is leading the Middle Eastern countries in the value of their projects by one trillion US Dollars (Deloitte, 2014). However, there have been several cases where AEC Industry in KSA shows its weaknesses in facing economics and cultural issues. From 1980 to 2015, KSA has two economics boom; the First was in the seventies and the KSA now living the second period of economic boom (Alhowaish, 2015).

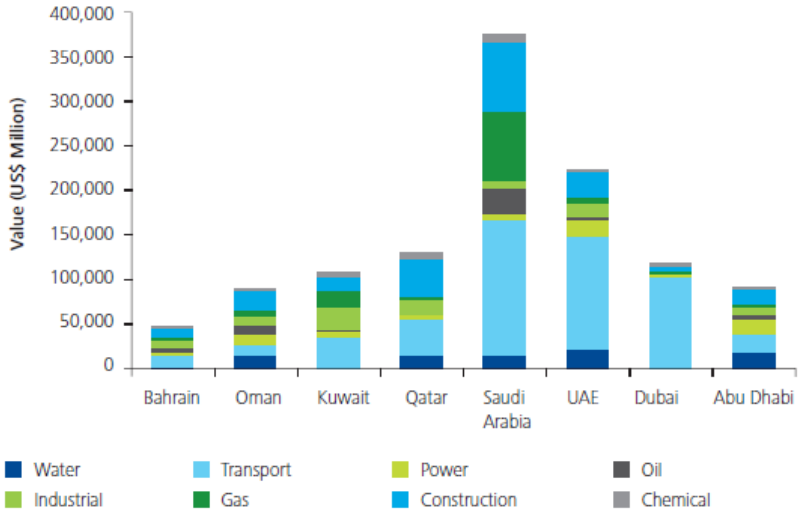



*Fig 2-15: Value of projects 2014 to 2020 (all sectors) within Middle Eastern countries (Deloitte, 2014)*

In the first period, the revenues from oil has brought remarkable financial support to the Saudi AEC Industry (Ikediashi et al., 2014). Within this period, it has been stated that more than 75% of projects were KSA government projects (CDS, 1994). However, the economic

boom did not last, the KSA had a negative experience with the economic crisis in 1980s. (Alhowaish, 2015; Ikediashi et al., 2014). The oil price dropped down which has caused many issues to the Saudi government's projects. According to Ikediashi et al. (2014), the Saudi government had to decide either abandon projects or renegotiate the payment issues with contracts (Ikediashi et al., 2014). In some cases, the Saudi government had switched from complex projects to more basic and to rely on local construction companies more than international construction companies (Al-Sedairy, 2001).

In the last decade, there has been a significant growth within the KSA construction sector which appears to be the second economic boom (Alhowaish, 2015). To a large extent, this growth is triggered by a number of mega-projects started by Saudi Government within housing, transportation and utilities sector, with project value exceeding one trillion dollar (Deloitte, 2014) (see Fig 2-15). This include projects such as construction of 11 new sports stadiums, with a capacity of 45,000 fans (Al-Arabiya-News, 2014). Complexity and scale of these projects have attracted many foreign construction companies to work in KSA building sector.

In term of cultural issues, there are some studies show that many of the AEC Industry's issues in KSA are caused by the lack of knowledge, management and experience in the project lifecycle (Jannadi, 1997). Besides that, the need of Saudi workers to cover the shortfall in personnel, as it has been stated that the Saudi AEC Industry has a lack of Saudi Architects and Engineers (Almsheeti, 2014). Although, Saudi Universities are providing the AEC Industry with a graduated architectural and engineering juniors, the output has not reached the expectations of the AEC Industry.

With the massive construction projects in KSA and the cultural issues, several international construction companies have started partnerships with local companies and firms. This would help to finish projects with a high standard level and to leverage the knowledge of the local companies and firms in solving their cultural issues. Anecdotal evidence suggests that many foreign construction consulting and contracting firms are using BIM based technologies and processes to support major construction work. However, there is limited drive on BIM uptake from the public sector owners. In KSA, the needs of BIM expertise has

increased significantly because of international construction companies working in KSA (Construction Week, 2013). That shows in the number of jobs' advertisement; the internationals companies are seeking more than 50 BIM position to be fill up by Saudis employees (glassdoor, n.d). Moreover, as the Saudi government's projects have to be designed, constructed and operated effectively in order to reduce the carbon dioxide and saving money, some of these projects have been decided to be delivered using BIM. For example, the 11 stadiums have been considered to be designed and constructed by using BIM (saudi-gazette, 2014).

In the Middle East, there are only limited examples of BIM adoption within the AEC Industry and academia. Although, Middle Eastern countries have many mega-projects, local architectural firms and construction companies show no signs of implementing BIM within their systems (Mandhar & Mandhar, 2013). Moreover, there are two recorded case studies which show that the University of Al-Shajah in the UAE and Aim-Sham University in Egypt have both taught BIM as stand-alone BIM class (Mandhar & Mandhar, 2013). However, from the social networks, the interest in BIM within KSA AEC Industry seems to be rapidly increased. In Linked-In website, there is a small group called "BIM Users in Saudi Arabia" created to share and discuss matters in content of BIM and KSA (Manago, 2013). Noticeably, the group creator and most of the members are non-Saudis. This has even noticed in the Facebook BIM group (Facebook, 2012).

### 2.5.1 *Architectural Programmes in KSA Universities*

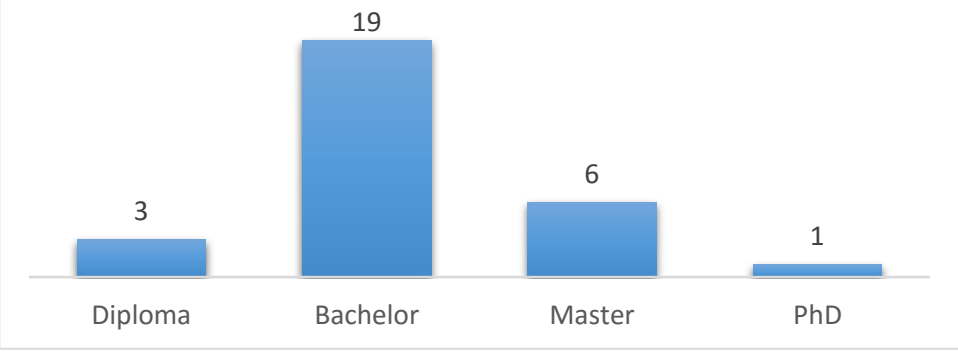



*Fig 2-16: Architectural Programmes Offered in Saudi Arabia Developed from the HESC report (HESC, 2014)*

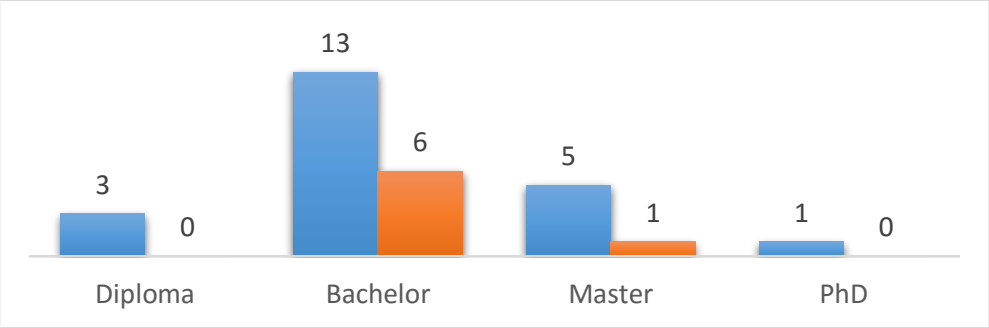



*Fig 2-17: Architectural programmes based on gender Developed from the HESC report (HESC, 2014)*

The aim of this research is to embed BIM within Undergraduate Architectural Programmes within KSA, by allowing students to experience the benefits of using BIM in a collaborative context. There are three different faculties "Engineering, Environmental Design; and Architecture and Planning" where the architecture programme has taught. Each faculty has its own curriculum and a different department, which is different from other faculties. Different administrative setup poses key challenges in this research. According to Higher Education Statistics Centre HESC, there are 18 architectural undergraduate programmes, 3 diploma, 5 master programmes and one PhD programme see Fig 2-16 (HESC, 2014). Furthermore, in comparison with the number of architectural programmes offered for the two genders, there are 22 programmes for males and 7 only for females see Fig 2-17 (HESC, 2014).

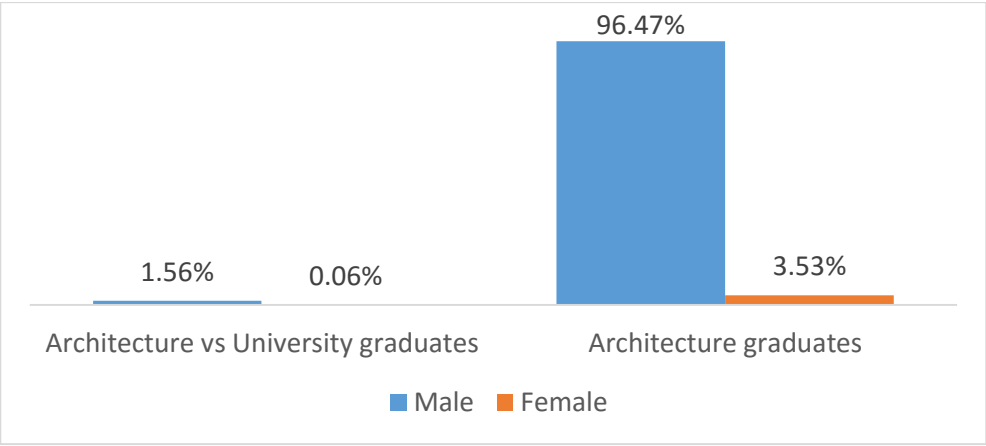



*Fig 2-18: The percentage of both genders graduate from architectural programmes in KSA (Al-Saih, 2013)*

Considering the number of projects in KSA and the need of architectural expert, the numbers of graduation students from both genders do not meet the needs of the labour. According to Talal (2013), in 2012, the number of architectural Saudi students' graduates from Saudi universities for both genders comparing with the number of all graduates was less than 2%, see Fig 2-18 (Al-Saih, 2013).

According to the Director of Public Relations at the Saudi Council of Engineers (2013), Engineer Nasser Abdullatif, the number of architects and engineers in KSA exceeded 175 thousand as the number of Saudi architects and engineers are 11,500 (Almsheeti, 2014) (see Fig 2-19). In additional to the low number of Saudi architects' graduated from architectural programmes in KSA, the quality of the outcome has not reached the expected level of the Saudi AEC Industry. Dr. Turkistani summarised his survey about the appropriateness of Saudi university graduates for the labour market in four issues; the graduated students have a lack of experience, lack of communication skills in English, lack of understanding the collaborative teamwork and curriculums not cope with the AEC Industry needs (Turkestan, 2009).

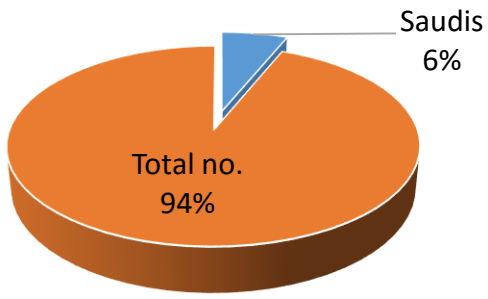



*Fig 2-19: Engineers and Architects within KSA (Almsheeti, 2014)*

There are two different Undergraduate Architectural Programmes taught in KSA; Architecture and Architectural Engineering. The differences between Architecture and Architectural Engineering programmes show in the content of the curriculum and the title of their bachelor degree. In term of the curriculum, one of the most significant differences between the two programmes is the number of Studio Design provided within the curriculum. For example, In one case, these two programmes have taught in one university; King Fahd University of Petroleum and Minerals KFUPM (KFUPM, n.d), in Undergraduate

Architecture Programme, they have eight Studios comparing with four in UGAEP (Architectural-Engineering-Department, n.d; Architecture-Department, n.d). There are several differences between two programmes; number of structure modules, MEP classes and so on. There are two programmes in Al-Baha University BHU and Umm-Al-Qura University UQU are taught as an Architectural programmes but students are being awarded the title of the Architectural Engineering.

The last few years, the KSA universities have made some changes on their educational system; students have to enrol in a preparatory year before pursuing their undergraduate programmes. Those have affected the length of getting a bachelor degree in KSA Universities including architectural programmes. Because of that some of the Undergraduate Architecture Programme have changed their programme length from five years to four year programmes; and other are planning to develop their curriculum to reduce the years. The Fig 2-20, designed using universities' websites, shows the impact of the preparatory year on the length of graduation years.

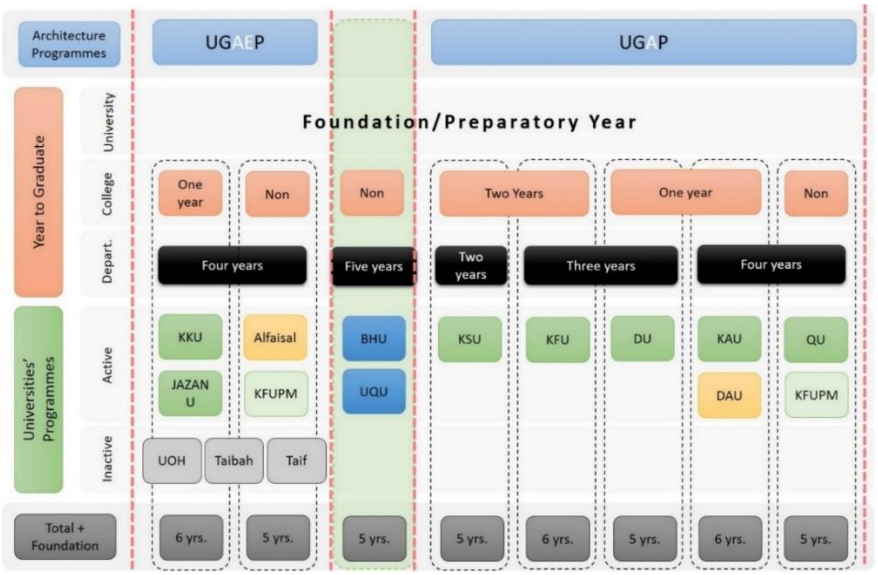



*Fig 2-20: Undergraduate Architecture Programme taught in KSA and the year to graduate (Designed based on universities' websites)*

From Fig 2-20, some programmes do not have a college year where student joins the college to study the first year as general then choose their future major. In other case, King Faisal University and King Saud University have two joint years. The number of joint years may

guide students to decide which degree he/she will pursue in the future, but that will not give them the knowledge in how to collaborate with other disciplinary. Most of the joint year's subjects are general and basic knowledge students have to understand them before choosing their major.

However, the aim of designing the Fig 2-20 is to show that there are around 16 universities in KSA, and almost each one of them has its own methods in teaching architecture. Although, there are some differences between universities in the number of years to graduate and if there is a joint year/s of not, their curriculums are significantly similar. For example, based on their curriculums, most of them have in each semester a studio design, between two to three MEP subjects and one or two working drawings classes.

### 2.5.2 *BIM within Saudi Architectural programmes KSA*

There is no sign of embedding BIM within Architectural programmes in KSA, but BIM technology has taught within the curricula (Mandhar & Mandhar, 2013). Moreover, Tekla, one of the international construction companies and software developers, has started to introduce BIM Architectural schools in order to fill a need in the private sector for BIM users (Construction Week, 2013). Autodesk works with a local company "Dar Al Riyadh" to leverage the knowledge of students in BIM (ConstructionWeek, 2012). There are a lack of information in this area, which will lead the PhD research to investigate that part. The PhD research will face some challenges during the process of designing the framework for embedding BIM within a multidisciplinary studio in Undergraduate Architecture Programme.

| 2.1 | 2.2 | 2.3 | 2.4 | 2.5 | 2.6 |
|---|---|---|---|---|---|
| BIM | BIM within AEC Industry | BIM in Academia | BIM Framework | BIM in KSA | Summary |

## 2.6 Summary

BIM as process and technology is a new way of managing the whole design process. It has several definitions, depends on the background of the definers. Some of scholars have

defined as a technology, other see it as a process. However, most of them prefer to say that BIM is a technology and process. BIM is an integrated design and delivery approach.

The growth of BIM within AEC Industry around the world is a significantly noticeable. The benefits behind the implementation of BIM which show in solving many issues within AEC Industry is the main deliver to this growth. It has improved the level of communications between disciplines, which leads to minimize conflicts and leverage the knowledge of the team. Moreover, it saves time in editing and redrawing; that leads to save the employees' working time. The benefits of BIM implementation has drove several governments to make the use of BIM mandatory; governments such as UK and USA. Along with that, number of construction companies and architecture firms have started to switch to implement the new method.

However, moving from the traditional method to the new method has some impacts on the technology and process. These can have a direct effect on people, cost and time. Firms and construction companies need to prepare their employees to be familiar with the new method. Hence, providing them with BIM technology and training them will cost them money and time. However, In fact, investment in BIM and the training of employees is actually cost-effective; in other words, the return of investment ROI is significantly noticeable with BIM integration (McGraw-Hill, 2014).

In addition, AEC Industry suffers from issues, which will have negative impact on the implementation of BIM, such as the lack of BIM users, resources and code of practice. The AEC-ES around the world have established to teach BIM within their curricula in order to reach the AEC Industry needs. Teaching BIM could be divided into two eras; stand-alone BIM classes and Integrated Design Studio. BIM was introduced as based technology until Penn-State University has developed a new concept in teaching BIM, which is the IDS.

The need of IDS is increasing within AEC Industry that has enhanced IDS using BIM to be taught within AEC-ES. Since the Penn-State University IDS, several ideas have been developed; inter-multi-trans disciplinary classed.

# CHAPTER 3

Research Strategies and Methodology

Sections

| 3.1 | 3.2 | 3.3 | 3.4 | 3.5 | 3.6 |
|---|---|---|---|---|---|
| Research Process | Research Philosophy | Research Design | Method of Data Collection | Data Collection Designs | Summary |

# Chapter 3. Research Strategies and Methodology

The research methodology in this chapter has been adopted in order to achieve the aim and the objectives of this research. This chapter starts with clarifying the research process used in this thesis. This is followed by discussing the research philosophy. Then, in the research design section, the chapter explains how this thesis will achieve each objective. After that, the methods and techniques which used to achieve the aim and the objectives of this research have covered in section 3.5. That is followed by the design used for each method.

| 3.1 | 3.2 | 3.3 | 3.4 | 3.5 | 3.6 |
|---|---|---|---|---|---|
| Research Process | Research Philosophy | Research Design | Method of Data Collection | Data Collection Designs | Summary |

## 3.1 Research Process

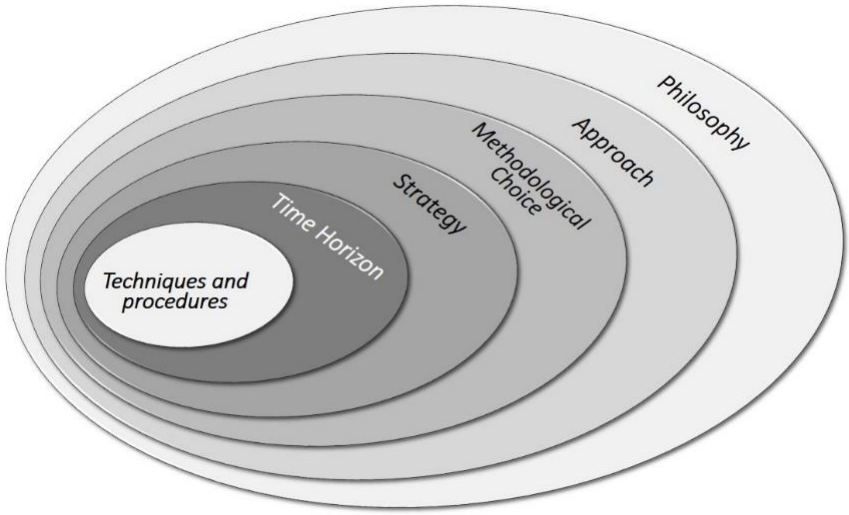



Fig 3-1: Onion model (Saunders et al., 2012)

The research methodology in this PhD research has built on the Saunders et al (2012) model. Their model is divided into six stages (see Fig 3-1) ; Philosophy, Approach, Methodological choice, Strategy, Time Horizon and Data collection techniques (Saunders, Lewis, &

Thornhill, 2012). The concept of the onion model is to begin in building the research methodology from outside 'Philosophy' to inside 'Techniques and Procedures.

| 3.1 | 3.2 | 3.3 | 3.4 | 3.5 | 3.6 |
|---|---|---|---|---|---|
| Research Process | Research Philosophy | Research Design | Method of Data Collection | Data Collection Designs | Summary |

## 3.2 Research Philosophy

It is an important for any researcher to understand the research philosophy from their research background. The research philosophy, according to Saunders et al. (2012), relates to the development of knowledge and the nature of that knowledge. Moreover, it leads to several assumptions in a way how researchers see the world and reality (Saunders et al., 2012). The research philosophy helps researchers to build a theoretical foundation based on the research objectives and questions. According to Easterby-Smith, Thorpe and Jackson (2012), the research philosophies are important for three reasons; 1) it will help researchers to clarify the research design, 2) to identify which research design will work and which will not and 3) to identify and create designs that may be outside their experiences (Easterby-Smith, Thorpe, & Jackson, 2012). In order to gain these benefits, the researchers have to understand the two assumptions "Ontological and Epistemological assumptions" within the research philosophies.

- **Ontology**

The ontology describes "what knowledge is" and assumptions about the nature of reality, it deals with question such as "what is the nature of being" (Saunders et al., 2012). It has been suggested by several scholars that the ontological considerations have two positions; Realism/Objectivism and Relativism/Constructivism (Easterby-Smith et al., 2012; Saunders et al., 2012). The traditional position of realism/objectivism emphasizes that the world is predetermined nature and structure. On the other hand, Relativism/Constructivism is an unknown reality and seen from different perspectives. Table 3-1 shows the differences between both positions.

*Table 3-1: Comparison between Realism and Relativism developed from(Easterby-Smith et al., 2012)*

| **Ontology** | **Realism (Objectivism)** | **Relativism (Constructivism)** |
|---|---|---|
| **Truth** | Single Truth | There are many truths |
| **Facts** | Facts exits and can be revealed | Facts depend on viewpoint of observer |

- **Epistemology**

*Table 3-2: Comparison between positivism and interpretivism/constructionism (Easterby-Smith et al., 2012)*

| **Epistemology** | **Positivism** | **Interpretivism/Constructionism** |
|---|---|---|
| **The observer** | Must be independent | Is part of what is being observed |
| **Human interests** | Should be irrelevant | Are the main drivers of science |
| **Explanations** | Must demonstrated causality | Aim to increase general understanding of the situation |
| **Research progresses through** | Hypotheses and dedications | Gathering rich data from which ideas are induced |
| **Concepts** | Need to be defined so that they can be measured | Should incorporate stakeholder perspectives |
| **Units of analysis** | Should be reduced to simplest | May include the complexity of 'whole' situations |
| **Generalization through** | Statistical probability | Theoretical abstraction |
| **Sampling requires** | Large numbers selected randomly | Small numbers of cases chosen for specific reasons |

There are several assumptions about how world knowledge can be accepted and acquired (Saunders et al., 2012), and it is concerned with the question (What is/should be). In term of the epistemology, there are two points views in how researchers should conducted; positivism and interpretivism/constructionism. The different between both aspects is that the positivism is the search for general laws and relations of cause and effect through rational; and the interpretivism/constructionism is an explanations of individual actions by human in

how they understand the world (Saunders et al., 2012). The table 3-2 adapted from Easterby-Smith et al. (2012) shows the differences between two areas.

The choice of the research philosophy for this research has influenced by considering the aim and the objectives of this research. First, the research choice is relativism (Constructivism) from the ontology that because there will be more than one truth which has been caused by different perspectives. Secondly, within the epistemology positions, the interpretivism/Constructionism will be the position of this research; this decision based on the table 2.

### 3.2.1 *Research Approaches*

Most scholars agree that there are three different research approaches; Deduction, Induction and Abduction. The relationship between theory and research could be driven by the choosing one of these approaches (Easterby-Smith et al., 2012; Saunders et al., 2012). The deduction approach presents when the researchers influenced by the question based on a theory; on the other hand, the induction is a building a theory based on case/s. The third approach is Abduction which taking the research frequency from theory to findings and back to theory (Saunders et al., 2012).

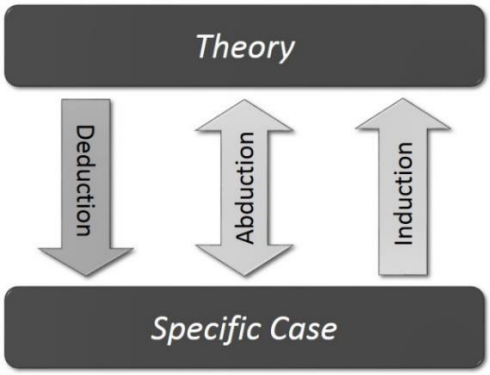



*Fig 3-2: The differences between the research approaches*

As there is no conclusion in how to embed BIM within the architectural programmes around the world, the research will build a theoretical framework to embed BIM within Undergraduate Architectural Programmes Undergraduate Architecture Programme in the Kingdome of Saudi Arabia KSA.

### 3.2.2 *Methodological Choices*

The research design is focused on the overall plan for the research, and it is different from the research techniques which will be explain later on this chapter. However, According to Saunders et al. (2012), the research design could be classified into three options; quantitative, qualitative and multiple methods (triangulation) which is a combination of both. The choice of the research design has influenced by the research question(s) and objectives (Saunders et al., 2012).

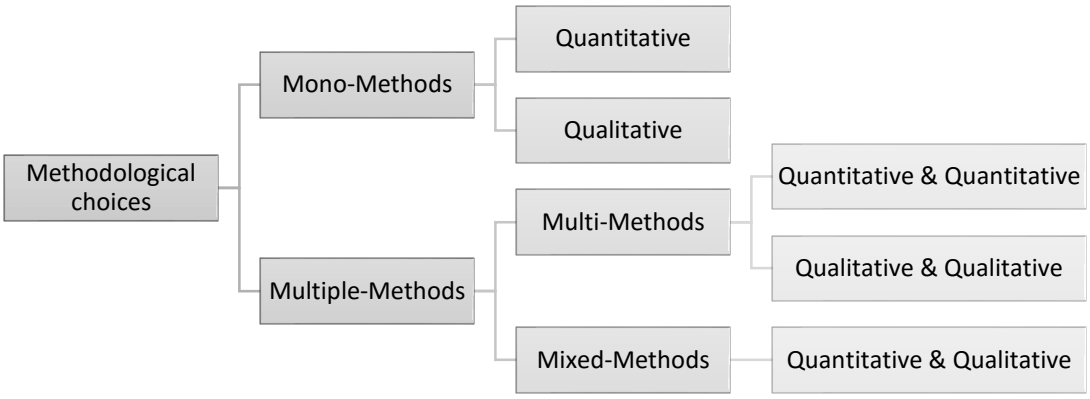



*Fig 3-3: Types of methodological choices (Saunders et al., 2012)*

- **Quantitative vs. Qualitative "Mono-methods"**

The differences between both options are characterized on the type of data, the quantitative studies is numeric data "number". On the other hand, the qualitative studies is non-numeric data "words, videos and imaging" (Saunders et al., 2012). There is a level of consensus about the position within the research philosophy for both options. When the researchers use a highly structured data collection, the quantitative studies becomes a positivism point-view (Newman, 1998; Saunders et al., 2012). On the other hand, with the qualitative studies, the research is associated with an interpretivism/constructionism philosophy (Saunders et al., 2012). However, according to Saunders et al. (2012), the positions of quantitative studies could be interpretivism/constructionism if the data based on opinion (Saunders et al., 2012); as presented on table 3.

*Table 3-3: Comparison between Quantitative and Qualitative (Creswell & Clark, 2007)*

| | Quantitative | Qualitative |
|---|---|---|
| **Area of research** | Scientific and quantity | Native setting and quality |
| **Research design** | Predetermined, structured | Flexible, emergent |
| **Sample** | Large | Small |
| **Gathering Data** | Inanimate instruments (tests, questionnaires, Surveys, computers) | Researcher as primary instrument, interviews, observations |
| **Mode** | Deductive data analysis | Inductive data analysis |

- **Multiple Methods**

This option has two areas of studies, according to Saunders et al. (2012), researchers have two multiple methods "Multi-method and mixed-methods"; see Fig 4. The differences between both methods show in how the researcher will gather information and how it will be analysed. For example, if a researcher has two stages of data collection and the decision made to use multi-methods, the researcher will be used for both stages quantitative or qualitative methods. On the other hand, if the researcher decides to use mixed-methods, in first stage, for example, the data collection starts with rather quantitative in the first stage followed by qualitative or with qualitative followed by quantitative studies.

| 3.1 | 3.2 | 3.3 | 3.4 | 3.5 | 3.6 |
|---|---|---|---|---|---|
| Research Process | Research Philosophy | Research Design | Method of Data Collection | Data Collection Designs | Summary |

## 3.3 Research Design

The data collection and the analysis were accompanied by the research design in a logical and structured manner to achieve the aim and the objectives of this PhD research. Hence, the five objectives of this research has linked with three research questions. According to Jupp (2006), an effective research design presents in how the research question associated with the research methods and techniques (Jupp, 2006). Therefore, the research design has been divided into four phases linked with the five objectives (Fig 3-4).

***The first phase*** is allied with the first objective, to undertake a state-of-the art review of the current strategies and attempts to integrate BIM within the Architecture Programmes. It has covered some well-known case studies such as Penn-State University, and accomplishment of BIM forums. The findings from this phase helped to identify the research gap, to design the research methodology and to develop the framework of embedding BIM within Undergraduate Architecture Programme in KSA.

***The second phase*** is linked with the second objective, *to review the existing approaches of BIM deployment within academia and AEC Industry in KSA.* It has been concluded in the literature review that there is lack of published material related to BIM deployment within AEC Industry in KSA and education. Thus, this phase is a preliminary study designed using the multi-methods quantitative data survey. The preliminary data has divided into two areas; BIM maturity level in both professionals and academics including students, and the Architecture Programmes system in KSA. The findings of this survey give:

1. An overall of understanding of the current situation and the future of BIM in KSA. This will help to determine the research methodology and to identify some key challenges facing the implementation of BIM within Undergraduate Architecture Programme and the Saudi AEC Industry.
2. Information in how architectural programmes in KSA have been structured, their future interest and the accreditation system used in KSA for architectural programmes.
3. A clarification in who have a proper level of experience in BIM and Architecture Programmes system, and willing to participate in the third phase of the research design.

In order to achieve these points, the multi-methods quantitative data survey has to attain the following principles; 1) identify the targeted group, 2) gathering the data within the time given, 3) and ensuring the credibility of the data. These principles have been covered in section 3.4 Method of Data Collection and 3.5 Data Collection Design and Procedures.

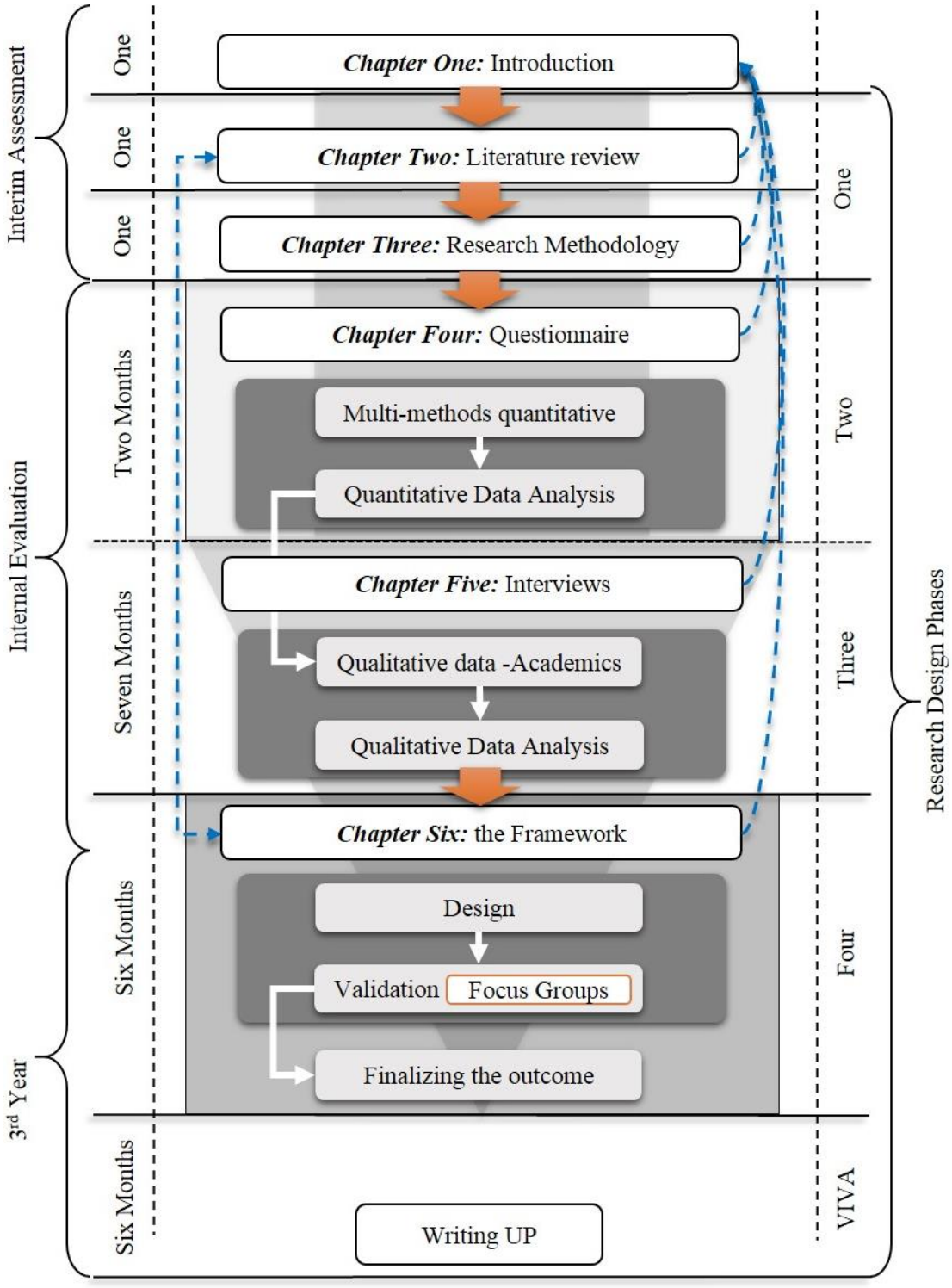



*Fig 3-4: The Research Process*

***The third phase*** is connected to the third and the fourth objectives, 3rd_ to identify key success factors pertinent to successful BIM adoption within architectural programmes in

KSA, 4th_ to develop the framework for embedding BIM effectively in the Architectural undergraduate programmes in KSA. As mentioned in section 3.2.1 Research Approach this PhD research has delivered by the outcome of the literature review in choosing the inductive approach. With this approach, according to Saunders et al. (2012), the best methodological choices is the qualitative data (Saunders et al., 2012). Hence, a semi-structured interview (qualitative data techniques) has been applied to achieving those two objectives. The findings will asset to develop the framework for embedding BIM within Undergraduate Architecture Programmes in KSA universities. To achieve that, based on the questionnaire in the second phase, participants will be chosen in relation of their expertise in Architecture Programmes system including the future studies and their level of BIM knowledge. That does not mean the participant has to have experience in in both areas. The sample choice will be clarified in the section 3.4.5 The Population and Sample Choice.

***The last phase*** is the validation of the developed framework which is the last objective; *5th_ to validate the developed framework with academics within architectural programmes and industry practitioners.* As the outcome of this framework will provide qualified architects to the AEC Industry in KSA with a mature level in using BIM, the validating should to have opinion from both sides, professionals and academics. That will help to bring together the theory of teaching and the life-experience. Therefore, focus groups as a qualitative data will be adopted to validate the framework.

| 3.1 | 3.2 | 3.3 | 3.4 | 3.5 | 3.6 |
|---|---|---|---|---|---|
| Research Process | Research Philosophy | Research Design | Method of Data Collection | Data Collection Designs | Summary |

## 3.4 Method of data collection

The research method has considered two different research styles; multi-methods quantitative studies and qualitative semi-structured interview. Each one of the chosen styles will help to achieve the research's aim and objectives, and each one of them has allocated within the research design. In the second phase of the research design, the multi-method quantitative questionnaire were used; then followed by the third and the fourth phase where

the semi-structured interviews were used as a qualitative method. The last phase, the focus groups (qualitative approach) was used to validate the framework.

### 3.4.1 *The Population and Sample Size*

The population is the complement of the sample size (See Fig 3-5). It possible to collect data from the entire population, but it is time consuming and it will affect the budget (Saunders et al., 2012). Therefore, using the sample size can help to get the seeking result with the right budget within the time given.

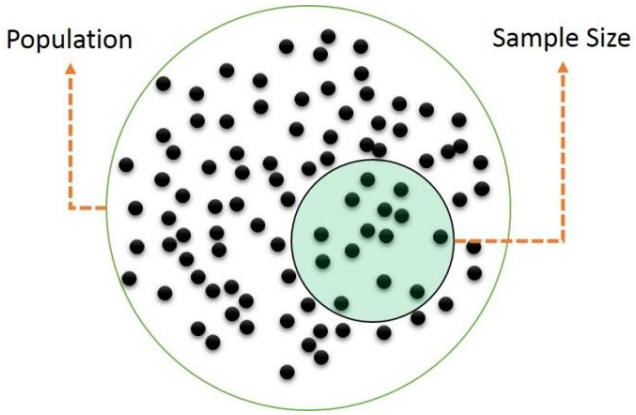



*Fig 3-5: The different between Population and the Sample Size*

The sample size is divided into two techniques; probability and non-probability. The probability means that each one from the population has chance to be chosen. In contrast, the non-probability is the probability not choosing equally (Saunders et al., 2012). According to Saunders et al. (2012), the probability is usually associated with survey research techniques (Saunders et al., 2012) which will be apply in the first phase of the research design. On the other hand, the non-probability is linked with the semi-structured/ in-depth interview (Saunders et al., 2012); and it will apply for the second phase.

- **Second Phase of the research design (Probability)**

1. The Population

Based on the research design, there are two targeted groups by this PhD project. In the first phase of the research design, the population for the preliminary study is 3395, which is

including AEC Industry profession and Architecture Programmes in KSA. In term of AEC Industry, there are 2785 construction companies, and 309 engineering consulting offices registered at the Ministry of Municipal and Rural Affairs MOMRA in Saudi Arabia (MOMRA, 2014). Although, the Saudi Council of Engineers SCE has more than 2000 registered architecture firms and more than 170000 specialists in the field of construction, the listed firms provided by MOMRA is more official than the SCE. Any company has accreditation from the MOMRA has the chance to work in any project in KSA based on their classifications (MOMRA, 2014). Therefore, the targeted professional group in this phase is the firms and construction companies registered in MOMRA.

The Architecture Programmes, on the other hand, there are more than 28 government universities and private colleges (HESC, 2014); 14 of these universities have an architectural programme and three are planning to establish the programme (see Fig 2-16 in section 2.5.1). Moreover, the architectural programmes in KSA has introduced through three different faculties in KSA; Engineering, Environmental Design; and Architecture and Planning. Hence, the cycle of this targeted group will be expended to include some of academics and students from other disciplines in order to seek their opinion about the BIM collaborative studio. Through universities' websites, it has been found that there are almost 200 faculties in architectural departments; some of them were accepted for a scholarship to get a PhD degree. For academics from other departments, it has been found that there are more than 400 faculties according to Saudi Universities' websites.

The last group is the architectural students studying in Saudi Universities or abroad. There are no records present the current number of architecture students within Saudi universities or abroad. At this case, a pilot study through an online questionnaire has been used to clarify the most effective number that will help to get an overall understanding about BIM from architectural students. From the result of the pilot study, the mean has been chosen as the number of architectural students for this PhD research; the mean is 82 architectural students (see the Pilot Study in appendix 3). The population size in this case is 3094 from AEC Industry profession, 600 academics within AEC educations and 82 architectural students; in total $N$=3776.

2. Sample Size

There are two different types of sampling size, continues and categorical. According to Kotrlik & Higgins (2001), the sample size number could be affected by the choice between these two types; it has to be considered by the researcher (Kotrlik & Higgins, 2001). If the variables are mostly categorical, the categorical formulas should be adopted (Kotrlik & Higgins, 2001). In this case, the data collection for this phase is a categorical type. Therefore, the formula which should be used is:

*Table 3-4: The sample size formula (Kotrlik & Higgins, 2001)*

| Formula | Description | | Result |
|---|---|---|---|
| $n_1 = \frac{n_o}{(1 + (n_o/N))}$ | $n_1$ | Sample Size | $n1 = \frac{384}{(1 + (384/3776))}$ <br> $n1 = 348.5$ |
| | $n_o$ | Required Return Sample Size, it will be 384 (Kotrlik & Higgins, 2001) | |
| | $N$ | Population | |

Similar result has been achieved using an active website called FluidSurvey to calculate the sample, which is 349 (FluidSureys, n.d) (see appendix 4). There is no big difference between these two results; where has been used $\pm$ 5% as the risk of this sample size (Kotrlik & Higgins, 2001), it is even called margin of error. Besides, the percentage of the confidence level is 95% which will help in reducing the risk (Israel, 1992).

- **Third Phase of the research design (Non-Probability)**

As aforementioned in the research design, this phase aims to design the framework for embedding BIM within the Undergraduate Architecture Programmes in KSA. The methodological choice for this stage is a semi-structured interview qualitative data. One of the second phase aims is to identify the targeted group in the third phase. The choice of the group will be mentioned in the Chapter Four: Results and Findings. However, the targeted group will be the academics in the Architecture Programmes s in KSA.

In this phase, the sample size depends on the level of consensus (Guest, Bunce, & Johnson, 2006). However, according to Saunders et al. (2012), the minimum sample size for a semi-

interview or in-depth interview is between 5 to 20 persons (Saunders et al., 2012). Moreover, Guest et al. (2006) states that 12 persons should be sufficed for reaching a consensus level (Guest et al., 2006). However, the number of interviewees for this research is 11 academics who are teaching in architecture programmes in KSA Universities.

The number based on who have agreed to be part of the second phase of this research. Participants were asked two times if they are willing to participant in the second phase. The first time was during the first phase of the data collection (the questionnaire). They have been asked in the end of the questionnaire if they want to be part of the second phase, if so, participants has given the choice to write their information (Name – Telephone – Email). Form this, the questionnaire has revealed 23 academics that are willing to participant for the next stage.

After designing the questions of the second phase (which has been described in section *Using semi-structured interviews*), participants were contacted by emails and phone. Because of the time period of this research and the availability of academics to set for interview, 11 academics have agreed to take the interview.

- **Fourth Phase of the research design (Non-Probability)**

The validation phase will be focus groups, bringing together professionals and academics to reach a consensus agreement on the framework. The sample size for the focus group presents in its definition, the focus group is a discussion group of six to ten participants (Berg & Lune, 2004). With this margin, the fourth phase will have two or three groups, and each group has both professionals and academics.

- **Research Ethics**

In term of researching, the researcher should to ensure credibility of research. Therefore, this PhD research will consider the following based on ensuring the credibility. For each phase of the research design phases, participant will be introduced to the topic and the purpose of each phase. Then for the second phase, the questionnaire, participants will be asked if they agree to participate or not. Participants who choose NO as an answer will be redirected to the Thank You Page. In term of the interviews and the focus groups, participant will be

receiving a "Letter of Invitation", which contains an introduction about the researcher, his topic and an invitation paragraph. If they accept the invitation, they will be given "Consent Form" to be signed by the participant. In all cases, the participant will be ensured that they could withdraw at any time without needing to give any reason. If they withdraw from the study all the information and data collected will be destroyed and you name removed from all the study files.

### 3.4.2 *Collecting Data*

- **Using multi-method quantitative data**

The questionnaire is one of the most popular data collection techniques (Saunders et al., 2012). Researchers may analyse the data as qualitative or quantitative depending on how those questions have been designed. Moreover, there are different techniques in how the data will be distributed and collected which could be classified into two types; Self-completed and interviewer-completed (See Fig 3-7 ) (Saunders et al., 2012).

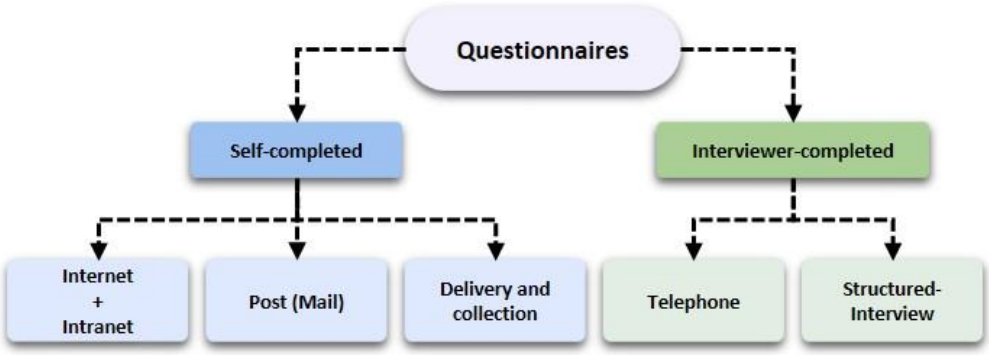



*Fig 3-6: Types of questionnaire (Saunders et al., 2012)*

There are three different types of the data collection techniques under the self-completed method; internet/intranet, post and delivery and collection (Saunders et al., 2012). To select appropriate research techniques, a comparison between those three types has made, see table 3-5. From the table and the aim of the preliminary study, the use of internet to distribute and collect data will help to cover a large sample in a short period of time comparing with other techniques. The using the internet technique has a highly confident that the right person will

respond to the questionnaire, but if the respondent has not got it through a direct link by his/her personal email the rate will be negatively affected.

On the other hand, the response rate in using the internet techniques is the lowest rate comparing with other techniques by 11% (Saunders et al., 2012). That could be improved by first, using a multi-method quantitative data (See the methodological choices section); which are an online questionnaire and a structured interviews. Second, sending the link of the online questionnaire by email to increase the confidently.

*Table 3-5: Comparing between self-completed methods Developed from (Saunders et al., 2012)*

| **Self-completed Methods** | **Internet/Intranet** | **Post (Mail)** | **Delivery and collection** |
|---|---|---|---|
| Confident that the right person has responded | High if using email | Low | Low, but could be checked at collection |
| Likelihood of contamination or distortion of respondent's answer | Low | May be contaminated by consultation with other | |
| Size of sample | Large | Dependent on number of field workers | |
| Likely response rate | • Within organization 30%-50%<br>• Using internet 11% | 30% - 50% | |
| Time take to complete | 2-6 weeks | 4-8 weeks | Dependent on size of sample, number of field workers, etc. |
| Data input | Automated | Closed questions can be designed so that responses may be entered using optical mark reader. | |

The second questionnaire technique is the use of a questionnaire form to interview people which is called interview-completed (Saunders et al., 2012). The data will be recorded by interviewees based on their answers. Interview techniques have three types; Structured interview, Semi-structured interview and unstructured interview/in-depth interview (Saunders et al., 2012). How questions will be designed and the way of asking them will state the type of the interview.

The choice of this research is the structured interview "Face to face and Telephone", where the interviewer will ask interviewees based on the questions in the questionnaire. The purpose of using this technique is to improve the data credibility in increasing the rate of responses. Furthermore, the research needs to be supported by opinions' of who have a great experience in the AEC Industry and the education; hence, the interview will be grantee that the chosen people will be respond.

Table 3-6: Comparing between interview techniques

| **Interview** | **Structured** | **Semi-structured** | **Unstructured** |
|---|---|---|---|
| **Questions** | Predetermined list of questions | ⟷ | No predetermined list of questions |
| **Technique** | Direct questions as written | ⟷ | Ask questions about the area concern with indirection |
| **Type of data** | Quantitative | ⟷ | Qualitative |

Having both techniques "Questionnaire and Interview" and using structured questions will lead to improve some of issues in both techniques. The research will take the multi-method type to help with the preliminary study.

- **Using semi-structured interviews**

As mentioned in the research approach that this PhD research has applied the inductive approach, accordingly, Saunders et al. (2012) state that the inductive approach is associated with qualitative research. First, before carrying out the semi-structured interview techniques, there are two methods in interviewing; standardised and non-standardised (See Fig 3-7). The standardised interviews or the structured interviews are when the interview will be analysed

as a quantitative data. This method was used in the first phase of the research design. On the other hand, non-standardised interviews or unstructured interviews will be analysed as a qualitative data; it is divided into two methods, semi-structured interviews and in-depth interviews (Saunders et al., 2012). In the semi-structured interviews, researchers will have some key questions in order to cover some aspects within the research; the unstructured interviews, on the other hand, are informal and used for exploring in-depth (see table 3-6) (Saunders et al., 2012).

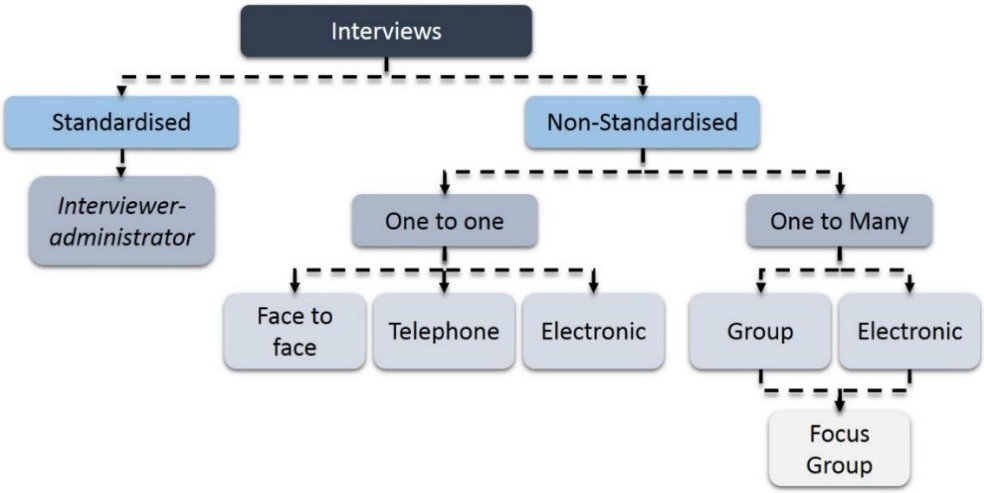



*Fig 3-7: Type of interviewing (Saunders et al., 2012)*

The research will take the semi-structured interview as data technique together information. This method will be adopted in the third and fourth phase of the research design phases. As it mentioned in the research design phases, the number of interviewees will be around 11 architectural educators within the KSA.

| 3.1 | 3.2 | 3.3 | 3.4 | 3.5 | 3.6 |
|---|---|---|---|---|---|
| Research Process | Research Philosophy | Research Design | Method of Data Collection | Data Collection Designs | Summary |

## 3.5 Data collection designs and procedures

The first part of this section discusses the design of the questionnaire and its content, then the techniques used to distribute the questionnaire. The last part of this section is the pilot study which has done for the questionnaire before distributing it.

### 3.5.1 *The questionnaire design and content*

The purpose of the questionnaire is to find three aims which have been mentioned on the second phase of the research design. The sample size, as is mentioned in the Sample Size section, could include any professional, academic and student in Saudi AEC Industry. Therefore, questions have been divided into five areas; general, BIM awareness, future of (Architecture Programmes and BIM in KSA) and Architectural Programmes in KSA (see table 3-7). Table 3-7 presents the number of questions for each targeted group; which is in total 58 questions. The questionnaire has designed to be analysed as a Nominal data and Categorical data. The information seeks from the questionnaire are:

*Table 3-7: Number of questions in relation to occupation*

<table>
<tr><td colspan="2" rowspan="2">Targeted Group</td><td rowspan="2">General</td><td colspan="2">BIM awareness and implementation</td><td colspan="2">Future of</td><td colspan="3">Arch. Education</td><td colspan="2" rowspan="2">Total</td></tr>
<tr><td>YES</td><td>NO</td><td>Arch. Edu</td><td>BIM</td><td rowspan="2">General</td><td colspan="2">development</td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="3">Academy</td><td>Arch./Arch. Eng.</td><td>14</td><td rowspan="2">7</td><td rowspan="2">3</td><td rowspan="2">4</td><td rowspan="2">2</td><td>4</td><td>3</td><td>1</td><td>34</td><td>28</td></tr>
<tr><td>Other Disciplines</td><td>11</td><td colspan="3">————</td><td>27</td><td>22</td></tr>
<tr><td>With Experience</td><td>1</td><td colspan="7">Professionals' Questions</td><td colspan="2">Adding 5-7</td></tr>
<tr><td rowspan="2">Professionals</td><td>Private</td><td>14</td><td>4</td><td>3</td><td rowspan="2">4</td><td rowspan="2">2</td><td colspan="3" rowspan="2">————</td><td>24</td><td>23</td></tr>
<tr><td>Government</td><td>11</td><td>2</td><td>1</td><td>19</td><td>14</td></tr>
<tr><td colspan="2">Students</td><td>10</td><td>5</td><td>3</td><td>4</td><td>2</td><td colspan="3"></td><td>21</td><td>18</td></tr>
</table>

1. General Information (Demographic information)

The survey has been designed to gather some information about participants which will help to give a deep understanding about the five areas based on these information. For example, if there a question has 45 % yes and 55% no, a comparison between Yes/No can be done based on qualification, occupation or age. The information or variables were divided into two part, general information for all participants and individual information. In the last question at the general information, participant will be redirected to their questions by answering if participant is an academic, professional or student. The individual questions are designed to cover aspects within their field.

2. BIM awareness and implementation

This area within the questionnaire has been developed to cover three aspects about BIM. The first is a basic question about if the participant knows about BIM or not. This question is located in the first part of the questionnaire with the general information page. The second part focuses in measuring the incorporation of BIM within AEC Industry and AEC-ES in KSA. That by choosing one of the following answers (Table 3-8):

*Table 3-8: BIM implementation with AEC Industry and AEC educations in KSA*

| **Academics and professionals** | | **Students** | |
|---|---|---|---|
| **1.** | Has not been incorporated and not considering | **1.** | I don't want to study it |
| **2.** | Has not been incorporated, but considering | **2.** | I'm planning to study it |
| **3.** | Has been partly incorporated into some projects | **3.** | I'm studying it |
| **4.** | Has been fully incorporated into the system | **4.** | I have already studied it |
| **5.** | I don't know | **5.** | I don't know what is BIM |

Responses will be redirected to the next questions based on their answers, Choice number one and five from the table 3-8 will lead participants to give their opinion about why BIM is not under consideration. On the other hand, who give two, three or four as an answer for this question they will be redirected. All participants were redirected to questions about when and how. Then a rating question using Likert Scale in how they think about what they are doing is BIM, which will help to understand the maturity level; that shows the third aspect.

3. Future of BIM and Architectural studies

By using Likert Scale, participant was asked about the future of BIM within the AEC Industry and AEC educations. The questions were about adopting BIM in Saudi projects, future BIM position and the demand of BIM. Then, participants were asked about the architecture future studies in KSA. They have been asked about the level of architectural students and if they have met the AEC Industry expectations. The need of developing the architectural curricula and what should be added taught for architectural students in KSA.

4. Architecture Programmes in KSA

This part was just for educators who are teaching in architectural department in KSA. Academics, in general, have been asked to select their department, if the answer was the architecture department they will be redirected to questions about the department. It was important to know when the programme has been started and if there is any accreditation method has been asked to achieve be the architectural programmes in KSA.

- **The questionnaire distribution**

Covering a large geographical area with a short period of time needs to use an online questionnaire (Saunders et al., 2012). Moreover, the use of a website such SurveyMonkey.com will help to gather the information so fast by the automated data input used by the website. The questionnaire has designed to have one link for all three groups which will help to distribute the questionnaire. It has been given a six weeks for participant to fill the questionnaire; and using four different approaches; social network, web link, email invitation and manually entry has help to reach people. Moreover, each week was reminder emails sent to those who have not respond to the first email, maximum of four reminder emails.

- **Pilot study for the questionnaire**

Before distributing the questionnaire, five academics and three professionals have evaluated the questionnaire three times in relation to the following categories; understand the questions, time needed to finish the questionnaire and sequence of questions. Based on their feedback, the questionnaire has developed and then sent to participants.

### 3.5.2 *The qualitative data design*

The aim of the qualitative data (Semi-structured interview) is to achieve the third and the fourth objectives of this research. Hence, the semi-structured interview was concentrated to identify key successful factors in relation to developing the framework. The following describes the interview's questions and stages.

First, a presentation (see appendix 5) was designed to introduce BIM properly for participants. This presentation was designed because of the maturity level of BIM within AEC Industry in KSA. It has been found that most of the professionals and academics within AEC Industry in KSA have a misunderstanding of BIM. The presentation designed to cover first, the definition, benefits and the concept in how BIM can be work. Then, the BIM increasing demand within the AEC Industry around the world followed by how BIM has been taught within AEC-ES. Finally, interviewees have exposed to the BIM situation in KSA. The last part was built based on some newspapers and the findings of the quantitative data (questionnaire). Each interviewee has given the presentation between 15 to 25 minutes and time for asking questions about BIM.

Second, after the presentation, participants have been asked to rate the presentation using Likert Scale. They have rated the presentation from 5 if their knowledge has improved to 1 if not. Then, interviewees were asked questions which have divided into:

1. General Questions: participants in this area have answered questions about their research interest, subjects which they have been teaching and their opinion about the future of BIM within Saudi AEC Industry.
2. BIM within their subjects: this area was aiming to determinate either BIM has been taught properly or not based on the BIM presentation. They have asked if they have taught BIM process, technology or both for their students or not, and giving some explanation in how it has been taught and for how long.
3. Teaching BIM: interviewees were asked few questions about teaching BIM within Undergraduate Architecture Programmes in KSA. These questions aim to determine how BIM should be taught within Undergraduate Architecture Programmes in KSA and when it should be introduced.

4. Integrated Design Studio: there are some methods in how IDS has been done such as (vertical studios vs horizontal studios) and (inter, multi and trans-disciplinary). Therefore, participants have given their opinion about the studios' teaching methods and the situation in KSA universities.

| 3.1 | 3.2 | 3.3 | 3.4 | 3.5 | 3.6 |
|---|---|---|---|---|---|
| Research Process | Research Philosophy | Research Design | Method of Data Collection | Data Collection Designs | Summary |

## 3.6 Summary

This chapter has outlined the research methodology and design used in this thesis. First, it has been clarified that the researcher has used the Onion Model (Saunders et al (2012) model). This model is divided into six layers; Philosophy, Approach, Methodological choice, Strategy, Time Horizon and Data collection techniques (Saunders et al., 2012). In the research Philosophy section, it has been covered the choice of research philosophy, the research approaches and the methodological choices. First, in this thesis, it has been chosen the Relativism/Constructivism assumption in the ontology, and the interpretivism/Constructionism in the epistemology; that based on the different human perspectives and the type of data. Second, the research design in this thesis has outlined the design process and how to achieve each objective in this research. Third, the methods and techniques have been explained with the population and the sample size for each stage of the research design. Finally, the way of how each stage has been designed was discussed in the last section of this chapter.

# CHAPTER 4

Quantitative Data: The Current Situation of BIM in KSA

Sections

| 4.1 | 4.2 | 4.3 | 4.4 | 4.5 | 4.6 |
|---|---|---|---|---|---|
| Total response rate | Survey Description | BIM Maturity Level | BIM Technology | Architecture Programmes in KSA | Summary |

# Chapter 4. Quantitative Data: The Current Situation of BIM adoption in KSA

The main aim of this chapter is to present the findings of the data collection of this PhD project. As aforementioned in chapter three (Research Strategies and Methodology), the data collection is divided into two phases. The first is the multi-method quantitative data based on a designed questionnaire, then the data from the semi-structured interviews. The multi-method Quantitative data was conducted with 337 professionals, academics and students from KSA; the survey was designed and distrusted using SurveyMonkey.com. In term of descriptive statistics, the data were analysed using SurveyMonkey.com and presented using tabulations and Figures. The chapter starts describing the total response rate and time for the questionnaire; then analysing the answers based on targeted groups, BIM maturity level and the future of BIM in KSA and architecture programmes in KSA. Finally, the chapter gives an outline to design the second phase of the data collection.

| 4.1 | 4.2 | 4.3 | 4.4 | 4.5 | 4.6 |
|---|---|---|---|---|---|
| Total response rate | Survey Description | BIM Maturity Level | BIM Technology | Architecture Programmes in KSA | Summary |

## 4.1 The total response rate and the response time

Although, the sample size for this phase of the data collection is 349 (section 3.5.1), this phase has got 337 responses from academics, professionals and students from KSA. To calculate the total response rate for this phase, the researcher has used a formula from Saunders et al. (2012) (table 4-1). There are seven of the responses have not met the research requirement. Hence, by using the formula in table 4-1, the total response rate is 98.5%.

*Table 4-1: Active Response Rate (Saunders et al., 2012).*

| Formula |
| --- |
| $$Active\ Response\ Rate = \frac{Total\ Number\ of\ Responses}{Total\ Number\ of\ Sample - (ineligible)}$$ |
| Result |
| $$Active\ Response\ Rate = \frac{337}{349 - (7)} = 98.5\ \%$$ |

In term of the average time response, the questionnaire has 58 questions targeting three different groups. The average time response for professionals was 16:32 minutes, academics was 15:28 mints and students was 7:49 mints. The different time was caused by the number of questions needed from each group, the directed path based on their answers and their background of each respondent.

| 4.1 | 4.2 | 4.3 | 4.4 | 4.5 | 4.6 |
| --- | --- | --- | --- | --- | --- |
| Total response rate | Survey Description | BIM Maturity Level | BIM Technology | Architecture Programmes in KSA | Summary |

## 4.2 Survey description

The questionnaire was conducted with academics, professionals and students within AEC Industry in KSA. It has 337 responses within six weeks of its distribution. 302 responses were agreed to participate in the questionnaire and 35 were disagreed. Four different methods were used to distribute the questionnaire; social network, web link, email invitation and manually entry. The highest number of responses by 151 respondents was from the web link, which has used the communication apps such as (What's App) and (Blackberry chat) to distribute the link. The email invitation becomes second highest method by 120 respondents; 512 academics within AEC educations and professionals in KSA have received an email created by the researcher containing information about the research and three links. The first link is specific for the receiver when the SurveyMonkey.com get a response, the

result will appear with his/her information. That will help in the reminder email for not to send an email for who had finished the questionnaire.

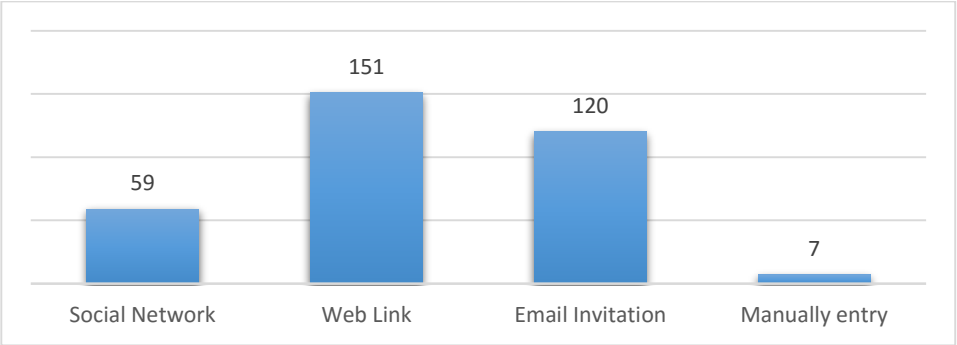



*Fig 4-1: The Number of Responses from different approaches*

The second link is the web link used to ask the receiver to share the questionnaire with colleagues. The last link if they do not want to participate and stop receiving emails. The Social Network link using Facebook and Linked-In has become the third by 59 respondents. The last was the manually entry which is based on 7 structured-interviews. Three of the 7 interviews were academics who have an experience in developing architectural curriculum in KSA. The other four interviews were professionals; two of them have a teaching experience and the other two have work with the government in developing projects.

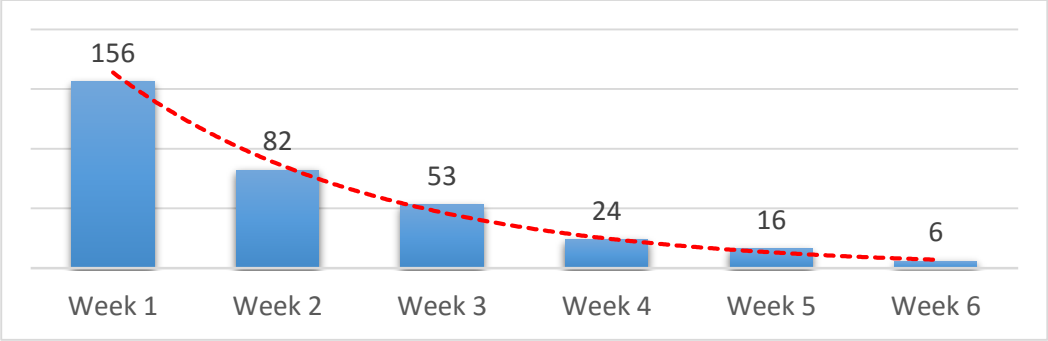



*Fig 4-2: The Curve of the Response Rate*

The response rate has started from the highest number in week one and dramatically the curve dropped down to five responses in week six (See Fig 4-2). To increase the response rate, after each week an automatic email has sent to remind who did not respond to the questionnaire. This technique was applied in the email invitation which has more than 400

invitations. 225 respondents out of 302 respondents have completed the questionnaire, which almost 74.5% completed responses and 25.5% partial responses.

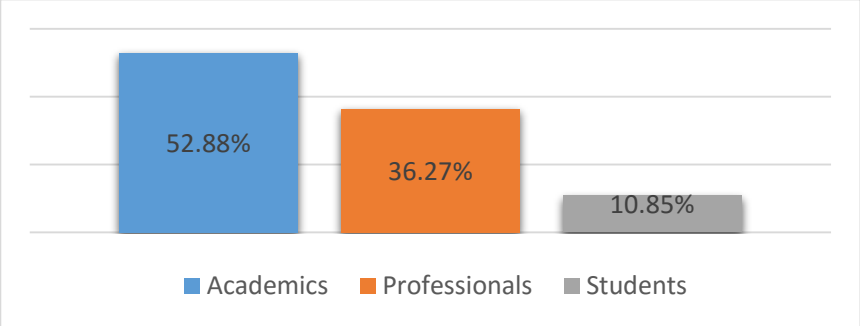



*Fig 4-3: Responses from different groups*

As the survey has got responses from different groups, the highest response was from academics followed by professionals then students. Fig 4-3 shows that the response rate for each targeted group. In addition, 58.82% of academics were mentioned that they have an experience in architecture field. Moreover, 31.4% of academics were studying abroad to get their post-graduate degrees. On the other hand, 11.53% of professionals were accepted for a scholarship to study abroad. Also, 41.21% of Saudi students were studying abroad.

Based on their choice on the occupation question, each respondent was redirected to a set of questions. These questions were designed to achieve the second objective by determining the following three key areas; BIM maturity level and the future of BIM within AEC-ES and AEC Industry in KSA, and the current situation of Architecture programme and its future.

| 4.1 | 4.2 | 4.3 | 4.4 | 4.5 | 4.6 |
|---|---|---|---|---|---|
| Total response rate | Survey Description | BIM Maturity Level | BIM Technology | Architecture Programmes in KSA | Summary |

## 4.3 The BIM maturity Level within KSA

Participants in this area have answered between 3 to 7 questions for each group. These questions has divided into three key areas related to understanding BIM. The first area is to identify if BIM has been introduced in KSA in both sectors, professional and education. The

second area is to identify the level of implementation if BIM has been used. Finally, the knowledge of BIM for participants will be measured to evaluate the maturity level of understanding BIM.

### 4.3.1 *BIM awareness*

This area was designed to have one question only, which participants were asked if they have heard about BIM or not. This question got 295 responses from academics, professionals and students; and 42 skipped. The findings of the survey is that 61.69% (n=182) are aware of BIM, and 38.31% (n=113) have not heard about BIM (see Fig 4-4). That shows many of participants have heard about BIM. However, to gain better understanding of the situation, a comparison between answers based on this question and others has been done. This comparison covers:

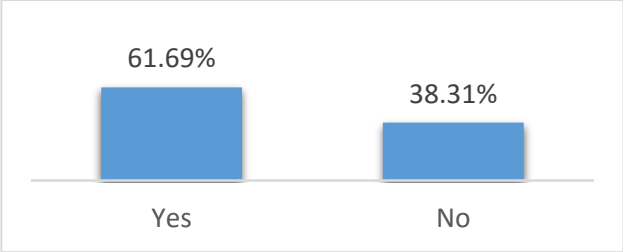



*Fig 4-4: BIM awareness with AEC educations and AEC Industry in KSA*

- **Occupation**

By comparing the result of this question based on the three occupations; academics, professionals and students, academics and professionals seem that they have more knowledge about BIM than students. Figure 4-5 shows that the percentage of who have heard about BIM is higher than who have not in both academics and professionals; academics got 66.03% (n=132) and professionals got 61.68% (n=97). On the other hand, the percentage of students who have not heard about BIM is lower than who have heard about it; they have got 59.38% (n= 19) of students have not heard about BIM.

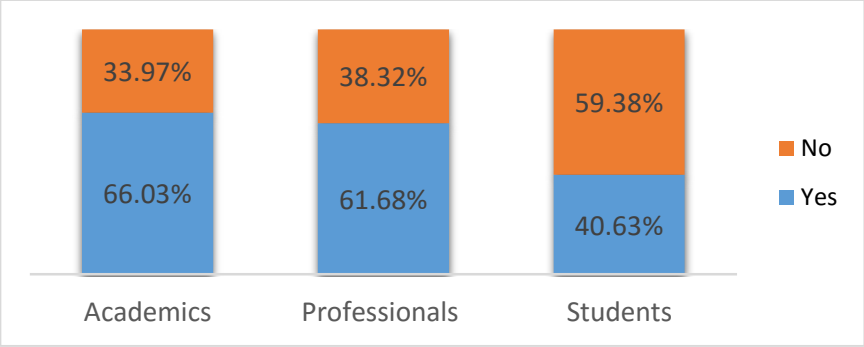



*Fig 4-5: Comparison between groups based in BIM awareness*

- **Scholarship**

Future to understand the BIM awareness, participants were given the choice to choose one of options about if they have a scholarship or not. The options were given were: 1) I have a scholarship from Saudi university, 2) I have a scholarship from government organisation, 3) I have a scholarship from a private sector or 4) I do not have a scholarship. The result of this question reveals a significant information about students and their BIM awareness. The percentage of students who have scholarship is 53.13% (n=17); 76.47% (n=13) of them were heard about BIM. On the other hand, 80% (n=12) of students who were studying within Saudi Universities have not heard about BIM yet, in contrast with 20% (n=3) of students who have heard about it. This shows a lack of BIM awareness within students studying in KSA.

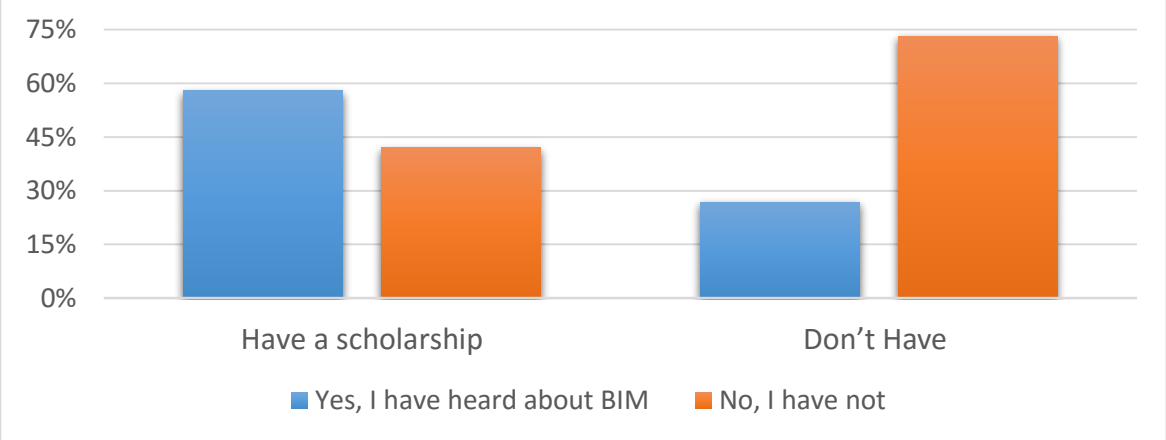



*Fig 4-6: Comparing BIM awareness between who have scholarship and who have not*

In addition to the scholarship question, some of academics and professionals have got the chance to pursue their post-studies outside KSA. The question has got 255 responses and 8 of participants (academics and professionals) have skipped the question. Fig 4-6 shows a comparison between academics and professionals about their BIM awareness based on who have scholarship and who have not. In both answers, the percentage of participants who knew about BIM is higher than who have not.

- **BIM across AEC education departments**

In this question, participants have given to choose one of the giving choices or to write their department if not giving. There were 151 academics from 9 different AEC education departments who have responded to this question. The highest percentage was from architecture department with 41.72% (n=63), and the lowest was from mechanical engineering department with 0.66% (n=1). Hence, the mechanical department has excluded for the low response; based on that, the lowest respond was from the electrical engineering department with 3.97% (n=6).

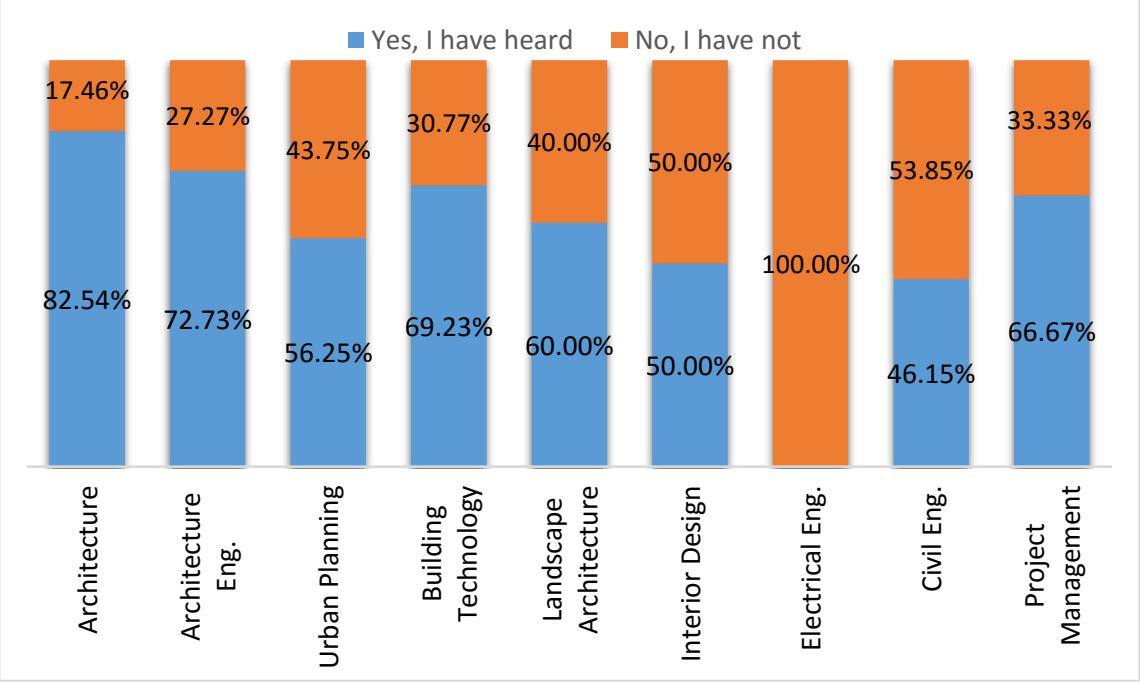



*Fig 4-7: BIM awareness cross AEC education departments in KSA*

Fig 4-7 presents the BIM awareness cross AEC education departments in KSA. Academics within architecture departments have got the highest responses in knowing BIM by 82.54% (n=52). The percentages of academics from other AEC departments who knew about BIM were between 45% and 72%. However, academics within engineering departments in KSA education system have lack of knowledge in BIM; in contrast with the designing and project management departments.

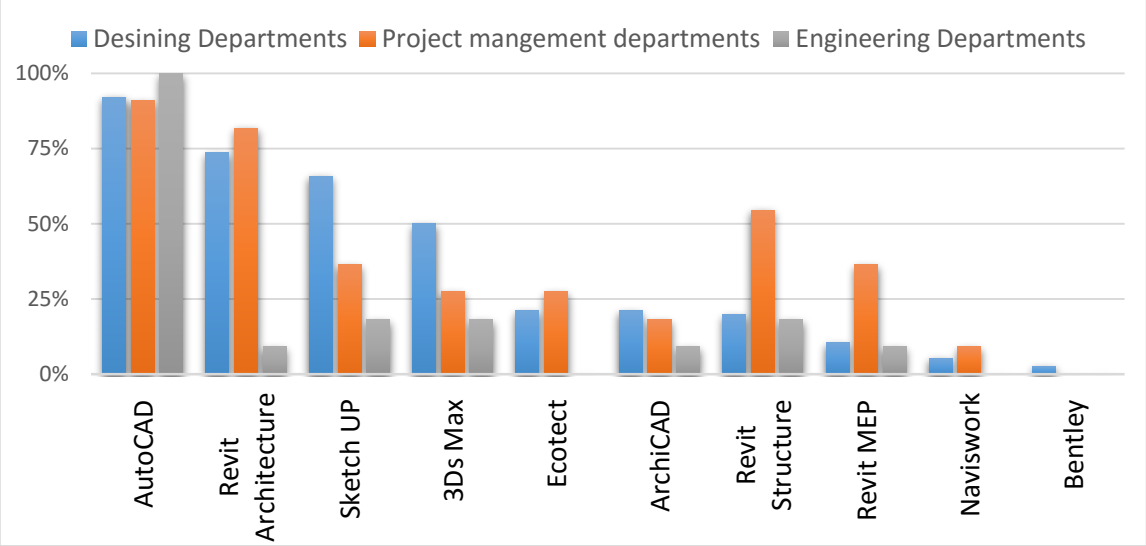



*Fig 4-8: The use of BIM technology among AEC-ES in KSA*

The use of BIM technology within designing departments (Architecture, Landscape Architecture, Urban Design and Interior Design) and project management departments may have cause the difference on the BIM awareness within AEC education in KSA. 97 Academics within AEC-ES in KSA have answered a question related to the use of computer applications with no skippers. Fig 4-8 shows that most of BIM technologies such as Revit Architecture, Revit Structure, Revit MEP, Navisworks and Ecotect have been taught within designing and projects management departments more than engineering departments in KSA.

- **BIM within AEC Industry in KSA**

The survey has got 186 responses from professionals within the AEC Industry in KSA. 44% of them (n=82) were academics with experience in the Saudi AEC Industry; the rest, 56% (n=104) were professionals. In general, most of the respondents from professionals had

heard about BIM. However, professionals have been classified on the questionnaire based on their positions. Each one of them has chosen one of the fourteen given positions including (Did not mention). There are two choices excluded from the results for not achieving a quorum is reasonable to do proper comparison between answers. First was the Draftsman choice, it has got no responses. Second, was Modeller choice, it has got one response only. However, the Modeller choice has been moved to be in the (Did not mentioned).

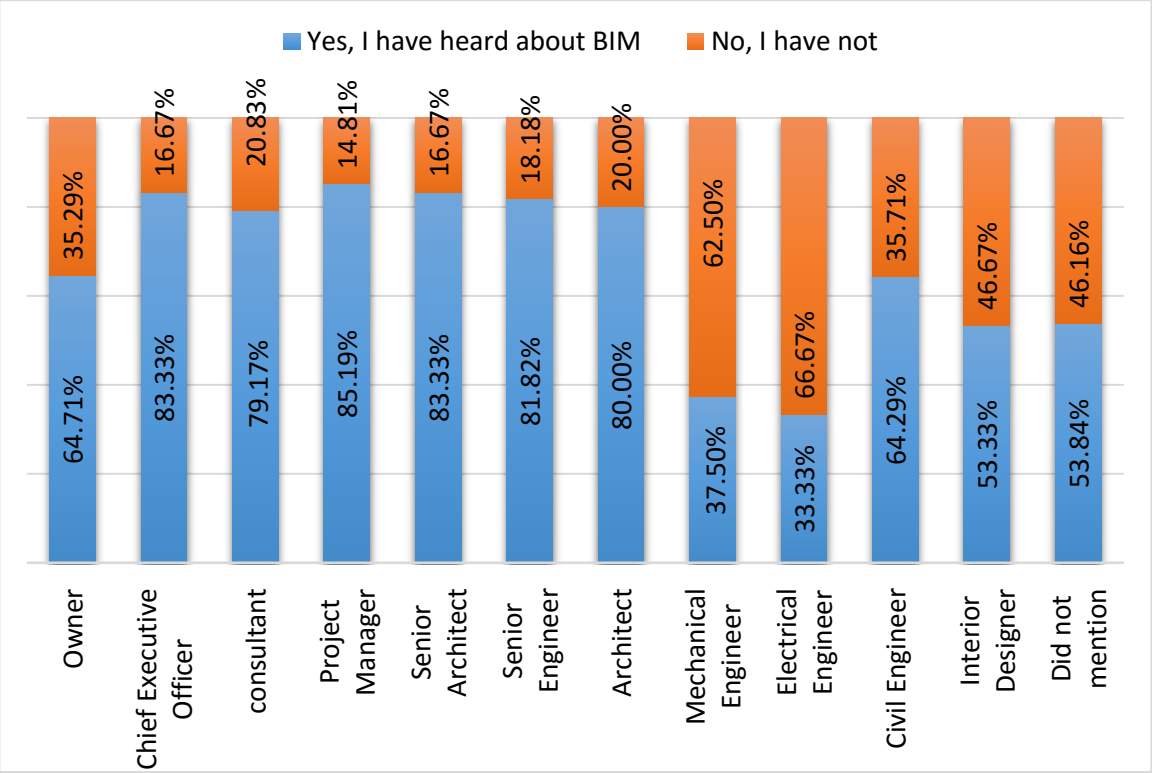



*Fig 4-9: BIM awareness within AEC Industry*

In general, most of decision makers had heard about BIM, such as owners, chief executive officer, project manager and AEC seniors (see Fig 4-9). Moreover, seniors comparing with juniors have got higher percentage in BIM awareness yet, junior architects have got higher percentage in BIM awareness more than seniors in other departments. Engineers, generally, have low knowledge about the new methods. This finding is similar to the findings from Fig 4-7, engineers from different departments were less knowledge in term of BIM, than other departments.

- **Nationalities**

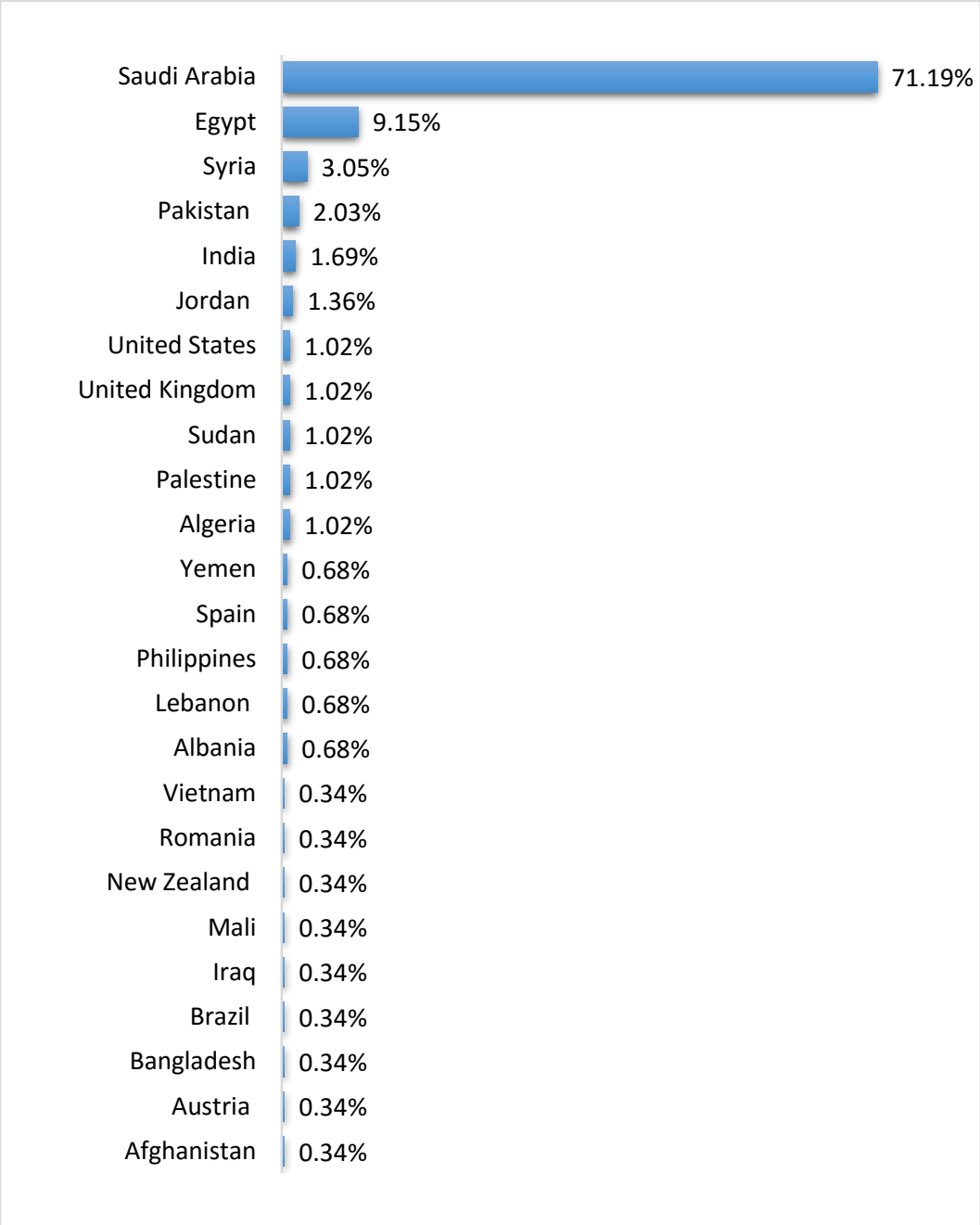



*Fig 4-10: Nationalities of workers in KSA who have responded to the questionnaire*

The survey has got 25 different nationalities working within AEC education and AEC Industry in KSA. The question of nationality has got 295 answered and 42 skipped. The highest percentage of respondents was from Saudis workers by 71.19% (n=210), which

leaves the 28.81% (n=85) of responses for other nationalities. The highest three non-Saudis groups were recorded to Egyptians, Syrians and Pakistanis.

However, by comparing non-Saudis with Saudis workers in relation to BIM awareness, the result reveals that the percentage of foreign workers who know BIM comparing with who do not is higher than the findings from Saudi workers. Fig 4-11 reveals that 68.24% (n=58) of non-Saudis were knew about BIM and 31.76% (n=27) were not. On the other hand, the findings about Saudi workers reveals that there is no significant different between Saudis workers who know about BIM and who do not know. However, most of non-Saudi workers were well-known about BIM. That shows that non-Saudi workers have better knowledge about BIM than Saudi workers. Fig 4-10 shows that 53.33% (n=112) knew about BIM and 46.67% (n=98) have not heard about it.

- **AEC Saudi students and BIM awareness**

The result of the questionnaire reveals that the percentage of architecture students who study abroad and knew about BIM is higher than who is studying in KSA. The survey has got 32 responses from undergraduate architecture students. Some of them studying in KSA universities and other outside. Fig 4-12 presents the differences between Saudi students who studying outside KSA with who studying inside KSA in relation to their knowledge about BIM. It has been found that 58.82% (n=10) of students studying abroad were knew about BIM and 41.18% (n=7) were not. In contrast with who studying in KSA, 20% (n=3) knew about BIM and 80% (n=12) were not. This findings shows that the gap of knowledge within KSA universities.

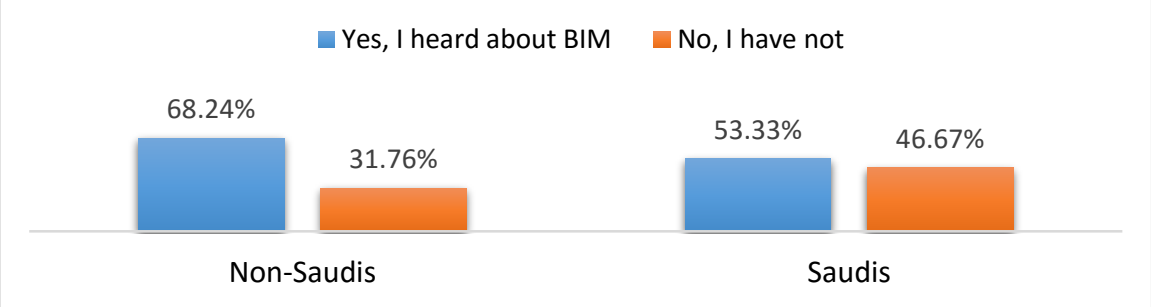



*Fig 4-11: Comparison between Saudi and non-Saudi from AEC educations and AEC Industry in KSA in who know BIM*

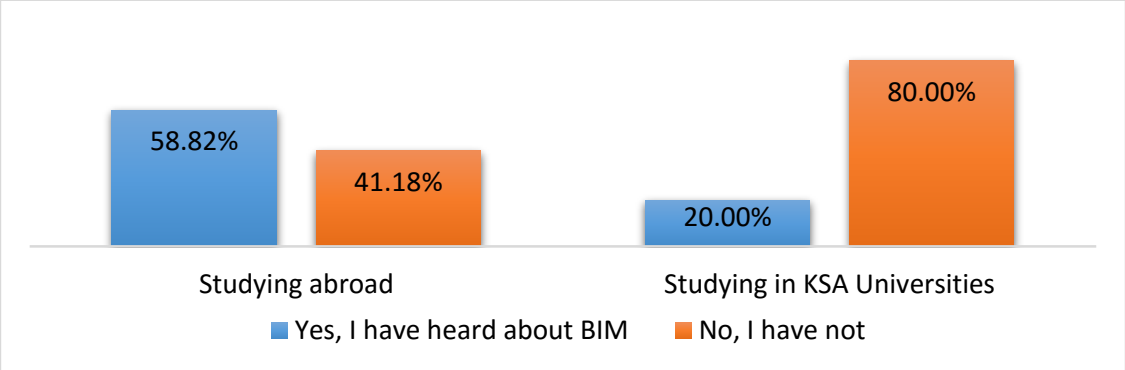



*Fig 4-12: Comparison between Saudi students who are studying abroad and who are studying within KSA Universities in relation to their knowledge about BIM*

These findings were shown the BIM awareness across stakeholders in KSA AEC Industry. In general, the concept of BIM has been introduced to the AEC Industry in KSA and most of academics and professionals have heard about it. However, at this stage, BIM is unbeknown topic for architecture students who are studying in KSA Universities. To gain deep understanding about BIM within KSA, the following covers the level of BIM implementation within KSA in both AEC-ES and AEC Industry.

### 4.3.2 *BIM Implementation*

*Table 4-2: BIM question about its implementation*

| | **Academics' choices** | **Professionals' choices** | **Explain the choices** |
|---|---|---|---|
| **1** | Has not been taught/incorporated and not considering | | Knowing the current situation and their future plan about BIM |
| **2** | Has not been taught/incorporated, but considering | | |
| **3** | Introduced within a class | Has been partly incorporated into some projects | Knowing the current situation and their level of implementation |
| **4** | Has been fully taught/incorporated into the system | | |
| **5** | I don't know | | To improve the credibility of the information |

This part has targeted academics and professionals within Saudi AEC Industry and AEC-ES. It has divided into two areas; the first area aims to determine the level of BIM implementation within both organisations in KSA. Then, the second area aims to identify the maturity level of BIM within KSA. Hence, the questionnaire is designed to have a question for both targeted groups. Participants have to choose one of the following choices in table 4-2. The following describes the findings from each group; BIM in KSA Universities and BIM within Saudi AEC Industry.

- **BIM in KSA Universities**

First, the survey has 156 academics responses who are teaching in AEC educations within KSA. For this question, there are 137 responses. First, 33.58% of academics (n=46) have stated that BIM has not been taught within their curriculum. Nevertheless, 37% (n=17) from them were not considering teaching BIM within their curricula; and the rest were considering to teach it in the future. Fig 4-13 shows the level of implementation within AEC-ES in KSA, and the most significant findings is that BIM has been taught within AEC classes. 45.25 % (n=62) of academics mentioned that BIM has already been taught within AEC-ES. However, the majority with 37.23% (n=51) were chose that BIM has been introduced within a regular class. On the other hand, 8.02% (n=11) assume that BIM has fully adopted BIM within the teaching system. The last choice was the "I don't know" which has got 21.17%, that presents academics who do not know about BIM.

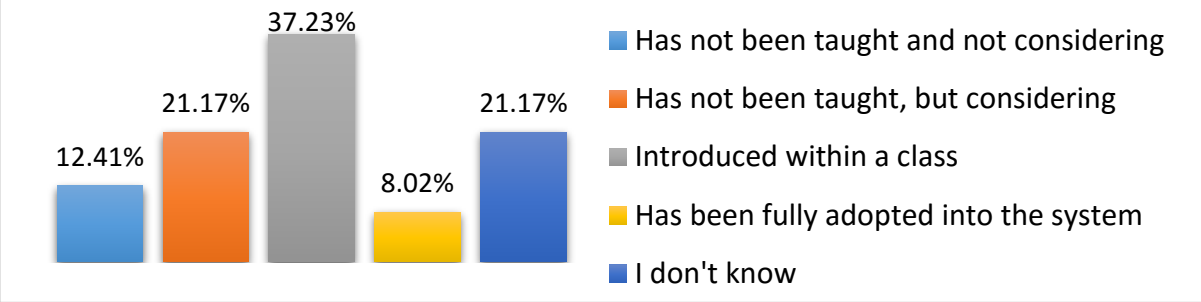



*Fig 4-13: BIM within AEC educations in KSA*

Based on their answers, participants were redirected to three areas with set of questions designed to suit their choice. If participants have choice the "Has not been taught and not considering", this choice will redirect them to an open-ended question asking them about

their opinion in not considering BIM. 12.41% (n=17) of academics have given some ideas about why BIM should not be considered in the future of AEC-ES in KSA. Most of the answers were written in Arabic and the rest were in English. However, these answers were classified into three areas based on the issue mentioned by them; curriculum, teachers and the maturity level of BIM within AEC-ES and Saudi AEC Industry.

First, 29.41% (n=5) of academics have mentioned that there is no room for BIM to be taught within the AEC curricula in KSA; the curriculum is packed. Second, the lack of BIM teachers has got the most mentioned issue comparing with the other three with 52.94% (n=9). Finally, 41.81% (n=7) of participants believe that the BIM maturity level for academics can be the barrier of teaching BIM within AEC-ES in KSA. It has been mentioned that the lack of BIM awareness within AEC Industry in KSA and the lack of BIM demand are reasons to not teach BIM within AEC-ES in KSA. These issues and more have been mentioned as some of challenges and difficulties facing the embedding of BIM within AEC-ES around the world (see section 2.3.4 Challenges and Difficulties for BIM Education).

The 17 academics were asked and who aware of BIM have answered a question about how BIM should be adopted within the curricula. The question was a multi choices question where participants choice one or more than one choice. Participants have given ten choices including “Not given” and “I Don’t Know”. As participants have not chosen one of these two choices, these two choices have moved out from the findings of the questionnaire. However, figure 4-14 shows that most of academics who aware of BIM and have no interest to adopt BIM were having misunderstanding about BIM. The question has given them the choice of “Fully integrated”, and the choice has got the lost choice accept academics from architecture departments.

That was a description for the findings of the first choice in Fig 4-12. However, for who have chosen one of the three choices “Has not been taught, but considering”, “Introduced within a class” and “Has been fully adopted into the system” have been redirected to the set of questions. These question aiming to determinate the method in how and when they have taught BIM and to identify the BIM maturity level based on that. Hence, this area was divided into three groups; module information, BIM topics and BIM maturity level

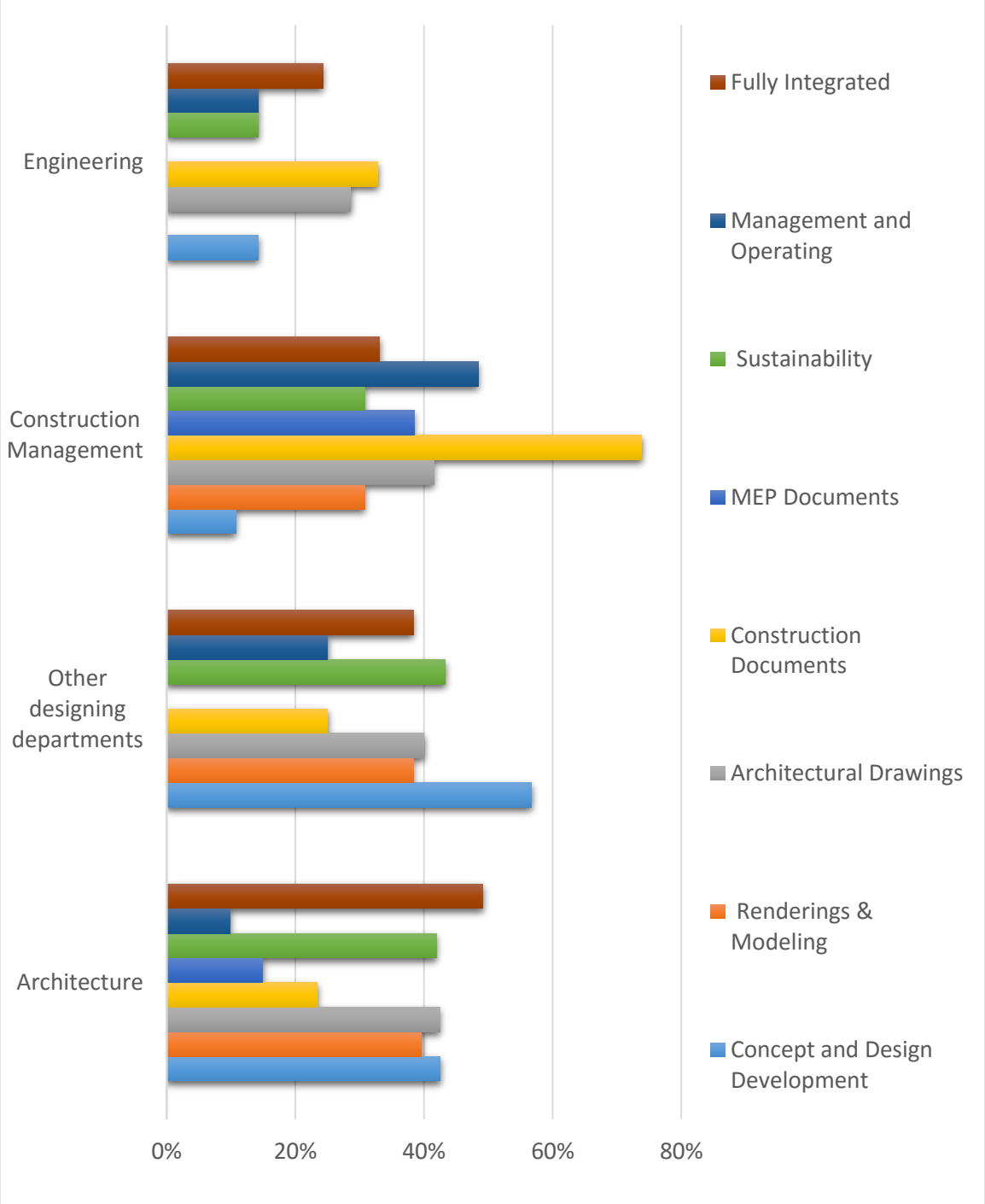



*Fig 4-14: How BIM should be adopting it within AEC-ES in KSA*

1. Module Information

The Module Information has set of questions aims to identify three main aspects needed to understand how BIM has been taught within AEC-ES in KSA. This area has got 66.42% (n=91) responses from AEC academics within KSA Universities. The three aspects were needed are the BIM module type, number of BIM classes and academic level in where BIM has been taught.

- Module Type

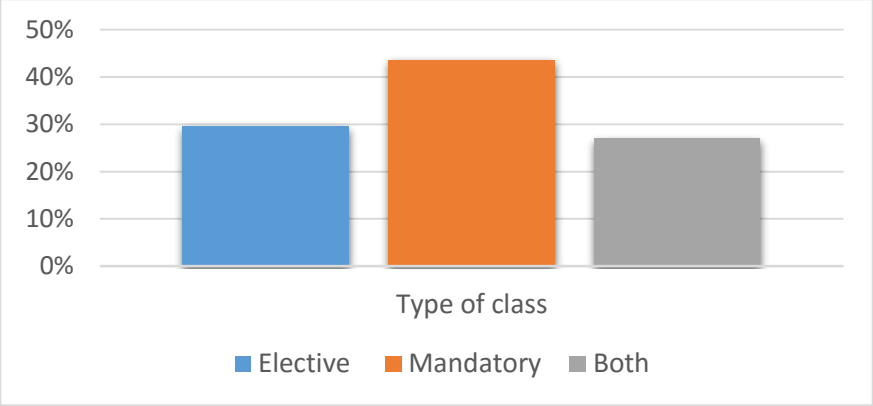



*Fig 4-15: BIM Module Type*

Participants have answered one choice question with three options; Elective, Mandatory and Both. BIM has taught mostly within mandatory module; it has got more than 40% responses. Then, with less than 30%, BIM elective classes becomes second and the last choice in having both types with 26.92% (see Fig 4-15).

- Number of BIM classes

The second aspect is the question about the number of BIM classes which will help to understand the size of the focus on teaching BIM. Fig 4-16 presents the number of BIM classes within AEC educations in KSA based on respondents' answers. From the graph, it seems that BIM has more classes in Architectural programmes comparing with other AEC Industry programmes in KSA. In addition, the number of BIM classes in Architectural programmes in KSA is a significantly higher than the number of BIM classes in other AEC Industry programmes.

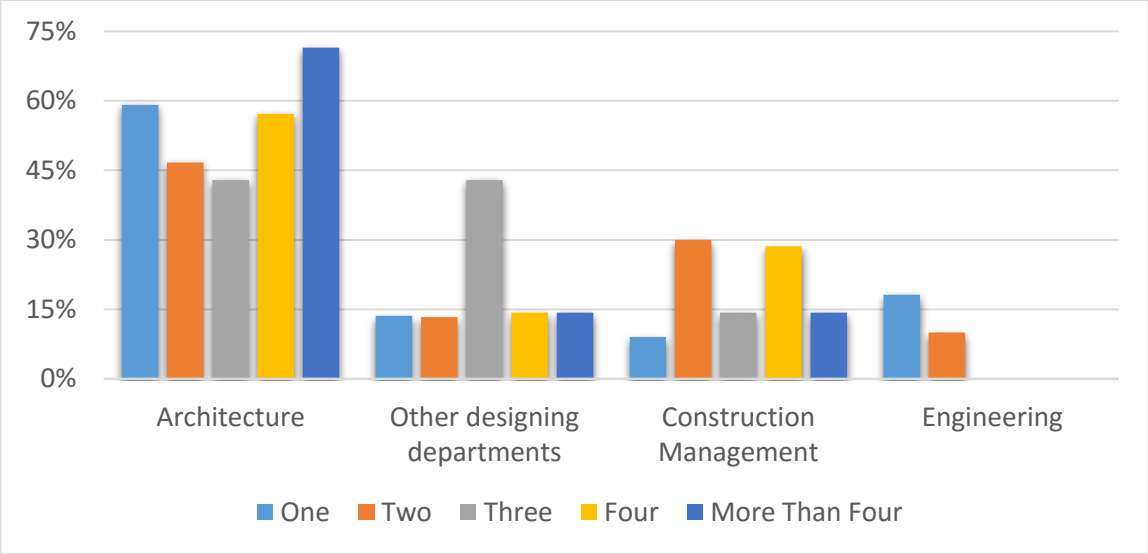



*Fig 4-16: Comparing the number of BIM classes between AEC programmes in KSA*

- Academic Level

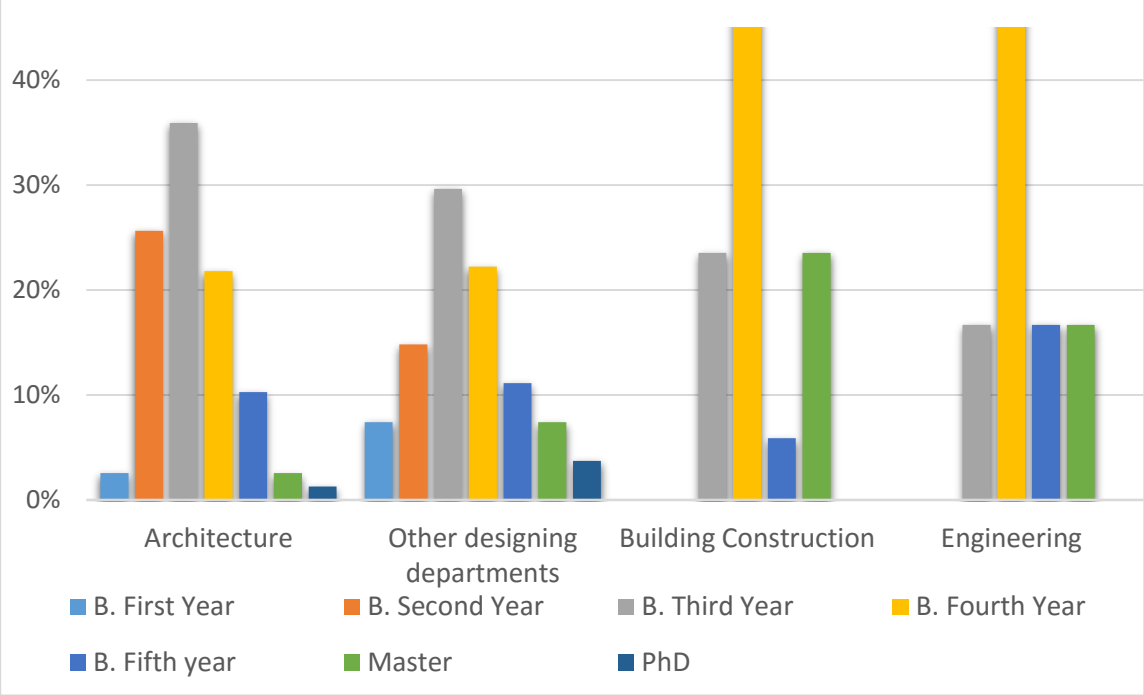



*Fig 4-17: Academic levels where BIM is taught*

BIM has been introduced within AEC-ES in KSA Universities in almost all the academic levels. Participants have answered a multiple choices question where each participant can give one or more than one answer. There are some differences between the designing

departments (Architecture, Landscape Architecture, Interior Design and Urban Design) and the engineering department and building construction departments. In the architecture departments and the other designing departments, BIM has taught from freshman year to post-graduate level. On the other hand, the building construction departments and engineering departments have introduced BIM to their students from the second year to the master level. Moreover, the third academic year in architecture and the designing departments has got the highest percentage of responses in where BIM has been introduced, in contrast with building construction and engineering departments where the fourth academic level has got the highest percentage.

2. BIM topics within AEC-ES

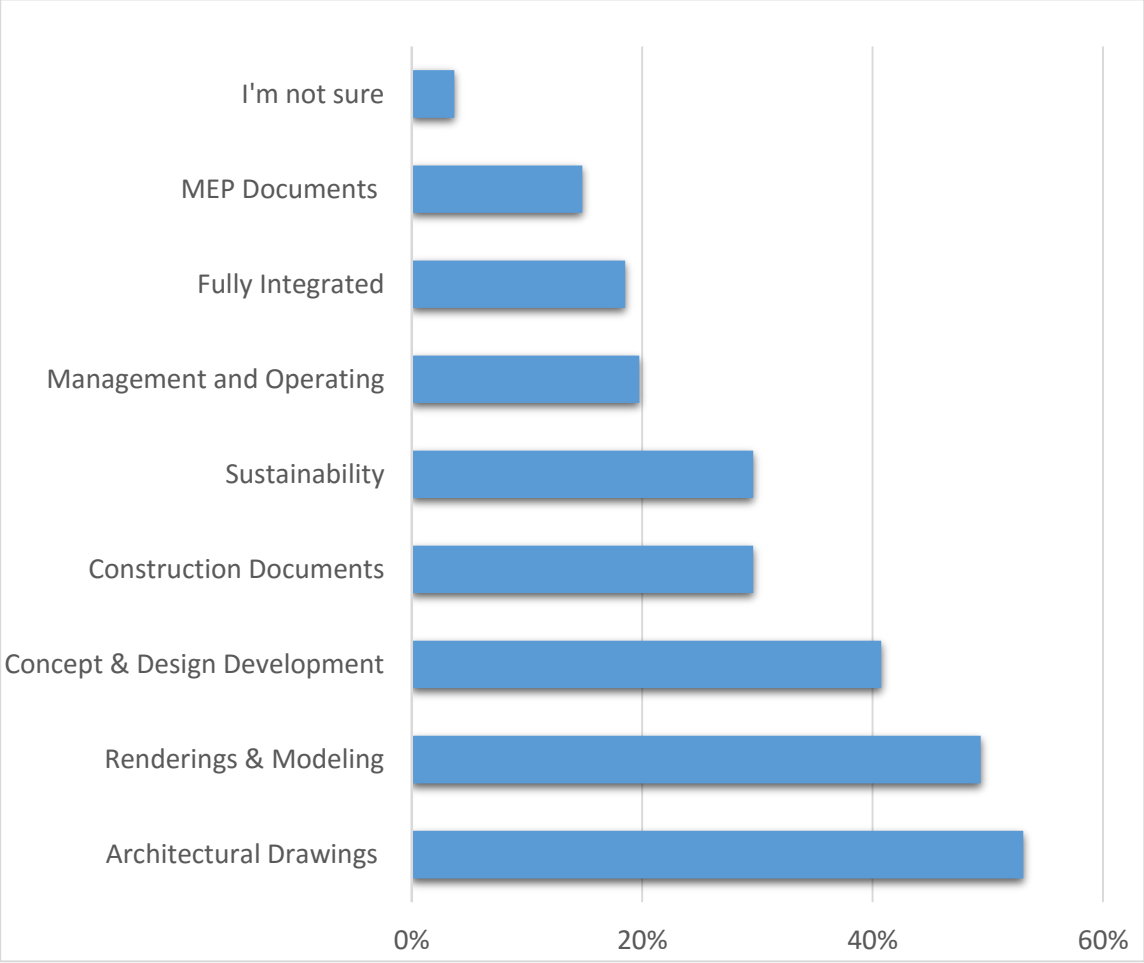



*Fig 4-18: BIM topics within AEC-ES in KSA*

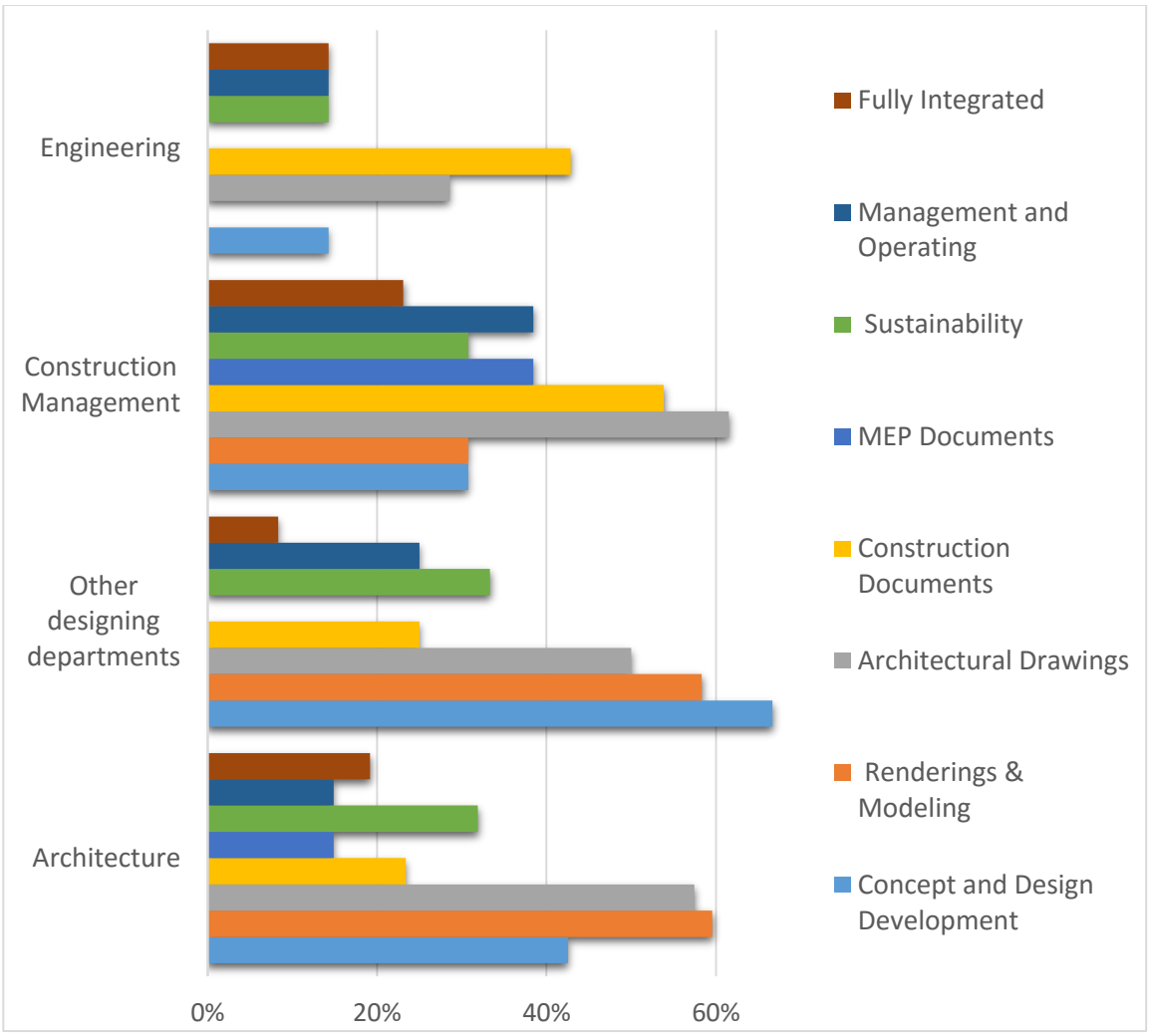



*Fig 4-19: The current state where BIM is taught within AEC-ES in KSA*

Within AEC-ES in KSA, BIM has been mostly used in the pre-construction phase (architectural drawings, rendering and modelling and design development). Fig 4-18 presents BIM chosen topic within AEC-ES in KSA. It shows that BIM has been used in the first stages of the design process. Moreover, the Fully Integrated choice has got the third lost percentage, which shows the level of interest in teaching BIM to cover most of the designing and construction phases.

However, Fig 4-18 shows a comparison between AEC programmes how BIM has been used. For architectural programmes and other designing department, BIM has mostly used in the first stages of designing process comparing with the other building educational departments where BIM has mostly used in the construction drawings. Moreover, for the rest of topics,

BIM has less classes focusing on other building issues such as sustainability and management and operation. Noticeably, there is no interest in MEP (Mechanical – Electrical – Pluming) within engineering departments.

3. BIM maturity level within AEC-ES in KSA

Based on these result, BIM has been taught within AEC-ES in KSA. However, there is a significant findings shows that most of AEC students have no idea about concept of BIM. In section (4.3.1 The BIM maturity level within KSA – BIM awareness – 6. AEC Saudi students and BIM awareness), the percentage of AEC Saudi students within AEC-ES in KSA who knew about BIM is 20%, lower than the percentage of AEC Saudi students who studying abroad. Moreover, the findings of this survey indicate some differences in academics' answers when it becomes to answer question such as "How many BIM classes your department have?". For example, Academics in one of the architecture schools have given different answers in the number of BIM classes (Fig 4-20).

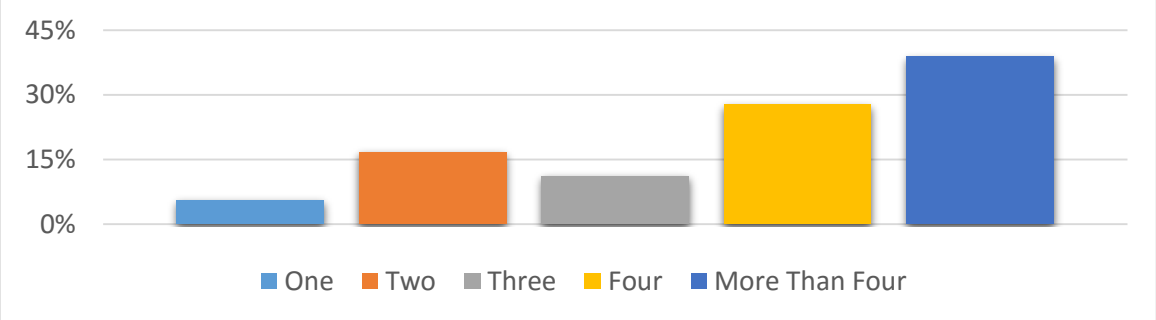



*Fig 4-20: Number of BIM classes in one of the architecture schools in KSA*

Hence, the survey was designed to clarify the maturity level of BIM within AEC-ES in KSA by asking participants about their BIM teaching methods. This area was divided into two parts based on who started to teach BIM and who are planning. A rating question asking two groups "To what extent do you think what you are teaching now is BIM".

The findings from who have started teaching BIM shows that 56.79% (n= 46) of academics were agreed/strongly agreed with the statement. In contrast with 13.58% (n= 11) of academics were disagreed/strongly disagreed. The rest of them were neither agreed nor disagreed or N/A. However, the 13.58% of academics who believe that what they are doing

know is not BIM is still a low percentage. It shows that most of academics have misunderstanding about the concept of BIM.

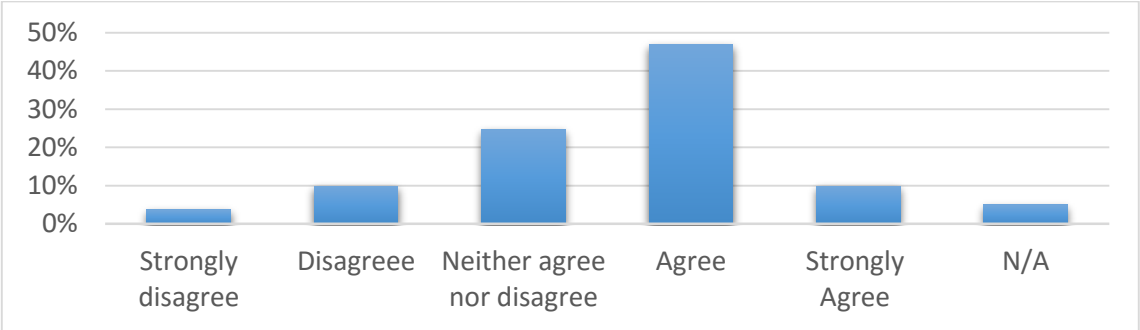



*Fig 4-21: To what extent do you think what you are teaching now is BIM*

On the other hand, BIM maturity for whom they are planning to teach BIM within AEC-ES in KSA is higher than the other group. Participants were answered a multiple question about in which area should we force on when we teach BIM. Fig 4-22 shows the future plans for teaching BIM within AEC-ES in KSA. Although, there are similarities in the results of both groups, the "fully integrated" has got the highest percentage comparing with other choices and with the current BIM teaching topics.

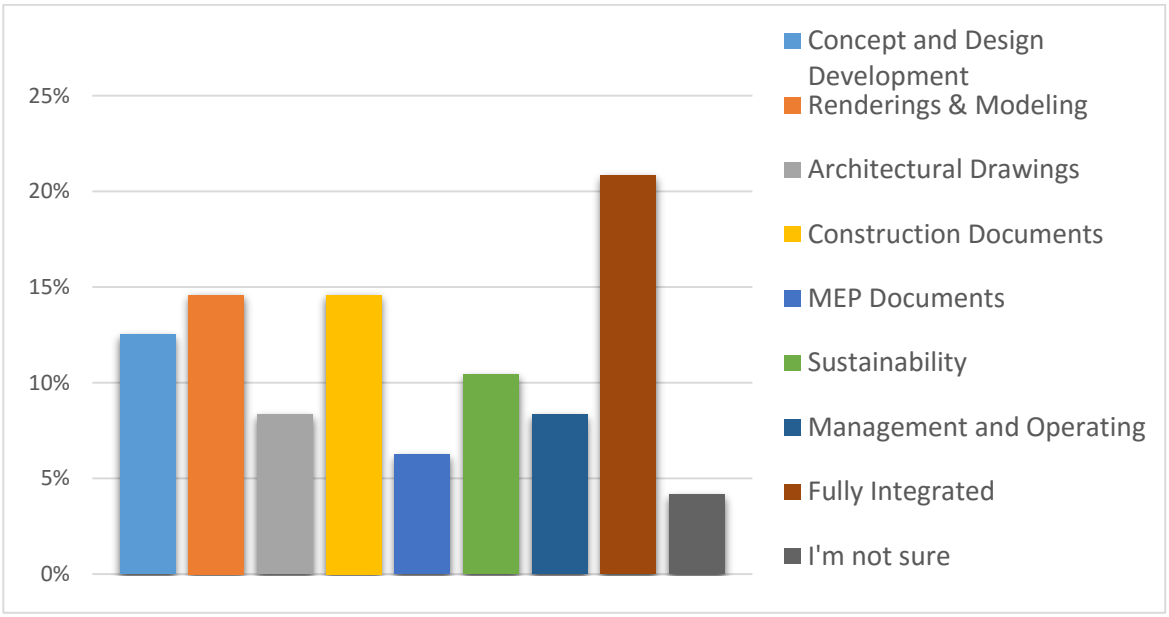



*Fig 4-22: BIM areas are introduced in Architecture programmes in KSA*

- **BIM in Saudi AEC Industry**

The number of responses for the question about BIM implementation within AEC Industry was 107 professionals and 79 academics who have a field experience; in total of 186 responses. Based on the explanations of the given choices on the implementation question (see table 4-2), 39% of responses (n=66) have stated that BIM has not been incorporated within their system. However, 18.93% (n=32) from the total responses are not considering BIM; and 20.12% (n=34) are planning to implement BIM with their system.

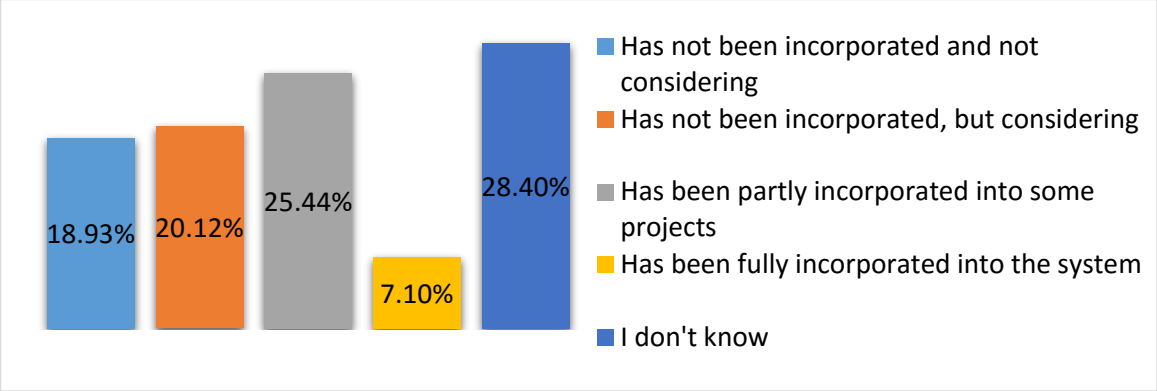



*Fig 4-23: State of BIM within AEC Industry in KSA*

Fig 4-23 shows the level of implementation within AEC Industry in KSA, it shows that BIM has been already implemented within the AEC Industry in KSA. Partly incorporated was got 25.44% (n=43) of the total responses and the percentage of the fully incorporated was 7.10% (n=12). Finally, the last choice "I don't know" has got the highest percentage by 28.40% (n= 48).

As the BIM implementation's question that academics were answered, this question was designed to redirect respondents to a related questions based on their choice. Option one, respondents whom chose option one "Has not been incorporated and not considering" were directed to an open-ended question asking them about their opinion in not considering BIM. The lack of knowledge in BIM has mentioned 26.92% of this question. Some of the participants suggest that "BIM is unknown", and other have a misconception about BIM when they compare it with the AutoCAD or other computer aided-design/drawings.

Moreover, some comments have revealed that some of respondents think that BIM is just only for big projects. One of the examples in this case is “We only have small projects”.

Second, the lack of BIM users has got the highest mentioned issue facing the BIM implementation within AEC Industry in KSA; it has got 46.15% of responses. Some of their comments were indicated that AEC educations in KSA have no plans to improve the AEC students in order to achieve the AEC Industry needs. This problem has faced the implementation of BIM for most of the architectural firms and construction companies around the world (see section 2.2.2). Third, several comments have concluded that BIM implementation has to be required by top management including Saudi government. For example, one of participants was stated that “I know the benefits of BIM but it has to be required by the Saudi government”. Some of the governments around the world have required BIM such as UK (see section 2.2.3).

Fourth, there is a lack of demand in BIM within the AEC Industry in KSA, 19.23% of responses have assumed that. Although, the percentage is quite low comparing with other issues, the benefits behind BIM implementation within AEC Industry have to be considered. Moreover, there are some projects in KSA are planned to be design and construct using BIM. Finally, 15.38% of responses were afraid of changing for the traditional method to BIM method. For example, one of the participants was stated that “some companies find it difficult and risky to move forward to BIM technology”. Most of these issues have already solved by construction companies in developed countries (see section 2.2.4).

Option two, three and four in this question, as it is presented in Fig 4-23 have redirected participants to answering questions in relation of the level of BIM implementation within AEC Industry in KSA. Therefore, the data were presented to compare between what existed and what will be done in the future about BIM implementation. Fig 4-24 shows a comparison between who think they have adopted BIM and who have not. This comparison is made to understand the maturity level of BIM implementation within AEC Industry in KSA. The graph shows some differences between these two groups, especially when it comes to compare the implementation of BIM in the designing phases (concept and design

development – renderings and modelling – architectural drawings) with the (fully integrated).

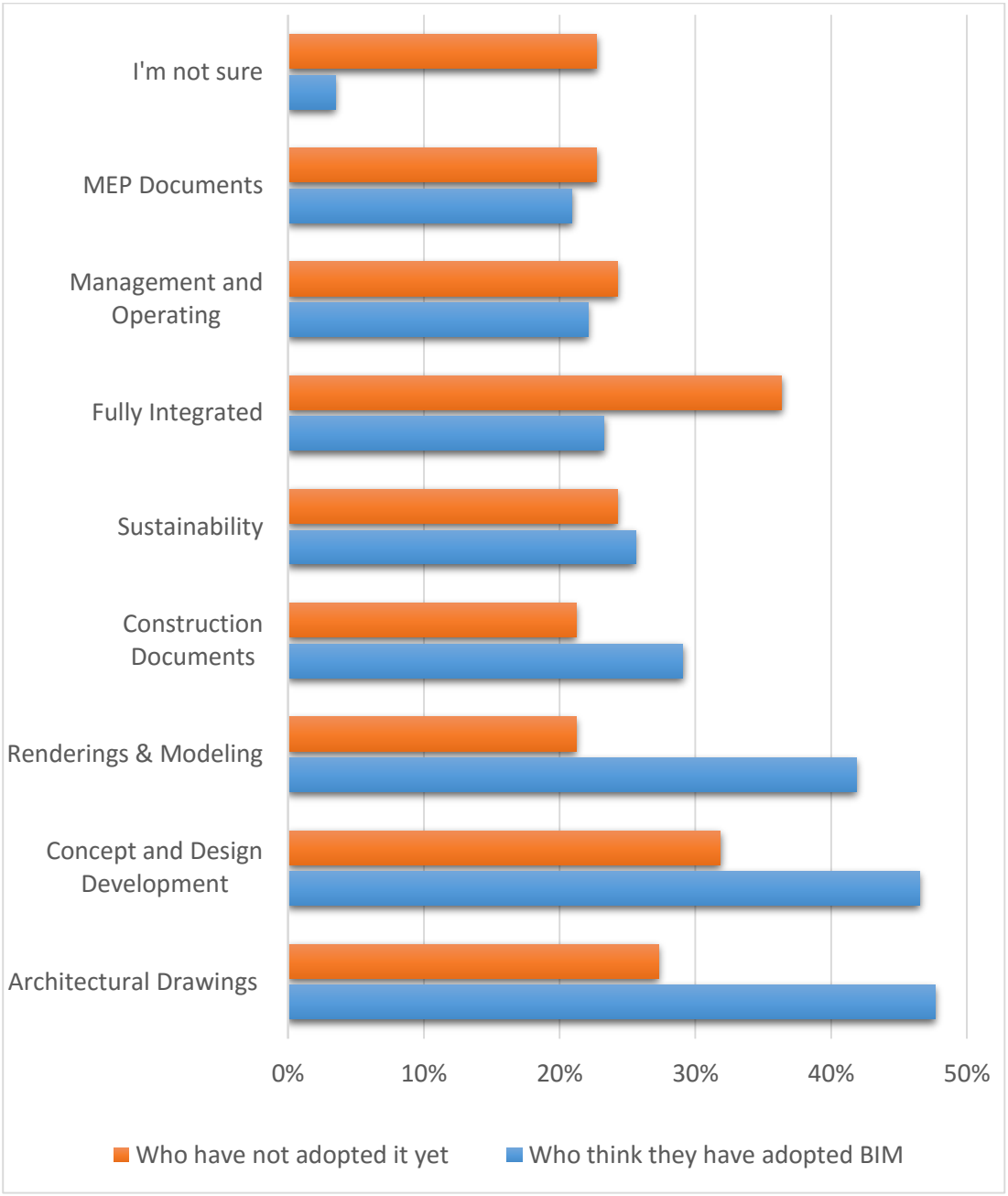



*Fig 4-24: Comparison between the current situation of BIM implementation and the future of BIM implementation within AEC Industry in KSA*

A multiple choice question was designed to ask participants to choose from the given choices and they have been instructed that if BIM has adopted in all design phases choose (fully

integrated). Hence, it seems that BIM has been used for doing concepts, modelling and producing architectural drawings more than using BIM for all the design phases. In fact, the (fully integrated) choice has almost got the lowest percentage with who have used BIM within their projects. Moreover, Fig 4-25 shows that most of participants agreed in what they are doing is BIM which lead that there is a misunderstanding of the BIM.

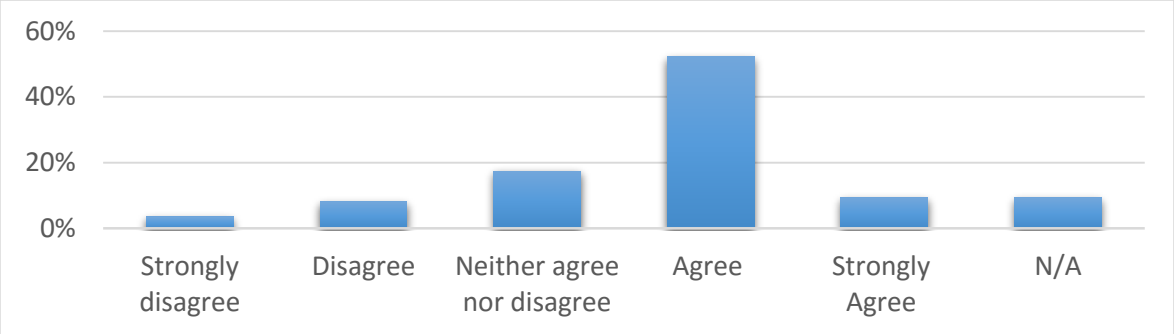



*Fig 4-25: To what extent do they think what they are doing now or planning to do is BIM*

### 4.3.3 *The Future of BIM in KSA*

- **Implementing BIM within AEC Industry in KSA**

Participants were asked number of questions to about the demand and the future of BIM within AEC Industry in KSA. First, Most of responses were agreed that the demand of BIM is increasing within AEC Industry in KSA. They have been asked to answer a rating question about the demand of BIM within KSA. 53.84% (n=98) of responses have agreed/strongly agreed that there is an increasing demand of BIM in KSA (see Fig 4-26). On the other hand, 7.69% (n=14) of responses were claimed that no need for BIM within Saudi AEC Industry. The rest of responses were chosen to be neutral or they do not know.

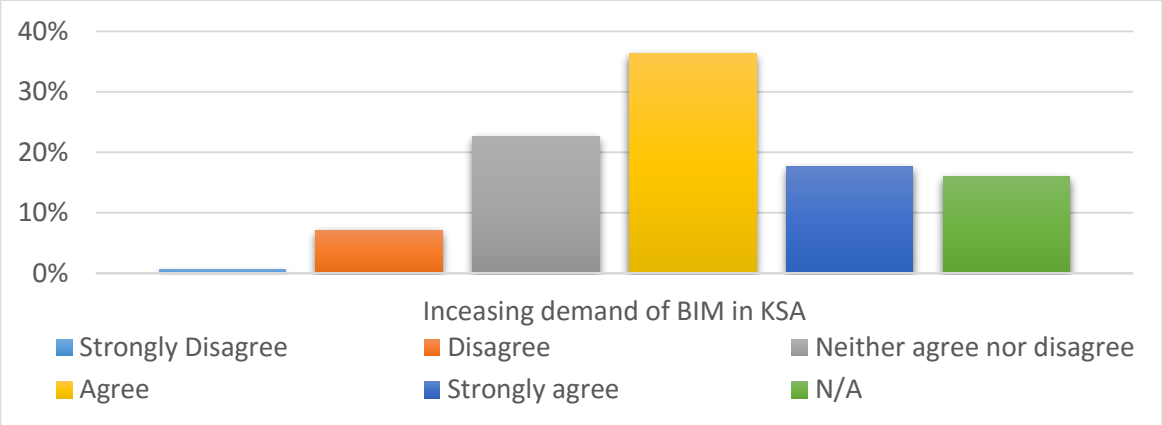



*Fig 4-26: The demand of BIM within AEC Industry in KSA*

Moreover, participants were asked to give their opinion about the future of BIM within both projects; public and private, in KSA. Responses were answered a matrix question which has four rows; public projects (Big – Small) and private projects (Big – Small). The aim of the question was to give more clarity about where will be BIM adopted more. The question has 174 responses from both academics and professionals. By comparing the size, fig 4-27 shows that 70.11% (n=122) of responses believed that BIM will be fully/partly adopted in private projects. On the other hand, less than half of responses considered that BIM will be fully/partly adopted within public projects, it has got 43.67% (n=76). Moreover, 52.30% (n=81) of responses claimed that implementing BIM need more than five years or even they do not think that will be happened in the future. However, most of responses were optimistic about implementing BIM within private projects comparing with public projects.

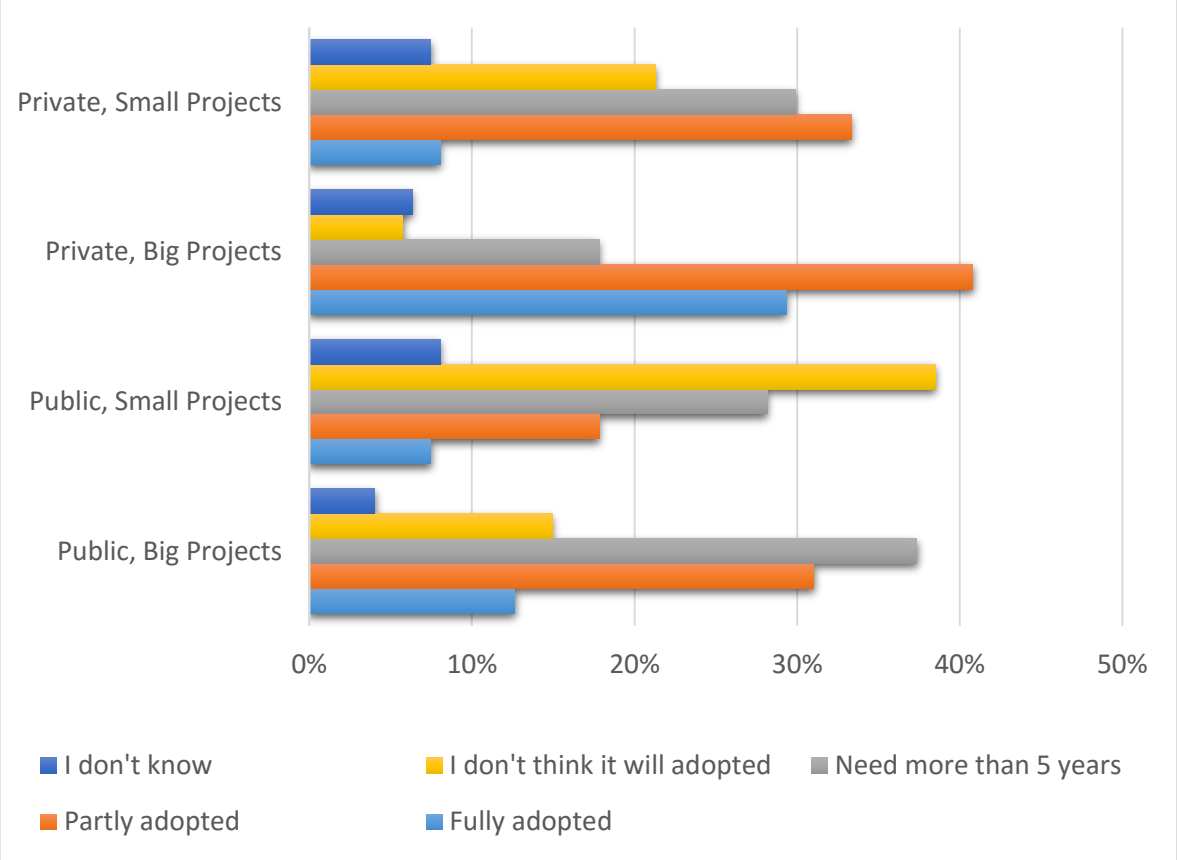



*Fig 4-27: The future of BIM adoption within the next five years*

- **BIM future jobs**

This part was aiming, first to identify the level of satisfaction about BIM users within AEC Industry in KSA, second to determine the future BIM jobs titles. These two aims have been reached by answering two questions. For the two questions, the questionnaire has got 184 responses. The first question was asking participant to what extent do you agree that to what extent do you think that Saudi labour market has the necessary cadres for the application of Building Information Modelling in the construction sector. 46.19% (n=85) of responses were disagreed/strongly disagreed with the statement comparing with 20.11% (n=37) of who agreed/strongly agreed.

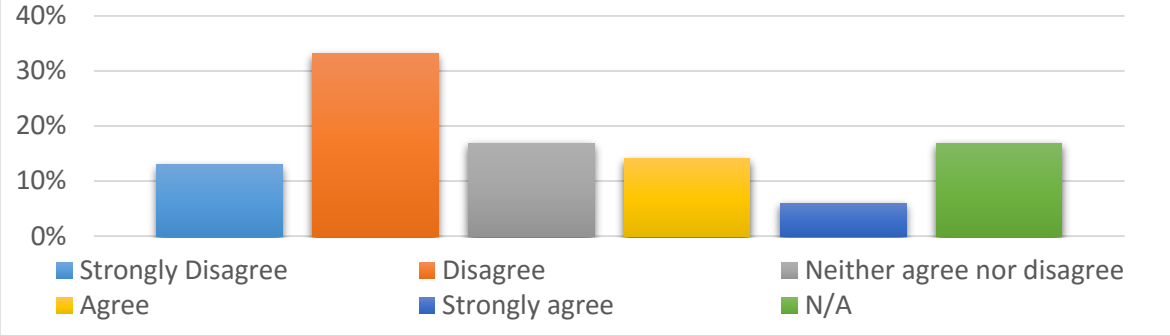



*Fig 4-28: Satisfaction of construction sector in relation BIM users within AEC Industry in KSA*

In the second question, participants were asked about the future BIM jobs titles within AEC Industry in KSA. Fig 4-29 reveals that AEC Industry in KSA mostly prefers a BIM engineer which has got the highest percentage. Then, the BIM consultant and coordinator have become second with more than 30% of the responses. The concept of BIM modeller has not got much attention; which has got the lowest percentage.

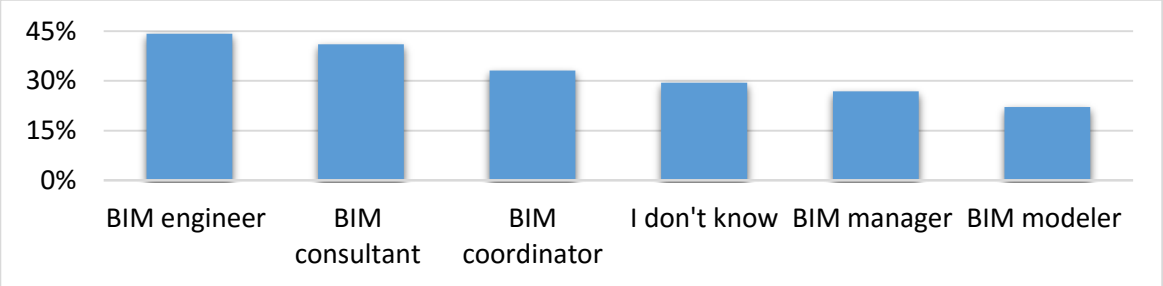



*Fig 4-29: BIM future jobs*

| 4.1 | 4.2 | 4.3 | 4.4 | 4.5 | 4.6 |
|---|---|---|---|---|---|
| Total response rate | Survey Description | BIM Maturity Level | BIM Technology | Architecture Programmes in KSA | Summary |

## 4.4 BIM computer applications used in KSA

The questionnaire asked participants about what computer applications have utilised to teach AEC students and to deliver projects. Fig 4-30 shows that AutoCAD is the most popular computer applications use to teach AEC students and delivering projects. Moreover,

AutoCAD is the only software which has been used more than being taught. In term of parametric software such as Revit and ArchiCAD, most of AEC Industry firms and AEC-ES are using Revit Architecture more than other parametric software.

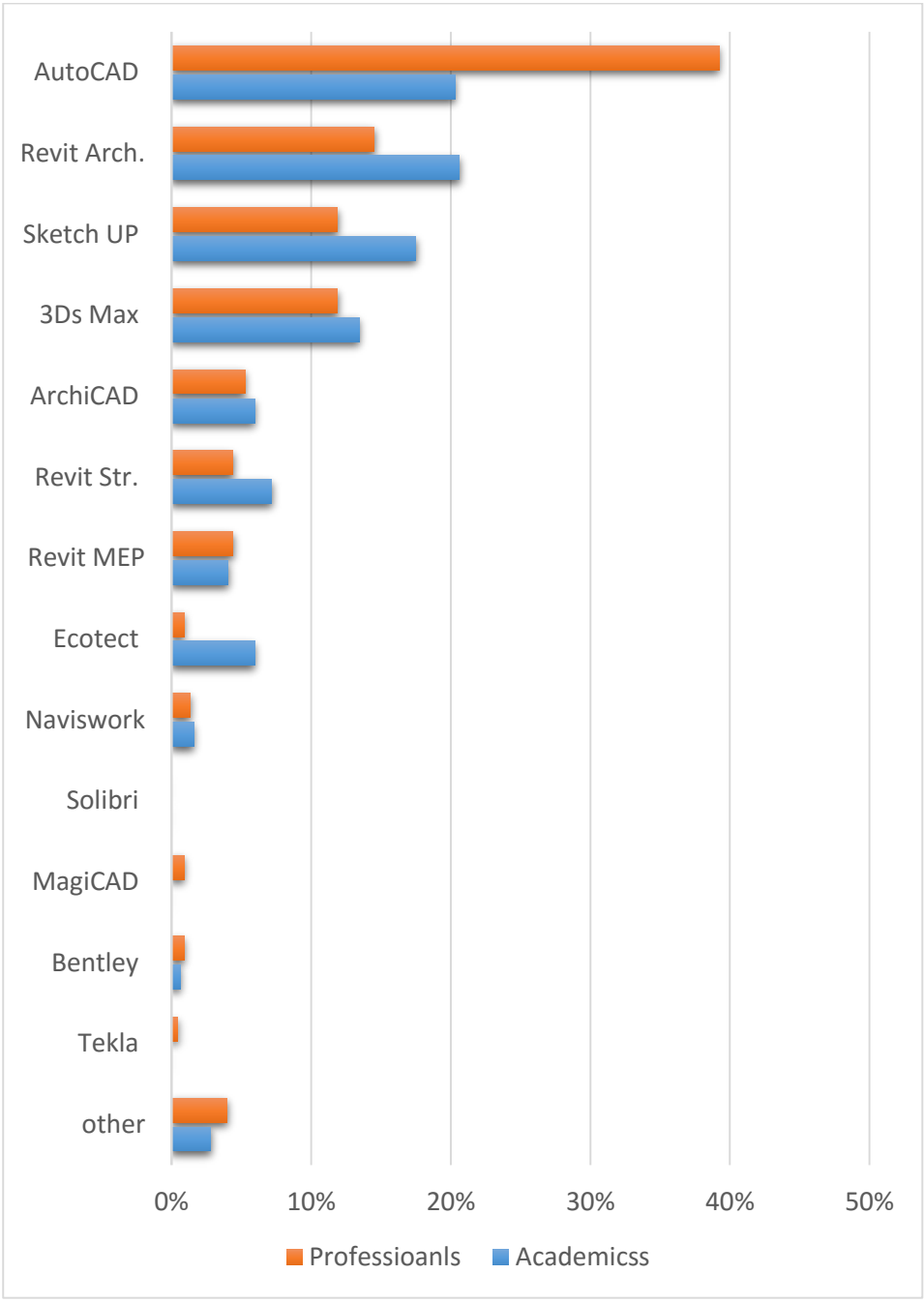



*Fig 4-30: Computer applications are used in both AEC-ES and AEC Industry*

In term of the undergraduate AEC programmes in KSA universities, a comparison was done in this survey between undergraduate programmes; architecture, other designing departments (Urban Design – Interior Design – Landscape Architecture), building construction and Engineering (Civil Eng. – Mechanical Eng. Electrical Eng.) in order to identify the most utilised software within these programmes. Fig 4-30 reveals that AutoCAD software is the most common programmes has been taught within AEC-ES in KSA. In the designing departments including Architecture departments in KSA, modelling tools such as Sketch UP, 3Ds Max and Revit Architecture are the second popular computer aided design/drawings CAD have been taught within their programmes. On the other hand, most of building construction programmes have taught Revit package (architecture – MEP – structure) within their systems.

The graph also shows that Revit Architecture is more common to be taught in most of AEC educational programmes in contrast with ArchiCAD. Moreover, software as Ecotect which helps designers to achieve a green building has introduced in architectural and building construction programmes more than other disciplinary. There are some other CAD programmes have mentioned such as Solidworks and GIS but their percentage have not exceeded 2% of the total responses. Finally, the Undergraduate Architecture Programmes in KSA are more familiar with AutoCAD, Revit Architecture, Sketch UP and 3Ds Max more than other CAD.

| 4.1 | 4.2 | 4.3 | 4.4 | 4.5 | 4.6 |
|---|---|---|---|---|---|
| Total response rate | Survey Description | BIM Maturity Level | BIM Technology | Architecture Programmes in KSA | Summary |

## 4.5 Architecture Programmes in KSA

The survey has received applications from academics in 15 universities and colleges in KSA (see Fig 4-32). The highest response rate by 26.28% was from AEC-ES in King Abdul-Aziz University, and the lowest response rate was Taibah University by 1.28%. Umm Al-Qura University UQU and University of Dammam UOD become second with almost a similar percentage; UQU 16.67% and UOD 18.59%. Moreover, three of presented universities were

a private colleges; Dar Al-Uloom, Effat University and Al-Faisal University. The highest response rate from these private colleges was Dar Al-Uloom by 8.33%.

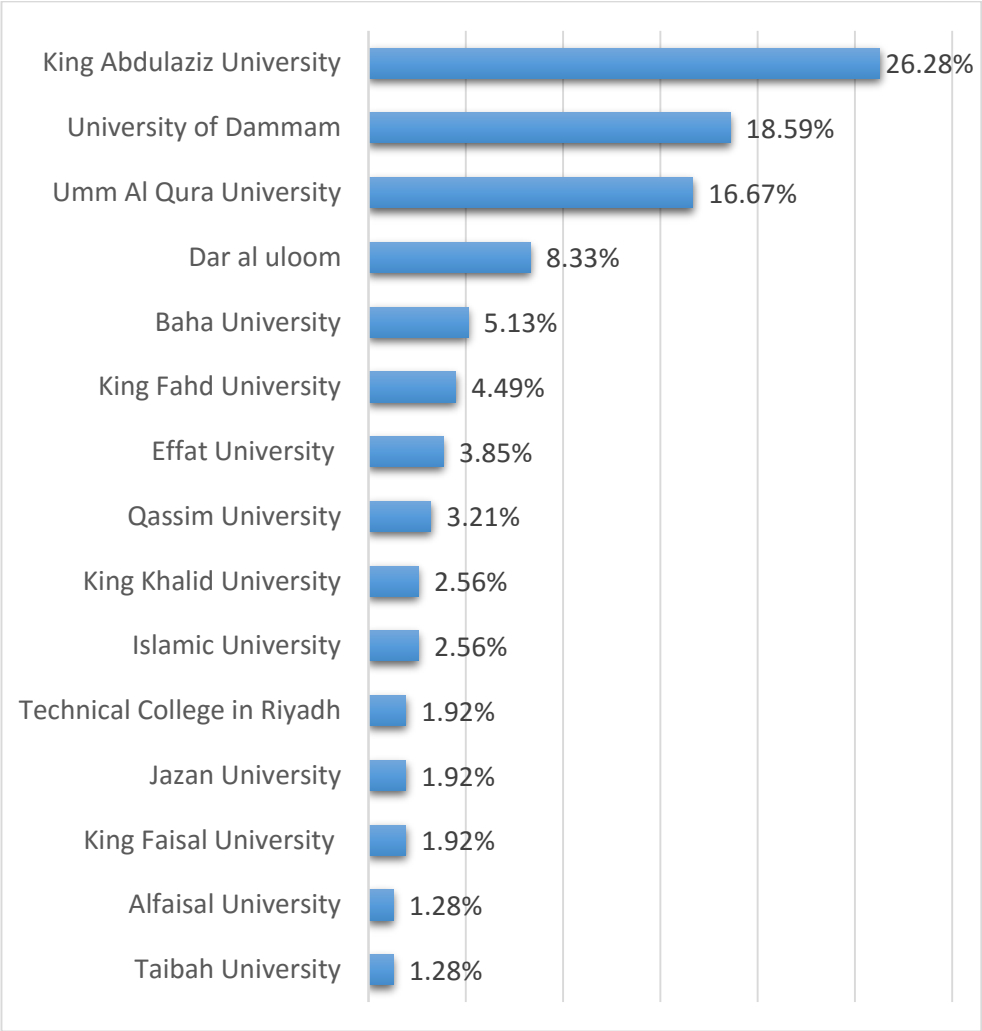



*Fig 4-31: Comparing KSA universities based on the responses*

In term of Architecture Programmes in KSA, the survey has got responses from 14 universities; which are the same mentioned universities in Fig 4-32. In addition, there are six different architectural degrees have been given by those KSA universities; Diploma, Tajseer, Bachelor, High Diploma, Master and PhD. To identify the years needed to graduate from each programmes, the survey asked academics from aforementioned universities about the duration of related degree within their educational system. Table 4-3 shows the duration of each architectural degree.

*Table 4-3: The duration of architectural programmes in KSA*

| Years to graduate | Minimum | Maximum |
|---|---|---|
| Diploma | 2.00 | 2.00 |
| Tajseer | 2.00 | 3.00 |
| Bachelor | 4.00 | 6.00 |
| High Diploma | 2.00 | 2.00 |
| Master | 2.00 | 2.00 |
| Ph.D. | 5.00 | 5.00 |

The table points to one of the significant issues facing undergraduate programmes. There are some differences in the duration time needed to graduate from the undergraduate programmes in KSA which include (Tajseer – Bachelor). Tajseer is a new system offered by some of the above universities for who have a Diploma in Architecture. Based on this system, the diploma will be equivalent in order to minimize the number years needed to get a bachelor degree (AlBaha-University, n.d). In this case, the gap between the minimum and the maximum number of years needed to graduate by applying the Tajseer system depends in the way of equivalency certificate system. On the other hand, from the table 4-3, studying a bachelor degree in architecture in KSA universities will need four to six years. However, there is a conflicting result between the minimum number of years and the maximum. That shows in the comparison between results of academics' answers from the same department and university. For example, some of the academics from architectural department in King Abdul-Aziz University have pointed that the duration of bachelor degree in architecture in their school is six years and other said five years. This conflict will be address in the second phase of the data collection.

- **Architectural Curriculum**

Academics from architecture departments within KSA universities have been asked to determine the reference of their architecture curriculum. Fig 4-33 presents a comparison between the references of architecture curriculums in old (started before 2004) and new (started after 2004) KSA universities. Either new or old university, the graph shows that most of architectural curriculums in KSA universities have designed based on international

standards. However, most of the new universities, which have opened after 2004, have got their architecture programmes from one of the old Saudi Universities.

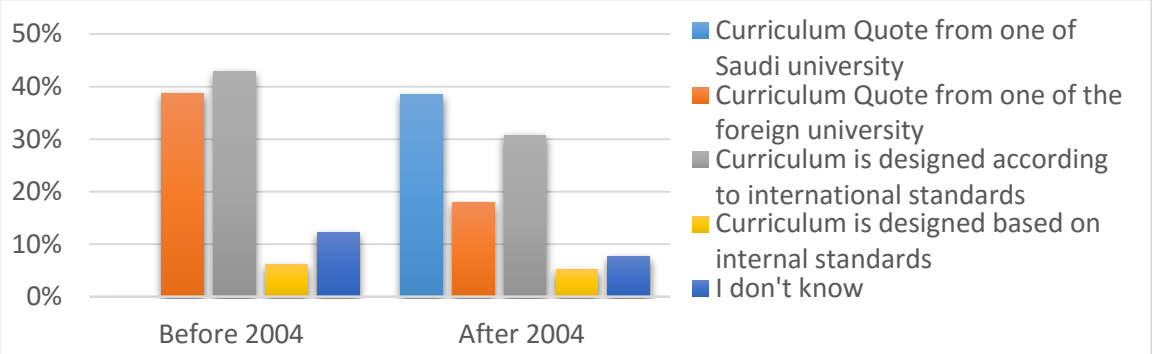



*Fig 4-32: Comparison between the references of architecture curriculums in old and new KSA universities*

The above mentioned question was followed by an open ended question asking academics to clarify the original reference of their architectural curriculum. Their comments were categorised into three categories based on regions; KSA, Arab countries and Western countries. US universities and their standards were the most popular choice for both schools to adopt their method from them. It has got more than 74% of the total response. However, for the new universities, the majority of them have quoted their curriculum based on one of the three KSA universities; King Saud University, Umm-Al-Qura University and King Fahd University of Petroleum and Minerals. Then, several of these architecture schools have developed their curriculums using one of the top 10 architectural schools curriculums in US. Most of the old universities in KSA have built their curricula based on American top architectural schools; For example, King Abdul Aziz University have quoted Harvard University Architectural programmes; according to the result of the open-ended question.

Participants in those two questions were asked if their curriculums have been developed or if they are planning to develop them within the next five years. Fig 4-33 shows that almost 60% of architecture curriculums within KSA universities have already developed; and more than 25% in progress of developing their curriculum. Who have selected one of these choices have redirected to an open-ended question asking them to determine the aim in developing their curriculum. From findings of this question, both developed or under development architecture curriculum have focused of sustainability more than other architectural issues;

it has got the highest mentioned by 56.52%. The second mentioned topic was IDS where some participants have stated that "working with other students from different AEC Industry degree"; it has got 19.57%.

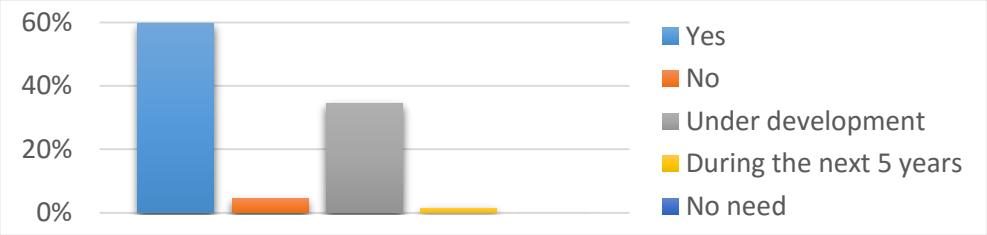



*Fig 4-33: Developed or planning to develop the architecture curriculums in KSA universities*

The most significant finding is that architecture programmes in King Khalid University are planning to adopt BIM within their curricula. As it has stated that their curriculum will be developed to be focus on sustainability, the development of holistic approaches and contemporary architecture with the use of BIM based technology. Moreover, they have reached an agreement with Autodesk to provide them within BIM applications such as Revit Architecture.

Finally, the majority of academics from the architecture department in KSA universities and who have responded to the survey agree that the architecture curriculum must be developed. Fig 4-34 shows the result of a Likert scale question asking them to select the most suitable answer. The question was to what extent you think the architecture curriculum should be developed. The graph shows that most of them strongly agree with the statement by 63.46% followed by agree with 21%.

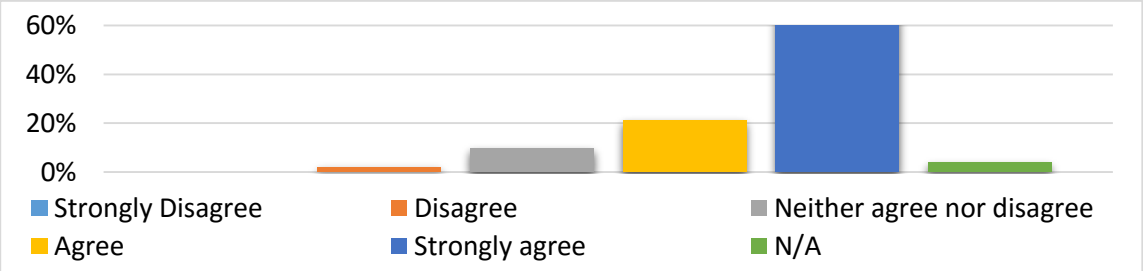



*Fig 4-34: The need to develop architecture curricula*

Besides that, professionals have different opinion about the architecture curriculum in KSA universities; in general, it has not reached their expectation yet. Fig 4-35 presents a comparison between academics and professionals opinions in this aspect. They have asked that if the curricula is well-developed to meet the AEC Industry needs. It seems that there is a split decision in agree or disagree from the academics' perspectives; in contrast, professionals disagree that the curriculum is well developed.

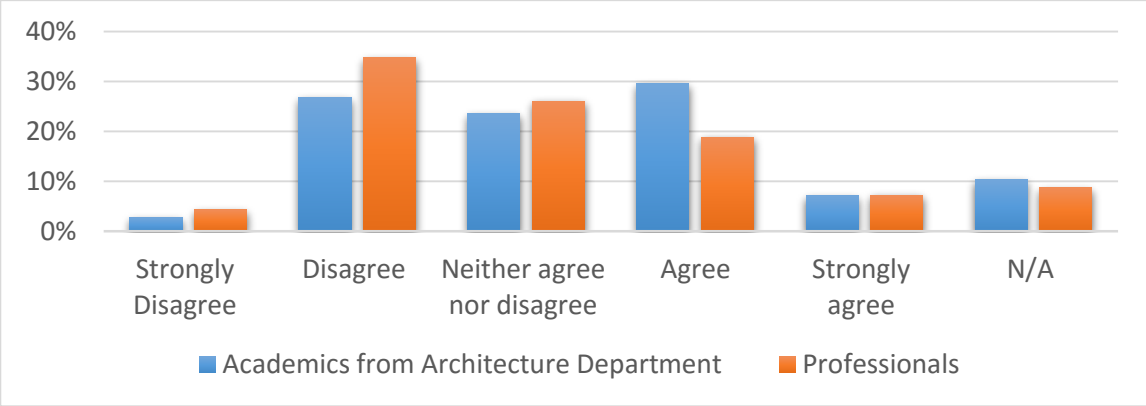



*Fig 4-35: A comparison between the satisfaction of AEC-ES and AEC Industry in relation to architecture curricula*

| 4.1 | 4.2 | 4.3 | 4.4 | 4.5 | 4.6 |
|---|---|---|---|---|---|
| Total response rate | Survey Description | BIM Maturity Level | BIM Technology | Architecture Programmes in KSA | Summary |

## 4.6 Summary

Although, the concept of BIM has been introduced in the AEC Industry and AEC-ES in KSA, there is a major concern in the BIM maturity level. Most of them seem either to understand BIM as in a based technology only or that BIM is a process for one or two phases during the project lifecycle. As one of the objectives for this questionnaire to help in designing the second phase of the data collection, the following are some of the key points to design the interview:

1. It has been found that most of academics have a misunderstanding about BIM. These results presented by linking the two figures (Fig 4-15 and Fig 4-16) with Fig 4-18. Although, the two figures (Fig 4-15 and Fig 4-16) show that BIM has been taught within AEC-ES in KSA and Fig 4-18 shows that most of academics agree in what they are doing is BIM, these results present a lack of understanding of BIM (see section 5.3.1-BIM maturity level within AEC-ES in KSA). Therefore, to obtain valuable information based on the level of knowledge in BIM, the interview stated by presenting a PowerPoint about BIM (see appendix 5).
2. As the figures in section (BIM maturity level within AEC-ES in KSA) show that BIM has been taught within Undergraduate Architecture Programmes in KSA, the interview was designed to evaluate their methods of embedding BIM based on their BIM maturity level.
3. It has been pointed by participants some of BIM barriers; no room for BIM within academia, lack of BIM teaching experience and lack of BIM understanding. However, it has been found in the literature review that there are 12 barriers including the aforementioned barriers which may affect BIM implementation within architecture programmes. These barriers have been ranked by interviewees during the second phase.

*Table 4-4: Number of academics and professionals who are willing to take the interview*

| Answer Choices | Academics | Professionals |
|---|---|---|
| Yes | 23.00%<br>23 | 24.78%<br>27 |
| No | 77.00%<br>77 | 75.22%<br>82 |
| Total | 100 | 109 |

4. The last key point is the number of participants who are willing to participant for the next phase of the data collection. Participants have asked if they are willing to be interviewed for approximately 25 to 35 minutes. 23 academics and 27 professionals have agreed to take the interview.

# CHAPTER 5

Qualitative Data: Semi-Structured Interview

Sections

| 5.1 | 5.2 | 5.3 | 5.4 | 5.5 | 5.6 | 5.7 |
|---|---|---|---|---|---|---|
| Interview Description | Interview Method and Analysis | Interview Findings | General Question | BIM within Their Modules | Teaching BIM | Summary |

# Chapter 5. Qualitative Data: Semi-Structured Interview

This chapter presents the structure of the semi-structured interview and its outcomes. The chapter includes a description of the interview and the findings. The interviews were with 11 academics and a focus students group.

| 5.1 | 5.2 | 5.3 | 5.4 | 5.5 | 5.6 | 5.7 |
|---|---|---|---|---|---|---|
| Interview Description | Interview Method and Analysis | Interview Findings | General Question | BIM within Their Modules | Teaching BIM | Summary |

## 5.1 Interview Description

The interviews have done in Arabic language, then all dialogs have translated from Arabic to English. Two different groups have been interviewed in this phase of data collection. First group was academics within architecture programmes in KSA. The sample size of this group was decided based on the questionnaire outcomes (3.4.1 – the second phase of the data collection). An email was sent to 23 academics from architecture departments in KSA Universities, 11 of them were able to participate at that time. The interview was done in two different technique; face to face and Skype. A presentation about BIM and its benefits was presented to all 11 academics. The aim of the presentation was to raise the level of knowledge among academics about BIM (4.6 – interview preparation).

The second group which has been interviewed was architecture students. The interview with architecture students was not planned, as the second phase of the data collection in this PhD research was planned to be interview academics only. However, during the interview with one of the academics, the interviewee mentioned that he has just started to teach BIM for architecture students. He asked if the researcher willing to use the same presentation in order to give two lectures to his students. He thought the presentation will help them to understand the concept of BIM. The two lectures were presented to them were given two months after the beginning of the semester. After the two lectures, students have been asked willingly if

they have no problem to be interviewed. The number of students for the two lectures was 34 architecture students and all of them in the third year. The architecture programmes in their school is a five year programme. 8 of the 34 students have agreed to do the interviewed. Because of the number of the students and the time, it has been decided to do a focus group instead of individual interview. The course's constructor stated that the aim of the course is to introduce the concept of BIM through the use of Revit Architecture programme.

*Table 5-1: Interviewees coding*

| No | Participants | | Time | Position |
|---|---|---|---|---|
| 1 | ***Academics*** | A1 | 61.23 | Assistant Professor |
| 2 | | A2 | 63.45 | Assistant Professor |
| 3 | | A3 | 56.35 | Assistant Professor |
| 4 | | A4 | 53.45 | Assistant Professor |
| 5 | | A5 | 54.23 | Assistant Professor |
| 6 | | A6 | 74.16 | Assistant Professor |
| 7 | | A7 | 92.34 | Assistant Professor |
| 8 | | A8 | 58.27 | Associate Professor |
| 9 | | A9 | 81.51 | Assistant Professor |
| 10 | | A10 | 53.52 | Associate Professor |
| 11 | | A11 | 69.34 | Assistant Professor |
| | ***Focus Group*** | | 73.25 | Architecture Students |
| **Average** | | | **65.925** | |

| 5.1 | 5.2 | 5.3 | 5.4 | 5.5 | 5.6 | 5.7 |
|---|---|---|---|---|---|---|
| Interview Description | Interview Method and Analysis | Interview Findings | General Question | BIM within Their Modules | Teaching BIM | Summary |

## 5.2 Interview method and Analysis

The interview with academics and architecture students were conducted using two different interview techniques; Skype and face to face interview. After getting their permissions, both techniques were recorded using two applications; the first one is Bandicam which used with Skype to record the presentation and the interview. The second application was downloaded in the researcher's mobile which is called Smart Voice Recorder, it has used with face to face interview only.

In term of presentation, each interviewee has a brief presentation about BIM and its benefits. The average time of the presentation for all interviewees including focus group was18.34 minutes. The presentation (Appendix 5) was design to cover the concept of BIM, its benefits, the demand of BIM and the current situation of Saudi AEC Industry and AEC education. Also, the current situation of BIM implementation within AEC education was presented to interviewees.

After the presentation, each participant was asked several questions in relation to BIM framework and the embedding of BIM within Undergraduate Architecture Programmes in KSA (Appendix 6). The interview designed to be a semi-structured interview; it has helped to determine the focus of the interview. All the interviews were recorded in Arabic, and it has been translated to English. The average time for the interview and the presentation was 65.925 minutes (Table 5-1).

Finally, to analyse the interviews, the analysis of this phase of data collection was divided into three areas. The first area was analysed as a quantitative method. In the interview, some of the questions were designed as Yes/No, Ranking, Rating and multiple choices questions. Hence, these kind of questions have to analyse using quantitative method. On the other hand, the second area was used a coding system in counting words. This technique has helped to develop the most choices words and phrases which have used by interviewees. The third area was used some of the academics statements.

| 5.1 | 5.2 | 5.3 | 5.4 | 5.5 | 5.6 | 5.7 |
|---|---|---|---|---|---|---|
| Interview Description | Interview Method and Analysis | Interview Findings | General Question | BIM within Their Modules | Teaching BIM | Summary |

## 5.3 Interview Findings

The findings of this phase of the data collection have structured based on the four areas of the qualitative data design; General Questions, BIM within their subjects, Teaching BIM and Integrated Design Studio (3.5.2 – The qualitative data design). However, the following describe the effect of the presentation on the interviewees.

In term of academics, 61.61% (n=7) of academics have agreed that the BIM presentation has developed their knowledge about BIM. The interviewees have been asked to rate their knowledge about BIM after the presentation on scale of 5; which 1 presents the lowest value and 5 is the highest value (See Fig 5-1). 27.27% (n=3) of academics were rated that the presentation has few new information but most of the information were familiar to them. For example, Academic A7 has stated that *"I have been in a workshop about BIM…it was in Dubai…most of these information you have provided were presented in their workshop"*. Another example, Academic A3 stated that *"I worked with an international construction companies which BIM is a part of their works…they have explained the benefits of BIM and the concept of collaboration"*. On the other hand, 9.09% (n=1) of academics was disagreed with the statement. He stated *"It's been more than six months since I started to read about it…I think it's a new area for researching"*

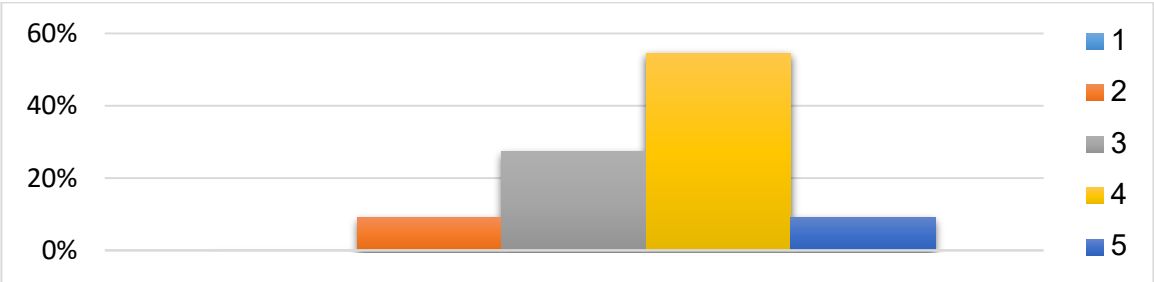



*Fig 5-1: The effect of the BIM presentation on academics*

In term of architecture students, seven of them have chosen number five and the last one has chosen four. This question was answered individually, which each one of them rate his knowledge after the presentation. One of the students has said:

> Student S1 said:
>
> *"I thought BIM is for architects only… and it will help us in modelling and rendering, but when we saw the presentation…, many things have changed" He have been asked to explain what he meant about* Many things have changed *"Now I have understood that BIM is a new language for designing, constructing and operating projects within AEC Industry.*
>
> Student S2 continued by saying:
>
> *"I thought BIM is just software…, Revit package (Architecture – Structure – MEP) help in designing only…, but… now I understood that BIM help in all design process and to communicate with other disciplines in the same project… especially when each disciplines use different BIM application"*

These were their answers after they have rated their knowledge, and most of the students were agreed with these statements. The rest of students have no comments on these statements. However, these comments and the rating questions reveal that the concept of BIM have not introduced properly to students. This conclusion was revealed during the analysis of the first phase of the data collection. However, the following section covers all the findings of the semi-structured interview with academics and architecture students. It covers; General Questions, BIM within their subjects, Teaching BIM and Integrated Design Studio.

| 5.1 | 5.2 | 5.3 | 5.4 | 5.5 | 5.6 | 5.7 |
|---|---|---|---|---|---|---|
| Interview Description | Interview Method and Analysis | Interview Findings | General Question | BIM within Their Modules | Teaching BIM | Summary |

## 5.4 General Questions

The 11 Interviewees were from six Saudi's Universities which is presented in Fig 5-2. The Fig 5-2 shows that 27.27% (n=3) of interviewees were from King Abdul-Aziz University. This is followed by 18.18% (n=2) of interviewee in three universities; Taibah, Al-Baha and Umm Al-Qura University. Finally, the researcher has interviewed 9.09% (n=1) from Dammam, and King Khalid University. All of these Universities have an architecture programme. However,

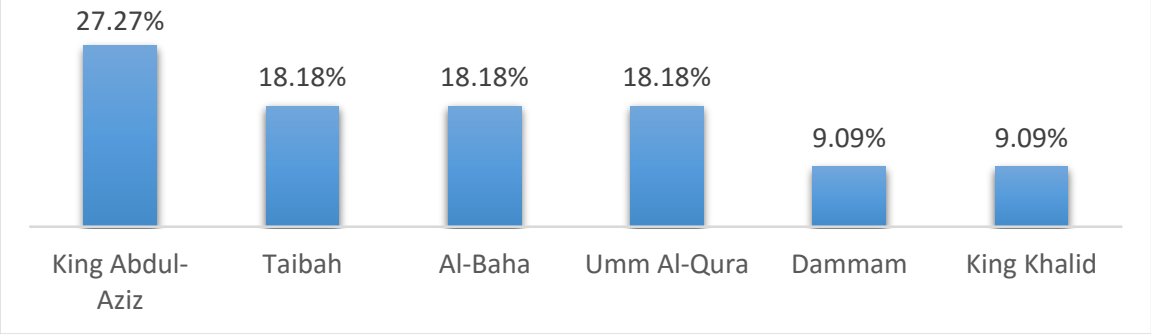



*Fig 5-2: The percentage of interviewees based on their university*

### 5.4.1 *Research interests*

Interviewees were asked to determinate their research interests, they have pointed out 10 research areas within AEC Industry studies. The highest mentioned area was architecture design which has got more than 28%, as it presents in Fig 5-3. However, the graph shows how diverse the interviewees are based on their area of interests. That leads to have varied opinions from academics.

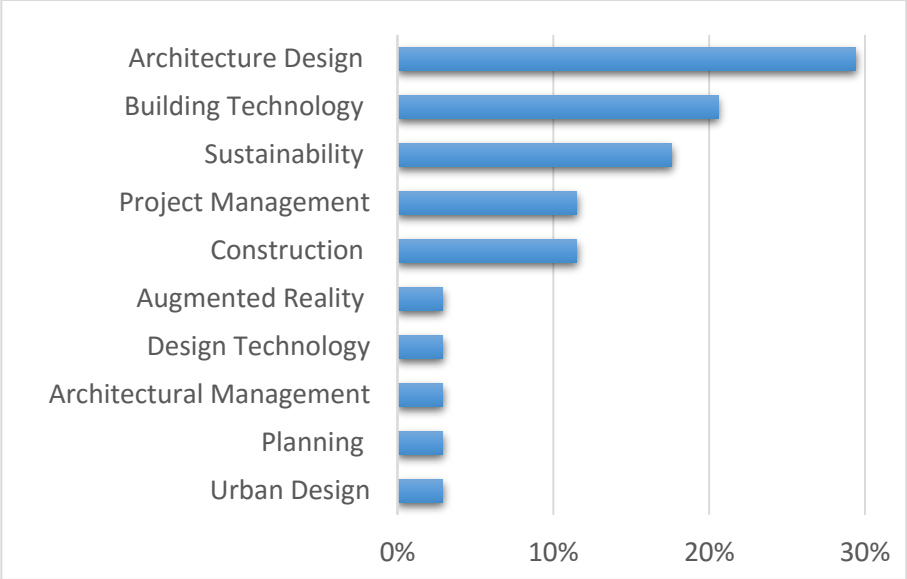



*Fig 5-3: The 10 research areas mentioned by academics within architecture programme in KSA*

### 5.4.2 *Taught subjects*

This question aims to understand the interviewees opinion based on their taught subjects within architecture programme. It has been appeared that all participants have taught architecture studio design. Three of them have even taught all the architecture studio design academic levels; from year one to year five (graduation level). However, Fig 5-3 shows the taught subjects for interviewees within architecture programme in KSA universities. It reveals that architecture studio design is the most mentioned subject. Moreover, interviewees have mentioned several taught subjects which has merge under the Other Subject column; subjects such as mechanical system, building construction, structure and furniture design.

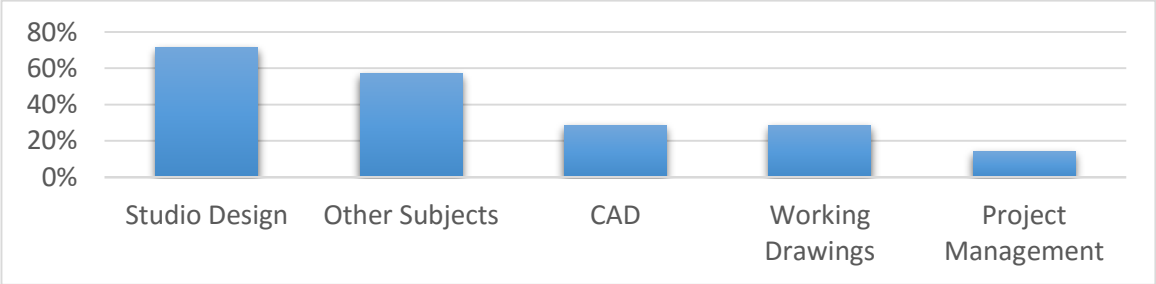



*Fig 5-4: Taught subjects*

In term of computer aided design/draft CAD, five of the interviewees have taught CAD. Three of them were teaching some BIM computer applications. These applications were Revit Architecture, Ecotect and Green Building website. Two of the three were specialised in sustainable buildings. The other two interviewees were teaching AutoCAD, 3Ds max and Photo-Editing Software such as Photoshop and CorelDraw. As 3Ds max is one of BIM applications, interviewee has been asked to determinate his method in how he taught it and what will be the outcome. He said:

> *"Students learn how to use the programme in order to model and present their works… they will learn how to choose material… and how to create perspectives … and how to get the best shot"*

Finally, three of interviewees have mentioned that they were teaching a working drawings class. Two of them were teaching this subject for students in their fourth academic year and one was teaching students in their graduation year. That because of the architecture programme, they were presenting three different architecture schools. The last subject in Fig 5-3 is the project management; two of participants from two different schools mentioned that, both of them teaching the subject for the graduation level.

### 5.4.3 *BIM within AEC Industry in KSA*

As one of the architecture schools' objectives is to achieve the AEC Industry needs, the interview was aiming to understand what interviewees think about the future of BIM within AEC Industry in KSA. Interviewees have been asked a direct question (Do you believe the use of BIM in the marketplace will continue to increase in KSA?). 10 of the academics have agreed that the use of BIM will continue to increase in KSA, but with some concerns from few academics. Few of academics have raised that BIM will be used for big projects only and by big construction companies in KSA.

For example, Academic A4 stated:

> *"I think the use of BIM will implemented within big projects only … and the big projects in my country … which most of them owned by the government … are assigned for big construction companies … such as Bin Laden and*

*Zoheer Faise… Hence, I think BIM will be adopted by big construction companies only… and no room for BIM within small firms."*

Academic A4 has been asked to clarify if that will have an impact on architecture students. He said:

*"That may have a negative impact on architecture graduate students if they become an expert in BIM … The percentage of the big construction companies in KSA is lower than the percentage of small construction companies and firms … and I think they have less chance to find jobs… in fact they are highly qualified for small construction companies … who cannot afford their salaries… and they will be no room for them in big construction companies because of the high level of competition with the big number of graduation"*

Where the search was based on direct analysis and use some of the valuable statements for asking other interviewees about these statements, it has been found that no one have agreed with what Academic A4 has said. The following presents some of interviewees' answers.

Academic A6 Said:

*"I'm totally disagreeing with him, first of all… BIM will help to improve the way of how stakeholders work together within AEC Industry… and if the government have required the use of BIM within their projects… that will lead small and big construction companies to use it… In addition to that, there are many small construction companies who work as subcontractors for these big construction companies… and I think that a good reason to encourage the small companies to use BIM".*

Academic A7 has mentioned what academic A6 said and he added in the top of that by saying:

*"Yes… students will be highly qualified for small companies… and this is better than having architects who are less than the AEC Industry*

*expectations… However, I think graduate architecture students with BIM skills will be rare… if we keep in mind the lack of Saudi architects and engineers' number within AEC Industry in KSA"*

However, both have agreed that the use of BIM will be increasing within AEC Industry in KSA. In addition of implementing BIM within AEC Industry in KSA, nine of them believe that the Saudi Government has to involve making it happen. As the Academic A6 said:

*"There is a potential to implement BIM within AEC industry in KSA… It has to be required by the KSA government such as UK"*

Moreover, Academic A1 support that by giving a brief history about the size and the number of projects in KSA, and the Saudi government have to require BIM for its projects by saying:

*"Saudi Arabia is in the middle of a huge construction boom. A lot of mega structure projects are planned to be executed within the next few years… The complexity of such projects requires effective collaboration between the different project stakeholders… I believe BIM is the answer… and the Saudi government have to require BIM for all its projects".*

| 5.1 | 5.2 | 5.3 | 5.4 | 5.5 | 5.6 | 5.7 |
|---|---|---|---|---|---|---|
| Interview Description | Interview Method and Analysis | Interview Findings | General Question | BIM within Their Modules | Teaching BIM | Summary |

### 5.5 BIM within their subjects:

Interviewees have asked if they have taught BIM based technology, process or both within their classes. The findings from the interview shows that BIM has been taught in architecture design studio and some other subjects such as working drawings and project management. Moreover, it shows that BIM has taught as process, technology and both.

### 5.5.1 *BIM as process*

It has been recorded that one of interviewees have introduced BIM to their students as a process only. He has explained the method of sharing data and how disciplines could work together in a 3D environment. As academic A1 said:

> *"I have just started to introduce BIM to students as a new way of designing and construction projects… I taught students that one of the significant benefits of implementing BIM is improving the communication between different disciplines"*

Academic A1's method in how BIM has been introduced to architecture students:

> *"I used a small project to explain the concept of BIM… the project I used was designed using Revit… the file wasn't well-developed…but It was helpful to introduce the idea of BIM… The aim of my class was to explain the value of data and how we can link data with drawings… then how data can be shared with disciplines"*

- He has been asked to determinate some of the challenges he had faced during his class.

  *"My class was one semester long and it was two hours per/week… I had faced some challenges…first, I knew that BIM will help students…but I do not know what is the best way to teach students BIM…I think we need to have a roadmap for that…Also, I don't know how to use and teach BIM based technology…and I don't know what is the best software to teach"*

- Have you heard about Autodesk Revit or ArchiCAD?

  *"Yes, I have heard about both programmes…but in this school… we are teaching Autodesk Revit…and the reason of teaching Revit instead of ArchiCAD is that we have few Assistant Professors who know how to use and teach Revit"*

### 5.5.2 *BIM as Technology*

Five of interviewees have taught BIM based technology only. All of them have taught Autodesk Revit for their students. Three of them (A3, A5 and A9) have taught it to explore the model and the rendering tools only. For example, academic A3 said:

> *"I teach Revit Architecture in a computer lab for the first year students… we are trying in the school of architecture to help students within our school to understand how to present and model their architecture projects by using better tool"*

- Can you specify why did you choose Autodesk Revit to introduce to your students?

> *"We used to teach AutoCAD for our students…until one of our professor had come cross Autodesk Revit…and that was in 2001…in that time was called Revit before Autodesk bought the company… However, he decided to learn the programme then teach it to the students… he believes that Revit was designed for architects and we should teach that software for or students…In that time I was in my fourth academic year…Now, I'm an Assistant Professor and I'm teaching Autodesk Revit…In term of the professor opinion, I'm totally agree with him and I'll add that now several of architectural firms in Jeddah (The second largest city in KSA) are seeking professional with Revit skills"*

It seems that Revit Architecture has taught as a computer aided draft; as they explained that Revit Architecture has replaced the old CAD tools. The other two academics (A7 and A11), on the other hand, have explored the other part of BIM technology when they used Revit Architecture as a computer aided design. The first, Academic A7, was used BIM based technology to help students to understand how they produce working drawings for building and to understand how building components work. He has taught his students in a studio specialised on working drawings, He said:

> *"I taught students the concept of how to do working drawings using Revit Architecture… the studio aims to help students to produce working drawings*

*documents… we want students to work in a 3D environment… that what made us to change from the traditional method in producing working drawing using AutoCAD to use a programme specialised for architects"*

- Have you thought to teach students working drawing studio using BIM concept?

  *"We just started in this semester to use Revit in order to produce these drawing…we even try to introduce the concept of BIM via this class…The idea of teaching BIM through working drawing studio was motivated by your questionnaire"* He meant the first stage of the data collection *"we started to read about the benefits students may gain from that"*

- Academic A7 was asked to evaluate their experience in using BIM based technology to teach working drawings. He said:

  *"For a two months experience… I think producing working drawings documents need to have a new strategy and rules… we've using Revit Architecture since 2001… and we use to produce rendering shots and architecture drawings… for working drawings documents, we used to use AutoCAD… we are facing some challenges because of the changing from 2D drawings to 3D drawings"*

- Can you specify some of these challenges?

  *"First, working in 3D environment using Autodesk Revit has help students to realise issues within their projects… issues related to mechanical, electrical and structural system… some of these issues we don't know how to solve it… and I think if we have someone how could help us in these situations that defiantly will help students to understand how to solve these issues…However, after your presentation… I believe that we need time to understand BIM…Technology, process and regulations…I think this is the most challengeable point"*

The second academic A11, he has taught Autodesk Revit within an architecture design studio to introduce the idea of building performance by using Ecotect software.

> *"The aim of the first semester in the third year architecture programme in our school is to teach students the concept of building performance…we want students to make decisions about their projects based on the energy consumption of their buildings…most of our students know how to model using Autodesk Revit… from there, we ask them to explore the model to Ecotect"*

- During your class, have you faced any challenges?

> *"One of the most challenging point we have faced was exploring Revit file to Ecotect…some of the students have issues with that…I think that because the Ecotect is too advance for students in their level"*

- What is your recommendation about the choice of energy simulation tools?

> *"I strongly believe that the choice of energy simulation tools should be decided based on academic experience and schools… what I meant about that…you can't choose a software which no one can teach it and you can't decide to teach something the school doesn't allow it"*

Both, Academic A7 and A11, were from a school where Autodesk Revit has taught in early stage of the architecture programme. Moreover, according to (A1, A3, A7 and A11), they have been teaching Revit since 2001. Their school is the only architecture school in KSA universities who applied the Vertical Design Studio or Multilevel Design Studio, according to (A3 and A7).

Academic A11 has mentioned that students in the first year programme in his Multilevel Design Studio were given small task to do using Autodesk Revit. He said:

> *"We have small experience with the first year programme… the aim was to understand building components… The project was a small coffee shop… and*

*students have to design all elements within the project… they have even designed the mechanical and structural system…what we have noticed that students trying to solve issues when duct hit beam in their project… they have done the plumbing and electrical system… Some of the students have changed their concept because of the number of issues which have been discovered".*

- Have you tried to have a multidisciplinary class? Or have you tried to ask specialist to work with your students?

*"No, we have not…organising such concept need time…and it need to be organised by our department and others departments within our school…I think brining experts to work with first year programme will be unfair for them to face the real world…However, I prefer If expert work with students in upper academic level than students in lower academic level"*

Students have already explored few benefits of using BIM technology such as modelling, rendering, improving building performance and producing working drawings. However, the words (Building Information Modelling BIM) have not been introduced yet; as none of interviewees who have taught BIM as technology have mentioned BIM process.

### 5.5.3 *BIM as process and technology*

The only case where BIM has been taught as process and technology was by Academic A2 who have taught BIM process and technology. That when he introduced the concept of BIM in helping Facility Management FM.

*"I taught students how to support the FM using COBie… I provided them with a BIM project… then I asked them to extract the data needed for FM in a table… In the end, students need to present their final project in an excel file… the file has to have the area and components within the project and it has to be linked with contact numbers + Name"*

- Can you evaluate your experience in teaching BIM to your students?

> *"BIM should be taught to cover all design processes not only a small aspect of the building lifecycle... However, I couldn't teach my students how to implement BIM within their project lifecycle… the main reason that the lack of BIM educators and BIM experts in our school and within the AEC industry in KSA"*

The rest of interviewees have not taught BIM, however, three of them have mentioned BIM within their classes to give students idea about the latest changes in the AEC Industry. To conclude the finding of this phase, there are some movement to teach BIM within architecture programmes in KSA. However, there are some challenges facing the embedding of BIM within architecture programmes; lack of understanding of the concept of BIM and BIM experts. Finally, none of them have explored teamwork within an Integrated Design Studio using BIM.

| 5.1 | 5.2 | 5.3 | 5.4 | 5.5 | 5.6 | 5.7 |
|---|---|---|---|---|---|---|
| Interview Description | Interview Method and Analysis | Interview Findings | General Question | BIM within Their Modules | Teaching BIM | Summary |

## 5.6 Teaching BIM:

### 5.6.1 *Benefits of teaching BIM*

Interviewees have been asked to give their opinion in how BIM should be taught within Undergraduate Architecture Programmes in KSA. The majority has agreed in that BIM should be embedded within Undergraduate Architecture Programmes except one of the academic who has disagreed in that. The reason behind that, he stated:

> *"BIM has not been required by the AEC Industry in KSA… and there is no evidence shows if the demand of BIM is increasing or not"*

- Do you believe embedding BIM within Undergraduate Architecture Programmes in KSA will have a positive impact on students?

  *"I think there are few benefits for teaching BIM technology to students…I believe it will add a new skills to their knowledge…but, I don't believe that BIM process will add any value to their knowledge"*

However, based on the findings of the preliminary data, the construction companies and architecture firms within AEC industry in KSA are looking BIM experts. Moreover, the majority of academics and professionals who have responded to the questionnaire were agreed that BIM implementation within KSA will increase within the next five years (see chapter 4).

On the other hand, academics how have agreed in teaching BIM within Undergraduate Architecture Programmes think that the embedding of BIM will benefits architecture students. As many of them have mentioned that teaching BIM will help students to improve their communication level with other disciplines and to get deep understanding of how building works. Moreover, several of them think if students have BIM skills that would defiantly help them to find better job. In addition, some of academics think that the use of BIM technology will benefits students; for example:

- Academic A8 stated:

  *"If you can provide the AEC industry with graduate architecture students who well-known about BIM, that will give our students the choice of choosing the best job of them"*

- Academic A3 said:

  *"Using BIM technology help students to visualise their work in 3D environment. That will make students to understand their projects during the design process"*

### 5.6.2 *Method of teaching BIM*

Interviewees have given several suggestions about how BIM should be embedded within Undergraduate Architecture Programmes in KSA. By analysing their answer, their suggestions could be organised in two methods.

First, the most mentioned method is teaching BIM within an Integrated Design Studio. Most of the academics have mentioned it as a best way to let students to understand the benefits of BIM and to improve their knowledge in collaboration and communication. It has been mentioned using different phrases; for example, collaborative design studio (twice), multidisciplinary (once), interdisciplinary (once) and working with other disciplines (three times). However, the percentage of repetitions of the concept in teaching BIM via an Integrated Design Studio has got more than 75%. For example:

- Academic A5 stated that:

  *"The concept of having a collaborative design studio…and teaching BIM through a new studio design… I think, it's the best method to teach such new system"*

- Do you think that BIM should be taught within a new studio design?

  *"The best way is to create a suitable environment for teaching BIM…I think, Yes, we need to have a new studio design created for BIM…teaching BIM within an existing architectural studio design may mislead students from the aim of the studio"*

- Academic A6 have said:

  *"I think…if we want to teach BIM in our school…I'd suggest teaching it via a multidisciplinary studio design… I believe that will improve their communication skills"*

- Do we need to create a new studio design for BIM?

*"I don't think so…actually, we have within our curriculum a modular suite the concept of BIM…we have the working drawing studio…this class helps students to understand how they can produce construction documents with less errors…I strongly believe this is the right environment for BIM… and I think the working drawings teachers will give you more information about that"*

- Academic A7 said:

*"I prefer to bring students from different departments to work with architecture students in my working drawing studio… I believe that the only subject where most disciplines are working together is this area… and most of architecture students who undertake this subject will be in their fourth year… which is a proper level to teach an Integrated Design Studio".*

Based on these two answers in where BIM should be taught, interviewees were asked the same question to give their opinion about these two choices and any other suggestions. 66.67% of them were agreed with Academic A6 when he suggests that BIM should be introduced via a working drawing studio. 16.67% of them were agreed with the other suggestion, and 16.67% were natural. The last academic, A11, was suggested that BIM should be taught via the two mentioned studios, He said:

*"Teaching BIM through both studios… working drawing studio and new design studio… seems a great chance for architecture students to understand how team works within projects… and it will give them deep understanding about how building works… The sustainability and the architecture design are my research interest… I started with the third year architecture students to teach them the sustainability within buildings… I think the idea of BIM and its technology will help to give them more understanding the aim of the class"*

Second, few of academics have mentioned that BIM should be embedded within the Undergraduate Architecture Programmes. They have suggested that BIM should be

introduced even with supported modular such as structural, mechanical, electrical systems and project management.

- Academic A7 said:

> *BIM should be embedding within educational system… We want to embed it within Structure, MEP and project management modules… we should teach even within an Integrated Design Studio… that would help them to gain the benefits of BIM by understanding BIM process and technology; and who they can work with other disciplines"*

In term of teaching BIM technology, the majority of them prefer to teach BIM software in the second year, and it should replace non-parametric software such as AutoCAD. However, few of them have raised an issue about what software should we teach. Some of academics prefer to teach Revit Architecture rather than other software, other have conclude that we should teach the most popular BIM tools have used within the AEC Industry in KSA.

### 5.6.3 *When should BIM be taught*

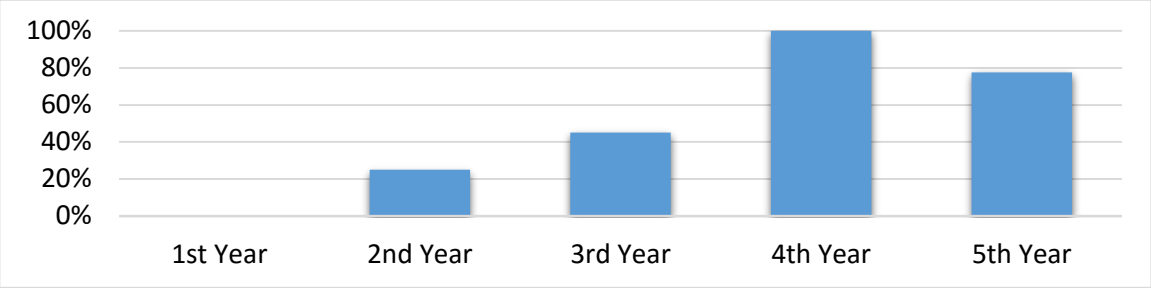



*Fig 5-5: When BIM should be introducing within Undergraduate Architecture Programmes*

A multiple choices question has been answered by interviewees about when BIM should be taught for architecture students. The most choosing year was the 4th year, followed by the 5th with almost 80%. Moreover, no one prefer to teach BIM from the first year; it has got 0%. Who have chosen the second year have mentioned it just to teach BIM technology.

### 5.6.4 *BIM topics*

As it has been found in the questionnaire that most academics have misunderstood the concept of BIM, this area has designed based on the literature review. The interviewees have asked to rank what should students learn when they using BIM. Fig 5-5 shows that Design has got the highest important topic that teachers should taught it using BIM for architecture students. Teaching Interoperability has got the lowest interest among academics. In general, there are eight topics which have got more than 9%, and the seven other topics have got less than 7%. Academics prefer to teach the top eight topics to their students using BIM process and technology.

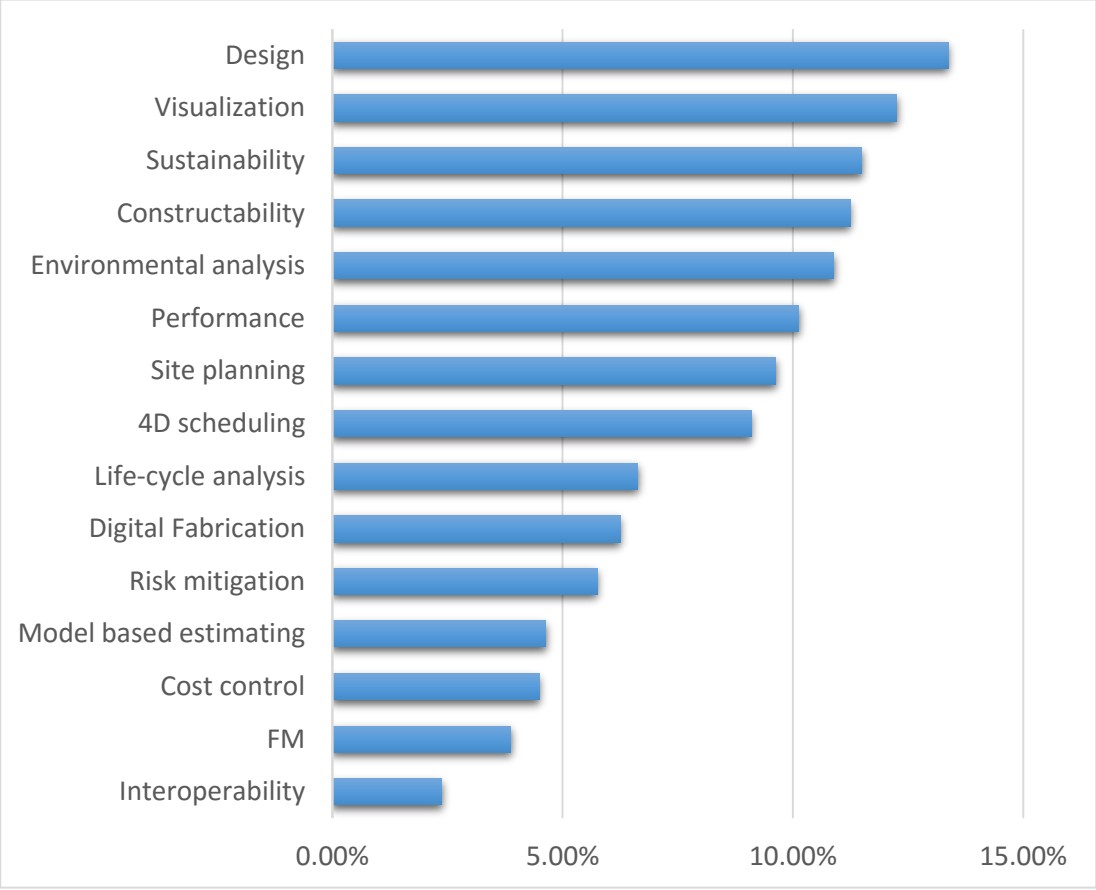



*Fig 5-6: Ranking BIM topics*

However, there were some comments given by five interviewees when they answered this question. Their comments were about the where and how to teach some of the BIM topics. For example, Academic A7 said

*"We could teach the constructability during a working drawing studio… teaching this subject need to be introduced for upper level students… because of the level of knowledge needed in that level"*

Moreover, in relation to sustainability and building performance, Academics A and D have agreed that sustainability should be introduced within a studio design using BIM.

❖ Academic A11 said:

*"It's important to teach sustainability within undergraduate architecture programmes… it's much important as teaching design for them"*

- Interviewee was asked to give an explanation

*"Now we can't design a building without thinking about the sustainability… it's become one of the main issues in AEC Industry… Students should learn how to improve building performance during the design process… hence, I think the best way to do that is through a studio design using technology such as BIM technology."*

Finally, it has been recommended by some of academics that teaching BIM based technology in early stage of academic programme will improve the visualization for students. For example,

❖ Academic A3 said:

*"Students should learn 2D and 3D from first year… we can use software such as Sketch UP along with freehand class… it would help students to understand the link between 2D and 3D… However, they should to learn parametric software such as Autodesk Revit in early level"*

❖ Academic A10 stated:

*"I think…BIM based technology will help students to understanding the different between non-BIM model and BIM model… I suggest if we can teach*

*them the differences in early stage of their academic level using BIM based technology"*

### 5.6.5 ***BIM barriers***

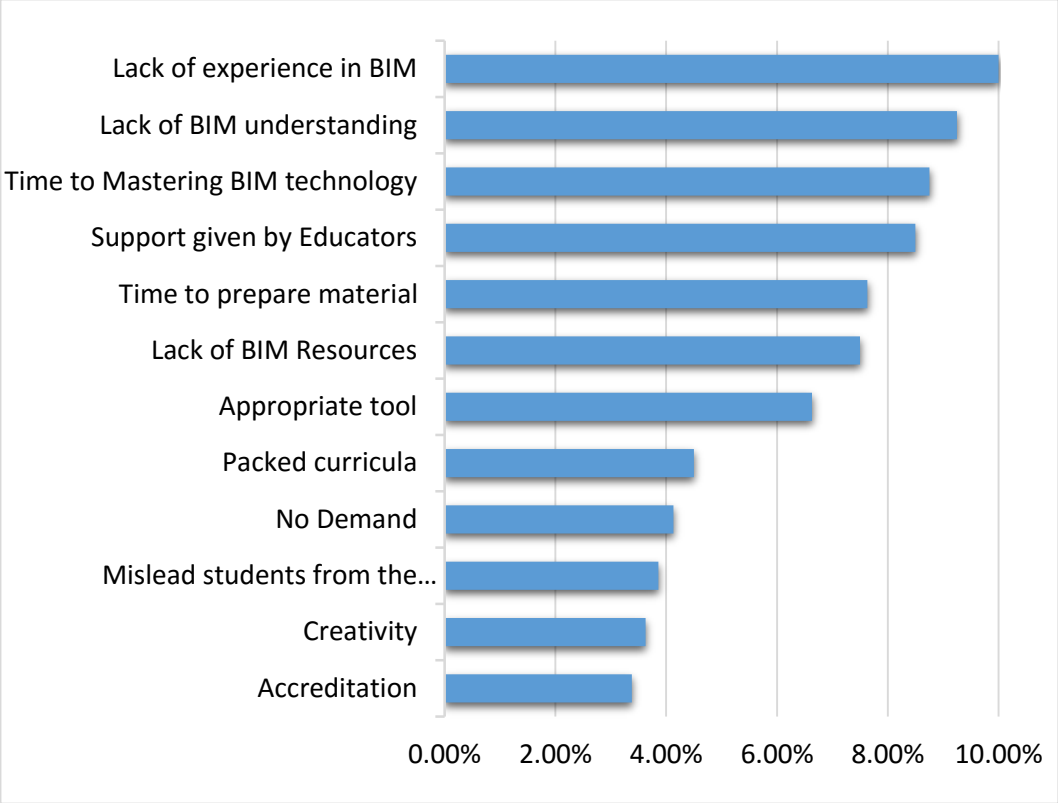



*Fig 5-7: Ranking BIM barriers*

Based on the literature review, it has been recorded that there are twelve barriers facing the implementation of BIM within AEC education sector. These barriers were organised in a ranking questions, and each interviewee was asked to rank them by identify the most important barriers to the less important. Fig 5-7 shows the ranking of these barriers based on interviewees' opinions. The highest seven barriers which have got more than 60% are: 1) Lack of experience in BIM, 2) Lack of BIM understanding, 3) Time to Mastering BIM technology, 4) Support given by Educators, 5) Time to prepare material, 6) Lack of BIM Resources and 7) Appropriate tool.

During the process of answering this question, some of interviewees have pointed some issues and gave some suggestions in how some of the issues may be solved. For example,

Academic A11 who has taught students to use Revit Architecture in order to build a small coffee; he said:

> *"We are… in the architecture department… very advance in using such as technology… we have started to teach advance computer aided design…and we try to improve our teaching method…along with that, other departments within our faculty… are still behind… they are still teaching manual tools and the use of A3 board to draw and present works… and that why we cannot even ask them to work with us in introducing such a new method"*

- Academic A7 said:

> *"We don't have the staff who may help us to teach BIM…I've been looking for expert to work with me in teaching working drawings studio using BIM…I found few…but none of them have any teaching experience…and they CVs are not worth it to sign a contract with them…About Time to Mastering BIM Technology…I think this is not an issue here in our school…I think that because we started to teach our students Autodesk Revit from the first year…Revit is one of BIM technology…and one of the important software …I think so"*

Noticeably, one of the most effective barriers facing the implementation of BIM within AEC education sector around the world is the accreditation. Most of academics think that embedding BIM within their Undergraduate Architecture Programmes will not have any negative impact on the accreditation.

| 5.1 | 5.2 | 5.3 | 5.4 | 5.5 | 5.6 | 5.7 |
|---|---|---|---|---|---|---|
| Interview Description | Interview Method and Analysis | Interview Findings | General Question | BIM within Their Modules | Teaching BIM | Summary |

## 5.7 Summary

The chapter presents the findings of the qualitative data. The aim of this chapter was to gain a deep understanding of how BIM should be embedded within Undergraduate Architecture Programmes in KSA by interviewing academics from architecture departments in KSA. Based on the findings, teaching BIM within Undergraduate Architecture Programmes can be divided into two areas; in a studio design and a supported modular. Teachers can teach students designing, sustainability, visualization and constructability via a studio design. Moreover, they can cover some of the architectural aspects within a supported classes such as project management (to teach 4D and 4D planning) and mechanical, electrical classes. Finally, academics within architecture departments in KSA have evaluated the barriers facing the implementation of BIM within Undergraduate Architecture Programmes differently. The highest seven barriers which have got more than 60% are: 1) Lack of experience in BIM, 2) Lack of BIM understanding, 3) Time to Mastering BIM technology, 4) Support given by Educators, 5) Time to prepare material, 6) Lack of BIM Resources and 7) Appropriate tool. On the other hand, most of academics believe that teaching BIM will not have a negative impact on accreditation.

# CHAPTER 6

The Development of BIM Framework

Sections

| 6.1 | 6.2 | 6.3 | 6.4 | 6.5 |
|---|---|---|---|---|
| Introduction | Key Findings | Initial BIM Framework | Validation | Summary |

# Chapter 6. The Development of BIM Framework

| 6.1 | 6.2 | 6.3 | 6.4 | 6.5 |
|---|---|---|---|---|
| Introduction | Key Findings | Initial BIM Framework | Validation | Summary |

## 6.1 Introduction

This chapter presents the development of the BIM framework as part of this research. The framework was developed from the two conceptual frameworks were presented in (Chapter Two), resulting from analysis of key literature in the area. The presented framework was further refined based on inputs gathered from Quantitative data (Chapter Four) and Qualitative data (Chapter Five). This chapter is divided into three parts, first, describing the findings of the three aforementioned chapters (Two, Four and Five), second, describing the initial framework to embed BIM within Undergraduate Architecture Programmes in KSA. Finally, the chapter presents the validation of the framework.

| 6.1 | 6.2 | 6.3 | 6.4 | 6.5 |
|---|---|---|---|---|
| Introduction | Key Findings | Initial BIM Framework | Validation | Summary |

## 6.2 Key findings from the three chapters:

### 6.2.1 *The literature review (Chapter Two)*

- **BIM in academia**

As discussed in Section (2.3), review of existing practice indicate that there has been different approaches to BIM Implementation within AEC education. It has been introduced as an advance CAD, integrated design or both. Although, there are two BIM frameworks to embed BIM within AEC education sector, there is no consensus in how to embed BIM. Also, these frameworks developed for the AEC education sector and not specified for architecture

programmes. However, there are four learning objectives extracted from these two frameworks which have helped to develop the initial proposal framework to embed BIM within Undergraduate Architecture Programmes in KSA. These four learning objectives which may call BIM learning curve are:

1- **The concept of BIM:** Architecture students should understand the concept of BIM and the benefits behind implementing it. That would help them to understand how BIM can work.
2- **BIM technology:** Architecture students should master BIM tools before entering the upper-level. This could help them to gain the needed skills for the BIM.
3- **BIM Process:** Architecture students should understand the process of sharing, communicating and the project lifecycle.
4- **BIM Integration:** Architecture students should go deep to work with other disciplines. That would prepare them for the real-world. Also, the findings from the literature review shows that there is an increasing demand in BIM collaboration cross-disciplines.

The two BIM frameworks (section 2.3.3) and most of the examples in how BIM has been embedded within the AEC curricula have indicated some of BIM learning curve in different ways. There are some cases where some of these points were merged with other like what happened with the BAF framework. They have merged the first and the second points in one point. Fig 6-1 shows an initial proposal to embed BIM within Undergraduate Architecture Programmes.

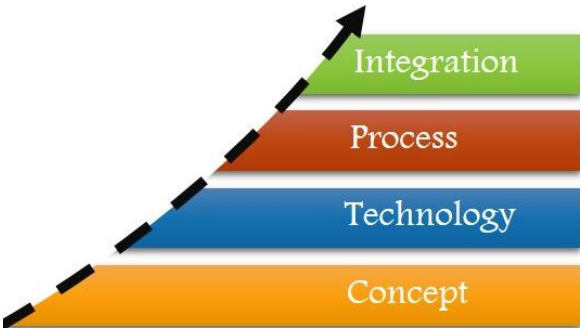



*Fig 6-1: An initial proposal to embed BIM*

- **Undergraduate Architecture Programmes in KSA**

There are some changes in higher education in KSA which have affected the Undergraduate Architecture Programmes. Most of the Universities in KSA have added a foundation year to their undergraduate academic programmes including Undergraduate Architecture Programmes (section 2.6.1 - section 4.5). This issue has caused some problems with the number of years needed to get an architecture bachelor degree in KSA (section 2.6.1 - section 4.5). The minimum years needed to graduate with a bachelor degree is four years and the maximum is six years. However, the BIM knowledge should be grow with the Undergraduate Architecture Programmes levels. According to Kocaturk and Kiviniemi (2013), teaching BIM needs to be gradual integrated within the education system (Kocaturk & Kiviniemi, 2013).


*Fig 6-2: The concept of linking academic levels in Undergraduate Architecture Programmes with BIM learning curve*

The BAF framework has linked the BIM learning curve with the AEC academic levels. That helps to unite the output of each departments. Therefore, the embedding of BIM should be done in a matrix way by linking the academic levels with the BIM learning curve. Fig 6-2 shows a concept of linking the four BIM learning curve with the academic levels in Undergraduate Architecture Programme in KSA.

### 6.2.2 *Key Findings from Quantitative Data analysis (Chapter 4)*

In term of Undergraduate Architecture Programmes in KSA, there are two kinds of schools, old schools and new schools. The old schools have started before 2004, almost all of these schools have adopted their undergraduate architecture programme from an international

university or standard. On the other hand, most of the new schools have adopted their programmes from the old schools. Hence, there will be some similarities in how architecture been taught within both schools. Moreover, it has been found that most of the architecture schools in KSA targeted the American standards or universities to implement their systems in how to teach architecture.

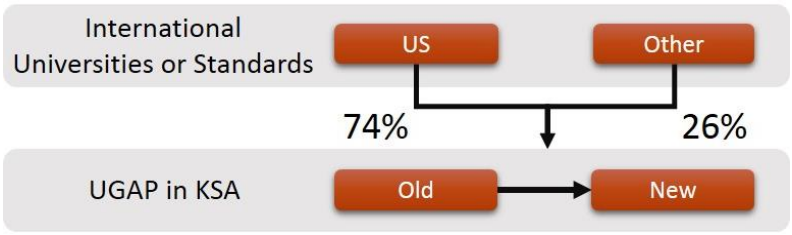



*Fig 6-3: The most targeted architecture programmes in KSA*

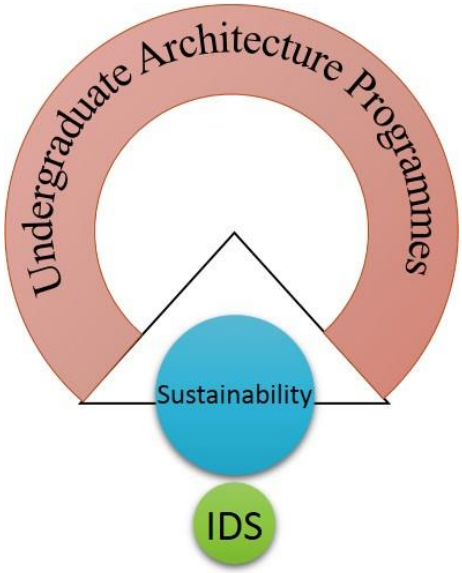



*Fig 6-4: The architecture topics interest the Undergraduate Architecture Programmes in KSA*

In addition to Undergraduate Architecture Programmes in KSA, most academics agreed that architecture curricula should be developed in order to meet the need of AEC Industry in KSA. From the findings, a number of Architecture Schools in KSA have already developed their curricula (section 4.3.4), and many of them have just started. Most of these schools were targeting the concept of sustainability to be embedded within their systems. Few of them have mentioned their interests in the concept of Integrated Design Studio (IDS). It has

been emphasised by some of the academics on encouraging students to work with other disciplines.

In term of BIM technology, one of the KSA Universities has mentioned that BIM technology will be used to help students to develop their works. There is some evidence to indicate that BIM technology has been used within KSA AEC Industry and AEC education sector (section 4.4). Also, it has been found that AutoCAD is the most popular software within AEC Industry and educational system in KSA. However, Revit as BIM based technology, is the second most popular software used in KSA after AutoCAD.

### 6.2.3 *Key Findings from Qualitative Data Analysis (Chapter 5)*

BIM has been taught differently, there are few examples in how BIM has been taught within AEC education in KSA (section 4.3.2). Based on qualitative data analysis, most academics believe that there is a vast potential to implement BIM within AEC Industry in KSA. That has led some of academics to introduce the idea on BIM to their students (section 5.5). BIM has been taught within Undergraduate Architecture Programme in KSA in different ways; process, technology or both. Even within the contacts of Undergraduate Architecture Programme in KSA, there is no consensus in how to teach BIM. However, the majority of academics think that embedding BIM within Undergraduate Architecture Programme will benefits architecture students (section 5.6.1).

The presentation which has been presented to the interviewees has helped to improve the knowledge of interviewees about the concept of BIM (section 5.3). Some of the academics start to think that BIM can be the useful method to achieve the aim of their classes. As some of them think that introducing sustainability through BIM can help students to get deep understanding about sustainability (section 5.6). That shows a development of embedding BIM and sustainability in Undergraduate Architecture Programme.

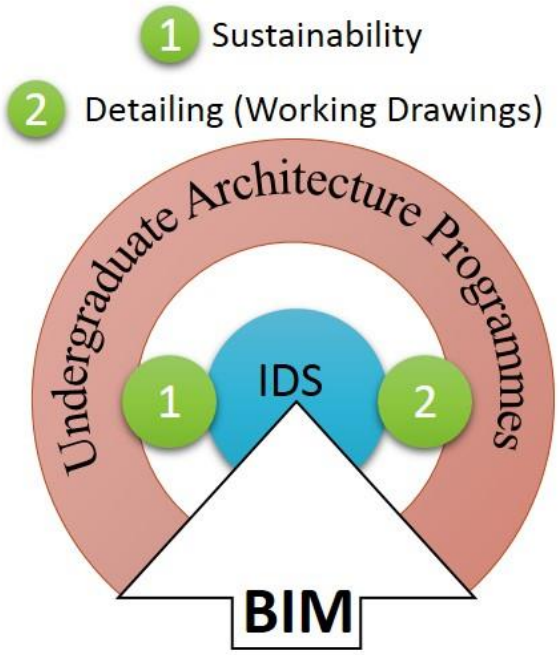



*Fig 6-5: The developing of interest in how to teach BIM and sustainability within Undergraduate Architecture Programmes in KSA*

Moreover, interviewees have ranked BIM topics in relation to what will be the best topic to be introduced to students via BIM. Some of these topics are too advance for freshman such as 4D planning and sustainability. Moreover, some of these topics such as Visualization should be taught from the early stage in order to develop their skills in using BIM tools. Therefore, these topics should be introduced to students based on their academic level.

Finally, Most of academics prefer to teach BIM in the upper-level of the Undergraduate Architecture Programmes in KSA, as many of them have chosen the fourth and the fifth grades Undergraduate Architecture Programmes. Moreover, few of them suggested that BIM should be introduce in the second and the third level of academics programme, but all the interviewees have agreed in not to teach BIM for the first year programme. However, teaching BIM for the upper-level needs to have a foundation knowledge. Based on the literature review, the concept of BIM and BIM technology are the foundation of BIM learning curve.

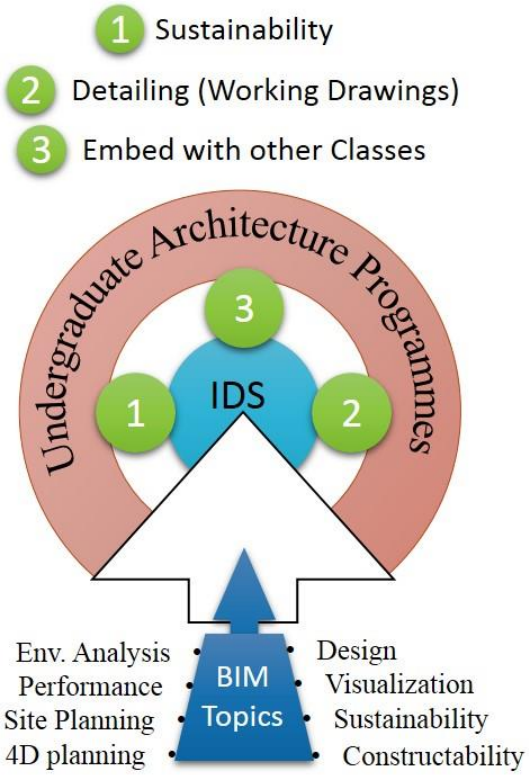



*Fig 6-6: The top eight BIM topics which should be taught from Undergraduate Architecture Programmes in KSA*

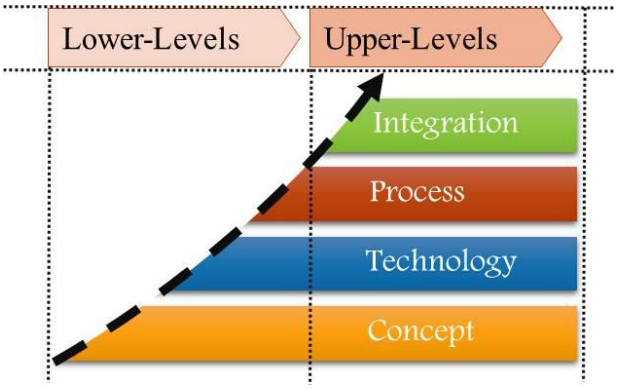



*Fig 6-7: The stages of BIM learning curve*

| 6.1 | 6.2 | 6.3 | 6.4 | 6.5 |
|---|---|---|---|---|
| Introduction | Key Findings | Initial BIM Framework | Validation | Summary |

## 6.3 Initial framework to embed BIM within Undergraduate Architecture Programmes in KSA

The framework has designed for a five year undergraduate architecture programme in KSA. It has divided into five columns based on the academic years. The initial BIM framework suggests that the BIM learning curve should be embedded within the Undergraduate Architecture Programmes from the first year. The following describes the initial BIM framework based on the BIM learning curve: describtion

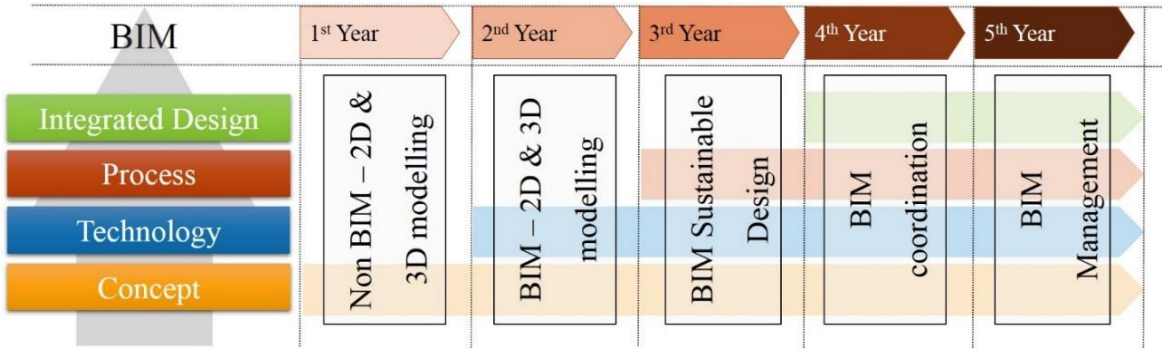



*Fig 6-8: Initial framework to embed BIM within Undergraduate Architecture Programmes in KSA*

*Table 6-1: Describtion of the initial BIM Framework to embed BIM within Undergraduate Architecture Programmes in KSA*

| UGAP | 1st Year | 2nd Year | 3rd Year | 4th Year | 5th Year |
|---|---|---|---|---|---|
| **Concept** | Understanding architecture drawings non-BIM model | Understanding the differences between non-BIM model and BIM model | How BIM process and Technology can help to improve building performance | Coordinating and communicating using BIM process and technology | BIM and construction phase, 4D and 5D |
| **Technology** | | BIM modelling tools | BIM simulation tools | BIM coordination tools | BIM management tools |
| **Process** | | | Designing and developing a project based on sustainability principles using BIM modelling and simulation tools | Using a semi developed BIM model to produce a working drawings | Using the semi developed BIM model to plan the construction phase |
| **Collaboration** | | | | Working with students cross-disciplines to minimize conflicts and errors using reports and meeting records | Working with contractors to minimize conflicts and errors using reports and meeting records |

### 6.3.1 *The concept of BIM:*

| Years | Explanation |
|---|---|
| **1st** | Students should learn how to draw 2D and 3D using manual or non-BIM tools such as Sketch UP and AutoCAD. Then, try to link their drawings with basic information "Dimensions – Names – Scales – Presenting Material" |
| **2nd** | Students should understand the differences between non-BIM model and BIM model. Educators can browse a developed BIM model to their students in order to understand the differences. They should to understand how editing any elements or information in a BIM model will be applied for all views. |
| **3rd** | Educators should teach their students how they could develop their projects from the schematic design phase until the pre-construction phase. Students need to understand how important the sustainability for buildings and how BIM process and technology can help to achieve it. Students should be given a brief about how BIM process work in relation to sustainability. Then, they should understand the process of explore and insert files using BIM tools, as the file will be explore from BIM modelling tools to BIM simulation tools. |
| **4th** | Students should understand that collaborative design using BIM can help to improve the quality of their projects. Students should learn how to use BIM process and tools to coordinate and communicate with other team members within the project. |
| **5th** | Students should understand how important to transfer the BIM model from the design phase to the construction phase. They should learn BIM policies and other policies to give them better understanding by comparing. |

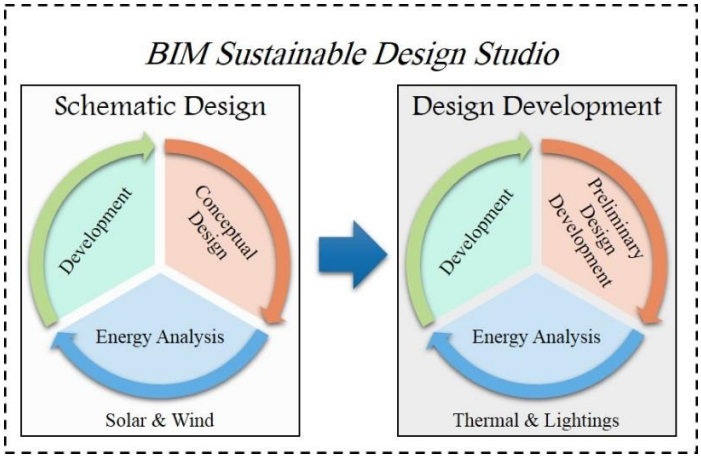
### 6.3.2 *BIM Technology:*

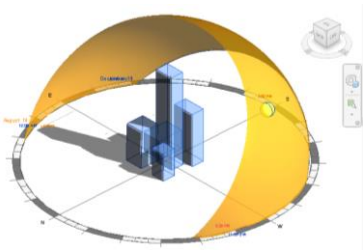
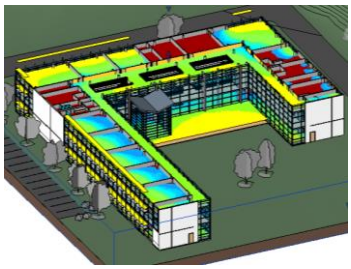
| Years | Explanation | |
|---|---|---|
| **1st** | ___No Changes___ | |
| **2nd** | Modelling | ***Through a stand-alone class:*** Students should to learn how to model and present an architecture project using BIM modelling tool. They should understand the concept of parametric |

| | | |
|---|---|---|
| | | software. This will be a foundation for students to start learning other skills and tools in their future studies. The framework suggests teaching the most popular BIM software used within AEC Industry in KSA. There are two BIM computer applications used for modelling and were used in AEC Industry in KSA; Autodesk Revit and ArchiCAD. However, Autodesk Revit is the most popular BIM computer application in the AEC Industry (Section 4.3.3). |
| **3rd** | Energy Simulation Tools | ***Through a studio design:*** Students should learn software to help them to develop building performance. There are several BIM energy simulation tools specialised in improving building performance such as Ecotect, Green Building and some add-in software for Revit. Educators can introduce any of these BIM software to their students based on their skills, knowledge and the aim of their classes. In this level, students will start to explore issues related to interoperability between software which can be helpful for the next stage of BIM learning curve. |
| **4th** | Coordination Tools | ***Through a working drawing studio:*** Students should learn how to share, link and coordinate BIM files with other team members using BIM process and technology. There are some BIM computer applications such as Navisworks and Solibri which can help to coordinate all BIM drawings in one file. These technologies can help students to minimise errors and omissions by learning how to coordinate and communicate with the team. Moreover, students should learn how to report issues based on clashes cross-disciplines and how to solve it. Then, producing pre-construction drawings and scheduling with almost zero mistakes. It will help them to build better understanding of what BIM model contains and this would help them for the next stage of BIM learning curve. |

| | | |
|---|---|---|
| **5th** | Managing Tools | ***Through a stand-alone class:*** Students can develop a deep understanding about how building should be planned and constructed by using BIM technology. First, students should understand building contracts can help to plan the construction phase and link the model with its data. Educators could teach the BIM coordination tools for their students to help them in managing 4D and 5D. |

6.3.3 ***BIM Process:***

| **Years** | **Explanation** | |
|---|---|---|
| **1st** | ___No Changes___ | |
| **2nd** | ___No Changes___ | |
| **3rd** | BIM Sustainable Design Studio | ***Through a studio design:***   *Fig 6-9: BIM Sustainable Design Studio* Developing projects based on sustainability should be divided into two phases; the schematic design and the design development phase. Fig 6-9 shows a conceptual idea in how to embed sustainability within the two phases of the design process. Students could use Energy Simulation Tools to make decisions in order to improve building performance. For example, in the first phase, students will learn how to orient their project based on solar and wind analysis. There are some BIM based technology's software have a solar analysis tools such as Autodesk Revit. In such software, |

| | | |
|---|---|---|
| | | students can set-up the real location of the project by using coordination (Fig 6-10). Then, based on that, students can use 3D sun path where it is linked with the project's location. This would help students make decisions about the orientation, form or other solutions.<br><br>*Fig 6-10: BIM Energy Simulation Tools*<br><br>In term of the design development phase, students may start to make decisions about the choice of materials and lighting components based on the<br><br>Solar analysis<br>  <br><br>Lighting analysis<br>  <br><br>energy simulation tools. Students can try to make some changes in materials or lighting components to achieve Zero Energy. Beside learning how to improve building performance, students will gain some knowledge in how |
| **4th** | BIM Coordination Process | ***Through a working drawing studio***:<br>Students should to start with a semi-developed project aiming to produce construction drawings with less conflicts and errors. Students should learn how to work with other disciplines and identify responsibilities among team members. They should learn how to have a BIM Central File, and how to work in a BIM Local File. The different between the BIM Central File and BIM Local File in term of collaboration, that students should work in the BIM Local File. Then, when they finalise their work, they should to save it in the BIM Central File. That will help other disciplines to make changes in their design based on the latest update. At BIM coordination stage (Fig 6-11), students will learn the process of reporting clashes and how to fix them with the team. Then how to update the BIM Central File. |

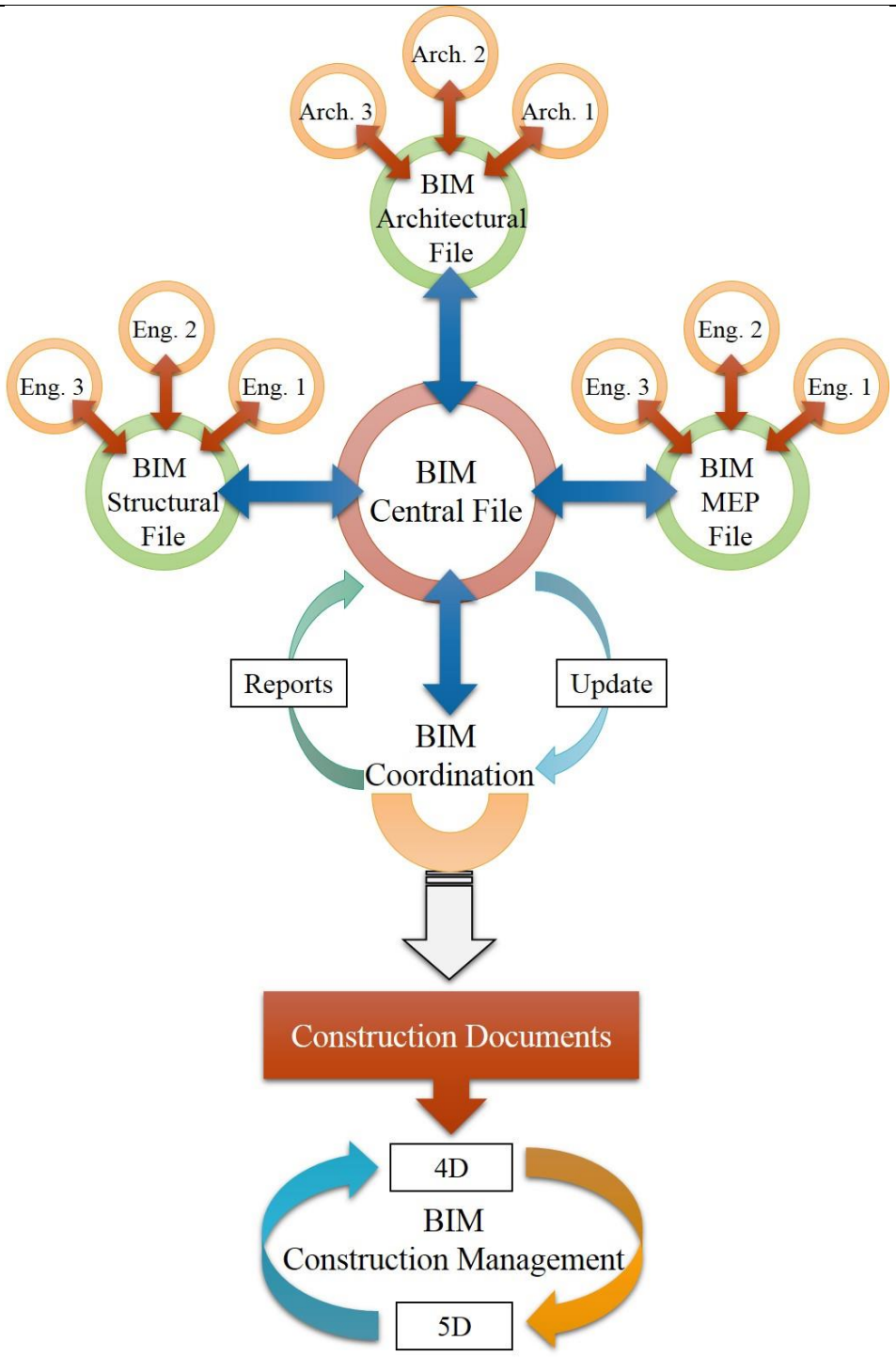



Fig 6-11: BIM Coordination Process

| | | |
|---|---|---|
| **5th** | BIM Managing Tools | ***Through a stand-alone class:*** This stage, students will carry on working in the previous work in BIM Working Drawing Studio to develop the 4D and 5D plan for their project. They should learn how to link the BIM model with time (4D) and cost (5D), see Fig 6-11. |

### 6.3.4 *BIM Integrated Design:*

| **Years** | **Explanation** | |
|---|---|---|
| **1st** | ___No Changes___ | |
| **2nd** | ___No Changes___ | |
| **3rd** | ___No Changes___ | |
| **4th** | BIM Integrated Design | ***Through a working drawing studio***: The studio should have two groups of students; from architecture programme and other disciplines. At this stage, the framework suggests Civil Engineering, MEP students to work with architecture students. Those students should be supervised by a team of educators from different AEC departments.<br><br>The framework suggests that each group will be given a semi develop project. They will be asked to produce a construction documents. Moreover, during the class, an owner will be involved in the project to make a change as a scenario to simulate a real situation. Students should be asked to deliver the following:<br><br>1. Students should learn how to share their model with other team member. Moreover, they should learn how to identify responsibilities for each member. |

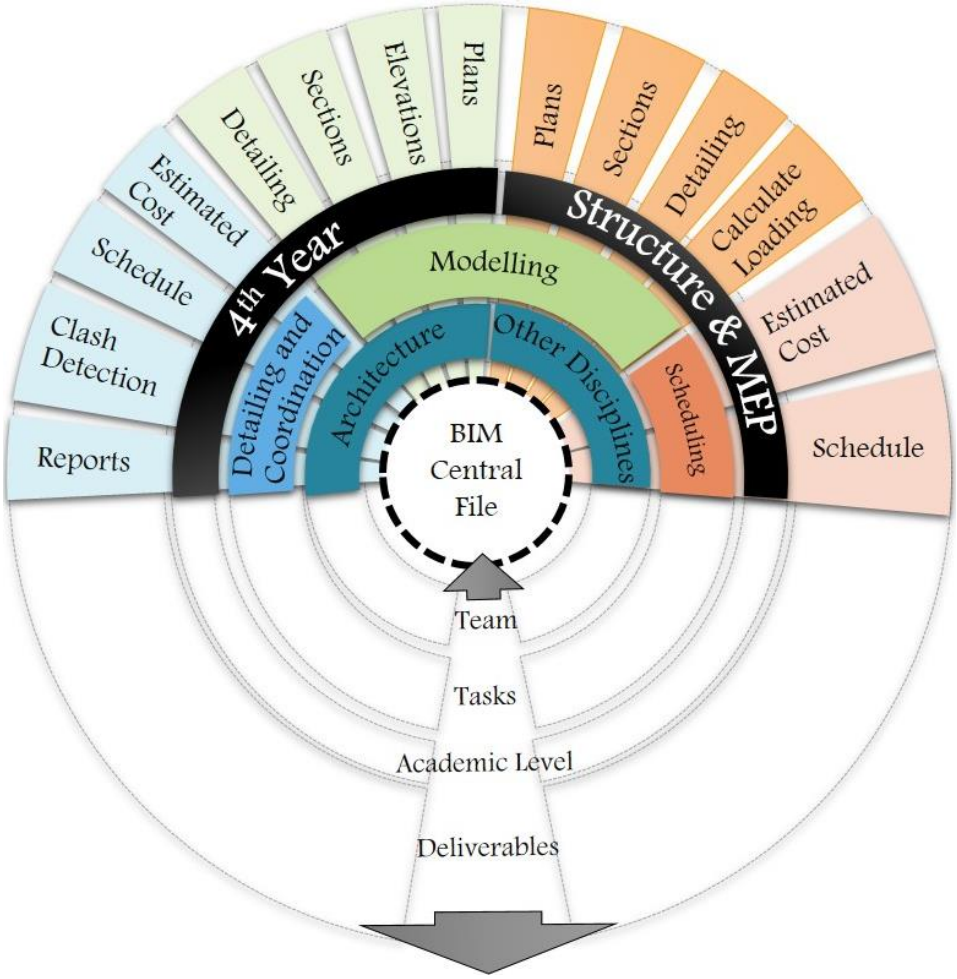



*Fig 6-12: Teamwork within Integrated Design Studio*

2. BIM model should have at least the following drawings plans, elevations, sections and detailing. In addition to those drawings, the model should contain schedules for architectural, structural and MEP elements. Students have to learn how to extract these schedules and how to build its data.
3. Using schedules to give an estimating cost for the building including all elements; architectural, structural and MEP elements.
4. Students need to know how to draw details for building elements in order to explain how these elements could be built.

| | | |
|---|---|---|
| | | 5. They should learn how to find clashes by using Navisworks, and then report them to the team. After that, based on their report, students will learn how to fix problems and redo the process again until reach zero error. |
| **5th** | BIM Integrated Management | ***Through a stand-alone class:*** Using the same project, students should work with professionals (if that possible) to simulate 4D and 5D plan for their project. Professionals will play a significant role in advising and guiding students in how to plan both assignments in a proper way. The framework suggests that this assignment should be introduced within a project management class. Students in this level will be exposed to the various number of building contracts and the differences between them. Hence, students will build a better understanding of regulations in AEC Industry. |

### 6.3.5 *Other Modules within Undergraduate Architecture Programmes:*

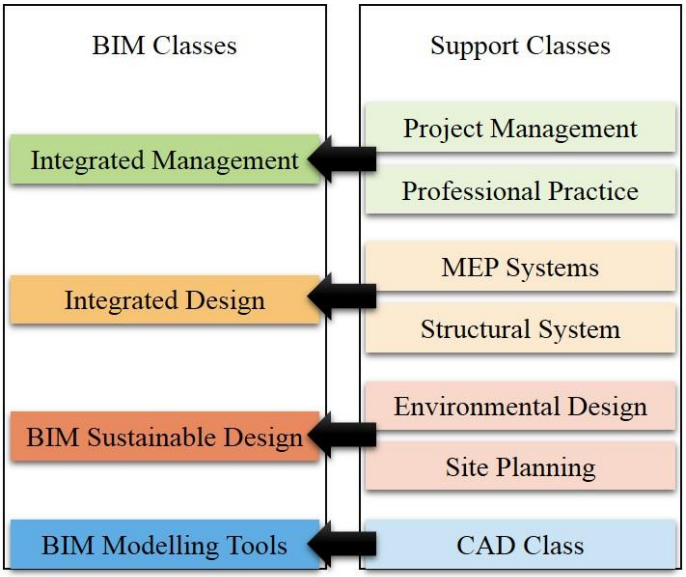



*Fig 6-13: The support of other classes*

BIM studios and classes need to be supported by other classes within the architecture programme. The concept of BIM can be introduced through these classes which can help to improve students' awareness about BIM as new process and technology. Some academics

have mentioned some of modules where BIM can be introduced. They have mentioned Structural System, Environmental Design, Project Management and CAD. However, the framework suggests few other modules such as Site Planning, MEP System and Professional Practice. Based on the Undergraduate Architecture Programmes, most of schools in KSA have the same modules, but some of them have named them in Arabic. The concept of BIM should be introduced via the seven modules. Fig 6-13 shows a conceptual idea in how those modules can support BIM classes. The sequence in the order of the modules has been influenced by the Undergraduate Architecture Programmes in KSA. Many of them have CAD classes in early stage with Environmental Design and Site Planning modules. Then, students start to learn about MEP and the Structural System in their mid-academic programme. Finally, students start to learn how to manage and coordinate along with understanding the construction phases.

| 6.1 | 6.2 | 6.3 | 6.4 | 6.5 |
|---|---|---|---|---|
| Introduction | Key Findings | Initial BIM Framework | Validation | Summary |

## 6.4 BIM Framework validation

In this stage, an email was sent to 23 academics and 27 professionals who have agreed to participant on this research. The email contained a brief information about BIM and its implementation within AEC Industry and AEC education, and the aim of the PhD research and the interview. Moreover, participants were informed that there will be a presentation for 20-25 minutes.

Nine academics and five of professionals agreed to be interviewed and responded with a suitable time for doing the interview. There were six Assistant Professors, two of them were the Head of their Schools, and three Associate Professors, and one of them was the Head of School. On the other hand, professionals who have interviewed were three of them Senior Architects with more than 15 years of experience and two Architects. Table 6-2 shows the interviewees' background and area of interests with the time of the interview. The average time of the presentation was 23.42 minutes, and the average time of the entire interview was 54.82 minutes (see table 6-2).

### 6.4.1 *The Presentation*

The presentation was divided into three areas based on the key findings from the; literature review, data collection (phase 1 and 2) and the description of the BIM framework. In the literature review, academics and professionals were introduced to the current situation of BIM and its implementation within AEC Industry and education. Then, the key findings from both stages of the data collection which have help in developing the BIM framework have presented in second stage. Finally, the initial framework was presented to them with a description of each section of the framework (see Appendix 7). In the end of the presentation, each participant was asked one question in relation to the BIM framework's validation. The following covers the analysis of their answers, key findings and the development of the framework.

*Table 6-2: Interviewees coding*

| No | Participants | Time | Position | Area/Level of expertise |
|---|---|---|---|---|
| 1 | A1 | 52.23 | Assistant Professor | Urban Design and Building Performance |
| 2 | A2 | 65.15 | Associate Professor | Architecture Design and Construction |
| 3 | A3 | 55.36 | Assistant Professor | Architecture Design |
| 4 | A4 | 59.13 | Head of School | Architecture Design and History of Architecture |
| 5 | A5 | 49.23 | Assistant Professor | Architecture Design, Mechanical System and Building Performance |
| 6 | A6 | 51.34 | Head of School | Architecture Design and Construction |
| 7 | A7 | 53.59 | Assistant Professor | Architecture Design and Interior Design |
| 8 | A8 | 54.54 | Associate Professor | Architecture Design and Project Management |
| 9 | A9 | 53.23 | Head of School | Architecture Design and Building Performance |
| 10 | P1 | 57.24 | Head of designing department | Senior Architect and Project Manager |
| 11 | P2 | 58.35 | Owner of a Construction Company | Senior Architect |
| 12 | P3 | 55.19 | Lead Architect | Senior Architect |
| 13 | P4 | 45.46 | Project Management | Architect and Project Manager |
| 14 | P5 | 57.51 | Designer | Architect and Interior Designer |
| | **Average** | **54.82** | | |

***Academics*** (A1–A9) ***Professionals*** (P1–P5)

### 6.4.2 *Findings of the questions*

The one question was asking participants "To what extent do you agree with the following five statements". Those statements were divided into two areas; understanding of the presentation and evaluating the framework. However, all five statements were used Likert Scale to evaluate participants' opinions in each statement. Participants were asked after each statement to give their reasons about their choice. The following explains the findings of the validation.

- **The presentation covered most of the point about BIM within academia, and I don't have any questions**

In general, most of participants agreed with the statement. Fig 6-14 shows that 57.14% (n=8) of the participants strongly agreed which is the highest percentage. Then, 35.71% (n=5) of them were chosen agree followed by 7.14% (n=1) who chose neutral. The findings of this shows that the majority of participants understood the presentation and the aim of the interview. However, one of the participants had mentioned that the presentation should have information about BIM regulations around the world. The researcher has advised him that because of the time given and the aim of the PhD research, this area could not be covered. However, participants has been informed with the latest update about BIM regulations and has been given some resources in relation to this area.

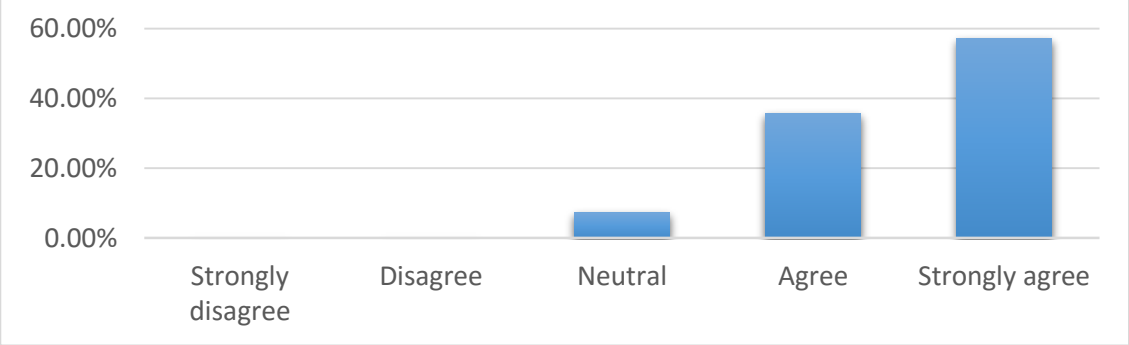



*Fig 6-14: Level of satisfaction of the presentation*

- **The presentation of BIM framework and how to embed it within Undergraduate Architecture Programmes in KSA was clear and easy to understand**

From this statement, it seems none of the participants have not understood the BIM framework or how to embed it within Undergraduate Architecture Programmes. Fig 6-15 shows that 71.43% (n=10) of participants were strongly agreed with the statement and 28.57% (n=4) were agreed. That shows the presentation of the BIM framework and the information delivered by the researcher had help participants to understand each aspect within the framework.

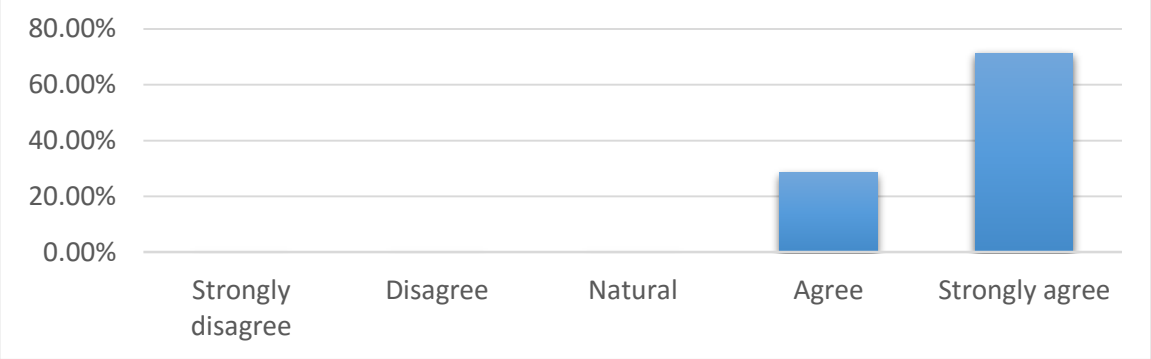



*Fig 6-15: Level of satisfaction of the presentation*

- **The initial framework will be applicable to embed BIM within Undergraduate Architecture Programmes in KSA**

Fig 6-16 shows that most of the participants were strongly agreed/disagreed with the statement. The highest percentage is 57.14% (n=8) of participants who chose agree with the statement, followed by an equal percentage between strongly agree and natural with 21.43% (n=3). In term of occupation, 20% (n=1) of professionals was strongly agreed and 80% (n=4) were agreed. That presents the applicability of the framework within the undergraduate architecture programmes in KSA is very high based on the professional opinions. On the other hand, 66.22% (n=6) of academics were strongly agreed/agreed. However, 33.33% (n=3) of academics were having some concerns about the mechanism of the framework.

- It has mentioned that some of architecture departments are within an engineering faculty that makes the communications between departments so difficult, because of the language used.
- Most of the departments have a mono-system method which makes the collaboration between departments more difficult.

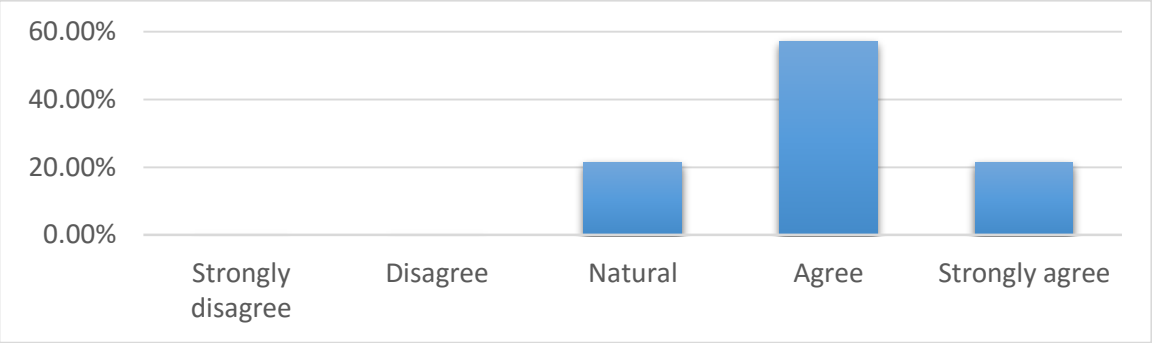



*Fig 6-16: The applicability of BIM framework*

Two of them were the head of their schools and each one of them has different concerns. For example, Academic A6 stated that

> *"The framework will help students to have a better communication with other disciplines… that will help them to understand how we should design buildings with less errors… but I have concern about how we can organise such studio with other department".*

Academic A6 was asked (Could you please explain what you meant about that). He said:

> *"Some of the departments in our faculty like to not collaborate with other departments… they think that will have a negative impact on their students… we tried to have similar idea in having a multi-disciplinary class… but we could not succeed".*

On the other hand, Academic A9 has agreed with academic A6 and he added *"Most of the academics within our faculty have no idea about BIM…I think the lack of BIM knowledge among educators will have a negative influence on students".* Finally, Academic A1 was concerned about the implementation of BIM within the Undergraduate Architecture

Programmes in KSA may have a negative impact on the creativity of the students. He thinks that the use of BIM technology will mislead students from being a designer to be a modeller.

- **Embedding BIM within Undergraduate Architecture Programmes in KSA using this initial BIM framework will increase students' knowledge about how to design an efficient building and improve their skills in using advance computer aided design software.**

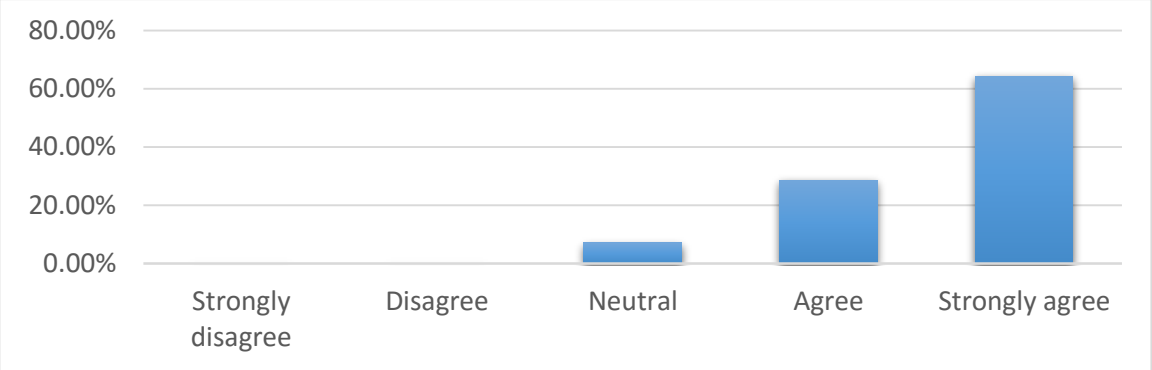



*Fig 6-17: The benefits of BIM framework for architecture students in KSA*

In general, most of participants were satisfied about the framework and its effect on architecture students. Fig 6-17 shows that 92.86% (n=13) of participants were strongly agreed/agreed with the statement, and 7.14% (n=1) was natural. The following are some of the key statements from academics and professionals:

Academic A3:

> *"We need to have such a method to help student to improve their communications with other…and understand that the design is a team work…especially, when we start to have complex building"*

Academic A2:

> *"I've been teaching architecture students for more than 30 years…I tried many time to push students to understand how important to have a building which can be constructed…I think the idea of embedding BIM within our system will help them to understand that…I like the idea of the clash*

*detection…this could increase their awareness about other elements within the project…I think they will start to make critical dissensions about their works based on that".*

Moreover, the three head of schools believed that architecture students will gain better knowledge by embedding BIM within their curricula. Academic A4 said:

*"BIM based technology by itself will help students to think more about design and to solve issues".*

In addition, academic A6 and A9 have stated most of the aforementioned points by other academics. However, Academic A1 who have some concerned about BIM has mentioned the same point in the previous statement. He stated that

*"I'm still having this concern about the effect of BIM on the students…I think we need to be very careful in teaching students this technology"*

On the other hand, all the professionals who have participated in the semi-structured interview were strongly agreed with the statement. Most of them believe that students with this level of knowledge will benefit the AEC Industry in KSA, and it will help them get a job quickly. Professional P3 said:

*"We use BIM based technology…but…we are not a BIM company… we haven't finished any project using BIM… we could say some of our project were semi-BIM…the reason is that we don't have BIM experts within AEC Industry in KSA… we need BIM expert to help us with this new method…I think this will close the gap… and it will help us to achieve our aim…along with that… students will get job very quickly".*

- **The initial BIM framework needs a further development, and I have some concerns in relation to embed BIM within Undergraduate Architecture Programmes in KSA using this framework.**

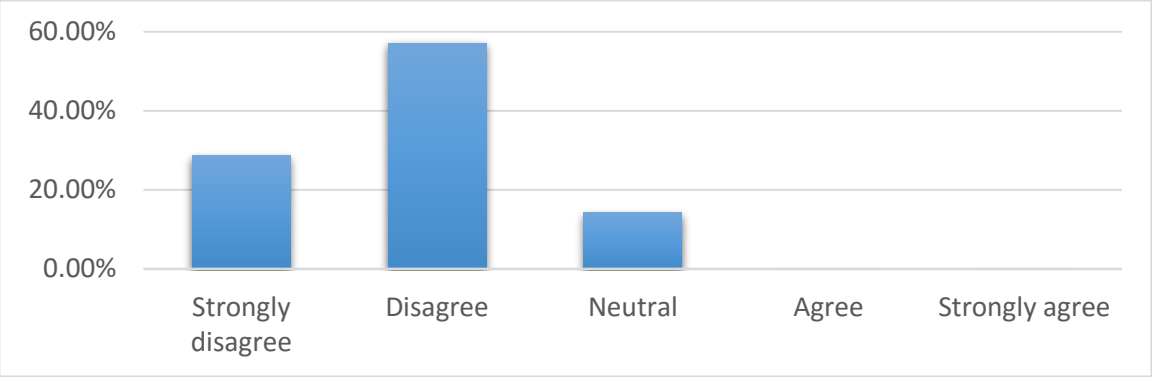



Fig 6-18: Needs to develop the BIM framework

Fig 6-18 shows that 85.71% (n=12) of participants strongly disagreed/disagreed with the statement. However, 14.29% (n=2) were chose to be natural with statement, one academic and one professional. Academic A1 who have chosen (natural) suggested developing a general framework for AEC education in KSA.

Academic A1 said:

> *"I know that your aim is to develop a framework for embedding BIM within Undergraduate Architecture Programmes in KSA…but…I think we need to think about developing a framework for AEC education…if you cannot do it in this stage you may develop that in the future"*

Moreover, Academic A5 suggested that if students can be introduced to MEP and structural system before the Integrated Design Studio; he said:

> *"I think we should to teach students the mechanical and the structural system before level four…before they start to work with other disciplines…I think that will help them to understand the key information about other majors"*

This suggestion has been forwarded to other academics to give their opinion about it. Academics A6, A7, A8 and A9 agreed with the academic A5's suggestion. Moreover, academic A8 added in a top of that

> *"We have to teach them these modules before the BIM working drawing studio…we can even teach them that in the first few weeks… we are planning to teach all theoretical modules in the first month of the semester…instead of teaching these modules parallel with the studio design… that will give students the level of knowledge needed to their academic level and time to work and apply what they have study in their studio design".*



| 6.1 | 6.2 | 6.3 | 6.4 | 6.5 |
|---|---|---|---|---|
| Introduction | Key Findings | Initial BIM Framework | Validation | Summary |



### 6.4.3 ***Summary:***

The chapter presents the development of the BIM framework to embed BIM within Undergraduate Architecture programmes in KSA. The development of the framework began with highlighting some of the key findings of the literature review followed by the findings from the two phases of the data collections. The initial framework has suggested embedding gradually the BIM learning curve with the five years architecture programme. Also, suggests to clearly identifying each level with an objectives. The initial framework was validated by academics and professionals within KSA AEC industry.

# CHAPTER 7

Discussion, Conclusion and Recommendation

Sections

| | | | |
|---|---|---|---|
| 7.1 | 7.2 | 7.3 | 7.4 |
| Introduction | Achievement of Research | Contribution to Knowledge | Recommendation |

# Chapter 7. Discussion, Conclusion and Recommendation

| 7.1 | 7.2 | 7.3 | 7.4 |
|---|---|---|---|
| Introduction | Achievement of Research | Contribution to Knowledge | Recommendation |

## 7.1 Introduction

The aim of this thesis is to develop and effective framework to embed BIM within Undergraduate Architecture Programmes in the Kingdom of Saudi Arabia Universities. The research methodology applied in this thesis was designed to answer the research questions (Chapter One). Hence, the research was divided into four sequenced phases, which have been linked with the objectives of this research. The Five sequenced phases were: Literature Review, Methodology, Preliminary Study, Framework Development and The Validation of The Framework.

First, the literature review (Chapter Two) has helped to develop a deep understanding of the current situation of BIM within AEC Industry and AEC education. It has help to identify the gap of research and highlight some of the key challenges facing the implementation of BIM within both sectors. Second, the methodology (Chapter Three) was designed to clarify the methodology and the method used in this research. Third, the preliminary data (Chapter Four) has led to understand the situation of BIM deployment and the maturity level of BIM within Saudi AEC Industry and AEC education.

Fourth, in Chapter Five, the development of the framework was driven first, by some of the findings from the literature review and the preliminary data. Then, from interviewing some of the academics within the architecture departments in KSA Universities (Chapter Six). Fifth, the Validation of the framework (Chapter Six) was done with academics and professionals from KSA. Finally, this thesis discusses the findings and presents the recommendation in the last chapter (Chapter Seven).

| 7.1 | 7.2 | 7.3 | 7.4 |
|---|---|---|---|
| Introduction | Achievement of Research | Contribution to Knowledge | Recommendation |

## 7.2 Achievement of Research; Aim and Objectives

The aim of this research is to develop a curricular framework to support embedding BIM within Undergraduate Architecture Programmes in the Kingdom of Saudi Arabia Universities. This section discusses the key findings of this research. Hence, the discussion was divided into four areas based on the objectives of this thesis. These objectives (Table 7-1) have guided the research to achieve the aim of the PhD research.

### 7.2.1 *Objective One: (Literature Review)*

- To review the current strategies and attempts to embed BIM within the AEC educations sector.

The purpose of this objective was to 1) create a solid foundation for this thesis about BIM and its implementation within AEC industry and education, 2) highlight the research gap in the field of embedding BIM within AEC education sector, 3) identify the most approach method in how to introduce BIM within AEC education, and 4) the needs of the AEC Industry. By achieving this objective, it has been found that:

1. BIM has been defined differently based on the definer perspective. It has been defined as technology, process or both. However, most of scholars in the field of BIM were agreed that BIM is an integrated design and delivery approach.
2. In term of BIM deployment within AEC Industry, the interest of adopting BIM is increasing among construction companies and architectural firms around the world. Moreover, several countries such as USA, UK and Australia, have made BIM mandatory for all public projects. The significant benefits of BIM implementation for all stakeholders and for the building lifecycle have led to embark these governments and construction companies to implement BIM.

*Table 7-1: Achievement of Research; Aim and Objectives*

| Objectives | Outcome | Methods | Ch. |
|---|---|---|---|
| **Objective 1:** To critically review the current strategies and attempts to embed BIM within the architectural educations. | Meanings<br>Benefits<br>Barriers<br>Guidance | Literature Review | Two |
| **Objective 2:** To investigate the current approaches of BIM deployment within architectural education and the AEC Industry in KSA | Benefits<br>Barriers<br>Components<br>Guidance | • Literature Review<br>• Preliminary Data, an Online Questionnaire | Two and Four |
| **Objective 3:** To develop a curricular framework to embed BIM effectively within Undergraduate Architecture Programmes in KSA. | How BIM can be embedded effectively | Semi-Structured Interview | Five |
| | Framework Development | Designing the Framework | Six |
| **Objective 4:** To validate the framework by examining the professional opinions of academics within architecture departments and professionals to refine it based on feedback. | To Validate the Framework and finalising the outcome | Semi-Structured Interview<br>Designing | Six |

However, there are some limitations in relation to implementing BIM within AEC Industry. These limitations have classified by some of scholars into three areas; People, Process and Technology. The lack of BIM users, understanding the concept of BIM process and the interoperability are some of the example of these areas. The improvement of these areas will help to effectively implement BIM and gain its benefits.

3. In term of BIM in academia, BIM has been introduced within the AEC curricula to cover the deficit in the number of BIM users in the AEC Industry. Moreover, to improve the communication and the level of how building should be designed and constructed for AEC students. Although, BIM has been taught within AEC education sector since mid-90s, it can be argued that there is no consensus in how BIM should be taught. In some cases, BIM has been taught as technology, others have introduced as process, and recently, through an Integrated Design Studio.
4. It has been found that there are few attempts to develop a framework for BIM to be embedded within AEC education sector. For example, the initial BIM framework which has developed by BAF-UK and the IMAC framework which has developed by Macdonald (2012). In term of architecture programmes, Kocaturk and Kiviniemi (2013) suggest that BIM should be taught in UK via a studio design and two separate modules.
5. From both frameworks, there are four learning curve points in relation to embed BIM within AEC education sector; Concept – Technology – Process – Integration.

However, there are some limitations in relation to BIM within academia; these can be classified into:

- Evaluation: Most of the examples in how BIM has been taught within AEC education sector have not been evaluated by a third-party. Most of the examples were explaining the case and the feedbacks from students. In few cases, Autodesk which is one of BIM software development has evaluated and awarded some of the universities who have used their software.
- Academic environment: This area was divided into three aspects related to; educators, students and programmes.
    - Educators: from the case studies and some of the academics reports, it has been found that the lack of BIM supporters, understanding the concept of BIM and BIM experts were the most mentioned barriers facing BIM education.
    - Students: One of the most mention barriers was the time needed to master BIM technology. However, few of scholars have some concerns about using

BIM technology may mislead students from the aim of the course and may even have a negative impact on their creativities.

- Programmes: This area could be divided into two parts: who have not embedded yet and who have embedded. First, some of scholars have stated that there is no demand for BIM to be embedded with the AEC education sector. Besides that, the curricula are packed and there is no chance to add a new module to the curriculum. In addition to that, the accreditation of some of the AEC schools may affected by embedding BIM within AEC education sector. Second, some of the academics have noted that the time to prepare materials and the lack of BIM resources are two of the significant limitations for BIM education.

- Technology: it has been found that the lack of BIM technology experience, understanding the BIM technology for educators and the choice of the appropriate tools are the most mentions barriers facing the implementing of BIM within AEC education sector.

### 7.2.2 *Objective Two: (Literature Review and Preliminary Data)*

- To review the current approaches of BIM deployment within AEC Education Sector and the AEC Industry in KSA

The purpose of this objective was to 1) create a solid foundation about AEC Industry and issues facing projects in KSA, 2) understand how architectural programmes in KSA have been structured, the future of architecture programmes and the accreditation system, 3) highlight the implementation of BIM within AEC Industry and AEC education and BIM maturity level in KSA, and 4) the needs of the AEC Industry in KSA and the satisfaction level of the graduate AEC students. However, the lack of academic resources has led to divide this objective into two parts: Chapter Two (Literature Review) and Chapter Four (Preliminary Data). The Preliminary Data was designed to create a solid foundation about BIM and its maturity level in KSA. From chapter two, it has been found that:

1- KSA is one of the biggest and leading countries in the Middle East and has one of the largest and rapidly growing construction sectors. To a large extent, this growth is

triggered by a number of mega-projects started by Saudi Government within housing, transportation and utilities sector, with project value exceeding one trillion dollar.

2- Challenges currently faced by the KSA building sector such as lack of knowledge, management and experience in the project lifecycle have similarities with those faced in 1980s. The oil crisis in 1980s have forced the KSA government to either to abandon projects or renegotiate the payment (Ikediashi et al., 2014). In other cases, the Government relied on local construction companies who have no experience in constructing a complex project to finish their complex projects (Al-Sedairy, 2001).
3- In term of the AEC education output, there is a noticeable deficit in the number of Saudis' engineers and architects to fill the gap in the AEC Industry. In addition, the level of the universities output has not achieved the AEC Industry expectations.
4- There are 19 Undergraduate Architecture Programmes in KSA. 16 of them have already started and three have not yet. Moreover, five of them have established before 2004 and the rest were after that.
5- The records show that less than 2% of the university's graduate students in 2012 were male and female architects.
6- In term of BIM within the Kingdom of Saudi Arabia, anecdotal evidence suggests that the demand of BIM is increasing within KSA. There are some social networks shows that several professionals and academics have started to discuss some issues related to BIM implementation in KSA.

However, as a limitation, there is a lack of academic resources about the current situation of BIM and its implementation within AEC Industry and Education in KSA. This has raised some questions about the current situation of BIM in KSA. Hence, a preliminary data was designed to fill the gap in the literature review.

- **Chapter Four (Preliminary Data):**

Chapter four creates a deep understanding about BIM in KSA by highlighting:

***BIM current situation in KSA***

1. More than 60% of responses (academics – professionals – students) were aware about BIM.

2. In term of professions, the percentage of Architects and Construction Managers who knew about BIM were higher than Engineers. This result applies for the AEC education, as the percentage of academics from architecture and construction departments who knew about BIM were higher than other departments.
3. In term of nationality of the workers in KSA and their awareness about BIM, the percentage of non-Saudi workers who knew about BIM is twice the percentage of the non-Saudi workers who have not heard about BIM. On the other hand, the percentage of Saudi workers who knew and who have not heard about BIM was almost similar.
4. In term of embedding BIM within AEC education sector in KSA, more than 80% of responses have stated that BIM has been taught within their curricula. More than 50% of them have fully/partly adopted BIM, and the rest mentioned that BIM has been introduced as a subject within their main modules.
5. More than 30% of construction companies and architectural firms in KSA has been already used BIM within their project. Less than 7% of the total responses have fully adopted within their projects.
6. The most popular BIM application used/taught within AEC industry and education in KSA is Autodesk Revit.

***BIM maturity level***

1. In term of AEC education, most of academics have misunderstanding about the concept of BIM. That shows when most of academics have agreed that BIM is for early design phase and some of them were confused about the number of BIM classes in their schools.
2. The same result has been applied for professionals as many of them agreed that BIM from the early design phase only. However, professionals who are planning to implement BIM within their system were well-educated about BIM and how BIM should be implemented.

***The Future of BIM in KSA***

1. More than 50% of responses were agreed that there is an increasing demand on BIM in KSA AEC industry, and less than 8% were disagree.
2. More than 50% of responses were agreed that there is a lack of BIM users in KSA AEC industry, and less than 20% were disagreed.
3. In the next five years, most of responses believe that BIM will be highly adopted within public projects than private projects.

***Architecture Programmes in KSA***

1. The academic years within architecture programmes in KSA are between four to six years, that because of the foundation year.
2. Most of the architecture programmes in KSA have been developed or under progress.
3. More than 65% of academics within architecture programmes believe that the architecture curricula need to be developed to meet the Saudi AEC industry.
4. Most of the architecture curricula in KSA were/are targeting the concept of building sustainability. Few of them have mentioned the concept of Integrated Design Studio IDS.

Although, these findings show that BIM has been used within KSA and there is an increasing demand on BIM, the same findings show that:

- Most of responses have misunderstanding about the concept of BIM. This can be one of the barriers facing the implementation of BIM within AEC industry and education in KSA. This will have a negative impact on the second phase of the data collection. Interview academics who may have misconception about BIM will affect the development of the framework.
- The differences between each architecture school in the number of academic years needed to graduate with a bachelor degree in architecture.

### 7.2.3 *Objective Three: (Development of the Framework)*

❖ To develop a framework to embed BIM effectively within Undergraduate Architecture Programmes in KSA.

The aim of this objective was to develop the best approach to embed BIM within Undergraduate Architecture Programmes in KSA based on literature review, preliminary data and academics' perspectives. The limitations facing the implementation of BIM within AEC education which have been highlighted in the literature review and preliminary data have helped to design the semi-structured interview. The interview has started with a presentation showing the concept of BIM. Most of the academics agreed that the presentation has made them to better understand BIM. By achieving this objective:

- **Chapter Five (Semi-Structured Interview):**

1. The majority of the interviewees believed that the demand on BIM will be increasing within AEC industry in KSA.
2. BIM has been taught within the Undergraduate Architecture Programmes in KSA. However, most of who have taught BIM has introduced as technology, and there is one case where BIM has introduced as process. Also, another case where BIM has taught as both; Technology and Process, it was to explore a small issue within a module.
3. The majority of interviewees agreed that teaching BIM for Undergraduate Architecture Students will benefit them.
4. BIM Teaching Methods:
    - Most academics prefer to teach BIM within an Integrated Design Studio. It has been suggests that BIM should be taught within either a new architecture design studio or a working drawing studio.
    - BIM should be embedded within the architecture programmes, it should be taught even within other supported modules.
5. When should BIM introduced:
    - The four academic years is the most popular level for academics to introduce BIM, and year one is the most popular year to not teach BIM.
    - Few academics believe that introducing BIM should be start from year two and three have got some.
6. Architectural education issues which can be explored using BIM:

- Based on a ranking question, the top eight architectural issues which can be explored using BIM are Design, Visualization, Sustainability, Constructability, Environmental analysis, Performance, Site planning and 4D scheduling.
- Some of these issues can be introduced through an architectural studio design and other could be through supported modules such as MEP system and project management.

However, there are some barriers facing BIM implementation within Undergraduate Architecture Programmes. Academics have ranked 11 issues facing the implementation of BIM within AEC education. These 11 issues have been extracted from the literature review.

- The highest seven issues which have got more than 6% are lack of experience in BIM, lack of BIM understanding, time to mastering BIM technology, support given by educators, time to prepare material, lack of BIM resources and appropriate tool.
- The lowest issue which has got the less than 3.5% is the accreditation. Most of academics believe that teaching BIM within Undergraduate Architecture Programmes will not have any negative impact on their accredited programmes.

- **Chapter Six (Designing the Framework):**

Based on the key findings of the literature review, preliminary data and the semi-structured interview, an initial BIM framework to embed BIM within Undergraduate Architecture programmes in KSA was developed. The research has managed to solve some of the limitations BIM implementation within Undergraduate Architecture programmes in KSA. The initial framework was designed using the four learning curve points; Concept – Technology – Process – Integration. These four points have linked with five academic levels (from year one to year five).

### 7.2.4 *Objective Four: (Validation of the Framework)*

- To validate the framework by examining the professional opinions of academics within architecture departments and professionals to refine it based on feedback.

The purpose of this objective was to discuss the initial framework with academics from architecture departments and professionals in KSA. The validation was planned to use a focus groups interview with academics and professionals. However, there were some limitations have led to change that to be an individual interview. By achieving this objective:

1. More than 75% of academics and professionals were believed that the applicability of the initial framework to embed BIM within Undergraduate Architecture Programme is very high. The rest of responses were chosen natural with some concerns.
    - It has mentioned that some of architecture departments are within an engineering faculty that makes the communications between departments so difficult, because of the language used.
    - Most of the departments have a mono-system method which makes the collaboration between departments more difficult.
2. More than 92% of responses believe that embedding BIM within Undergraduate Architecture Programmes will lead to improve students' knowledge about how projects should be effectively designed and constructed.
3. More than 85% of interviewees believe that the initial framework to embed BIM within Undergraduate Architecture Programmes does not need any further development. However, most of the interviewees have mentioned that there will be some limitations such as organising the Integrated Design Studio with other departments and lack of BIM educators.

| | | | |
|---|---|---|---|
| 7.1 | 7.2 | 7.3 | 7.4 |
| Introduction | Achievement of Research | Contribution to Knowledge | Recommendation |

## 7.3 Research Originality and Contributions to Knowledge

The Following are the main contribution to knowledge which has been presented by this thesis:

- BIM has been introduced differently within architecture programmes around the world (Barison & Santos, 2010a; Mandhar & Mandhar, 2013; Poerschke et al., 2010). Moreover, there were some attempted BIM frameworks to teach BIM within AEC education (BIM Academic Fourm, 2013; Macdonald, 2012). However, there is a lack of academic resources in relation in how BIM should be taught effectively within architecture curricula (Kocaturk & Kiviniemi, 2013), and those frameworks have not been evaluated yet and none of them have been designed from Undergraduate Architecture Programmes. The PhD research suggests through a designed framework how to embed BIM effectively within Undergraduate Architecture Programmes in KSA.
- Most of the examples of how to teach BIM within AEC education sectors were pointed as short-term teaching, for one or two semesters (Holland et al., 2013; Stivers, 2012; Vinšová et al., 2014). However, the only one case where BIM has taught for more than two semester was Flemish region (Belgium) (Boeykens et al., 2013). The research originality was to embed BIM within the whole curricula including supported modules, and from the first year to the last academic year within the Undergraduate Architecture Programmes in KSA (see Fig 7-1).

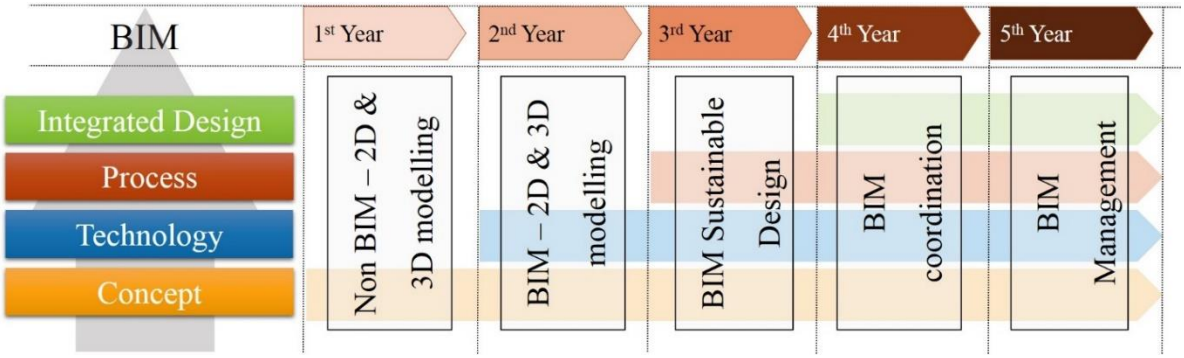



*Fig 7-1: Initial framework to embed BIM within Undergraduate Architecture Programmes in KSA*

- In KSA, there is a paucity of academic journals in BIM, the thesis could be considered as one of the pioneering research in KSA about the BIM in education. The Preliminary Data collection within this thesis has made a solid foundation for this research to understand the current situation of BIM within AEC industry and

education sector in KSA. The outcome of this data collection can be used for any future studies in relation to BIM within AEC industry and education in KSA.

| 7.1 | 7.2 | 7.3 | 7.4 |
|---|---|---|---|
| Introduction | Achievement of Research | Contribution to Knowledge | Recommendation |

## 7.4 Recommendations

### 7.4.1 *Recommendations for Saudi AEC industry:*

- Develop BIM framework, regulations and rules to implement BIM within Saudi AEC industry. That can help to outline the Saudi AEC industry needs and issues related to BIM implementation within the AEC industry.
- The need of future research in relation to BIM and its implementation within Saudi AEC industry. Scholars should present cases, issues and limitations facing the implementation of BIM.
- Develop an official website to present the latest achievements about BIM and its implementation within AEC industry around the world and in KSA. Also, to help AEC education sector in KSA in developing their curricula.

### 7.4.2 *Recommendations for Saudi AEC education:*

- The framework of this thesis should be used within architecture programmes in KSA. Academics within architecture departments in KSA should try to embed the BIM framework and develop it based on their systems.
- Develop an official website for teaching BIM within AEC education sector in KSA to cover issues, future research and cases.
- The need of conferences, workshops and academic publications for BIM education to discuss and present experiences and resources about BIM education.

### 7.4.3 *BIM Future Research:*

The following is some recommendations for future studios in relation to BIM:

- Linking BIM and GIS: GIS is one of the most popular methods use in most countries around the world. It contains a lot of data such as Utilities, Topography, Land use and streets. Both methods deal with information, and there is an increase interest in linking both methods.
- Exploring and evaluating the benefits of BIM within AEC industry which should include; clash detection, fabrication, costing, scheduling, communication, planning, quality control, on-time completion, cost, safety, dollars per unit performed, and units per man hour.
- Improving communications and sharing information within construction process using augmented reality.
- Exploring the benefits of BIM for improving building performance during designing and construction process.
- Improving health and safety during construction process using BIM.

## 7.5 Conclusion

Several governments and owners around the world have required BIM within their projects. That has increased the demand of BIM and the need of BIM experts in AEC industry. Many architecture schools have started to teach BIM within their curriculum. It has been taught as technology, process or both. Also, it has been taught in the early stages of undergraduate architecture programmes and the upper level. However, in the last decade, the demand of teaching BIM through a collaborative design studio has increased, and was motivated by the need of AEC industry.

In term of framework to embed BIM within education, there are two BIM frameworks (BAF initial Framework and IMAC framework). These two frameworks were designed for AEC education and not specific for architecture programmes. Also, both frameworks have not evaluated yet. Academics have not reached to a consensus in how BIM should be taught within undergraduate architecture programme.

BIM has been introduced in KSA, but the vision is unclear. That because of the lack of the academic resources. However, the number, size, cost and complexity of projects in KSA worthy to motivate Saudi Government and construction companies to implement BIM. The Saudi's government should implement BIM within their projects to prevent most of the issues within the design, construction and operation. The aim of this PhD research is to embed BIM within undergraduate architecture programme in KSA. To achieve that, four objectives were designed and linked with four stages of the research methodology.

First, understanding and critical review for the current situation of teaching BIM within AEC education and the AEC industry perspectives in relation to BIM implementation. Second, filling the gap of the literature review by establishing the preliminary data. It has been found that most professionals and academics in KSA either have not heard about BIM or have a misunderstanding about BIM. Moreover, most academics who have taught BIM has taught it as a technology. Also, 75% of participants want to introduce the sustainability within architecture programmes, and 20% of them want to teach interdisciplinary classes.

Third stage was developing BIM framework to embed BIM within undergraduate architecture programmes. It has guided by the key findings of the literature review, the preliminary data and the semi-structured interview which has done with academics in architecture departments in KSA Universities. Because of the lack of understanding of BIM, a presentation was done for each interviewee to leverage their knowledge about BIM. Most interviewees prefer to embed BIM within architecture programmes and use it to introduce other aspects in architecture such as sustainability, interdisciplinary and 4D-5D process.

Finally, the proposed BIM framework was validated by academics and professionals. A semi-structured interview was done in order to understand what can be done to improve the framework. Most comments were about educate educators and try to engage professionals. Also, organise workshops and conferences to present the latest researches and needs in relation of BIM implementation within AEC industry and education.

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# Appendix 1

**Ethical Approval - 2015**

**Academic Audit and Governance Committee**

**College of Science and Technology Research Ethics Panel (CST)**

University of Salford MANCHESTER

**MEMORANDUM**

**To** Yasser Almutiri (and Dr Zeeshan Aziz)

**cc:** Professor Hisham Elkadi, Head of School of SOBE

**From** Nathalie Audren Howarth, College Research Support Officer

**Date** 29/01/2015

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**Subject:** Approval of your Project by CST

**Project Title:** Embedding BIM within Architectural undergraduate programmes within The Kingdom of Saudi Arabia (KSA) universities

**REP Reference:** CST 14/58

Following your responses to the Panel's queries, based on the information you provided, I can confirm that they have no objections on ethical grounds to your project.

If there are any changes to the project and/or its methodology, please inform the Panel as soon as possible.

Regards,

Nathalie Audren Howarth
College Research Support Officer

For enquiries please contact:
College of Science and Technology
College Research Support Officer
The University of Salford
Maxwell building, (7th floor, room 721)
Telephone: 0161 295 5278
Email: n.audren@salford.ac.uk

# Appendix 2

**Preliminary Survey – An Online Questionnaire 2015**

# Embedding BIM within Architectural Education in KSA??? ?????

Dear Brother and sister
أخي الكريم, اختي الكريمة

I am a PhD candidate at the University of Salford, UK. As part of my research project, this survey has been designed to identify issues in embedding Building Information Modeling BIM within Undergraduate Architectural Programs in Saudi Arabia. This study targeted all professionals and academics in building industry within KSA
أنا أحد المرشحين للحصول على درجة الدكتوراه من جامعة سالفورد بالمملكة المتحدة. وكجزء من مشروع رسالة الدكتوراه, تم تصميم هذا الإستبيان لتحديد القضايا التي تتعلق بتضمين نمذجة معلومات البناء ضمن برنامج العمارة لمرحلة البكالوريوس في المملكة العربية السعودية. هذه الدراسة تستهدف كل المهنيين والأكاديميين بقطاع البناء في المملكة العربية السعودية

For more information and/or if you have any concerns please do not hesitate to contact me.
إذا كان لديكم أي استفسارات أو أي قضايا تخص هذا الايميل أو الدراسة فأرجو منكم الاتصال بي

Yasser Almutiri
yalmutiri@gmail.com

Thank you for your participation

Best Regards

***1. I agree to give consent to my participation in the research project "Title: Embedding BIM within the Undergraduate Architectural Programmes in Saudi Arabia"**
**اوافق على مشاركتي في المشروع الدكتوراه " دمج نمذجة معلومات البناء ضمن مرحلة البكالوريوس لبرنامج الهندسة المعمارية في المملكة العربية السعودية "**

- ◯ Yes نعم
- ◯ No لا

## Embedding BIM within Architectural Education in KSA??? ?????

### demographic information معلومات عامة

***2. Gender الجنس**

- ◯ Female أنثى
- ◯ Male ذكر

***3. Nationality الجنسية**

***4. Age العمر**

- ◯ 18-22
- ◯ 23-27
- ◯ 28-35
- ◯ 36-45
- ◯ 46-54
- ◯ 55 or older - 55 او اكبر

***5. Academic qualification المؤهل العلمي**

- ◯ Thanawia الثانوية
- ◯ Diploma دبلوم
- ◯ Bachelor بكالوريوس
- ◯ Higher Diploma دبلوم عالي
- ◯ Master ماجستير
- ◯ Ph.D. دكتوراه
- ◯ Did not mention لم تذكر

Other (please specify) ارجو منك حدد ذلك

**6. Do you have a scholarship? هل لديك منحة دراسية - مبتعث**

- ◯ From Saudi University من جامعة سعودية
- ◯ From government organization من إدارة حكومية
- ◯ From a private sector من مؤسسة خاصة
- ◯ I don't have لا املك بعثة

## Embedding BIM within Architectural Education in KSA??? ?????

***7. Years of experience**
**سنوات الخبرة**

- ◯ No experience لا توجد خبرة
- ◯ Less than 1yr اقل من سنة
- ◯ 1 - 5
- ◯ 6 - 10
- ◯ 11 - 15
- ◯ 16 - 20
- ◯ 21 - 25
- ◯ More than 25 اكثر من

***8. Are you aware of BIM?**
**هل أنت على علم بنمذجة معلومات البناء**

- ◯ Yes نعم
- ◯ No لا

***9. Occupation المهنة**

- ◯ Students الطلاب - الدارسين في الجامعات السعودية أو مبتعث على برنامج الملك أو على حسابه الخاص
- ◯ Academics الأكاديميين - على رأس العمل أو مبتعث من جامعته
- ◯ Professionals المهنيين - على رأس العمل او مبتعث من مؤسسة حكومية او خاصة

# Embedding BIM within Architectural Education in KSA??? ?????

## Professionals المهنيين

***10. Your current job الوظيفة الحالية**

- [ ] Owner مالك
- [ ] Chief Executive Officer الرئيس التنفيذي
- [ ] consultant مستشار
- [ ] Project Manager مدير المشروع
- [ ] Senior Architect مهندس معماري مسؤول
- [ ] Senior Engineer مهندس مسؤول
- [ ] Architect معماري
- [ ] Mechanical Engineer مهندس ميكانيكي
- [ ] Electrical Engineer مهندس كهربائي
- [ ] Civil Engineer مهندس مدني
- [ ] Interior Designer مصمم داخلي
- [ ] Draft man رسام
- [ ] Modeler مصمم مجسمات
- [ ] Did not mention لم تذكر

Other (please specify) ارجو منك تحديد ذلك

***11. Select your sector حدد القطاع**

- ◯ Government حكومي
- ◯ Private خاص
- ◯ Both كلاهما

## Embedding BIM within Architectural Education in KSA??? ?????

### Private Sector القطاع الخاص

***12. Select where your company is located projects related with the Saudi Arabia regions**

**حدد أين تقع مشاريع الشركة من حيث توزيع المناطق بالمملكة العربية السعودية**

- ☐ Riyadh الرياض
- ☐ Jawf الجوف
- ☐ Jazan جازان
- ☐ Mecca مكة المكرمة
- ☐ Tabuk تبوك
- ☐ Baha الباحة
- ☐ Medina المدينة المنورة
- ☐ Northern Border الحدود الشمالية
- ☐ East الشرقية
- ☐ Qassim القصيم
- ☐ Asir عسير
- ☐ Hail حائل
- ☐ Najran نجران

***13. About how many employees work at your company?**

**تقريباً, كم عدد الموظفين في الشركة**

- ◯ Less than 15 أقل من
- ◯ 16 - 30
- ◯ 31 - 100
- ◯ 101 - 500
- ◯ 500 - 1000
- ◯ 1001 - 5000
- ◯ more than 5001 أكثر من

***14. Which of the following best describes the principal industry of your organization?**

**أي من العناصر التالية يطابق طبيعة عمل الشركة**

- ☐ Architectural Designing التصميم المعماري
- ☐ Construction company شركة مقاولات
- ☐ Urban Development تطوير عمراني
- ☐ Office Consultant مكتب استشاري
- ☐ Did not mention لم تذكر

Other (please specify) أرجو منك تحديد ذلك

***15. In which sector does your company seek construction work?**

**ماهي المشاريع التي تتطلع لها الشركة**

- ◯ Government حكومية
- ◯ Private خاصة
- ◯ Both كلاهما

## Embedding BIM within Architectural Education in KSA??? ?????

### Government حكومي

**16. What is your job role?** ماهو دور وظيفتك

## Embedding BIM within Architectural Education in KSA??? ?????

### Building Information Modeling نمذجة معلومات البناء

***17. How has BIM been incorporated into your organization?**
**هل تم دمج نمذجة معلومات البناء في المؤسسة؟**

- ◯ Has not been incorporated and not considering لم يدمج وليس من اهتماماتنا
- ◯ Has not been incorporated, but considering لم يدمج ، ولكن نفكر
- ◯ Has been partly incorporated into some projects دمج جزئيا في بعض المشاريع
- ◯ Has been fully incorporated into the system دمج بالكامل في النظام
- ◯ I don't know لا أعلم

## Embedding BIM within Architectural Education in KSA??? ?????

**18. In few points, could you please indicate Why it's not in your consideration?**
**في حد أعلى ثلاثة نقاط, تستطيع ان تذكر سبب عدم الآهتمام في تطبيق نمذجة معلومات البناء**

***19. In your opinion, BIM could help with..... ? (Check Fully integrated use if it all)**
**من وجهة نظرك, نمذجة معلومات البناء تساعد في.....- اختار دمج كلي اذا كانت جميع ماذكر**

- ☐ Concept and Design Development الفكرة وتطوير التصميم
- ☐ Renderings & Modeling الإخراج وعمل المجسمات
- ☐ Architectural Drawings الرسومات المعمارية
- ☐ Construction Documents عمل المخططات الإنشائية
- ☐ MEP Documents عمل المخططات الميكانيكية والكهربائية والإنشائية
- ☐ Sustainability الإستدامة
- ☐ Management and Operating الإدارة والتشغيل
- ☐ Fully Integrated Use دمج كلي - كل ما سبق
- ☐ I'm not sure غير متأكد
- ☐ Did not mention لم تذكر

Other (please specify) أرجو منك تحديد ذلك

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## Embedding BIM within Architectural Education in KSA??? ?????

***20. For approximately how many years have your organization been using BIM tools and processes?**

**تقريبياً, ماهي الفترة التي تم فيها تطبيق نظام نمذجة معلومات البناء في الشركة**

- ◯ Preparation stage مرحلة الإعداد
- ◯ less than one year أقل من سنة
- ◯ 1 - 2
- ◯ 3 - 4
- ◯ More than 4 years أكثر من 4 سنوات

***21. Please, indicate in which area/areas your organization has used BIM for (Check Fully integrated use if it all)**

**العمل بنمذجة معلومات البناء في معظم دول العالم ينحصر في احدى المجالات التالية. من خلال آلية العمل في إدارتكم, أي من المجالات التالية تطابق طريقتكم في تطبيق نمذجة معلومات البناء - اختار دمج كلي اذا كانت جميع ماذكر**

- ☐ Concept and Design Development الفكرة وتطوير التصميم
- ☐ Renderings & Modeling الإخراج وعمل المجسمات
- ☐ Architectural Drawings الرسومات المعمارية
- ☐ Construction Documents عمل المخططات الإنشائية
- ☐ MEP Documents عمل المخططات الميكانيكية والكهربائية والإنشائية
- ☐ Sustainability الإستدامة
- ☐ Management and Operating الإدارة والتشغيل
- ☐ Fully Integrated Use دمج كلي - كل ما سبق
- ☐ I'm not sure غير متأكد
- ☐ Did not mention لم تذكر

Other (please specify) أرجو منك تحديد ذلك

***22. To what extend do you think what are you doing know is BIM? الى أي مدى تعتقد ان ما تقوم به حاليا هو نمذجة معلومات البناء**

| Strongly disagree لا أوافق بشدة | Disagreee لا أوافق | Neither agree nor disagree محايد | Agree أوافق | Strongly Agree أوافق بشدة | N/A لا اعلم |
|---|---|---|---|---|---|
| ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |

# Embedding BIM within Architectural Education in KSA??? ?????

## Academy

***23. Your current primary academic position الوظيفة الاكاديمية**

- ◯ Teaching assistant مساعد - معيد
- ◯ lecturer محاضر
- ◯ Assistant Professor أستاذ مساعد
- ◯ Associate Professor أستاذ مشارك
- ◯ Professor أستاذ
- ◯ Did not mention لم تذكر

Other (please specify) ارجو منك تحديد ذلك

**24. Your University الجامعة**

**اختار لم تذكر اذا لم تجد الجامعة**

Other (please specify) ارجو منك تحديد ذلك

***25. Your department إذكر القسم**

- ◯ Architecture العمارة
- ◯ Architecture Eng. الهندسة المعمارية
- ◯ Urban Planning التخطيط العمراني
- ◯ Urban Design التصميم العمراني
- ◯ Building Technology تقنية البناء
- ◯ Landscape Architecture عمارة البنية
- ◯ Interior Design التصميم الداخلي
- ◯ Mechanical Eng. الهندسة الميكانيكية
- ◯ Electrical Eng. الهندسة الكهربائية
- ◯ Civil Eng. الهندسة المدنية
- ◯ Project Management إدارة المشاريع
- ◯ Did not mention لم تذكر

Other (please specify) ارجو منك تحديد ذلك

## Embedding BIM within Architectural Education in KSA??? ?????

### Architecture and Architecture Eng. العمارة و الهندسة المعمارية

***26. when was your college established**
**متى تم أنشئت الكلية**

- ◯ Before 2004 قبل
- ◯ After 2004 بعد
- ◯ I don't know لا أعلم

***27. What Degrees offered by your department ما هي الدرجات العلمية التي تمنح في القسم**

- ☐ Diploma دبلوم
- ☐ High Diploma دبلوم عالي
- ☐ Tajesser تجسير
- ☐ Master ماجستير
- ☐ Bachelor بكالوريوس
- ☐ Ph.D. دكتوراه

**28. How many years that the student needs to graduate**
**كم عدد السنوات التي يحتاجها الطالب للتخرج**

| | |
|---|---|
| Diploma دبلوم | |
| Tajseer تجسير | |
| Bachelor بكالوريوس | |
| High Diploma دبلوم عالي | |
| Master ماجستير | |
| Ph.D. دكتوراه | |

**29. Most of the universities' programs has adopted their curriculum from other universities or designed it based on intenational or local standards, specify if there is a adoption**
**اغلب الجامعات السعودية تبني منهجها الدراسي من احدى الجامعات أو بناءا على معايير دولية أو داخلية ، اختار من ما يلي**

- ☐ Curriculum Quote from one of Saudi university اقتبس المنهج الدراسي من احدى جامعة سعودية
- ☐ Curriculum Quote from one of the foreign university اقتبس المنهج الدراسي من احدى جامعة اجنبية
- ☐ Curriculum is designed according to international standards صمم المنهج الدراسي بناءا على معايير دولية
- ☐ Curriculum is designed based on internal standards صمم المنهج الدراسي بناءا على معايير داخلية
- ☐ I don't know لا اعلم

## Embedding BIM within Architectural Education in KSA??? ?????

**30. Please identify the main source of curriculum** يرجى تحديد المصدر الرئيسي للمنهج

## Embedding BIM within Architectural Education in KSA??? ?????

**31. Has the curriculum been changed or developed your department?**
**هل تم تعديل أو تطوير المنهج الدراسي في القسم**

- ◯ Yes نعم
- ◯ No لا
- ◯ Under development تحت التطوير
- ◯ During the next 5 years خلال الخمس السنوات القادمة
- ◯ No need for that لا حاجة لذلك

## Embedding BIM within Architectural Education in KSA??? ?????

**32. Determine the future direction for the development of your curriculum, "sustainability - Building Technology - collaborative design between the various disciplines....."**

**تحديد التوجه المستقبلي في تطوير المنهج الدراسي**

**"الإستدامة - تقنية البناء - التصميم التعاوني بين مختلف التخصصات ....."**

## Embedding BIM within Architectural Education in KSA??? ?????

***33. Has been BIM taught within your school's Programs هل تم تدريس نمذجة معلومات البناء في القسم**

- ◯ Has not been taught and not considering لم يدرس وليس من اهتماماتنا
- ◯ Has not been taught, but considering لم يدرس ، ولكن نفكر
- ◯ In some area, within a class في بعض المواضيع, ضمن منهج
- ◯ Has been fully adopted into the system دمج بالكامل في النظام
- ◯ I don't know لا أعلم

## Embedding BIM within Architectural Education in KSA??? ?????

**34. In few point, could you please indicate Why it's not in your consideration?**
**في حد أعلى ثلاثة نقاط, تستطيع أن تذكر سبب عدم الإهتمام في تدريس نمذجة معلومات البناء**

***35. In your opinion, BIM could help with..... ? (Check Fully integrated use if it all)**
**من وجهة نظرك, نمذجة معلومات البناء تساعد في.....- اختار دمج كلي اذا كانت جميع ماذكر**

- ☐ Concept and Design Development الفكرة وتطوير التصميم
- ☐ Renderings & Modeling الإخراج وعمل المجسمات
- ☐ Architectural Drawings الرسومات المعمارية
- ☐ Construction Documents عمل المخططات الإنشائية
- ☐ MEP Documents عمل المخططات الميكانيكية والكهربائية والإنشائية
- ☐ Sustainability الإستدامة
- ☐ Management and Operating الإدارة والتشغيل
- ☐ Fully Integrated Use دمج كلي - كل ما سبق
- ☐ I'm not sure غير متأكد
- ☐ Did not mention لم تذكر

Other (please specify) أرجو منك تحديد ذلك

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## Embedding BIM within Architectural Education in KSA??? ?????

### Teaching Building Information Modeling BIM تدريس نمذجة معلومات البناء

**36. Are you teaching elective or mandatory هل تدريس المادة اختياري أو اجباري**

- ◯ Elective اختياري
- ◯ Mandatory إلزامي
- ◯ Both كلاهما

**37. At what level BIM has introduced in your School? في أي مرحلة دراسية تم تقديم نمذجة معلومات البناء**

- ☐ Diploma دبلوم
- ☐ Freshman السنة الاولى بكالوريوس
- ☐ Sophomore السنة الثانية بكالوريوس
- ☐ Junior السنة الثالثة بكالوريوس
- ☐ Senior السنة الرابعة بكالوريوس
- ☐ Fifth year السنة الخامسة بكالوريوس
- ☐ High Diploma دبلوم عالي
- ☐ Master ماجستير
- ☐ Ph.D. دكتوراه

Other (please specify)

**38. How BIM has been introduced? كيف تم تدريس نمذجة معلومات البناء**

- ☐ 3D modeling software برنامج حاسوبي لعمل المجسمات
- ☐ Stand-alone class مادة منفصلة
- ☐ Integrated studio مدمجة مع المرسم
- ☐ Within a modular جزء من منهج
- ☐ Did not mention لم تذكر

Other (please specify) ارجو منك تحديد ذلك

**39. How many classes that are taught Building Information Modeling كم عدد الفصول الدراسية التي من خلالها تدرس نمذجة معلومات البناء**

- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ More than 4 أكثر من

## Embedding BIM within Architectural Education in KSA??? ?????

***40. Please, indicate in which area/areas BIM has been taught in your school (Check Fully integrated use if it all)**

**تدريس نمذجة معلومات البناء في معظم دول العالم ينحصر في احدى المجالات التالية، من خلال آلية العمل في قسمكم, أي من المجالات التالية تطابق طريقتكم في تدريس نمذجة معلومات البناء - اختار دمج كلي اذا كانت جميع ماذكر**

- [ ] Concept and Design Development الفكرة وتطوير التصميم
- [ ] Renderings & Modeling الإخراج وعمل المجسمات
- [ ] Architectural Drawings الرسومات المعمارية
- [ ] Construction Documents عمل المخططات الإنشائية
- [ ] MEP Documents عمل المخططات الميكانيكية والكهربائية
- [ ] Sustainability الإستدامة
- [ ] Management and Operating الإدارة والتشغيل
- [ ] Fully Integrated Use دمج كلي - كل ما سبق
- [ ] I'm not sure غير متأكد
- [ ] Did not mention لم تذكر

Other (please specify) أرجو منك تحديد ذلك

***41. To what extend do you think what are you doing know is BIM? الى أي مدى تعتقد ان ما تقوم به حاليا هو نمذجة معلومات البناء**

| Strongly disagree لا أوافق بشدة | Disagreee لا أوافق | Neither agree nor disagree محايد | Agree أوافق | Strongly Agree أوافق بشدة | N/A لا اعلم |
|---|---|---|---|---|---|
| ○ | ○ | ○ | ○ | ○ | ○ |

## Embedding BIM within Architectural Education in KSA??? ?????

### Academics with Field Experience الاكادميين مع خبر عملية

***42. Do you have a field experience?** هل لديك خبرة ميدانية

- ◯ Yes نعم
- ◯ No لا

# Embedding BIM within Architectural Education in KSA??? ?????

## Students

**43. What grade are you in? في أي مستوى تدرس**

- ◯ Diploma دبلوم
- ◯ Freshman السنة الأولى بكالوريوس
- ◯ Sophomore السنة الثانية بكالوريوس
- ◯ Junior السنة الثالثة بكالوريوس
- ◯ Senior السنة الرابعة بكالوريوس
- ◯ Fifth year السنة الخامسة بكالوريوس
- ◯ High Diploma دبلوم عالي
- ◯ Master ماجستير
- ◯ Ph.D. دكتوراه
- ◯ Did not mention لم تذكر

Other (please specify) ارجو منك تحديد ذلك

***44. What are you studying? ماهو مجال الدراسة**

- ◯ Architecture العمارة
- ◯ Architecture Eng. الهندسة المعمارية
- ◯ Urban Planning التخطيط العمراني
- ◯ Urban Design التصميم العمراني
- ◯ Building Technology تقنية البناء
- ◯ Landscape Architecture عمارة البنية
- ◯ Interior Design التصميم الداخلي
- ◯ Mechanical Eng. الهندسة الميكانيكية
- ◯ Electrical Eng. الهندسة الكهربائية
- ◯ Civil Eng. الهندسة المدنية
- ◯ Project Management إدارة المشاريع
- ◯ Did not mention لم تذكر

Other (please specify) ارجو منك تحديد ذلك

***45. Studying BIM دراسة نمذجة معلومات البناء**

- ◯ I have already studied it قمت بدراسة النظام
- ◯ I'm studying it انا حاليا أدرس النظام
- ◯ I'm planning to study it في مخططاتي المستقبليه
- ◯ I don't want to study it لا اريد دراسته
- ◯ I don't know what is BIM أنا لا اعرف ما هي نمذجة معلومات البناء

Other (please specify)

## Embedding BIM within Architectural Education in KSA??? ?????

**46. Are you teaching elective or mandatory هل تدريس المادة اختياري أو اجباري**

- ◯ Elective اختياري
- ◯ Mandatory إلزامي
- ◯ Both كلاهما

**47. How did you study BIM? كيف درست/تدرس نمذجة معلومات البناء**

- ☐ 3D modeling software برنامج حاسوبي لعمل المجسمات
- ☐ Stand-alone class مادة منفصله
- ☐ Integrated studio مدمجة مع المرسم
- ☐ Within a modular جزء من منهج اخر
- ☐ Did not mention لم تذكر

Other (please specify) ارجو منك تحديد ذلك

***48. In your opinion, BIM could help with..... ? (Check Fully integrated use if it all) من وجهة نظرك, نمذجة معلومات البناء تساعد في.....- اختار دمج كلي اذا كانت جميع ماذكر**

- ☐ Concept and Design Development الفكرة وتطوير التصميم
- ☐ Renderings & Modeling الإخراج وعمل المجسمات
- ☐ Architectural Drawings الرسومات المعمارية
- ☐ Construction Documents عمل المخططات الإنشائية
- ☐ MEP Documents عمل المخططات الميكانيكية والكهربائية والإنشائية
- ☐ Sustainability الإستدامة
- ☐ Management and Operating الإدارة والتشغيل
- ☐ Fully Integrated Use دمج كلي - كل ما سبق
- ☐ I'm not sure غير متأكد
- ☐ Did not mention لم تذكر

Other (please specify) أرجو منك تحديد ذلك

***49. To what extend do you think what are you doing know is BIM? الى أي مدى تعتقد ان ما تقوم به حاليا هو نمذجة معلومات البناء**

| Strongly disagree لا أوافق بشدة | Disagreee لا أوافق | Neither agree nor disagree محايد | Agree أوافق | Strongly Agree أوافق بشدة | N/A لا اعلم |
|---|---|---|---|---|---|
| ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |

## Embedding BIM within Architectural Education in KSA??? ?????

### Finally

***50. In your opinion, What are the positions needed to be fill by BIM expertise**
**ماهي الوظائف المتوقعه في سوق العمل السعودي للمختصين في نمذجة معلومات البناء**

- ☐ BIM manager مدير
- ☐ BIM consultant إستشاري
- ☐ BIM coordinator منسق
- ☐ I don't know لا أعلم
- ☐ BIM modeler صانع مجسمات
- ☐ Did not mention لم تذكر
- ☐ BIM engineer مهندس

Other (please specify) ارجو منك تحديد ذلك

**51. In your opinion, How do you see BIM in KSA within 5 years?**
**ماهي نظرتك المستقبلية عن نمذجة معلومات البناء في السعودية خلال 5 سنوات**

| | Fully adopted مطبق كاملا | Partly adopted تطبيق جزئي | Need more than 5 years يحتاج إلى اكثر من خمسة سنوات | I don't think it will adopted لا أعتقد انه سوف يطبق | I don't know لا أعلم |
|---|---|---|---|---|---|
| Public sector projects with large size مشاريع القطاع الحكومي ذات الحجم الكبير | ◯ | ◯ | ◯ | ◯ | ◯ |
| Public sector projects of small size مشاريع القطاع الحكومي ذات الحجم الصغير | ◯ | ◯ | ◯ | ◯ | ◯ |
| Private sector projects, large-size مشاريع القطاع الخاص ذات الحجم الكبير | ◯ | ◯ | ◯ | ◯ | ◯ |
| Private sector projects of small size مشاريع القطاع الخاص ذات الحجم الصغير | ◯ | ◯ | ◯ | ◯ | ◯ |

Other (please specify)

**52. In few words, What do you think we need to improve the level of Architecture and engineering students in KSA?**
**في حد أعلى ثلاثة نقاط, ما الذي تقترحة لتطوير الطلاب السعوديين في مجال العمارة والهندسة؟**

## Embedding BIM within Architectural Education in KSA??? ?????

**53. To what extend do you agree or disagree with the following statements الى أي مدى توافق او لا توافق مع العباراة التالية**

| | Strongly Disagree لا أوافق بشدة | Disagree لا أوافق | Neither agree nor disagree محايد | Agree أوافق | Strongly agree أوافق بشدة | N/A لا اعلم |
|---|---|---|---|---|---|---|
| studying BIM will get you a better job دراسة نمذجة معلومات البناء تساعد في الحصول على فرصة عمل أفضل | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| The level of university graduates in construction field within KSA ملائمة خريجي الجامعات في تخصصات البناء مع متطلبات سوق العمل | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| The level of university curricula in the field of construction compared to the needs of the market مستوى المناهج الجامعية في تخصصات البناء مناسب لإحتياجات السوق | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| The need to develop curricula architectural الحاجة إلى تطوير المناهج المعمارية | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| Increased demand For BIM in Saudi Arabia إزدياد الطلب على نمذجة معلومات البناء في سوق البناء السعودية | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| Saudi labor market has the necessary cadres for the application of Building Information Modeling in the construction sector سوق العمل السعودي لديه الكوادر اللازمة لتطبيق نمذجة معلومات البناء في قطاع البناء | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |

**54. to what extent do you agree or disagree with the following statements in which area should architectural program be developed?**

**إلى أي مدى توافق أو لا توافق على ادراج العناصر التالية في الخطة الدراسية للبرنامج المعماري؟**

| | Strongly Disagree لا أوافق بشدة | Disagree لا أوافق | Neither agree nor disagree محايد | Agree أوافق | Strongly agree أوافق بشدة | N/A لا اعلم |
|---|---|---|---|---|---|---|
| Sustainability الاستدامه | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| Building Technology تقنية البناء | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |
| BIM Building Information Modeling نمذجة معلومات البناء | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |

Other (please specify) ارجو منك تحديد ذلك

## Embedding BIM within Architectural Education in KSA??? ?????

***55. Which computer applications do you teach/use? (Please check all that apply)**
**ماهي برامج الكمبيوتر التي تستخدمها او تدرسها**

- [ ] AutoCAD
- [ ] Revit Structure
- [ ] MagiCAD
- [ ] Sketch UP
- [ ] Revit MEP
- [ ] Bentley
- [ ] 3Ds Max
- [ ] Ecotect
- [ ] Tekla
- [ ] ArchiCAD
- [ ] Naviswork
- [ ] (All that apply)
- [ ] Revit Architecture
- [ ] Solibri Model Checker
- [ ] Didn't mention لم تذكر

Other (please specify)

**56. Any other comments you wish to add أي ملاحظات تريد إضافتها**

**57. Are you happy to be contacted to take part in a 10-20 minutes interview following up this questionnaire to answer some questions regarding to embed BIM within architectural program.**
**هل لديك الامكانية لتشارك في المرحلة الثانية من البحث وهي عمل مقابلة شخصية من 15 - 25 دقيقة عن دمج نمذجة معلومات البناء في البرنامج المعماري**

- ◯ Yes نعم
- ◯ No لا

## Embedding BIM within Architectural Education in KSA??? ?????

### 58. Your information

**Name:**

**Email Address:**

**Phone Number:**

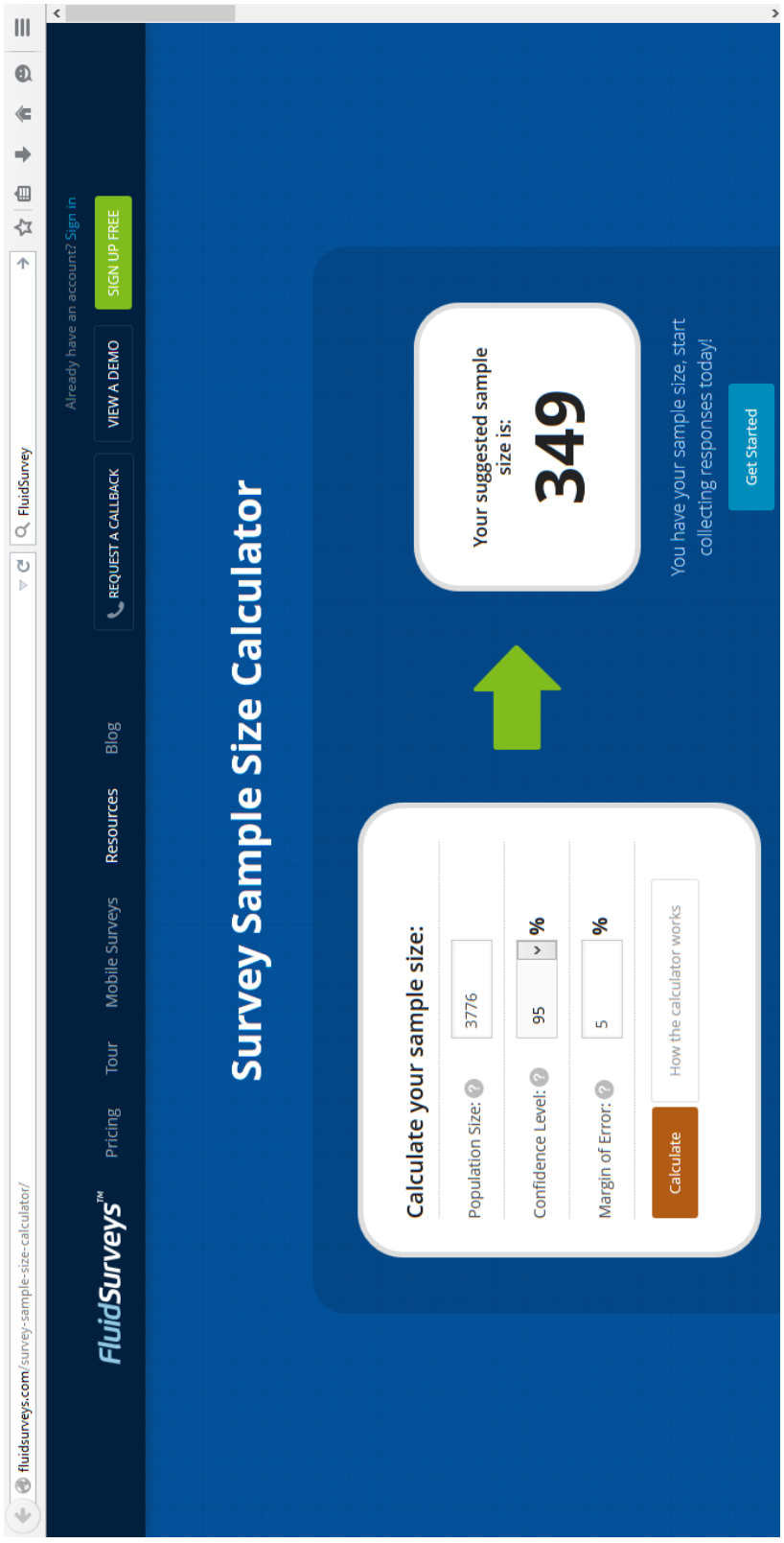
# Appendix 3

**Pilot Study – The number of architecture students 2015**

| | Minimum | Maximum | Median | Mean | Standard Deviation |
|---|---|---|---|---|---|
| Please write a positive number | 25.00 | 250.00 | 55.00 | 81.50 | 65.19 |

# Appendix 4

**Sample Size – Calculating the sample size based on FluidSurvey website**


fluidsurveys.com/survey-sample-size-calculator/
FluidSurvey
FluidSurveys™
Pricing
Tour
Mobile Surveys
Resources
Blog
REQUEST A CALLBACK
VIEW A DEMO
Already have an account? Sign in
SIGN UP FREE
Survey Sample Size Calculator
Calculate your sample size:
Population Size: 3776
Confidence Level: 95 %
Margin of Error: 5 %
Calculate
How the calculator works
Your suggested sample size is:
349
You have your sample size, start collecting responses today!
Get Started

# Appendix 5

**Presentation – 15-25 min presentation for interviewees before the interview**

## Contents

- What is BIM
- Collaborative Design
- BIM Benefits
- Increasing demand
- BIM in Academia
- KSA situation

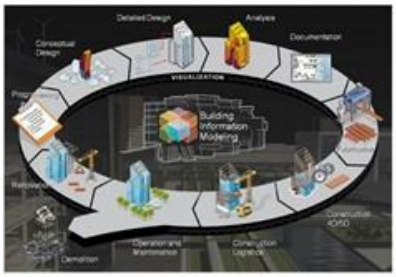
## Embedding Building Information Modelling within Undergraduate Architecture Programmes in KSA

Yasser Almutiri – PhD Candidate
Lecturer at Albaha University, KSA

Dr. Zeeshan Aziz – Supervisor

Salford University

## Concept




## What is BIM

**Different** definitions depending on **the identifier's perspective** -

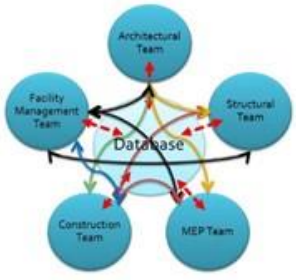
Technology, Process or both

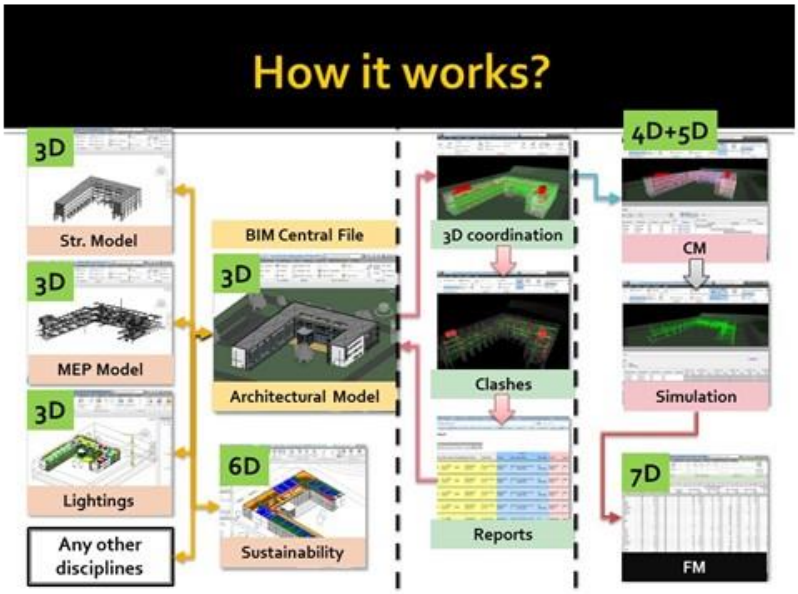
**HOWEVER**

BIM is an integrated design and delivery approach

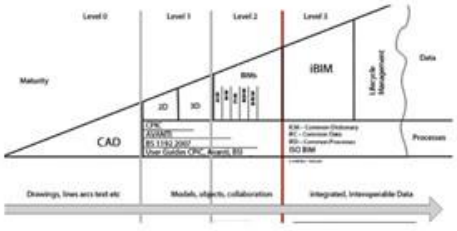
## BIM Benefits


## Collaborative Design

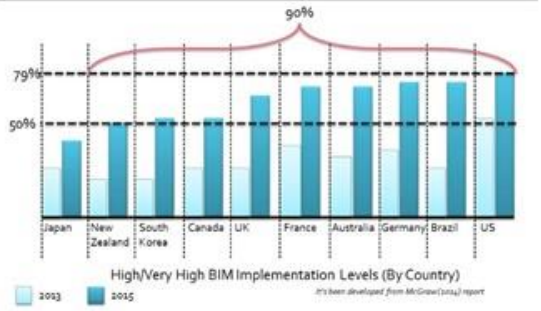





## UK




## BIM Around The World




## Saudi Arabia

***Building Industry***

- Construction boom
- Lack of Saudi architects and engineers

***Architecture Education***

- Lack of development
- Unaccepted output

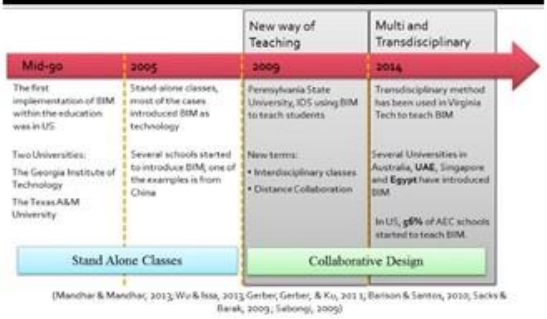
***BIM In Building Industry***

- Misunderstanding
- Increasing demand
- Lack of BIM experts

***BIM In Arch. Education***

- Misunderstanding
- BIM technology are introduced
- Lack of BIM educators

## BIM in Academia




(Mandhar & Mandhar, 2013; Wu & Issa, 2013; Gerber, Gerber, & Ku, 2011; Barison & Santos, 2010; Sacks & Barak, 2009; Sabongi, 2009)

# Appendix 6

**Interview – The questions of the semi-structured interview**

**1. What is your name?**

**2. Name of your university**

- ◯ King Abdul-Aziz University
- ◯ Taibah University
- ◯ Al-Baha University
- ◯ Umm-AlQura University
- ◯ Dammam University
- ◯ King Khalid University

**3. Research Interests**

- ☐ Sustainability
- ☐ Architecture Design
- ☐ Urban
- ☐ Planning
- ☐ Construction
- ☐ Building Technology

Other (please specify)

**4. Could you please tell me what subject/s have you taught?**

**5. To what extend do you think the presentation has changed your level of understanding BIM**

| Strongly disagree | Disagree | Neither agree nor disagree | Agree | Strongly Agree |
|---|---|---|---|---|
| ◯ | ◯ | ◯ | ◯ | ◯ |

**6. Do you believe the use of BIM in the marketplace will continue to increase in KSA?**

- ◯ Yes
- ◯ No

**7. Why**

**8. Have you Used/taught BIM Process?**

◯ Yes

◯ No

Other (please specify)

**9. How Long**

**10. How have you taught it?**

**11. Have you Used/taught any of BIM technology?**

◯ Yes

◯ No

Other (please specify)

**12. How Long**

**13. How have you taught it?**

**14. Should BIM taught in undergraduate architecture programmes**

◯ Yes

◯ No

**15. Why**

**16. Can students gain better knowledge by using BIM technology?**

- ◯ Yes
- ◯ No

**17. Why**

**18. How do you think we should teach BIM**

**19. Rank what do you think is most important to be taught to architecture students using BIM**

- ☐ Visualization
- ☐ Site planning
- ☐ Sustainability
- ☐ Risk mitigation
- ☐ Constructability
- ☐ Model based estimating
- ☐ Performance
- ☐ Life-cycle analysis
- ☐ Interoperability
- ☐ Environmental analysis
- ☐ FM
- ☐ Digital Fabrication
- ☐ Design
- ☐ Cost control
- ☐ 4D scheduling

**20. Other**

**21. In which level should BIM taught**

- [ ] 1st Year
- [ ] 2nd Year
- [ ] 3rd Year
- [ ] 4th Year
- [ ] 5th Year
- [ ] All

**22. Please, Obstacles facing the implementation of BIM within architecture programmes**

- [ ] Time to prepare material
- [ ] Time to Mastering BIM technology
- [ ] Lack of BIM Resources
- [ ] Accreditation
- [ ] Packed curricula
- [ ] Creativity
- [ ] Lack of BIM understanding
- [ ] Appropriate tool
- [ ] No Demand
- [ ] Lack of experience in BIM
- [ ] Mislead students from the actual course content
- [ ] Support given by Educators

**23. Other**

**24. What objectives have to be reached by students in these year?**

| | |
|---|---|
| 1st Year | |
| 2nd Year | |
| 3rd Year | |
| 4th Year | |
| 5th Year | |
| In General | |

**25. Have you taught a collaborative design**

◯ Yes

◯ No

**26. What do yo think about having a collaborative design studio**

**27. How diverse should be the collaborative design time**

**28. Have you developed or participated in developing a curricula?**

◯ Yes

◯ No

**29. Did the new curriculum has been evaluated? and What about accreditation?**

**30. Have you evaluated the outcome? and what do you think about that?**

**31. What do you think in having a Multilevel design studio MDS where architecture students from different level work in one environment.**

**32. Do you think such system could help to improve Architecture students?**

◯ Yes

◯ No

**33. Why**

# Appendix 7

**Presentation – 20-25 min presentation to present the initial BIM framework**

11/3/2015

## Embedding BIM within Undergraduate Architecture Programme (UGAP) in KSA Universities

Yasser Razgan Almutiri – PhD Candidate
Lecturer at The Architecture Department, Al-Baha University, KSA

Dr. Zeeshan Aziz – Supervisor

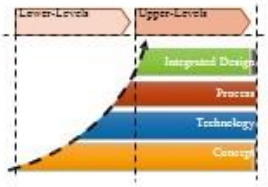
## The Aim

Developing an effective framework to embed BIM within Undergraduate Architecture Programmes UGAP in KSA

## BIM in Academia


## BIM Learning Curve (BIM-LC)

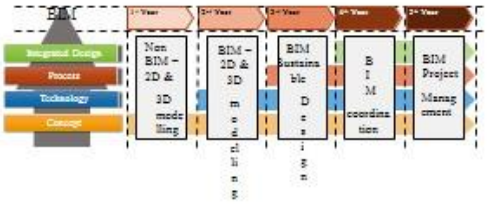
- Four Key points in teaching BIM
- BIM-LC
- Embed BIM-LC with UGAP




## Academics within UGAP in KSA

- Quantitative Data Analysis
  - Sustainability.
  - Integrated Design Studio (IDS).
- Qualitative Data Analysis
  - BIM should be embedded within IDS.
  - Sustainability and working drawings via IDS.
  - Other subjects via other classes.


## Initial BIM Framework to Embed BIM within UGAP in KSA



11/3/2015

1st Year

## Non-BIM Model

Concept

- Learning architecture drawings.
- Using Non-BIM technology.
- Understand the value of information.


2nd Year

BIM Stand-alone Class

## BIM Modelling

Concept

- Non-BIM model Vs. BIM Model.

Technology

- Learning BIM Modelling Tools.
- Learning how to link data with BIM model.


3rd Year

BIM Studio Design

## BIM Sustainable Design

Concept

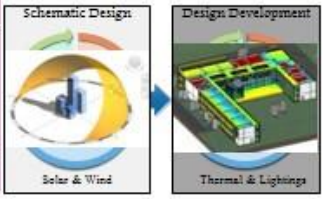
- Building performance and BIM Model.

Technology

- Learning BIM Energy Simulation Tools (EST).

Process

- Develop project from concept to pre-construction phase using BIM-EST.




4th Year

BIM Working Drawing Studio

## BIM Coordination

Concept

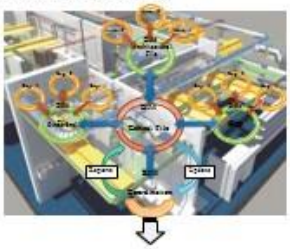
- Relay races Vs Football Team.

Technology

- Learning BIM Coordination Tools (BIM-CT).

Process

- With a team, produce working drawing BIM project

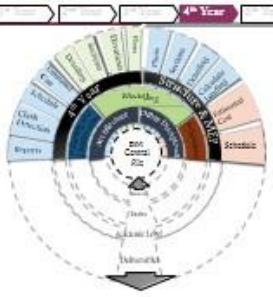


4th Year

## BIM Coordination

Integrated Design

- Planning project and organizing team.
- Learning to Share with identifying responsibilities
- Learning reporting and fixing clashes.



5th Year

BIM Stand-alone Class

## BIM Management

Concept

- Regulations and Contracts

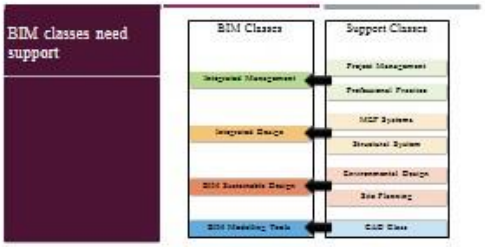
Technology

- Using BIM-CT to plan 4D & 5D.

Process & Integrated Design

- Working with experts, planning 4D and 5D.

11/3/2015


BIM classes need support
BIM Classes
Support Classes
Integrated Management
Integrated Design
BIM Sustainable Design
BIM Modeling Tools
Project Management
Professional Practice
MEP Systems
Structural System
Environmental Design
Site Planning
CAD Class