INTEGRATION OF BUILDING INFORMATION MODELING INTO CONSTRUCTION MANAGEMENT CURRICULUM: LESSONS LEARNT FROM DEVELOPED COUNTRIES

A thesis submitted in partial fulfillment of the

requirements for the degree of

Masters of Science

in

Construction Engineering and Management

by

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has been accepted towards the partial fulfillment

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This thesis is dedicated to my loving family members for their supports & encouragement

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ABSTRACT

Didactical methods are changing in construction education in contemporary times: the advent of Information and Communication Technology (ICT) and modern tools are influencing this otherwise traditional field. It is very important for the engineering universities to introduce new ICT tools in the Construction Engineering and Management (CE&M) education. Building Information Modeling (BIM) is a promising tool for this purpose. Recent results show that construction industry around the world demands engineers with BIM skills and many universities around the world now consider or have started to integrate BIM into their academic programs. Currently several universities worldwide offer BIM courses in CE&M programs and many are under the process of integrating BIM in their curricula. In fact most of the universities have yet to completely understand the BIM application, functions, strategy of teaching and its barriers faced during the integration process. The aims and objectives of this research are to capture the current state of CE&M curriculum with regard to BIM in Pakistani engineering universities and the industry expectations from the CE&M students. It further aims at providing a framework and postgraduate level BIM course outline for step towards the integration of construction industry and academia. To achieve the objectives, a better understanding regarding BIM was required. It is accomplished through study of different articles, journal papers, websites, conference papers and BIM curriculum of different US universities. On the basis of literature review, the role of BIM in construction industry and academia is identified. Preliminary questionnaires

were developed and were evaluated through the pilot survey. In the light of recommendations received from the pilot survey, the final questionnaires were developed for the execution of detailed survey. Detailed survey was conducted for collecting the data from construction industry and academia. The data obtained from questionnaires were analyzed through SPSS & MS-Excel software. For the analysis, two analysis techniques were used (1) descriptive analysis was done by frequency distribution technique (2) inferential analysis was carried out by hypothesis t-testing. Results obtained from the local construction industry and academia indicate that majority of the professionals are in favor for implementing BIM on construction projects and AEC education but the most significant barrier is the lack of BIM trained professionals. On the basis of these results, a framework and postgraduate level BIM course are developed for CE&M students. After development of BIM course it is more improved by taking feedback from the US universities BIM experts.

The output of this research will strengthen the engineering universities' CE&M programs with current ICT based knowledge, because apparently most of them have little knowledge of the content, principles, and methods of education in these ICT tools that include BIM. The output of this research will also provide educators with guidelines to implement BIM content in their CE&M programs so that postgraduate engineers can polish their skills up to current BIM industry requirements.

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LIST OF ABBREVIATIONS

CM	Construction Management
CE&M	Construction Engineering and Management
AEC	Architecture, Engineering and Construction
BIM	Building Information Modeling
ICT	Information and Communication Technology
3D	Three Dimensional
CAD	Computer Aided Design/Drafting
SPSS	Statistical Package for Social Sciences

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Construction management (CM) encompasses the appropriate use of available resources; organize of the scope of the work, effective project scheduling, the prevention of delays, variations and disputes; refining project design, construction quality and best potential flexibility in procurement. Information is of great significance during the CM process. Advancements in Information and Communication Technology (ICT) allow retrieving more accurate and current as well as visual information, which in turn allows monitoring CM processes more effectively.

For accomplishing high-quality and efficient CM during the life cycle of a project, ICT systems are used today comprising Building information modeling (BIM) tools among many other. BIM is an emerging technology in which digital information models are made. Therefore, Architecture, Engineering and Construction (AEC) industry are found to promptly embrace BIM (Sacks and Pikas, 2013). The continuous adoption of ICT by most participants in the AEC industry may also cause revolutions in academia. Academic institutions however, are generally slow to adopt change especially if it forced by a continuous change of new technologies (Sharag-Eldin and Nawari, 2010).

Adoption of BIM in AEC programs is relatively latest effort and its main reason is the fast implementation of BIM in construction industry around the world that demand BIM education, training and research, not only just for BIM implementation in academia but also for fulfill the construction industry requirements and its evolution purpose, so that when these university graduates entering the industry they must have necessary knowledge and capabilities in this area according to the latest construction industry requirements (Smith, 2014, Maghiar et al., 2103).

In Pakistan, there are several degree programs to support AEC industry including civil engineering, architecture, architectural engineering, and construction engineering & management (CE&M) degree programs, but very few of them incorporate BIM content. The challenge is that, most of the universities are struggling because to date, there is no understanding of what skills are needed in the industry. Moreover little is known about, the content, principles, and methods of instruction in field that requiring BIM.

There exists an overwhelming need of incorporating advanced ICT based knowledge applications in CE&M education. This research study include development of postgraduate level BIM curricula and integration framework based on the expectations of Pakistani construction industry experts and academic professionals within the area of BIM and based on the BIM programs and initiatives of different US universities.

This research was carried out through different connected task i.e. literature review, preparation of questionnaires, visit of AEC industries and engineering universities for collecting the data, taking experts feedback from US universities and finally the preparation of thesis report.

The output of this research have analyze the Pakistani construction industry requirements and come across a framework and postgraduate level BIM curriculum, which will provide educators with guidelines to develop and implement BIM content in their CE&M programs so that graduate engineers can polish their skill up to the current BIM industry requirements.

1.2 REASONS FOR SELECTION OF THE TOPIC

The following were the reasons for the selection of this topic:

a) This research work was oriented to build an awareness of BIM among the stakeholders like academia, Engineers, Contractors, Sub-contractor, Developers, project Managers, and Facility Owners.
b) This research can provide help to strengthen the engineering universities CE&M programs with current ICT based technology, because apparently most of them have little knowledge of the content, principles, and methods of education in these ICT tools that include BIM.
c) This research can also provide help to explore the BIM potentials for graduate engineer up to the construction industry requirements.

1.3 AIM AND OBJECTIVES

a) To study current state of CE&M curriculum with regard to BIM in Pakistani engineering universities.
b) To identify barriers to integrating BIM into CE&M curriculum in Pakistani engineering universities.
c) To study current expectations of Pakistani construction industry from construction engineering graduates within the area of BIM.
d) To develop a postgraduate level BIM curriculum for the integration into CE&M education.

1.4 RELEVANCE TO NATIONAL NEEDS

One of the necessary requirements of CE&M education like other technical education is to remain up to date and current. It is quite important for AEC universities to adopt new technologies in construction education. BIM as a new technology and tool is one of the latest developments in construction industry (Solnosky and Parfitt, 2015, Ahbab et al., 2013, Sabongi and Arch, 2009). However, in Pakistan, the research on BIM from academic and construction perspective is quite uncommon (Hussain and Choudhry, 2013). BIM education is lacking in formal and informal settings. Universities across country are facing a serious lack of focus on CE&M skills and education. This puts even more stress on the need of such skills as 60-70% of civil engineering graduates join contractors and rest go to other domains (Masood et al., 2014). This study will provide a foundation

to educators who desire to include BIM in CE&M programs and will also provide guidelines that will be helpful into development and implementation of BIM content so that graduate engineers can polish their skills up to the current local and international construction industry requirements.

1.5 ADVANTAGES OF THE RESEARCH WORK

This research work would help:

a) To provide educators with guidelines to implement BIM content in their CE&M programs so that postgraduate engineers can polish their skills up to current BIM industry requirements.
b) To provide a framework for academia for meeting the industry requirements.
c) To create the better understanding of BIM technology within the academia and construction industry perspectives.
d) To bridge the gap between the academia and construction industry requirements.

1.6 AREAS OF APPLICATION

Area of application of this research, its processes and scope includes academia and the participants of AEC industry like Engineers, Architects, general / specialty contractors, consultants, construction management firms, and developers / facility owners, etc. Since not much work is performed on this ICT tool in local

context, so this research is act as a stepping stone for further development in this area.

1.7 THESIS ORGANIZATION

The thesis work is organized in the following five chapters .The structure of thesis work is summarized as following.

- **Chapter 1:** Explains the background of the research. It provides the introduction to guide the reader about research topic. The problem statement, research questions, aims & objectives and outline of the thesis are included in this chapter.
- **Chapter 2:** Describes the literature review that covers BIM introduction, benefits, applications, its uses in worldwide and local construction industry, BIM education in worldwide and its challenges for implementation in engineering universities and construction industry.
- **Chapter 3:** Defines the methodology applied on this research.
- **Chapter 4:** Includes the analysis of the data which was collected through surveys.
- **Chapter 5:** Deals with the findings, conclusions and recommendations.

1.8 CHAPTER SUMMARY

In this chapter introduction related to thesis work was given in detail. This chapter describes objectives of the project that is to provide a framework of BIM for the industry requirements and CE&M curriculum which was based on identification

of the current requirements of Pakistan construction industry related to BIM, study the current state of AEC curriculum with regard to BIM and identification of the barriers related to BIM within CE&M curriculum in Pakistani Engineering universities. The methodology of the thesis work was split in to six phases. First phase is to collect the literature on BIM introduction in detail in worldwide construction industry and in engineering universities, second phase is to developed questionnaire on the basis of literature review, third phase is to determine the views of professional about questionnaire through pilot survey and improve the questionnaire on the basis of professional reviews regarding questionnaire and to collect the data of different AEC firms and engineering universities through the questionnaire, fourth phase is to analysis the data which was collected in detailed survey, fifth phase is the curriculum development and in last phase present the findings and conclusions and recommendations.

In the next chapter the literature review related to BIM in local and worldwide construction industry and integration of BIM education in CE&M curriculum are explained in detail.

CHAPTER 2

LITERATURE REVIEW

2.1 BACKGROUND

Owing to a shift in global perspectives and socio-economic needs, construction industry is subject to risky and complex projects. BIM provide solutions to many problems and systemic failures in the construction industry. Nowadays, various design firms as well as construction management firms, consultants and other organizations have implemented BIM in their construction offices to facilitate Construction Management (CM) processes and services (Sacks and Pikas, 2013, Zoghi et al., 2012).

The vital role of BIM in construction industry is best expressed in a statement from Young et al.,(2008) in BIM Smart Market Report: *"your career and the prosperity of your company depend on becoming familiar with the tools, processes and value propositions of BIM"*.

Owing to such increasing awareness many universities around the world are seriously considering or have already started to integrate BIM in Architecture, Engineering and Construction (AEC) programs. To understand the reasons of importance of BIM as a modern ICT tool in construction industry and academia, it is necessary to comprehend the BIM definition first.

2.2 BIM

According to NBIMS (2010), *"BIM is a digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life cycle; defined as existing from earliest conception to demolition"*.

The Associated General Contractors (2005) defined BIM as: *"Building Information Modeling is the development and use of a computer software model to simulate the construction and operation of a facility. The resulting model, a Building Information Model, is a data-rich, object-oriented, intelligent and parametric digital representation of the facility, from which views and data appropriate to various users' needs can be extracted and analyzed to generate information that can be used to make decisions and improve the process of delivering the facility*".

So it is clear from above two definitions that BIM is not just software. Rather, it is a combination of process and technology as shown in Figure 2.1.

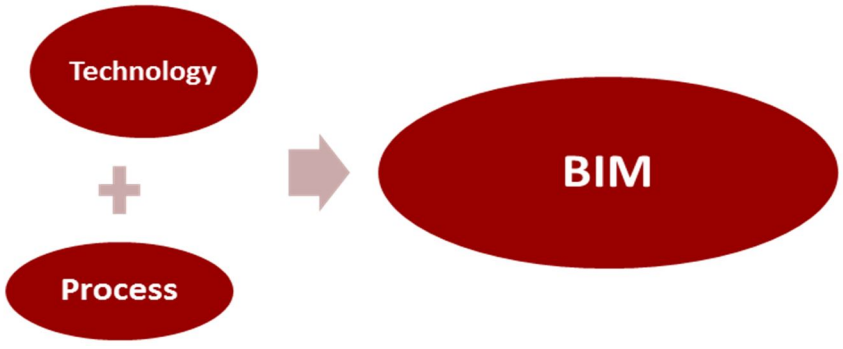

Figure 2.1: BIM definition

2.2.1 BIM as a Technology

From technology a building information model demands for project simulation comprising of 3D models of project constituents with relations to all the required information linked with pre project planning, designing, construction operation and facility management as shown in Figure 2.2.

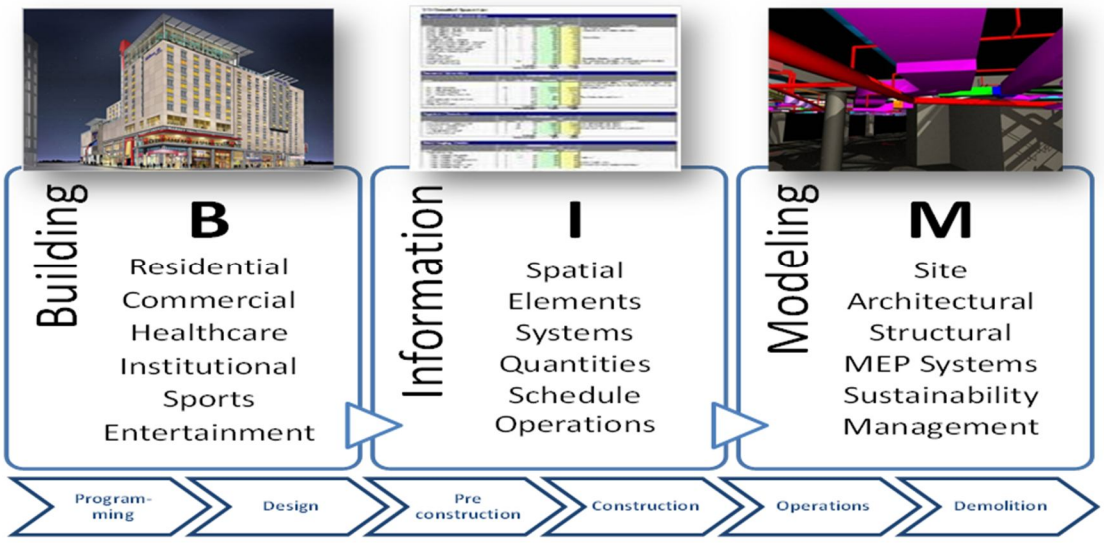

Figure 2.2: A visual representation of BIM concept (Azhar et al., 2012)

2.2.2 BIM as a Process

From the process aspect, BIM can be viewed as a virtual process that encompasses all aspects, disciplines, and systems of a facility within a single, virtual model (Azhar et al., 2012) as shown in Figure 2.3. It allows all project team members including client, architects, engineers, contractors, subcontractors and material suppliers to work together more accurately and efficiently than through

traditional ways. Once the model is created, project team members are continuously refining and adjusting their portions according to project drawings and specifications and to ensure the model is as accurate as possible before the project hits the ground.

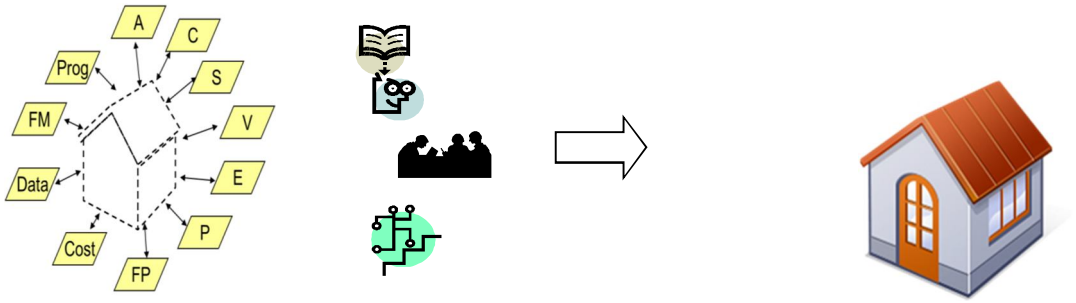

Figure 2.3: BIM as a process (Azhar et al., 2012)

2.3 APPLICATIONS OF BIM

A building information model can be used for the following purposes (Azhar et al., 2012).

2.3.1 Visualization

With the help of BIM applications a 3D model can be created and renderings can be done easily obtained with little additional effort.

2.3.1 Fabrication/Shop drawings

BIM applications provide an easy way to produce shop drawings for various building systems.

2.3.2 Code reviews

Fire departments and other officials may also use BIM models for their review of building projects.

2.3.3 Cost estimating

BIM software has incorporated many cost estimating features. Material quantities are automatically extracted and updated when any changes are made in the model.

2.3.4 Construction sequencing

A building information model can be also be efficiently used to coordinate material ordering, fabrication, and delivery schedules for all building components.

2.3.5 Conflict, interference, and collision detection

A building information models created in 3D space but it also provides the opportunity that we can extending up to indefinite dimensions, so all major systems of project can be instantly and automatically checked for interferences. For example, this process can verify that piping does not intersect with steel beams, ducts, or walls.

2.3.2 Forensic analysis

A building information model can be used to graphically illustrate potential failures, outflows, plans etc.

2.3.3 Facilities management

A building information model can be used by facilities management departments for renovations, space planning, and maintenance operations purposes.

2.4 BENEFITS OF BIM

Construction CRC Construction Innovation (2007) study highlight the several benefits of BIM but the major benefit of a BIM model is its ideal geometrical representation of elements of a building which combine an integrated data environment. Other related benefits are as follows:

- Its serves as a faster and effective process in distribution of architectural, structural, MEP, models and other information is further easily distributed which can be value-added and reused.
- It provides better design in shape of nD models. Building proposals can also be thoroughly analyzed and simulations can be performed quickly.
- Due to different availability of information in shape of material characteristics and its functions lifecycle costs (LCC) can also be controlled. Further, environmental performance is more predictable, and LCC are well understood.

- Better production quality: Documentation output is flexible and can be used easily.
- It provides better customer service due to its accurate visualization. Different alternative proposals can easily be made with the help of BIM technology.
- All lifecycle data stored in building information models can be used in facilities management.

Based on 32 major projects using BIM, Gilligan and Kunz (2007) mentioned some benefits of BIM such as :

- Removal of unbudgeted modification up to 40%
- Cost estimation precision within 3%
- Reduce in time to produce a cost estimate up to 80%
- Clash detections savings up to 10% of the contract value. And up to 7% saving in project time.

2.5 N DIMENSIONS OF BIM WITH APPLICATION

Table 2.1 n Dimensions of BIM with application (Masood et al., 2014)

Dimension	***Application***
3D Coordination	Visually analyze design errors
4D Scheduling and Sequencing	Activities scheduling and sequencing with 3D model.
5D Cost Estimation	Material quantities are extracted automatically
6D Procurement	Integration of all subcontractor and supplier data into separated models.

Prefabrication Structural Analysis Lightening Analysis Mechanical (HVAC) Analysis Energy Analysis	Optimization of prefabricated construction components. Integration with MEP components. External analytical engine develop architecture design to structure and then analyzed for loading. Creation of effective and constructible lightening systems with improvement in quality, cycle time and cost. Clash and conflict detection with visualization Energy analysis, day lighting analysis, solar analysis, orientation analysis, and site analysis.
7D Operation and Maintenance	Facilities management for renovations, repairs, restorations, space planning, and operations maintenance.
8D Modeling with PTD	Risk assessment of design component of facility for prevention through design.

2.6 BIM IN CONSTRUCTION INDUSTRY AROUND THE WORLD

BIM is fast rising among Architecture, Engineering and Construction (AEC) industry. In UK, majority of respondents (43%) had not considered of BIM in 2010. By 2016 all British public sector projects will be carried out using BIM. According to (NBS 2014) Report, knowledge of BIM in UK is raised from 58% in 2010 to 95% in 2013. Only 5% of participants are unaware of BIM. Similarly in North America adoption of BIM has also increased fast in the past few years. According to Construction Smart Report (2012), BIM adoption in North America is increased to 71% in 2012 from 49% in 2009 and 28% in 2007 respectively.

In the US, BIM and related processes are being explored by contractors, architects and developers. A McGraw Hill Construction study determines

contractors' use of and attitudes toward BIM (The Global Building Information Modeling Study, 2013) showed that in the US alone, 291 organizations indicated that they were involved with or using BIM practices. The research was conducted through an extensive online survey and a total of 727 responses were received from the 10 countries around the world. Of these 727 respondents the majority (60%), reported medium to very high engagement with BIM (Construction Skills Queensland 2014).

In Asia, several countries are also inclined to adopt BIM in their AEC industry and some have already taken the lead in BIM. India is one of the rapidly increasing markets in BIM technology. It has various BIM experts who are trying to implement this technology in Indian construction projects and also provide assistance to many other countries including UK, USA, Middle East, Singapore, Australia, and North Africa (Construction Skills Queensland 2014). All this research indicates awareness relating BIM is increasing with a blinding pace and most of the AEC industry is adopt this technology due to some reasons as mentioned in Figure 2.4.

Figure 2.4**:** Factors influencing non- users to adopt BIM (Construction Smart Report, 2012)

2.7BIM IN PAKISTANI CONSTRUCTION INDUSTRY

In Pakistan, most of the professionals are unaware of the significance of BIM. It is not used during planning, designing and operation stage. Its only use for purpose of presentations and, to some extent, used in architectural firms only for architectural design review process that do not contain any information beyond material characteristics and functions including materials, colors, spatial relationships, and textures, etc. Very few architectural firms in Karachi including Ahmed Associates, Khatri Associates, Schematics, Icon, etc. have adopted BIM for architectural design purpose and many other AEC firms are in process to adopt BIM. In Pakistani, Design Bid Build, a traditional contract system is the main barrier in adoption of BIM due to which other stakeholders are not engaged in the process until the design is completed (Mankani, 2009).

However, in the recent past, there appeared some promising development in this sector. Most of the medium to large architecture firms have at least a basic understanding of BIM. The input and feedback obtained from the Pakistan construction industry also indicate that the most of the AEC professionals are in favor for implementing BIM in construction projects. According to a research, (Umer et al., 2012) majority of AEC professionals (85%), have agreed that BIM has a reputable progress in future of Pakistani construction industry. While

remaining 15% professionals might have confronted some difficulties in the shape of training people or maybe some ownership of model issues.

According to the latest research Hussain and Choudhry (2013) and Masood et al. (2014) in Pakistan there is an increasing level of awareness about BIM technology and there is development in this regard day by day. Most of the professionals in Pakistan construction industry have some knowledge of BIM.

2.8 INTEGRATING BIM INTO CE&M CURRICULUM

AEC educations being conventional in some regards impose some problems that need to be identified and addressed effectively. Sheppard et al. (2008) and Andersson (2013) highlight the traditional way of teaching as a reason why AEC education is criticized. They explain this education to be much inclined towards theory and disciplinary knowledge with little consideration paid to additional skills, e.g. personal, inter-personal and professional skills.

Currently most CE&M programs are focused on teaching traditional management techniques and are not sufficient to handle construction projects efficiently. The problem is that traditional CE&M education provides well-structured programs and knowledge that barely cater real ICT based solutions. As a result, university graduates often find it difficult to use the classroom knowledge while dealing with complexities and uncertainties of real projects (Wang et al., 2014).

The input and feedback from the construction industry indicates that the significance of adopting additional skills and subjects such as BIM must be incorporated into AEC education (Andersson, 2013, Andersson and Andersson, 2010). Many researchers are found to emphasize the incorporation of BIM in CE&M program.

NATSPEC (2014) report has established that education relating BIM gets attention at different levels of implementation across the globe. Some countries have successfully implemented this integration while the others are in process. Studies by Peterson et al. (2011); Forgues et al. (2011) and Elinwa and Agboola (2013) also established some strong points for introducing BIM concept into CE&M education and found that BIM serve as a promising technological approach to constructive learning and productive teaching. For satisfing the AEC industry requirements , some of the universities have started to integerate BIM concept into AEC education (Barison and Santos, 2010a, Barison and Santos, 2010b, Sacks and Pikas, 2013).

Due to this reasons teaching programs are now offered in many universities around the world; however they are usually inclined towards software training. The awareness relating BIM is increasing with a blinding pace and demand that BIM education must be integrated in all CE&M programs on all levels of graduate and post-graduate degree (Magiera, 2013).

Many researchers have conducted surveys in which they have inquired expectations of US construction industry form AEC students in regards of BIM. Nejat et al. (2012); Lee and Hollar (2013) and Langar and Pearce (2014) conducted a brief survey of US industry requirements and existing AEC programs. They rated different BIM skills mostly demanded from AEC graduates. These studies concluded visualization, constructability review, clash detection, four-dimensional (4D) modeling, spatial trade coordination and site logistics to be main skills desired by US construction industry.

Study of construction companies conducted by Ku and Taiebat (2011) revealed that US companies prefer hiring graduates that have BIM software skills as well as conceptual knowledge. These studies emphasize the adoption of BIM education across AEC education, to satisfy a growing need of BIM educated engineers.

Studies of Liu and Killingsworth (2012) and Ahbab et al. (2013), have also established that visual drawings in the shape of 3D models is improving the way of teaching CE&M topics by refining demonstration of complex concepts such as building components.

2.9BIM EDUCATION APPLICATIONS

Several researchers highlight the BIM education applications on introducing and integrating BIM concept in university education.

2.9.1. Plan reading skills

Plan reading skills are considered as essential for CE&M students because they assist in understanding the major construction methods, materials, and processes. BIM, though reasonably new, have already shown that a positively influences plan reading skills of CE&M students when incorporated in CE&M curriculum (Gier, 2007, Ahbab et al., 2013, Wang et al., 2014). Moreover, Clevenger et al. (2010) and Panuwatwanich et al. (2013) suggested the use of BIM into CE&M curriculum for facilitating the learning experience.

2.9.2. Cost estimation skills

Estimation of quantity take offs form drawing is the key job of any successful CE&M professional. Lacking ability in this area puts a CE&M student difficult position in later professional stages as well as the beginning stages of his professional career (Chico, 2008). Many researchers highlight the effect of integration of BIM in CE&M programs. Studies by Gier (2007) and Chico (2008) have shown that BIM incorporation in estimating courses have a positive influence on estimating skills of CE&M students because it provides visualization that may improve estimating skills of CE&M students and increase the effectiveness of CE&M students to do estimating in their jobs.

2.10 BIM INTEGRATION INTO CE&M CURRICULUM WORLDWIDE

Currently several worldwide CE&M programs are offering BIM courses to their students. Due to its significant role in construction industry and academia, it is clearly highlighted that it should be integrated in every CE&M program (Ahn et al., 2013). Panuwatwanich et al. (2013) have also recognized the need to incorporate BIM into university education to equip CE&M graduates with adequate understanding of BIM concepts according to the construction industry requirements. In fact, a number of world universities have already attempted to incorporate BIM into their CE&M curriculum (Pikas et al., 2013).

Upon conducting a survey of American education institutions Gerber et al, (2011) found that most of the BIM courses offered in US universities are elective with focus on, constructability review, 4D scheduling, model based estimation, design, visualization and cost control. Table 1 shows some US universities CE&M programs and their BIM courses. In some studies Ahn et al. (2013) and Sacks and Barak (2009) highlighted some US universities and their BIM course in this regard.

Table 2.2 Some US Universities, CE&M programs and BIM courses

Course names	**Institutions**	**Credit Hours**
Construction Information System	Auburn university	3
CNMG 2318, BIM	University of Arkansas at Little	3
MCM-602, Construction Information Modeling	Philadelphia University	3
CM 414, Virtual Construction	University of Washington	3

CE 570, BIM Collaborative CM	University of Southern California,	3
ECIV 309, BIM in Construction	Montana State university	2
CGT 46000, BIM for Commercial Construction	Purdue University	3

Different BIM tools are available that can be used for different purposes. Jiang (2011) studied various software packages that are used across the construction industry and academia as BIM tools; they are summarized in Table 2.3

Table 2.3 BIM Tools (Jiang, 2011)

Company	**Software**	**Primary Usage**
Autodesk	Revit	BIM Model generation
	Navisworks	Clash Detection,4D Scheduling, Quantity Takeoff
	Robot Structural Analysis	Structural Analysis
	Green Building Studio	Energy Analysis
Graphisoft	ArchiCAD	BIM Model generation
	Estimator	Estimation
	EcoDesigner	Energy Analysis
Bentley	AECOsim	BIM Model Generation
	Project Wise Navigator	Review and Analysis
Tekla	Tekla Structures	Structural Model generation and Detailing
	Tekla BIMsight	Review and Analysis
Vico	Vico Control	4D Scheduling
	Takeoff Manager	Quantity Takeoff

2.11 STRATEGIES FOR IMPLEMENTING BIM IN CURRICULUM

Many researchers are trying to find appropriate ways for integrating ICT in construction education. Studies by Andersson and Andersson (2010); Becerik-Gerber et al. (2011) and Andersson (2013) emphasized that adoption of ICT based knowledge which can enhance additional skills of CE&M student such as BIM applications must be integrated in CE&M curriculum. These additions can meet latest construction industry demand and still allow for the continuous learning of technical knowledge.

Taylor et al. (2008) and Azhar et al. (2010) investigated the alternative methods for integration of BIM into CE&M curriculum. The initial method was the self-taught BIM project in which students complete the project by using different BIM software with no formal training given to students. The next method was the introductory BIM course added to CE&M curriculum. The course covered beginner to intermediate issues including architectural, structural and MEP modeling, estimating project schedule, reviewing site plan, energy analysis and the rendering of project for presentation purpose. Similarly, another method was BIM related theses expected from students for research purpose.

Barison & Santos, (2011) and Ghosh et al.(2013) classify different familiar approaches for promoting BIM education in CE&M including

1. Presenting BIM as optional course or a in a workshop

2. Integrate it in a higher degree program
3. Restructure the existing CE&M curriculum to incorporate BIM
4. Integrate it with the current CE&M curriculum.

Furthermore, the study of Barison and Santos (2011) highlight that for incorporating BIM in CE&M education different universities demonstrate BIM in one or two courses or use BIM in several educational courses, as shown in Figure 2.5.

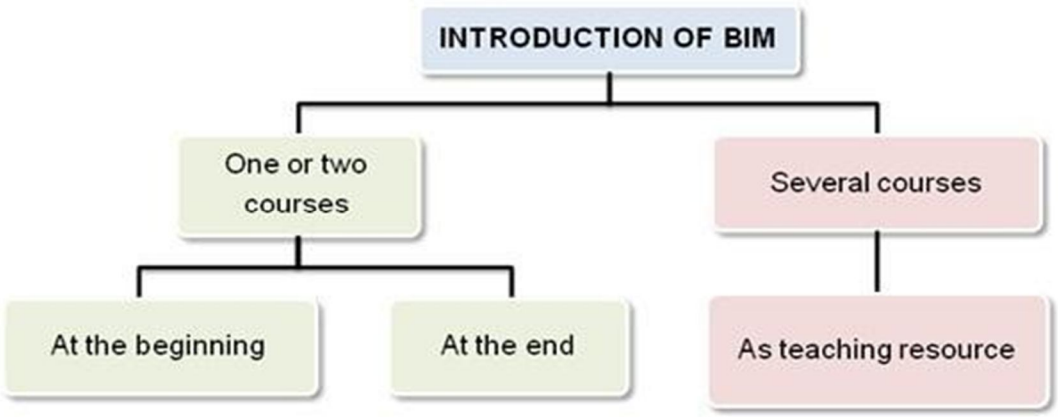

Figure 2.5: Strategies used by universities when implementing BIM in the curriculum (Barison and Santos, 2011**)**

In the first method, BIM tools and applications are explained at the beginning of the programs and it is mainly designed for fresh students. In the second method, BIM model is generally used as a teaching foundation to provide CE&M students an understanding in certain issues. The trainer can make a model while using BIM and demonstrate difficult aspects of theory parts. For example it can be used in risk management or construction safety class (Barison and Santos, 2011).

2.12 FACTORS AFFECTING IMPLEMENTATION OF BIM IN CE&M CURRICULUM

The imperative requirement of BIM education in CE&M programs has been aptly stressed globally and cannot be ignored. However, the current challenge for higher education institutions is how to implement BIM in their educational curriculum (Molavi and Shapoorian, 2012). A major challenge for integrating BIM in higher education institutions is to find appropriate ways of integration (Molavi and Shapoorian, 2012).

The universities that are planning to introduce BIM in CE&M curriculum face a number of obstacles as shown in Figure 2.6 that can be grouped into three type's i.e. academic circumstances, misunderstanding of BIM concepts and difficulties in using BIM tools. An analysis of 119 building construction schools in US found that only 9% include BIM related studies at a degree level. The main obstacles indicated by respondents include as: lack of time and resources to prepare a new curriculum, lack of space in established curriculum to include new courses and a lack of suitable materials for BIM related training (Barison and Santos, 2011, Sabongi, 2009). Same blockages are also identified by another survey involving 101 architecture, civil engineering and CE&M programs in US. Moreover, the survey has also revealed a lack of trained professional personnel for BIM, and the accrediting bodies for CE&M programs lacking clear guidelines for BIM (Becker et al., 2011).

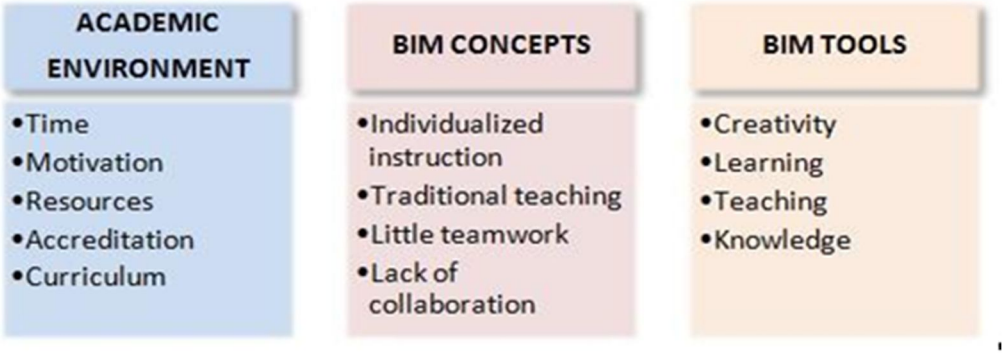

Figure 2.6: Factors affecting the implementation of BIM in the curriculum (Barison and Santos, 2011)

2.13 BIM LEARNING AND TEACHING APPROACHES

BIM learning and teaching approaches can vary depending on the level at which the skills are being educated. A study by Barison and Santos (2010b) highlight three basic skill levels for BIM education learning and teaching purpose which are introductory, intermediary and advanced as summarized in Figure 2.7.

2.13.1 Introductory Level

The main objectives at this level are to learn basic BIM tools that are most commonly used and to build a foundation of BIM concepts. It further aims to investigate basic concepts of modeling and to comprehend different manners to easily communicate different types of information. When learning this type of course, it is not essential to know CAD or have sophisticated computer skills. The main purpose is to develop the skills of a BIM Modeler (Barison and Santos, 2010b).

2.13.2 Intermediary Level

In this level it is prerequisite, that student must know about some design fundamentals concept, and must have some preliminary BIM concepts, and have some experience of BIM tools and application. The objective at this level is to further learn about BIM tools and advanced modeling techniques which can help in building structure systems and to determine more features in BIM tools .The objective of this level is to strengthen skills of a BIM Modeler (Barison and Santos, 2010b).

2.13.3 Advanced Level

The aim of this level is to develop some skills of a BIM Manager. As a prerequisite, students should have knowledge of BIM professional practice, construction methods and construction materials. Moreover, students should have experience in use of some major BIM tools (Barison and Santos, 2010b).

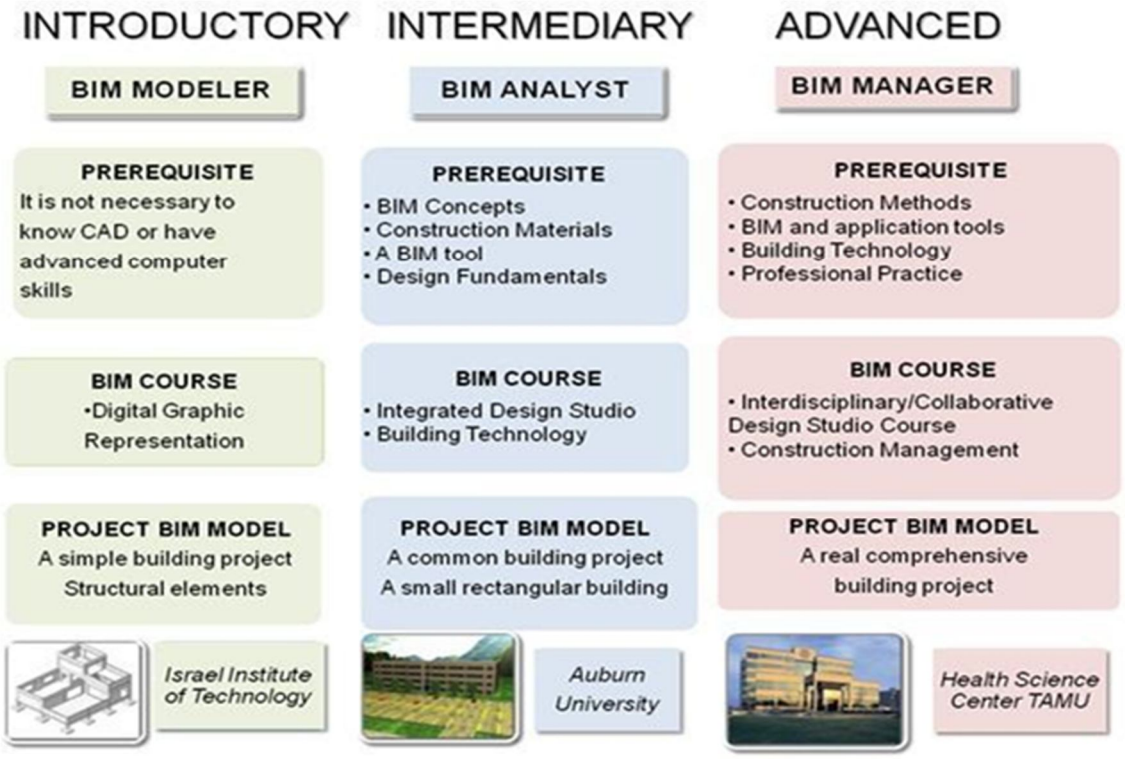

Figure 2.7: Levels of BIM proficiency (Barison and Santos, 2010b)

2.14 Summary

In this chapter BIM definition, its benefits with the applications and tools, awareness in local and international construction industry environment, strategies of integrating BIM in construction education, and its barrier faced during the integration in academia were given in details. List of some universities who offer BIM in their CEM programs is also presented in this chapter.

In the next chapter methodology of the entire thesis work will present that was made to achieve the thesis objectives smoothly and easily.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter defines the methodology adopted for this thesis. In order to achieve the objectives the work was split into six parts. At first a preliminary study to the topic was conducted, after then a detailed literature review was carried out. The aims of the literature review was to develop a basic understanding regarding the subject of the thesis work i.e. BIM definition, its applications, benefits and barriers faced during the integration in construction industry and engineering universities. It is accomplished through study of different articles, journal papers, websites, conference papers and BIM curriculum of different US universities.

Based on literature review two preliminary questionnaires were developed. One questionnaire deals with the construction industry and its purpose is to capture the expectations of Pakistani construction from CE&M students within the area of BIM. Second questionnaire deals with Pakistani engineering universities and its purpose is to study the current state of CE&M curriculum with regard to BIM and identify the barriers to integrating BIM into CE&M curriculum. After the completion of preliminary questionnaire, pilot survey was conducted. It was conducted to improve the questionnaire's effectiveness in view of the experience professional persons. Only those respondents were selected who have sound

theoretical and practical knowledge related to BIM. These improvements lead in the development of the final questionnaire. The methodology adopted for this research is shown below in Figure 3.1:

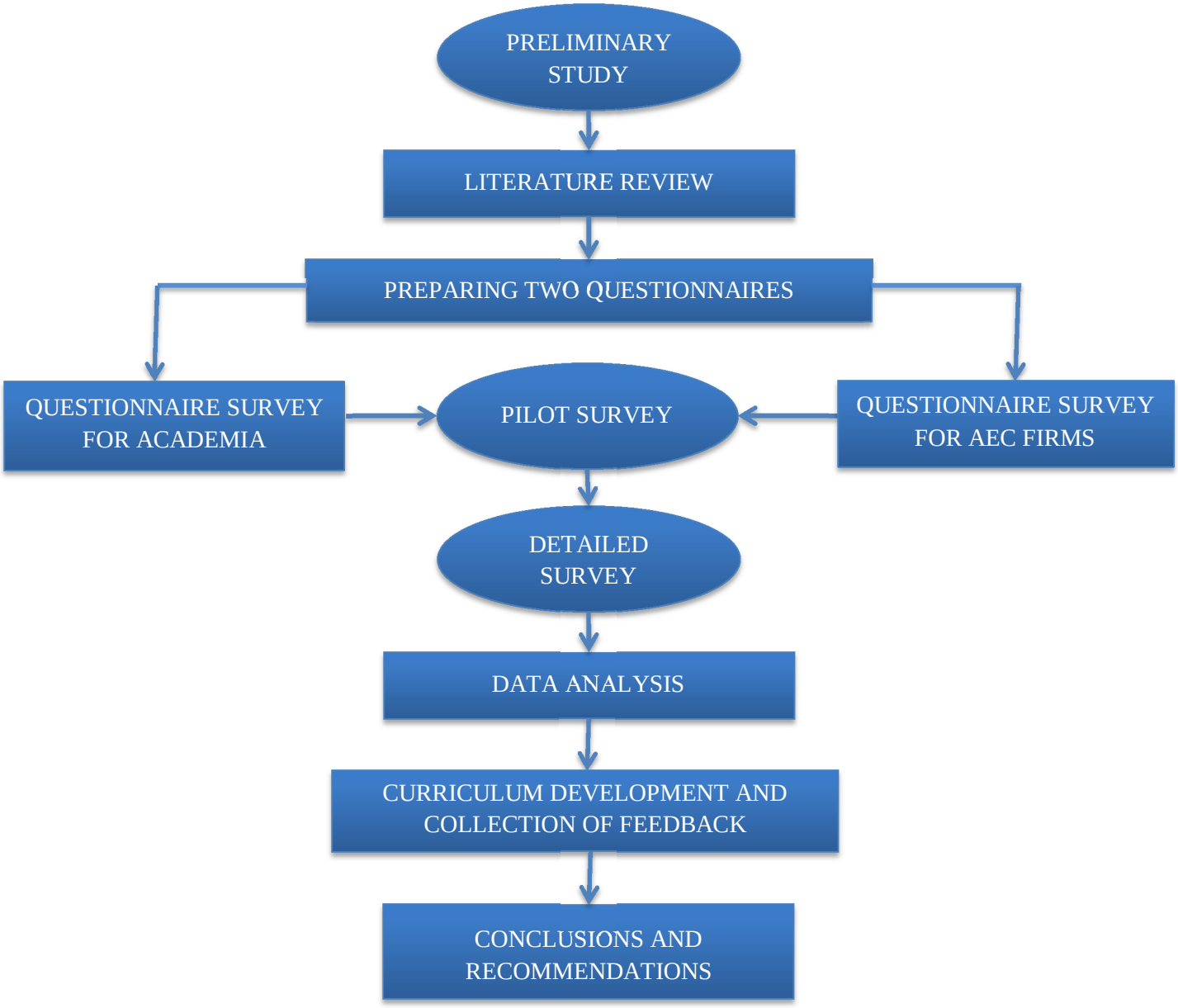

Figure 3.1: Research methodology

The final academia questionnaire was prepared to study the current state of CE&M curriculum and to identify the barriers in integration of BIM into CE&M. The survey has been carried out from the architectural, architectural engineering, civil engineering and CE&M faculty members of Pakistani engineering universities. Total 62 responses were collected from different 29 AEC related universities across the country. The questionnaire form consists of following subsection.1.Personal Information 2.University Information 3.Evaluation of current state of BIM in the CE&M curriculum 4.Barriers to integrating BIM in CE&M curriculum.

Similarly, the construction industry questionnaire was prepared to study the current exposure of Pakistani construction industry in regards with BIM and to capture the expectations of construction industry from CE&M students within the area of BIM. It further aims was to identify the barriers to integrating BIM in AEC industry. This questionnaire form consists of following subsection.1.Personal information 2.firm/industry information 3.firm industry exposure to BIM 4.industry requirements from CM students within the area of BIM 5. Barriers to integrating BIM in AEC industry.

For collecting the data related to engineering universities and construction industries some questionnaires were sent by e-mails and some of them delivered by hand to obtain the information. After the collection of data it was analysis through different analysis technique with the help of MS excel and SPSS. Based on the analysis data and based on study different US universities CE&M programs BIM

curriculums was develop. It was more refine by taking the US academic BIM experts. In the last phase conclusions and recommendation were drawn.

3.2 RESEARCH INSTRUMENT DESIGN

In order to get the good responses from the respondents following points were considered during the development of questionnaires:

1 Kept questionnaire short & concise because mostly, professionals are busy in their professional's works.

2 Collected the appropriate information, i.e. only which sufficient for achieving the thesis objective's.

3 Kept in a simple language so that one can easily understand it.

4 Provided short introduction in start of questionnaire regarding questionnaire.

5 Make the online questionnaire for time saving the respondent and to get easily responses.

6 Used simple rating scales or lists of choices for answers so that it takes less time of responding person.

7 Put the questions of questionnaire in logical order so that one question logically followed the previous one in a relevant section.

8 Conduct a pilot survey so that it highlights the strong and weak areas of the questionnaire.

3.2.1 Survey Scale

A five-point Likert scale was used in the both questionnaires, with 1 being strongly disagree to 5 being strongly agree. It was developed to judge the current requirements of construction industry from CE&M students within the area of BIM and to study the current status of university programs within the area of BIM. The main purpose for using Likert scale in the survey forms was to examine the extent to which respondents were agree or disagree with individual research variable (Cormack, 2000).

There were also several multiple choice research variables in both academia and construction industry questionnaires which were analyzed by frequency analysis technique.

3.2.2 Sampling Criteria

A random sample technique was used for this research study. The sample was selected from the participants of Pakistani construction industry and academia. Responses were collected from Engineers, Architects, Designers, Planners, Consultants, Contractors, Sub-contractors, Developers, Project management firms, Facility Owners, Academia and from other construction industry related members.

3.3 DATA ANALYSIS TECHNIQUES

With the help of SPSS and MS Excel data were analyzed. This research study follows the level of significance of 95%. Following techniques were utilized for statistical analysis purpose.

3.3.1 Reliability of Survey

The reliability of a study determines that the research mechanism accomplishes its intended function. It may be define as:

"The consistency of a calculation and to the probability of obtaining alike results if the measure is to be duplicated"(Oppenheim, 1992)

To establish the reliability, an extensive literature review and pilot survey is conducted. It enhanced the reliability of questionnaires. The data is analyzed using MS excel and SPSS-18 with the use of frequency analysis, normality test, and hypothesis test for non-parametric data. This all test highlight the significant difference between the opinions of respondent with regard to question.

3.3.2 Normality Test

This was performed to evaluate the normality of collected data. It was conducted to understand whether the data was normally distributed or not or and to examine whether the collected data was parametric or non-parametric. Shapiro-Wilk test is normality suitable for the collected data of about two thousands (2000)

elements or less. According to this test significance value should be non-significant to be considered as sufficiently normal and this means it should be larger than 0.05.

3.3.3 Hypothesis Testing

In Hypothesis Testing, data were analyzed by t-distribution test. In this testing, average was determined for each sample and analyzed by t- test. With the help of hypothesis testing decided from sample data whether to recognize or reject an assumption about the value of a population factor.

3.4 SUMMARY

In this chapter, methodology of thesis has been discussed in a detail, which is adopted for achieving the objectives of this thesis report. Methodology of this research study was divided into six phases. Initially literature was collected through different sources to develop a basic understanding of BIM applications in construction and academia then questionnaires were developed for pilot survey with the help of literature review. After this a pilot surveys were conducted to strengthen the initial questionnaires, and then questionnaires were upgraded with respect to the result of pilot survey. After this, final surveys were performed and data was obtained from Pakistani construction industry and academia.

After the data analysis, make a draft BIM curriculum on the basis of Pakistani construction requirements, responses from faculty members of Pakistani AEC universities and with the help of study BIM programs and initiative of US

universities. Expert opinion has taken into account from US BIM expert. At the end, conclusions & recommendations were present with help of data obtained from the result of analysis of questionnaires and from the professional BIM expert feedback.

CHAPTER 4

DATA ANALYSIS AND RESULTS

4.1 INTRODUCTION

In this chapter, the information received from academia and construction industry was analyzed. To analyze the data correctly and accurately, statistical analysis was applied on data, and for this MS-EXCEL and SPSS software was used. Different tests such as validity, reliability, frequency and hypothetical analyses were carried out on data through statistical analysis.

4.2 ANALYSIS OF ACADEMIA QUESTIONNAIRE

The respondents of this survey were faculty members of architecture, construction management and civil engineering of Pakistani engineering universities. The analysis relating academic questionnaire has been presented in following sequence:

a. Respondents' information
b. University information
c. Statistical analysis of collected data

4.3 RESPONDENTS' INFORMATION

Respondents' information was first part of the questionnaire. The purpose of this part was to make sure that respondents' sample size is relevant to survey with sufficient qualification, professional teaching experience and designation.

4.3.1 Respondents' Sample Size and Response Rate

Forty (40) universities were targeted who offer architecture, architectural engineering, construction management and civil engineering program in their undergraduate, graduate and PhD programs. From these universities, 29 universities responded to questionnaire and with a total of 62 responses collected. The overall response rate was 72.7% as 29 universities responded out of 40 universities.

4.3.2 Respondents' Qualifications

From majority of respondents 61.3% held master degree. The details with frequencies and percentages are shown in Table 4.1 and Figure 4.1.

Table 4.1: Respondents' qualification

Respondent's Qualification	Frequency	Percent	Cumulative Percent
Bachelor Degree	7	11.3	11.3
Master Degree (MS/M Phil)	38	61.3	72.6
Doctorate (PhD)	17	27.4	100
Total	62	100.0	

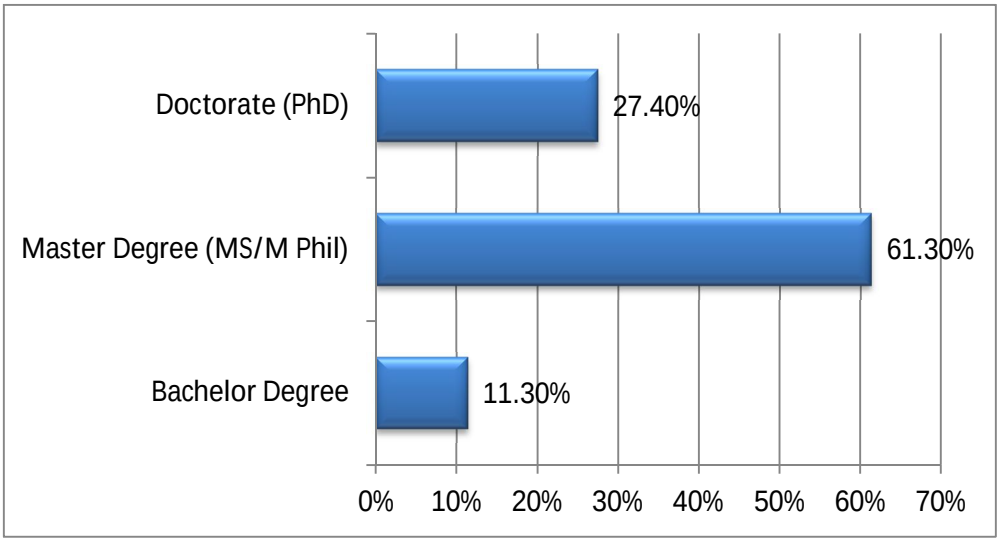

Figure 4.1: Respondents' qualification

4.3.3 Respondents' Teaching Experience

The respondents of the survey possessed varied professional teaching experience but majority of respondents (45.2%) had more than 5 years professional teaching experience. Details relating this are shown in Table 4.2 and Figure 4.2.

Table 4.2: Respondents' teaching experience

Respondents' experience (in years)	**Frequency**	**Percent**	**Cumulative Percent**
Less than 1 years	11	17.7%	17.7
1-3 years	14	22.6%	40.3
3-5 years	9	14.5%	54.8
More than 5 years	28	45.2%	100
Total	62	100.0	

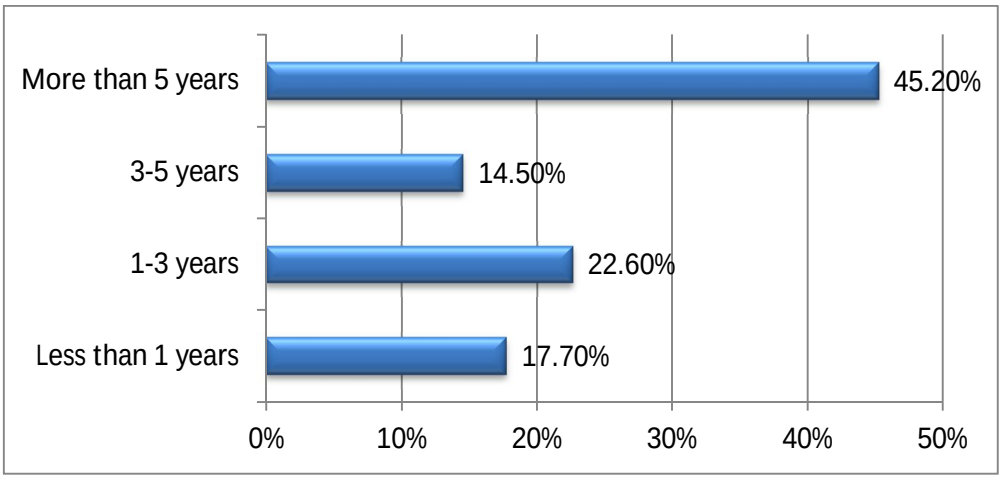

Figure 4.2: Respondents' Professional Experience

4.3.4 Respondents' Designation

Majority of respondents' were lectures (35.48%) and assistant professors (25.8%). The details with frequencies are shown in Table 4.3 and Figure 4.3.

Table 4.3: Respondents' designation in university

Respondents' designation	**Frequency**	**Percent**	**Cumulative Percent**
Adjunct / Visiting Faculty	5	8.06%	8.06%
Lecturer	22	35.48%	43.54%
Assistant Professor	16	25.8%	69.34%
Associate Professor	9	14.51%	83.85%
Professor	10	16.15%	100%
Total	62	100.0%	

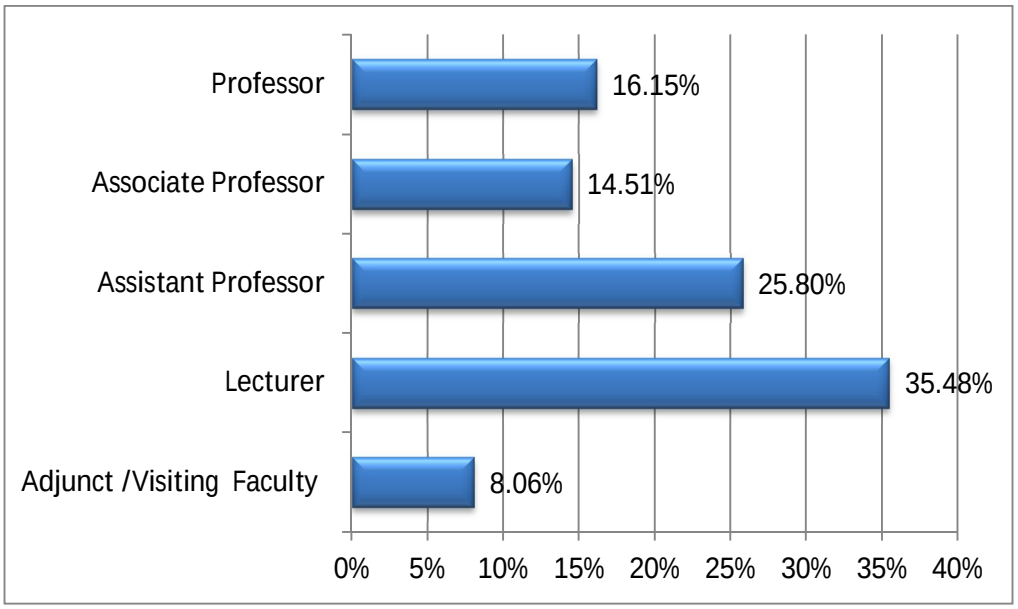

Figure 4.3: Respondents' designation in university

4.3.5 BIM User Experience (Professional / Non-professional)

Very few (9.7 %) of respondents had more than 5 years hands on experience of using BIM. Majority of respondents (59.7%) had no experience of using BIM applications. However the group reported to have at least little knowledge of BIM. The details are shown in Table 4.4 and Figure 4.4.

Table 4.4: BIM user experience (Professional/Non-professional)

Respondents' experience (in years)	**Frequency**	**Percent**	**Cumulative Percent**
No Experience	37	59.7	59.7%
Less than 2 years	10	16.1	75.8%
2-5 years	9	14.5	90.3%
More than 5 years	6	9.7	100%
Total	62	100.0	

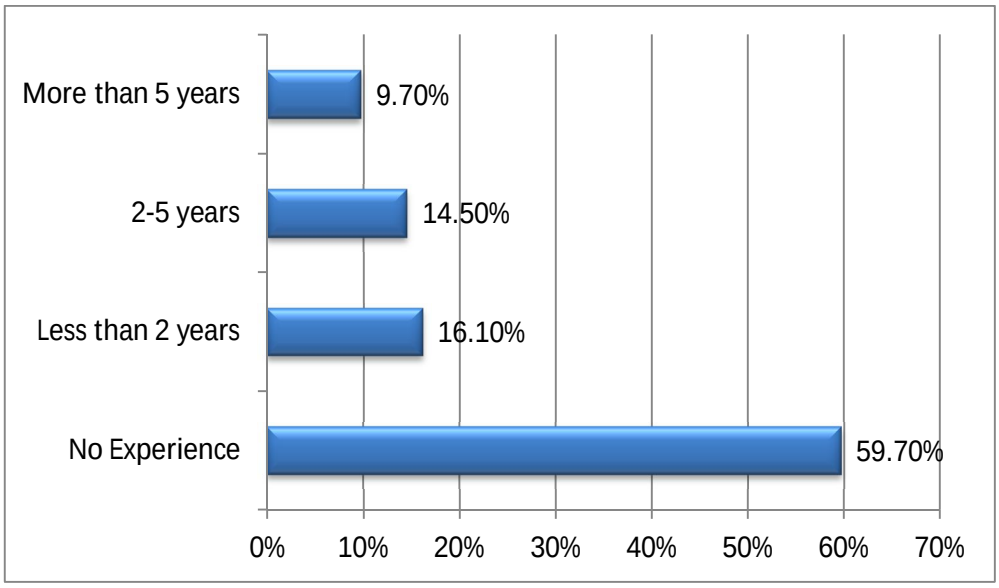

Figure 4.4: Respondents' experience with BIM

4.3.6 Respondents' Level of Knowledge Relating BIM

The respondents of this survey had varied knowledge of BIM but majority of respondents (37.1%) had general knowledge relating it. Further details regarding this are shown in Table 4.5 and Figure 4.5.

Table 4.5: Respondents' level of knowledge relating BIM

Respondents' level of knowledge relating BIM	**Frequency**	**Percent**	**Cumulative Percent**
Little	20	32.2%	32.3%
General	23	37.1%	69.3%
Working	14	22.6%	91.9%
Expert	5	8.1%	100%
Total	62	100.0	

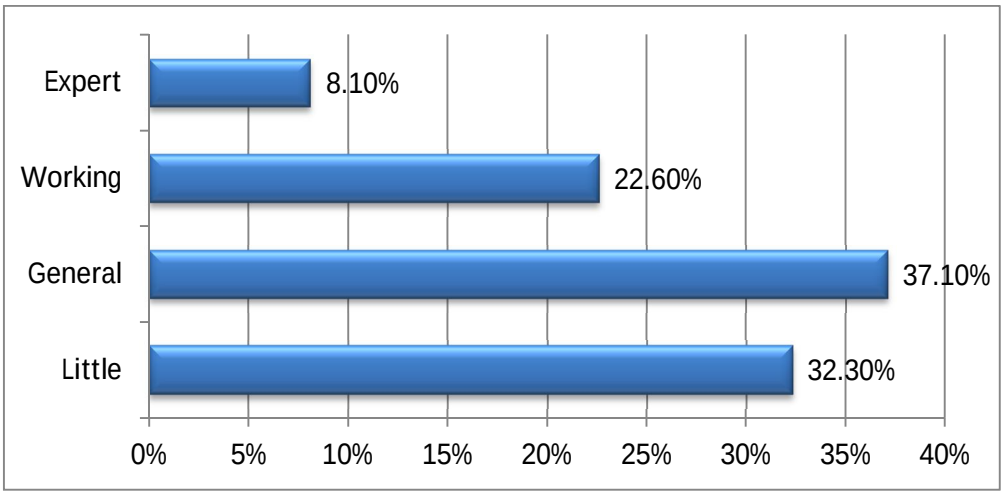

Figure 4.5: Respondents' level of knowledge relating BIM

4.4 RESPONDENTS' UNIVERSITY INFORMATION

4.4.1 Geographical Location of Universities

The geographic locations of engineering universities from where data was collected are shown in Table 4.6 and Figure 4.6.

Table 4.6: Geographical location of universities

Geographical Location	Responses		Percent of Respondents
	N	Percent	
Federal Capital	12	19.35%	19.35%
Punjab	19	30.64%	50.0%
Sindh	15	24.2%	74.3%
Khyber Pakhtunkhwa	11	17.7%	92.0%
Balochistan	3	4.8%	96.8%
Azad Kashmir	2	3.2%	100%
Total	62	100.0%	

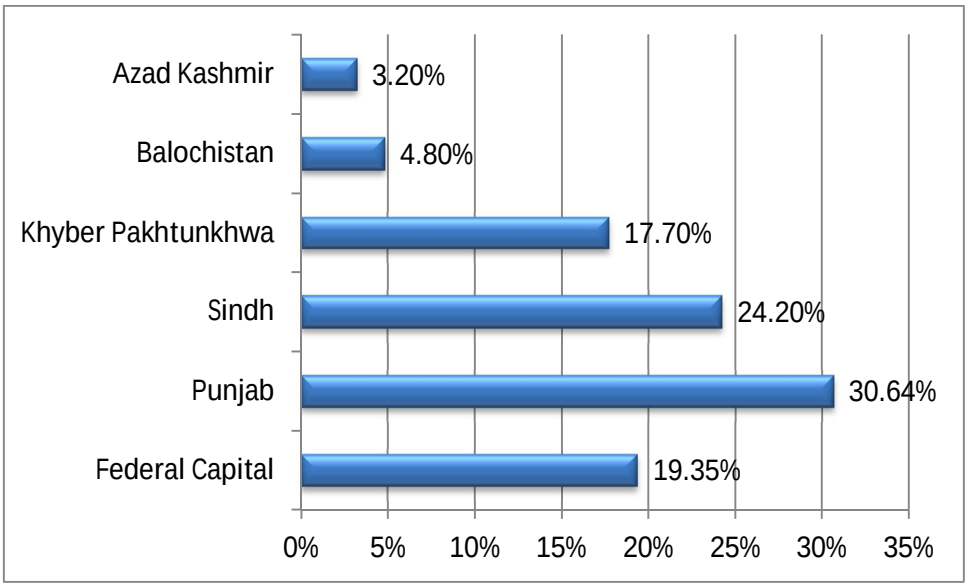

Figure 4.6: Geographical location of universities

4.4.2 University Response

The data was gathered from Pakistani universities which offer architecture, architectural engineering, civil engineering and construction engineering and management programs in their undergraduate, graduate and PhD level. The names of participant universities are shown in Table 4.7 along with frequencies.

Table 4.7: Names of respondents' universities

Name of Universities	No. of Responses	Name of Universities	No. of Responses
NUST (Islamabad)	4	Swedish College of Engineering & Technology (Wah Cantt)	3
NUST (Risalpur)	1	NFC Institute of Engineering and Technology (Multan)	1
NED University of Engineering and Technology (Karachi)	5	Pakistan Institute of Engineering and Technology (Multan)	1
COMSATS (Islamabad)	5	Hazara University (Mansehra)	1
University of South Asia (Lahore)	1	Gandhara Institute of Science and Technology(Peshawar)	1
UET (Lahore)	4	Sarhad University (Peshawar)	1
Sir Syed University of Engineering and Technology (Karachi)	3	University of Engineering & Technology (Bannu)	1
The University of Lahore(Lahore)	4	University of Gujrat (Gujrat)	1
QUEST (Nawabshah)	1	National University of Computer and Emerging Sciences(Lahore)	1
Mehran University of Engineering and Technology, Jamshoro	2	COMSATS (Lahore)	2
Mirpur University of Science and Technology (Azad Kashmir)	2	COMSATS (Wah Cantt)	4
Abasyn University (Islamabad)	1	Indus University (Karachi)	1
Mohammad Ali Jinnah University (Islamabad)	1	Indus Valley School of Art & Architecture (Karachi)	2
International Islamic University (Islamabad)	1	BUITEMS, Quetta	2
Balochistan UET (Khuzdar)	1	University of Engineering & Technology (Peshawar)	4

4.5 STATISTICAL ANALYSIS

Different tests such as validity, reliability, frequency and hypothetical analyses were carried out on data through statistical analysis techniques.

4.5.1 Reliability Testing of Sample

As Cronbach's coefficient alpha method is the most popular method to find internal consistency (reliability) of data and in the survey form, some questions were also on Likert scale so this method was used to check the reliability. According to this method if Cronbach's coefficient alpha value is higher than 0.7, this indicates that data is reliable for analysis. By using SPSS, its value is calculated as 0.774 of the overall questionnaire as given in Table 4.9. According to Gliem and Gliem (2003) study normal range of Cronbach's coefficient alpha value is between 0 and 1, and the higher values reflect a higher degree of internal consistency. Its higher value, as shown in Table 4.8, indicate that the data is consistent and reliable for analysis.

Table 4.8: Reliability statistics

Sr. No.	Case Processing Summary	No. of Responses		Percentage of Responses	No. of Variables	Cronbach's Alpha
1.	Over all Questionnaire	Valid	62	100	8	.774
		Excluded[a]	0	0		
		Total	62	100.0		

4.5.2 Normality Test

Shapiro Wilk normality test was conducted to check normality of the collected data as sample size is less than 2000. It is performed to identify whether the data is normally distributed or not, i.e. the data is parametric or non-parametric in nature. Significance values found are 0.000 which are less than 0.05. Significance value should be larger than 0.05 for the data to be sufficiently normal. As shown in Table 4.9, the data is not normally distributed and non-parametric tests are required for further analysis. Table 4.11 shows the data regarding normality test by Shapiro Wilk test.

Table 4.9: Normality test for BIM and university curriculum

Sr. No	Research Variables	Shapiro-Wilk Test		
		Statistic	df	Sig.
1.	Level of satisfaction with current status of BIM education within AEC curriculum in respondents university	0.915	62	0.000
2.	Level of satisfaction with current status of BIM education within their AEC curriculum in other universities of Pakistan	0.848	62	0.000
3.	Level of belief that a class or course on BIM in a university curriculum can be beneficial to CE&M students	0.807	62	0.000
4.	BIM education offered in Pakistani engineering universities in CE&M programs can prepare students for jobs in local construction industry	0.881	62	0.000
5.	BIM education offered in Pakistani Engineering universities in CE&M programs can prepare students for jobs in international construction industry	0.875	62	0.000
6.	Use of BIM in the Pakistani construction industry will increase in coming five years	0.878	62	0.000
7.	Demand of students equipped with BIM knowledge in AEC industry of Pakistan will increase in coming years	0.865	62	0.000
8.	Demand of students with BIM knowledge in international AEC industry will continue to increase in coming years	0.853	62	0.000

4.5.3 Frequency Analysis of Collected Data

4.5.3.1. BIM and university curriculum: Frequency analysis

To study the current state of BIM in Pakistani universities several question were asked in the questionnaire. As the Table 4.10 shows, 41.37% universities teach or discuss BIM in university education, at undergraduate, graduate and Ph.D. level in AEC programs. The details with frequency are shown in Table 4.10.

Table 4.10: BIM and university curriculum

Sr. No	BIM and University curriculum	Response	Frequency	Percent	Cumulative Percent
1.	Teach or discuss BIM in AEC programs	Yes	28	41.37.%	41.37%
		No	34	58.62%	100%
2.	Faculty member(s) researching on BIM	Yes	24	38.7%	38.7%
		No	38	61.3%	100%

In these universities, majority of the respondents (89.25%) were taught BIM concept at undergraduate level. Further details with frequency are shown in Table 4.11 and Figure 4.7.

Table 4.11: Respondents' universities teach or discuss BIM in AEC programs

Respondents' university teach or discuss BIM in AEC programs	Frequency	Percent
Undergraduate level	25	89.25%
Graduate level	11	39.28%
PhD level	2	7.14%

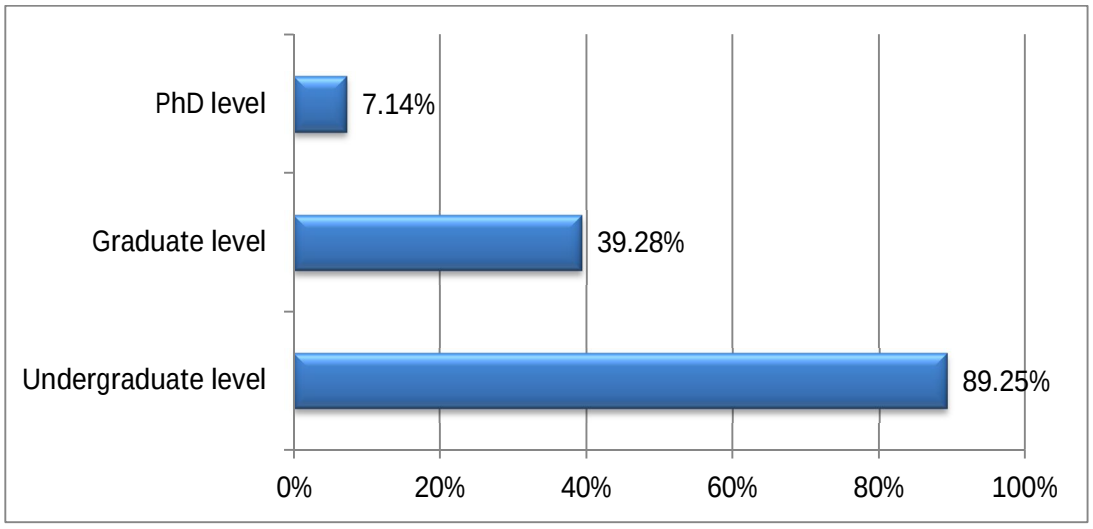

Figure 4.7: Respondents' universities teach or discuss BIM in AEC program

4.5.3.2. BIM becoming part of respondents' university: Frequency analysis

Table 4.12 and Figure 4.8 show the respondents' university AEC program information in regards of duration for which BIM has become part of AEC programs in respondents' university.

Table 4.12: BIM becoming part of respondents' university

BIM become part of respondents' university	Frequency	Percent
Earlier than 2008	5	18.85%
2008-2012	7	25%
2013-14	8	28.57%

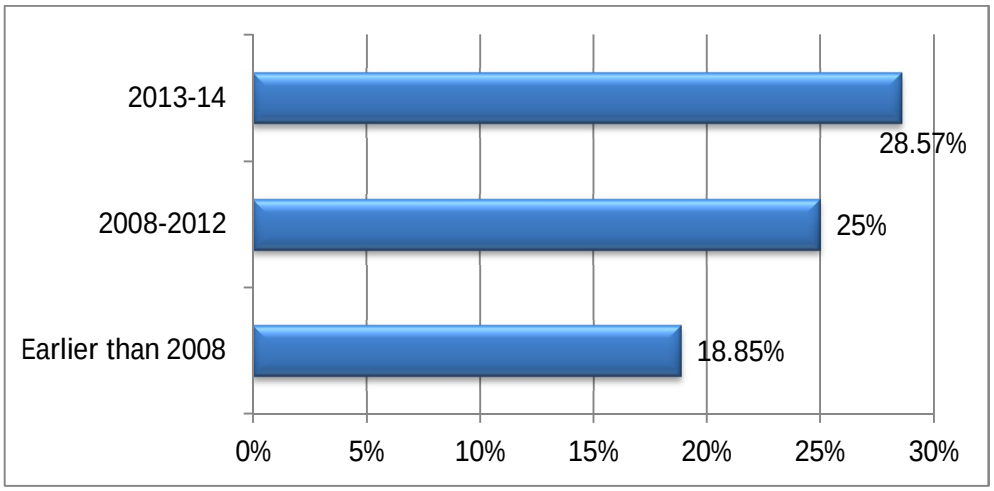

Figure 4.8: BIM become part of respondents' university

4.5.3.3. BIM courses included in respondents' university: Frequency analysis

Table 4.13 and Figure 4.9 show respondents' university AEC program information in regards of BIM related courses included in AEC programs. Out of the AEC universities which taught BIM to students, 60.71% included 1-2 BIM courses for this purpose.

Table 4.13: BIM courses included in respondents' university

BIM courses included in respondent's university	Frequency	Percent
1-2 courses	17	60.71%
3-5 courses	2	7.14%
Not included yet	11	39.28%

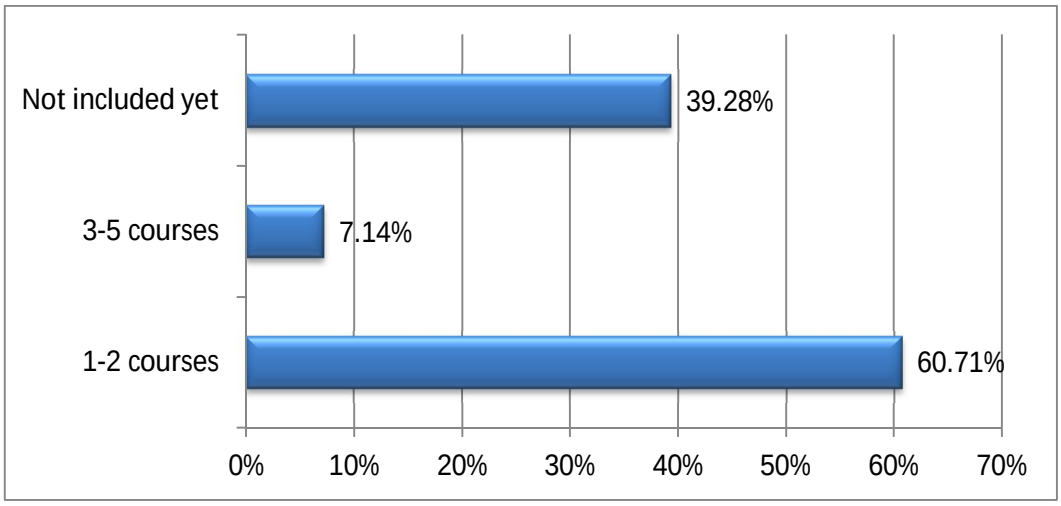

Figure 4.9: BIM courses included in respondents' university

4.5.3.4. BIM applications used in respondents' university: Frequency analysis

Table 4.14 and Figure 4.10 show BIM applications which are being used in respondents' universities. From universities which had started using BIM applications in their construction programs, 92.85% use Autodesk Revit (Arch, Structure), while 32.14% use other BIM applications i.e. Autodesk QTO, Rhino, and Autodesk Civil 3D in their AEC programs.

Table 4.14: BIM applications used in respondents' university

BIM applications used in respondents' university	Frequency	Percent
Autodesk Revit Arch, Structure, MEP	26	92.85%
Autodesk Navisworks	4	14.28%
Graphisoft ArchiCAD	1	3.57%
TEKLA Structures	3	10.71%
Other	9	32.14%

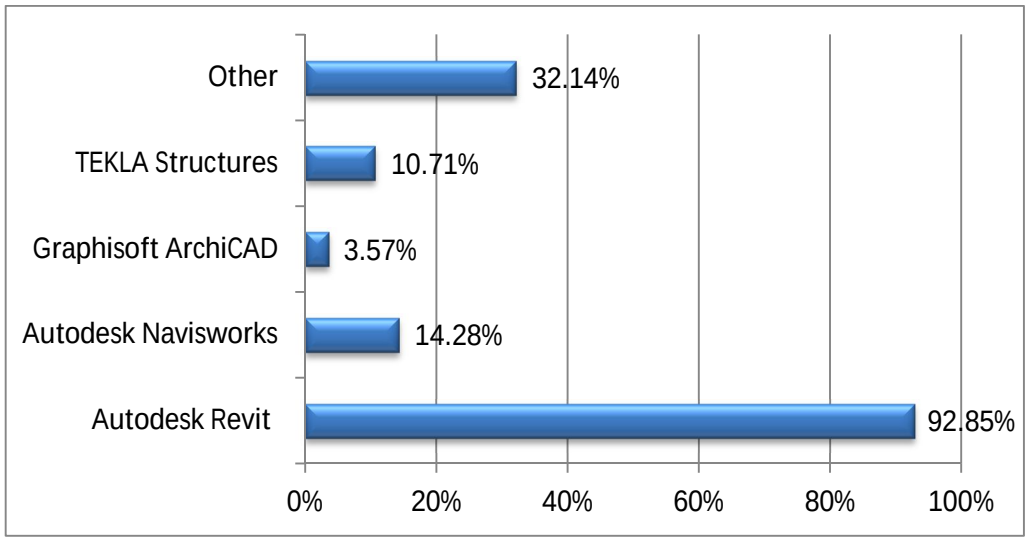

Figure 4.10: BIM applications used in respondents' university

4.5.3.5. BIM course concentration topics: Frequency analysis

Those universities which had started to use BIM applications in their construction programs, out of these, majority of 78.3% were used introduction topics related to BIM in their construction programs. The details with frequency and percentage are shown in Table 4.15 and Figure 4.11.

Table 4.15: BIM course topics in respondents' university

BIM course topics in respondents' university	Frequency	Percent
Introduction to BIM	22	78.3%
Project visualization	21	75%
Constructability reviews	12	42.85%
Model based estimating and cost controls	5	17.85%
Construction sequencing/4D Scheduling	7	25%
Cost estimation and control	9	32.14%
Conflict and collision detection	8	28.57%
Facilities management	7	25%

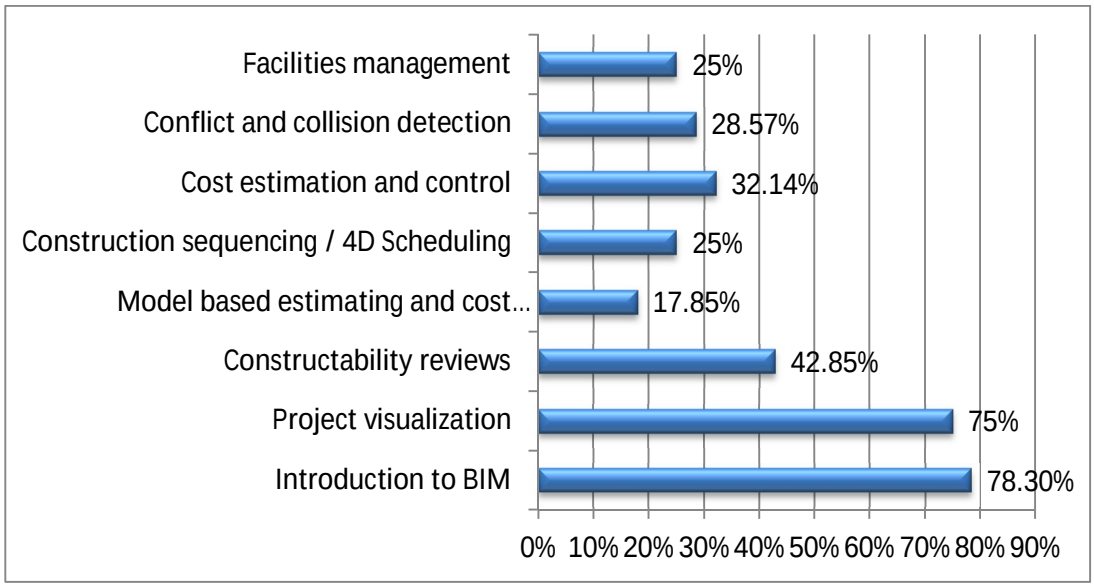

Figure 4.11: BIM course topics in respondents' university

4.5.3.6. BIM skills essential for CE&M students: Frequency analysis

According to responses of AEC faculty members following BIM skills as shown in Table 4.16 and Figure 4.12 are essential for CE&M students and should be developed in CE&M students before they enter into construction industry.

Table 4.16: BIM Skills essential for CE&M students

BIM skills essential for CE&M students	**Frequency**	**Percent**
Drawing reading	21	75%
Cost estimation from drawing	15	53.57%
Software configuration	14	50%
System understanding	20	71.42%
Modeling and analysis of model	23	82.14%
Other	2	7.14%

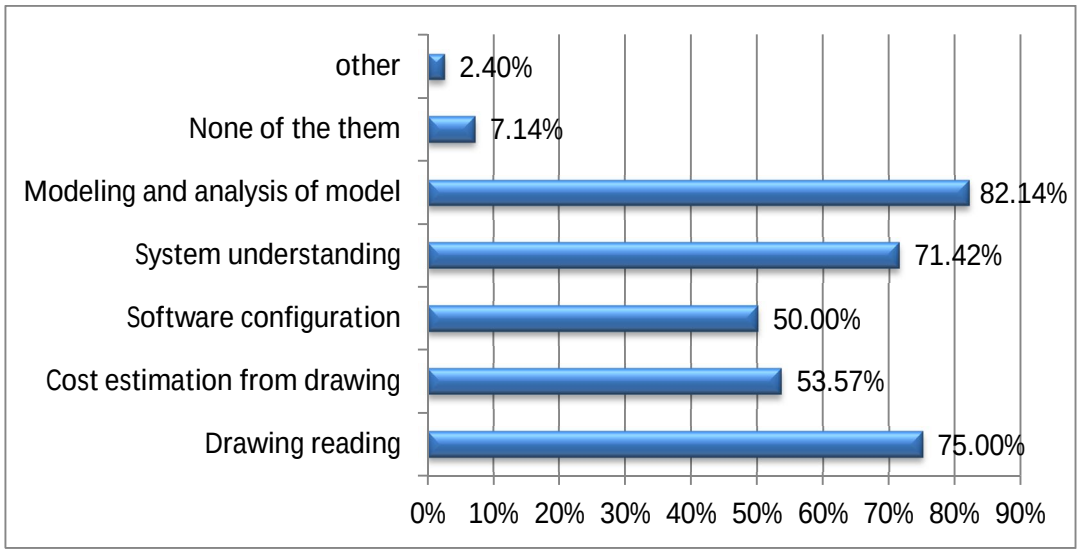

Figure 4.12: BIM skills essential for CE&M students

4.5.3.7. Respondents' confidence level about BIM knowledge and skills: Frequency analysis

Table 4.17 and Figure 4.13 indicates that majority of the respondents' had intermediate level about own knowledge and skills about BIM. The details are shown in Table 4.17 and Figure 4.13.

Table 4.17 Respondents' confidence level about BIM knowledge and skills

Respondents' confidence level about BIM knowledge and skills	**Frequency**	**Percent**
Confident	18	29%
In between	24	38.7%
Not confident	20	32.3%
Total	62	100

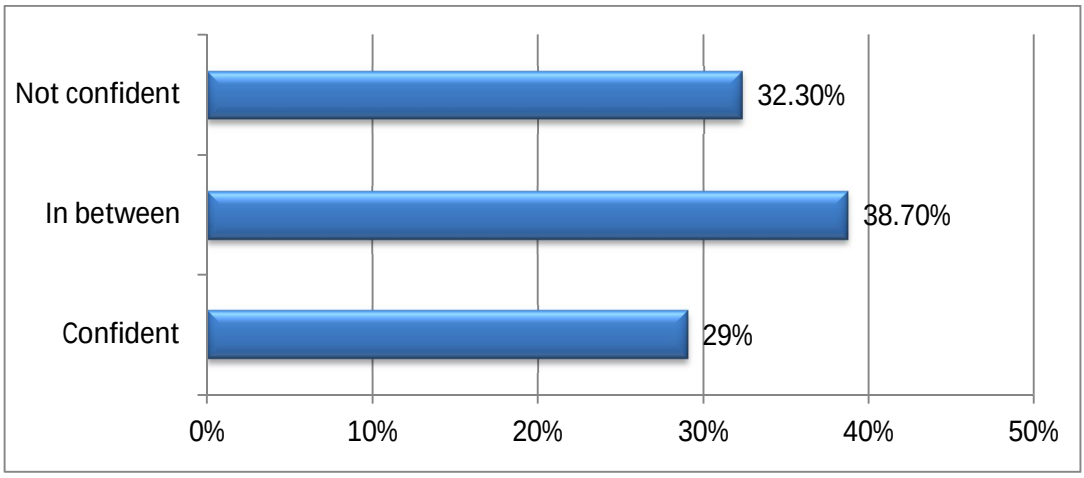

Figure 4.13: Respondents' confidence level about BIM knowledge and skills

4.5.3.8. Time required for BIM adoption in AEC programs: Frequency analysis

The percentage of time that might take AEC universities for integration of BIM applications are shown in Table 4.18 and Figure 4.14. Most of the universities 69.3% might take 3-5 years of time for complete BIM adoption in their AEC programs.

Table 4.18: Time required for BIM adoption in AEC programs

Time required for BIM adoption in AEC programs	Frequency	Percent
Currently use BIM	8	12.9%
In one year's time	9	14.5%
In three years' time	16	25.8%
In five years' time	27	43.5%
Don't want to see	2	3.2%
Total	62	100

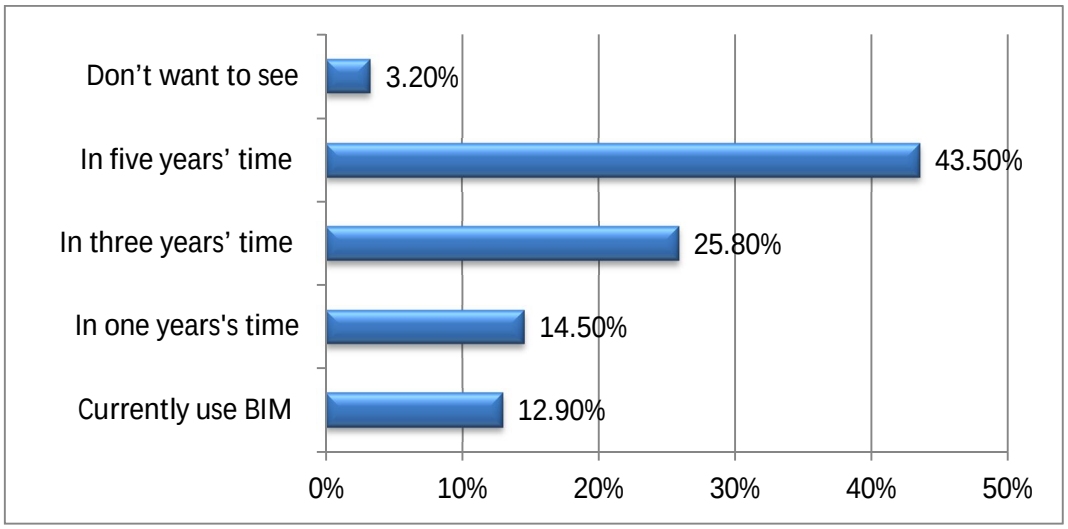

Figure 4.14: Time required for BIM integration in AEC programs

4.5.3.9. Strategies required for integration of BIM: Frequency analysis

Different strategies were highlighted by the respondents' for integration of BIM in AEC programs among these 69.35% suggested arranging BIM workshops/presentation and 62.9% suggested teaching standalone BIM as the best strategies for integration of BIM in Pakistani engineering universities. The details are shown in Table 4.19 and Figure 4.15.

Table 4.19: Strategies required for integration of BIM

Strategies required for integration of BIM	**Frequency**	**Percent**
Teach standalone separate BIM course	39	62.90%
Integrate BIM contents into traditional courses	37	59.67%
Arrange BIM workshops/presentations	43	69.35%
Restructure existing CE&M curriculum to include BIM	29	46.77%
Expect from CE&M students to learn BIM skills by themself	8	12.9%

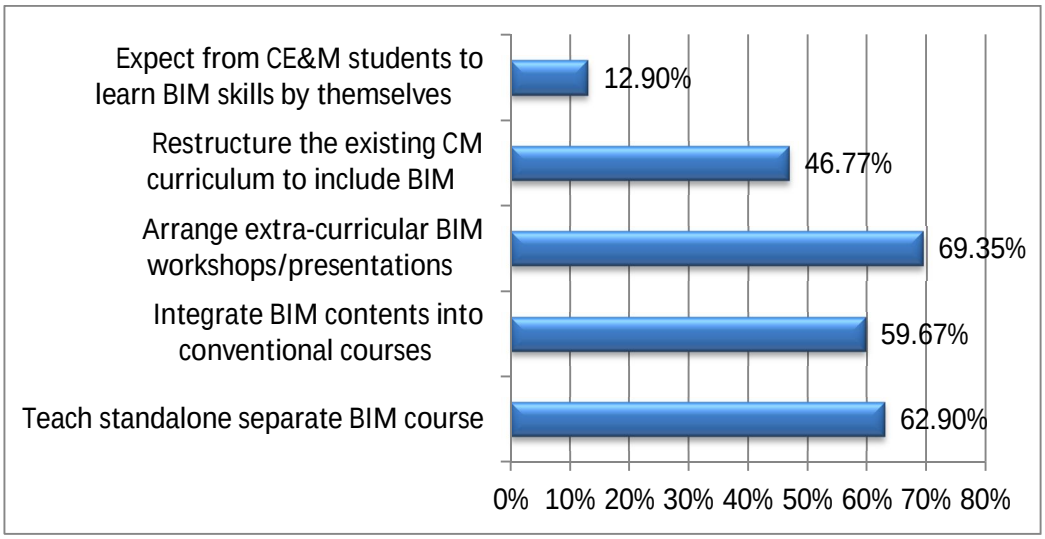

Figure 4.15 : Strategies required for integration of BIM

4.5.3.10. BIM contents essential for CE&M students: Frequency analysis

Table 4.20 and Figure 4.16 indicates the AEC faulty members responses related to the BIM contents which should be taught to CE&M students before they enter into construction industry.

Table 4.20: BIM contents essential for CE&M students

BIM contents essential for CM students	Frequency	Percent
BIM theory and literature	48	77.41%
Applications of BIM software for model creation and detailing	47	75.80%
Applications of BIM software for model analysis	43	69.35%
BIM for integrated project delivery system	26	41.93%
BIM for lean construction	32	51.61%
Other	1	1.61%
Don’t know	8	12.90%

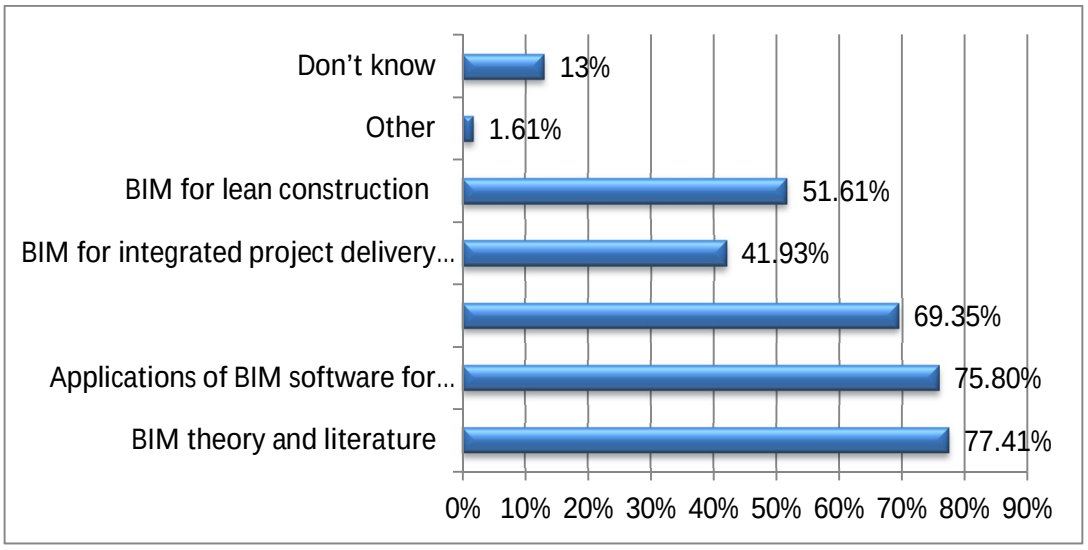

Figure 4.16: BIM contents essential for CE&M students

4.5.3.11. BIM and university curriculum: Frequency analysis

A detailed frequency analysis regarding the BIM significance in the CE&M curriculum is shown in Table 4.21.

Table 4.21: BIM and University curriculum

Sr. No	Research Variables	Responses	Frequency	Percent	Cumulative Percent
1.	Level of satisfaction with current status of BIM education within the AEC curriculum in respondents' university	Very Low	17	27.4	27.4
		Low	23	37.1	64.5
		Medium	15	24.2	88.7
		High	6	9.7	98.4
		V .High	1	1.6	100
2.	Level of satisfaction with the current status of BIM education within their AEC curriculum in other universities in Pakistan	Very Low	11	17.7	17.7
		Low	29	46.8	64.5
		Medium	11	17.7	82.3
		High	0	0	82.3
		V .High	0	0	82.3
		Don't Know	11	17.7	100

3.	Level of belief that a class or course on BIM in a university curriculum can be beneficial to CE&M students	Very Low	1	1.6	1.6
		Low	3	4.8	6.4
		Medium	8	12.9	19.3
		High	34	54.8	74.2
		V .High	16	25.8	100
4.	BIM education offered in the Pakistani engineering universities in CE&M programs prepares the students for jobs in the local construction industry	Very Low	7	11.3	11.3
		Low	13	21	32.3
		Medium	29	46.8	79.1
		High	10	16.1	95.2
		V .High	3	4.8	100
5.	BIM education offered in the Pakistani Engineering universities in CE&M program prepares the students for jobs in the international construction industry	Very Low	10	16.1	16.1
		Low	8	12.9	29
		Medium	11	17.7	46.7
		High	21	33.9	80.6
		V .High	12	19.4	100
6.	The use of BIM in the Pakistani construction industry will continue to increase in coming five years	Very Low	2	3.2	3.2
		Low	6	12.9	16.1
		Medium	18	29	45.1
		High	28	45.2	90.3
		V .High	6	9.7	100
7.	Demand of students with BIM knowledge in the AEC industry of Pakistan will increase in coming years	Very Low	1	1.6	1.6
		Low	6	9.7	11.3
		Medium	21	33.9	45.2
		High	29	46.8	92
		V .High	5	8	100
8.	Demand of students with BIM knowledge in the international AEC industry will continue to increase in coming years	Very Low	1	1.6	1.6
		Low	4	6.5	8.1
		Medium	12	19.4	27.5
		High	27	43.5	71
		V .High	18	29	100
		Don’t Know	0	0	100

4.5.3.12. Barriers to Integrating BIM in CE&M Curriculum: Frequency Analysis

There were number of barriers that affect the successful integration of BIM in CE&M programs in Pakistani engineering universities. Most of the respondent 95.16% considers lack of professionally trained BIM faculty and 58.06% consider traditional CE&M structures are the two main barriers in integrating BIM in Pakistani engineering universities. The detailed are shown in Table 4.22 and Figure 4.17.

Table 4.22: Frequency Analysis for barriers to integrating BIM in CE&M curriculum

Sr. No	Research Variables	Frequency	Percent
1	Lack of professional trained BIM faculty	59	95.16%
2	Disagreement over BIM concept	9	14.51%
3	Inadequate funding	27	43.54%
4	Traditional CM curriculum structures	36	58.06%
5	Need for strong fundamental knowledge	21	33.87%
6	Need for industry involvement	32	51.61%
7	Unwillingness to change the existing curriculum	24	38.70%
8	Faculty time and resources required to develop a new course	22	35.48%
9	Lack of BIM handbooks and training materials	14	22.58%
10	Lack of student demand	10	16.12%
11	Professional accreditation issues	9	14.51%
12	Other	5	8.06%

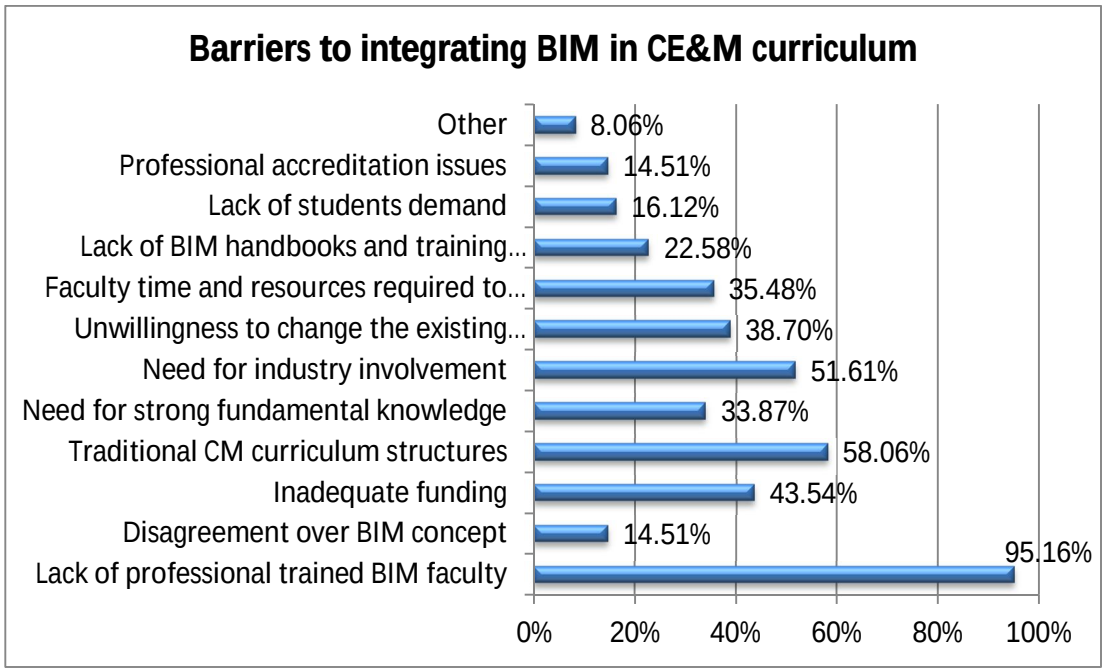

Figure 4.17: Barriers to integrating BIM in CE&M curriculum

4.5.4 Hypothesis Testing

To analyze the data, obtained by detailed survey, hypothesis t- tests were applied. Results are shown in the Table 4.23.

To assess the current status of BIM education in Pakistani universities, a null hypothesis was established that "current status of BIM education in Pakistani universities is very low to low medium". This statement can also be expressed as "$\mu \leq 3$". Here "μ" is the test value of population mean. The t value from the Table was found to be 1.667 at the significance level of 95%, but the calculated value was -7.65, which is less than the value obtained from the t Table. This means that the null hypothesis has not to be rejected, so it can be said that the current status of BIM

education in Pakistani universities in the respondent university is “very low to low medium”.

Similarly to check the BIM class or course in Pakistani AEC universities, a null hypothesis was established that “BIM class or course in university curriculum is very low to medium level beneficial for CE&M students”. The t value from the Table was found to be 1.664 at the significance level of 95%, but the calculated value was 9.02, which is less than the value obtained from the t Table. All other variables have tested in the same way with the details shown in Table 4.24.

Table 4.23: Hypothesis Testing of BIM and University curriculum

Null Hypothesis	tobs	tcalc	Result	Outcome
H1: Current status of BIM education within the AEC curriculum in the respondent university is very low to medium i.e. $\mu \leq 3$	1.664	-7.65	tobs < tcalc	Do not Reject H1
H2: Current status of BIM education in other Pakistani engineering universities within their AEC curriculum is very low to medium i.e. $\mu \leq 3$	1.664	-10.92	tobs < tcalc	Do not Reject H2
H3: A class or course on BIM in a university curriculum can be beneficial to CE&M students is very low to medium level i.e.	1.664	9.02	tobs > tcalc	Reject H3
H4: BIM education offered in the Pakistani engineering universities in CE&M programs prepares the students for jobs in local construction industry is very low to medium level i.e. $\mu \leq 3$	1.664	-1.91	tobs >tcalc	Do not Reject H4
H5: BIM education offered in Pakistani Engineering universities in CE&M program prepares the students for jobs in international construction industry is very low to medium i.e. $\mu \leq 3$	1.664	1.71	tobs >tcalc	Reject H5
H6: Use of BIM in Pakistani construction industry is very low to medium level will increase in coming years i.e. $\mu \leq 3$	1.664	3.73	tobs >tcalc	Reject H6
H7: Demand of students with BIM knowledge	1.664	4.66	tobs >| tcalc	Reject H7

in the AEC industry of Pakistan will increase is very low to medium in coming years level i.e. $\mu \leq 3$				
H8: Demand of students with BIM knowledge in the international AEC industry is very low to low level will increase in coming years i.e. $\mu \leq 3$	1.664	7.65	tobs >| tcalc	Reject H8

4.5.5 Ranking of Research Variables and Objectives by Percentage

The ranking of research variables was analyzed collectively through percentage by using MS Excel and SPSS.

4.5.5.1. BIM application used in AEC programs: Comparison of ranks

Table 4.24 gives the comparison of ranks for BIM applications used in AEC programs in university level.

Table 4.24: BIM applications used in respondents' university

BIM applications used in respondent university	Frequency	Percent	Overall Rank
Autodesk Revit Arch, Structure, MEP	26	92.85%	1
Autodesk Navisworks	4	14.28%	3
Graphisoft ArchiCAD	1	3.57%	5
TEKLA Structures	3	10.71%	4
Other	9	32.14%	2

4.5.5.2. BIM skills essential for CE&M students: Comparison of ranks

The Table 4.25 indicates overall raking about BIM skills that should be developed in CE&M student before they enter into construction industry, in which

modeling and analysis of model is the top skill, followed by drawing reading skill. All other variables ranking is shown in Table 4.26.

Table 4.25: BIM Skills essential for CE&M students

BIM skills essential for CE&M students	Frequency	Percent	Overall Rank
Drawing reading	21	75%	2
Cost estimation from drawing	15	53.57%	4
Software configuration	14	50%	5
System understanding	20	71.42%	3
Modeling and analysis of model	23	82.14%	1
Other	2	7.14%	6

4.5.5.3. Strategies to integrate BIM into CE&M curriculum: Comparison of ranks

Table 4.26 show overall ranking regarding the integrating strategies that were recommended by respondents to integrate BIM concept into CE&M curriculum.

Table 4.26: Strategies required for integration of BIM

Strategies required for integration of BIM	Frequency	Percent	Overall Rank
Teach standalone separate BIM courses	39	62.90%	2
Integrate BIM contents into conventional courses	37	59.67%	3
Arrange extra-curricular BIM workshops/presentations	43	69.35%	1
Restructure existing CE&M curriculum to include BIM	29	46.77%	4
Expect from CE&M students to learn BIM skills by themself	8	12.9%	5

4.5.5.4. BIM topics: Comparison of ranks

Table 4.27 gives the comparison of ranks about the respondents' university BIM topics.

Table 4.27: Respondents' university BIM study topics

Respondents' university BIM courses concentration topics	Frequency	Percent	Overall Rank
Introduction to BIM	22	78.3%	1
Project visualization	21	75%	2
Constructability reviews	12	42.85%	3
Model based estimating and cost controls	5	17.85%	7
Construction sequencing/4D Scheduling	7	25%	6
Cost estimation and control	9	32.14%	4
Conflict and collision detection	8	28.57%	5
Facilities management	7	25%	6

4.5.5.5. Time required for BIM integration in AEC programs: Comparison of ranks

Table 4.28 gives comparison of ranks that might take respondents' universities for integration of BIM in their CE&M programs.

Table 4.28: Time required for BIM adoption in AEC programs

Time required for BIM adoption in AEC programs	Frequency	Percent	Overall Rank
Currently use BIM	8	12.9	4
In one year's time	9	14.5	3
In three years' time	16	25.8	2
In five years' time	27	43.5	1
Don't want to see	2	3.2	5
Total	62	100	

4.5.5.6. Barriers to integrating BIM in CE&M curriculum: Comparison of ranks

Table 4.29 indicate the overall ranking of barriers to integrate BIM in CE&M curriculum, in which lack of professionally trained BIM faculty is the most significant barrier, followed by traditional CE&M curriculum structures.

Table 4.29: Barriers to integrating BIM in CE&M curriculum

Sr. No	Research Variables	Frequency	Percent	Overall Rank
1	Lack of professional trained BIM faculty	59	91.93	1
2	Disagreement over BIM concept	9	13.2	10
3	Inadequate funding	27	39.7	4
4	Traditional CE&M curriculum structures	36	52.9	2
5	Need for strong fundamental knowledge	21	30.9	7
6	Need for industry involvement	32	47.1	3
7	Unwillingness to change the existing curriculum	24	35.3	5
8	Faculty time and resources required to develop a new course	22	32.4	6
9	Lack of BIM handbooks and training materials	14	20.6	8
10	Lack of student demand	10	14.7	9
11	Professional accreditation issues	9	13.2	10
12	Other	5	7.4	11

4.6 ANALYSIS OF FIRMS/ORGANIZATIONS QUESTIONNAIRE

Respondents of this survey were AEC professionals working in Pakistani construction industries. The analyses of Firms/Organizations questionnaire have been presented in the following sequence:

a Respondents' Information

b Respondent Firms/Organizations information

c Statistical Analysis of collected data

4.7 RESPONDENTS' INFORMATION

Respondents' information was first part of the questionnaire. The purpose of this part is to make sure that respondents' sample size is relevant to survey with sufficient qualification, professional practical experience and designation.

4.7.1 Respondents' Sample Size

A total of 84 responses were obtained from AEC professionals, 10 responses were rejected as respondents of these had very little experience of BIM. The findings of the survey are based on a total of 74 responses. Further, responses were received by Architect/Designer (28.40%), Engineer (63.50%), General/Specialty Contractors (2.7%), Revit Specialist (2.80%), Consultant Engineer (1.4%), others

(1.4%). The details with frequencies and percentages are shown in Table 4.30 and Figure 4.18.

Table 4.30: Respondents' grouping

Respondents' Profession	**Frequency**	**Percent**	**Cumulative Percent**
Architect/Designer	21	28.40%	28.4%
Engineer	47	63.50%	91.90%
General /Specialty Contractors	2	2.70%	94.6%
Revit Specialist	2	2.80%	97.4%
Consultant Engineer	1	1.4%	98.8%
Other	1	1.40%	100
Total	74	100.0	

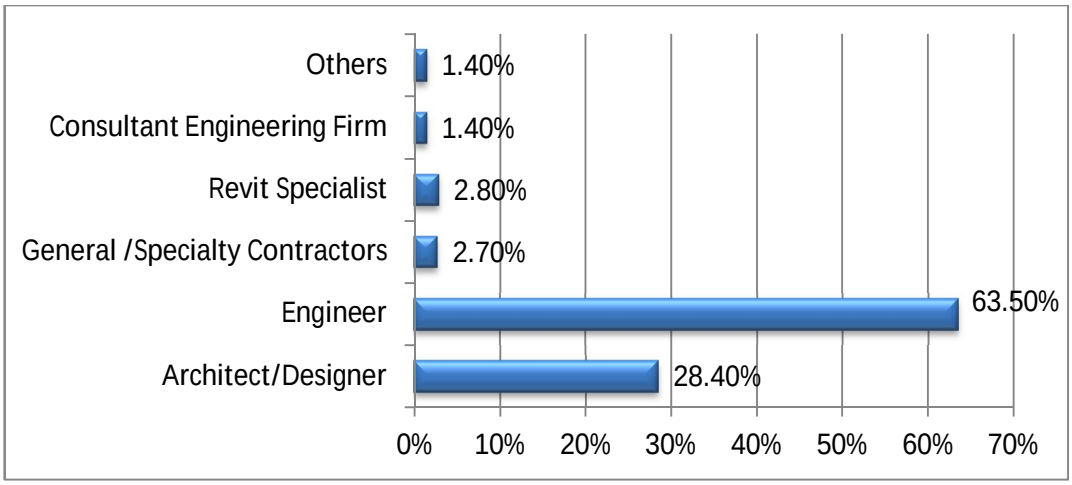

Figure 4.18: Respondents' grouping

4.7.2 Respondents' Qualifications

The qualifications of the respondents were Doctorate (2.7%) and Masters (37.8%). The details with frequencies and percentages are shown in Table 4.31 and Figure 4.2.

Table 4.31: Respondents' qualification

Respondents' Qualification	Frequency	Percent	Cumulative Percent
Bachelor Degree)	44	59.5%	59.5%
Master Degree (MS/M Phil)	28	37.8%	97.3%
Doctorate (PhD)	2	2.7%	100%
Total	74	100.0	

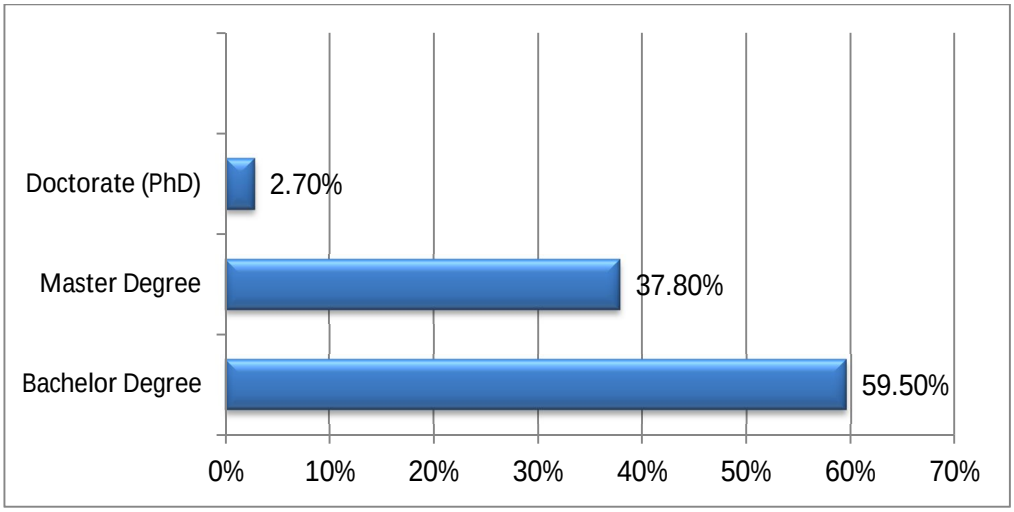

Figure 4.19: Respondents' qualification

4.7.3 Respondents' Professional Working experience

The respondents of this survey possessed varied professional working experience: 18.9% had more than 10 year professional working experience and 20.3% had 6 to10 year experiences. Details with frequencies and percentages are shown in Table 4.32 and Figure 4.20.

Table 4.32: Respondents' professional working experience

Respondents' experience (in years)	Frequency	Percent	Cumulative Percent
Less than 2 years	20	27.02%	27.02%
2-5 years	25	33.78%	60.8%
6-10 years	15	20.3%	81.1%
More than 10 years	14	18.9%	100%
Total	74	100.0	

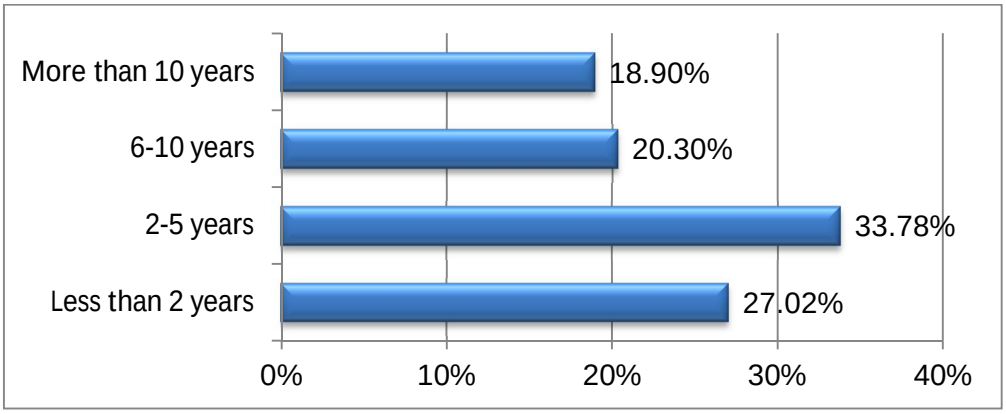

Figure 4.20: Respondents' professional experience

4.7.4 Respondents' Designation

The respondents of this survey possessed varied role/designation in organizations. Most of the respondents (40.5%) were project architect/Engineer/ Planner. The details with frequencies are shown in Table 4.33 and Figure 4.21.

Table 4.33: Respondents' role/designation in organizations

Respondents' role / designation	Frequency	Percent	Cumulative Percent
Managing Director	6	8.1%	8.1%
Project Director/Manager	8	10.8%	18.9%
Construction Manager	5	6.7%	25.6%
Project Architect/Engineer/ Planner	30	40.5%	66.2%
Contract Manager	6	8.1%	74.3%
Site Manager	17	22.9%	97.3%
Site Supervisor	2	2.3%	100%
Total	74	100.0%	

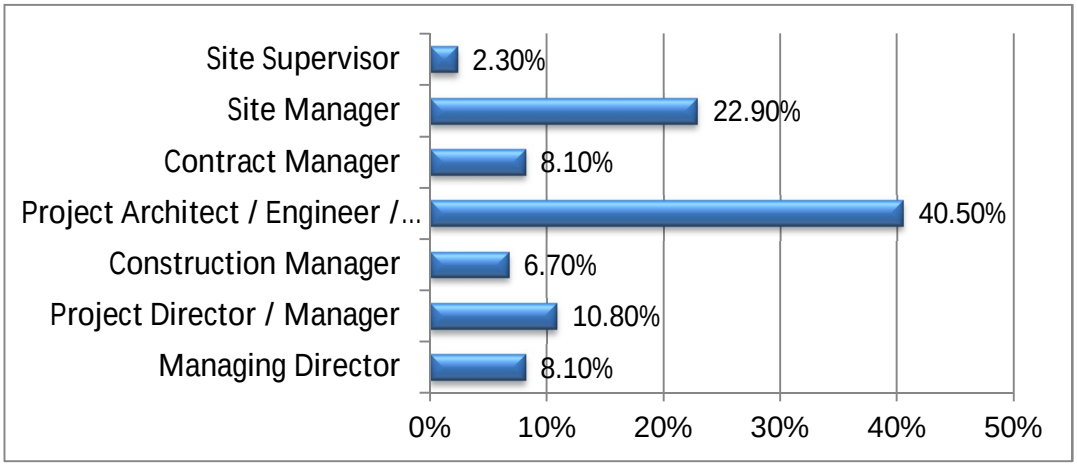

Figure 4.21: Respondents' role/designation in organizations

4.8RESPONDENTS' FIRM/ORGANIZATION INFORMATION

4.8.1 Geographical Location of Firms

The geographic location of firms for collecting data were Punjab (52.7%), Sindh (39.2%), KPK(6.7%), Baluchistan (0%) and Azad Kashmir (1.4%) as shown in Table 4.34 and Figure 4.22 .

Table 4.34: Geographical location of firms

Geographical Location	Responses		Cumulative Percent
	N	Percent	
Sindh	29	39.2%	39.2%
Punjab	39	52.7%	91.9%
Khyber Pakhtunkhwa	5	6.7%	98.6%
Balochistan	0	0%	98.6%
Azad Kashmir	1	1.4%	100%
Total	74	100.0%	

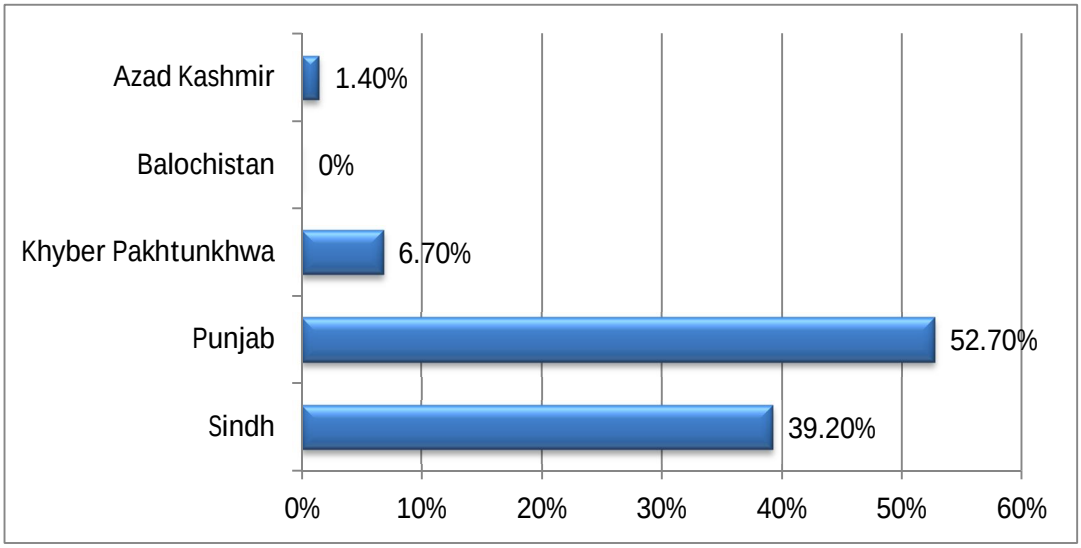

Figure 4.22: Geographical location of firms

4.8.2 Respondents' Firms

The information was collected form respondents in this survey about the type of firms/organizations they belonged to. Most of the firms (25.67%) were consultant/engineering firms. The details are shown in Table 4.35.

Table 4.35: Types of Firms/Organizations

Type of Firms/Organizations	Responses		Cumulative Percent
	N	Percent	
Architectural firm	16	21.6%	21.6%
Consultant/Engineering Firm	19	25.67%	47.27%
General Contractor	17	22.97%	70.24%
Design Builder/Project Management Firm	11	14.86%	85.1%
Trade/Specialist Contractor	2	2.7%	87.8%
Client	3	4.05%	91.85%
International Design Build Firm	1	1.4%	93.25%
Public Sector Organization	2	2.8%	96.05%
EPC Contractor	1	1.4%	97.45%
Surveyor	1	1.4%	98.85%
Other	1	1.4%	100%
Total	74	100.0%	

4.8.3 List of Firms Responding to Survey

The respondents of this survey belonged to different firms/organizations across whole country. The details of firms/organizations with frequencies are shown in Table 4.36.

Table 4.36: List of Organizations/Firms responding to survey

Sr. No.	Name of Firms/Organizations	No. of Responses
1.	National Engineering Services Pakistan (NESPAK)	6
2.	Halcrow Pakistan	1
3.	Descon Engineering Limited	3
4.	B.L. Harbert International	1
5.	EA Consulting	2
6.	TH construction group	1
7.	HQ 491 gp FWO	2

8.	ESS I AAR Consulting Engineers	1
9.	Tameer Construction Pvt. Ltd.	1
10.	SUH Design Consultants	1
11.	Techno Consult Intl.,	1
12.	Associated consulting engineers (ACE)	1
13.	Sadaf fatima Structural Engineer	1
14.	Paragon	1
15.	NDC, NESCOM	1
16.	Attock Petroleum	1
17.	Izhar Construction Company	1
18.	Naveed Aslam & Associates	1
19.	Associated Constructors ltd.	1
20.	P&D Directorate FJWU	1
21.	Alkhayarin group	1
22.	AAA Engineering Consultants (Pvt) Ltd	1
23.	B.F Enterprises	1
24.	Ahed Associates	1
25.	Archilinks Constructions	1
26.	AJM Construction	1
27.	Logix-Pm	1
28.	FWO	2
29.	MES	1
30.	Habib Rafique Pvt Ltd.	1
31.	Design works	1
32.	Professional Resource Associates	1
33.	Willayat Ullah & Sons	1
34.	Arif Belgaumi Architects	1
35.	HASM Architecture	1
36.	Lucky One (PVT) LTD	1
37.	Mushtaq and Bilal Consulting Engineers	1
38.	Creek Developers (Pvt) Ltd, A.K.D Group of Companies	1
39.	Mushtaq & Bilal Consulting Engineers	1
40.	TH construction group	1
41.	Arshad Shahid Abdullah	1

42.	Army Engineers	1
43.	Goldroof Pvt. Ltd	1
44.	Army Survey Group of Engineers	1
45.	Fatima Jinnah Women university	1
46.	Pearl Real Estate Pvt Ltd.	1
47.	CENCON Associates	1
48.	SCHEMATICS	1
49.	ARCOP	1
50.	National Highway Authority	1
51.	Palm group of companies	1
52.	UPDL	1
53.	Asian consulting engineers	1
54.	MC Group	1
55.	Infinity consultants	1
56.	JERs	1
57.	Dimensions Studio & Kohistan Group	1
58.	Classified	1
59.	BLHI	1
60.	DMD	1
61.	Techno Legal Consultants (Pvt.) Ltd	1
62.	Habib Construction Services	1
63.	PMO NUST	1
64.	Arshad Shahid Abdulla(Pvt.)	1
65.	Hammad Husain Architects	1
66.	AHR-Ali Naqvi	1
Total		74

4.9 STATISTICAL ANALYSIS

Different tests such as validity, reliability, frequency and hypothetical analyses were carried out on data through statistical analysis techniques.

4.9.1 Reliability of Sample

As Cronbach's coefficient alpha method is most popular method to find internal consistency (reliability) of data and in the survey form, some questions were also on Likert scale so this method was used to check reliability. According to this method if Cronbach's coefficient alpha value is higher than 0.7, this indicates that data is reliable for analysis. By using SPSS, its value is calculated as 0.735 of the overall questionnaire as given in Table 4.37. According to Gliem and Gliem (2003) study normal range of Cronbach's coefficient alpha value is between 0 and 1, and the higher values reflect a higher degree of internal consistency. Its higher value, as shown in Table 4.37, indicates that data is consistent and reliable for analysis.

Table 4.37: Reliability statistics

Case Processing Summary	**No. of Responses**		**Percentage of Responses**	**No. of Items / Variables**	**Cronbach's Alpha**
Over all Questionnaire	Valid	74	100	5	**.735**
	Excluded[a]	0	0		
	Total	74	100.0		

4.9.2 Normality Test

Shapiro Wilk normality test was conducted to check normality of the collected data as sample size is less than 2000. It is performed to identify whether data is normally distributed or not, i.e. the data is parametric or non-parametric in nature. Significance values found are 0.000 which are less than 0.05. Significance value should

be larger than 0.05 for the data to be sufficiently normal. As shown in Table 4.38, the data is not normally distributed and non-parametric tests are required for further analysis.

Table 4.38: Normality Test

Sr. No	Research Variables	Shapiro-Wilk Test		
		Statistic	df	Sig.
1.	Level of formal education of BIM	0.852	74	0.000
2.	BIM usage would be a beneficial to your company	0.851	74	0.000
3.	A class or course on BIM in a university curriculum would beneficial to CE&M students	0.739	74	0.000
4.	Use of BIM in the Pakistani construction industry will increase in coming five years	0.883	74	0.000
5.	Having BIM knowledge would make someone a more desirable applicant	0.889	74	0.000

4.9.3 Collected Data: Frequency Analysis

In this section detailed frequency was done of each variable and the results are shown with the help of tables and figures.

4.9.3.1 Firms Exposure to BIM: Frequency Analysis

To make the reliable analysis, several questions were asked about the respondent's awareness of BIM. Only those responses were consider for further analysis purpose, which have at least some basic understanding of BIM. Some findings from responses are summarized in Table 4.39. It is found that 10.8% of

AEC firms use BIM applications for most of their projects, 32.4% use BIM for some of their projects and 56.8% AEC firms do not use BIM applications at yet.

Table 4.39: Frequency analysis of firms' exposure to BIM

Sr. No	Firm Exposure to BIM	Response	Frequency	Percent	Cumulative Percent
1.	Respondents' knowledge about BIM	Yes	74	100%	100%
		No	0	0%	100%
2.	BIM adoption for project	Yes, for most projects	8	12.12%	12.12%
		Yes, for a few projects	24	21.21%	21.21%
		No	42	66.67%	100%

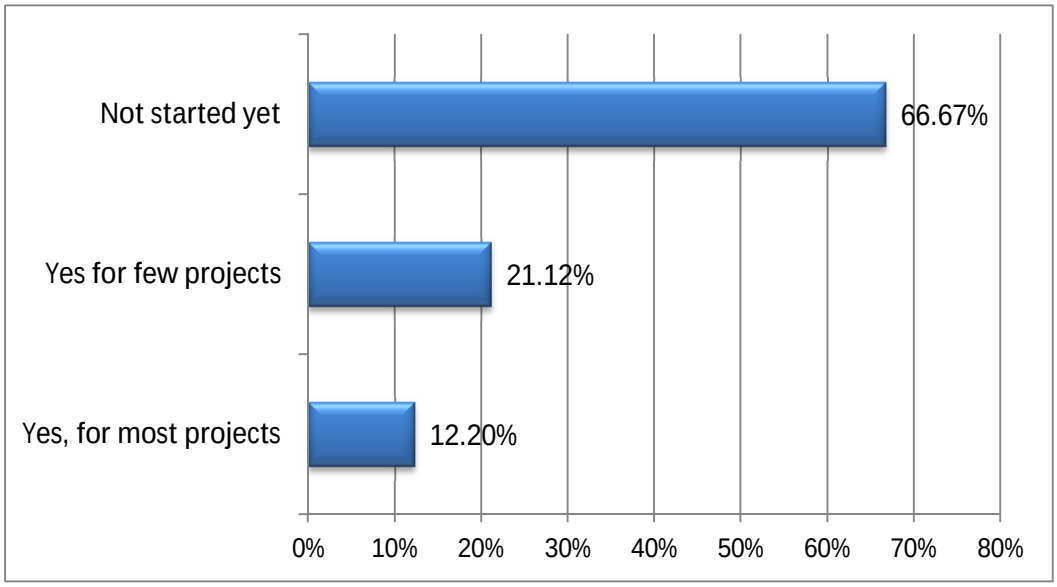

Figure 4.23: BIM applications used by Respondents Firms/Organizations

4.9.3.2 BIM applications used in respondents' firms: Frequency analysis

Table 4.40 and Figure 4.25 show BIM applications which are being used in the respondent's firms/organizations. From these AEC firms/organization which had started using BIM applications in their construction project, 36.8% use Autodesk Revit (Arch, Structure, MEP) while 2.7% use other BIM applications i.e. Synchro, and Autodesk 3D.

Table 4.40: BIM applications used in respondents' Firm/Organization

BIM application(s) currently in use in respondent's firm	**Frequency**	**Percent**
Autodesk Revit (Arch, Structure, MEP)	32	43.24%
Autodesk Navisworks	7	9.45%
Graphisoft ArchiCAD	1	1.35%
VICO (Constructor)	1	1.35%
Other	2	2.70%

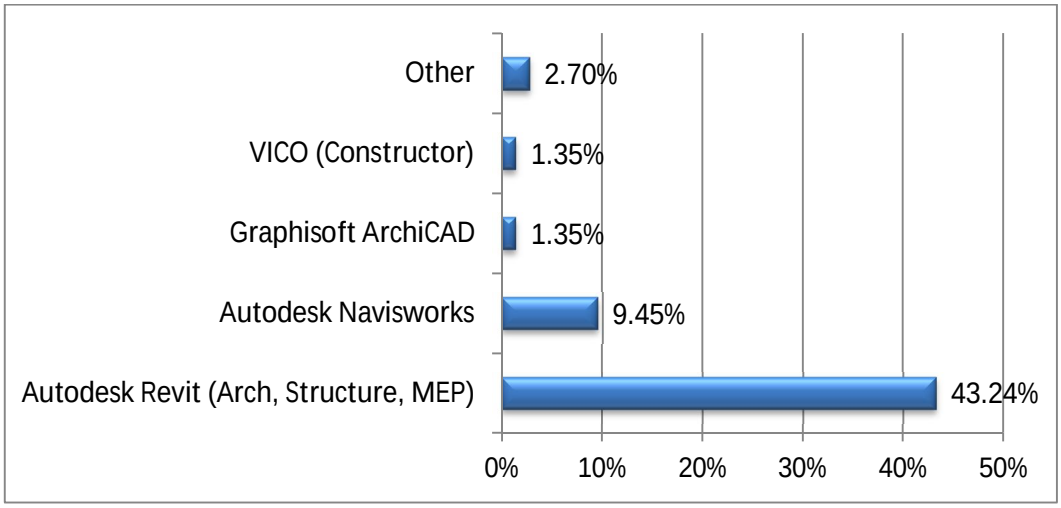

Figure 4.24: BIM applications used in respondents' Firm/Organization

4.9.3.3 Purpose of utilization of BIM: Frequency analysis

Those AEC Firms/Organizations which had started to use BIM applications in their construction projects, out of these, majority of 32.1% were used BIM for project visualization purpose. The details with frequency and percentage are shown in Table 4.41 and Figure 4.25.

Table 4.41: Purpose of utilization of BIM in respondents' firms

Purpose of utilization of BIM	Frequency	Percent
Project visualization	27	32.1%
Constructability reviews	17	20.2%
Model based estimating and cost controls	19	22.6%
Construction sequencing /4D Scheduling	13	15.5%
Conflict and collision detection	16	19%
Processes improvement and faster documentation	15	17.9%
Facilities management	6	7.1%
Due to client demand	5	6%
Competitors using it	1	1.2%
Other	2	2.4%

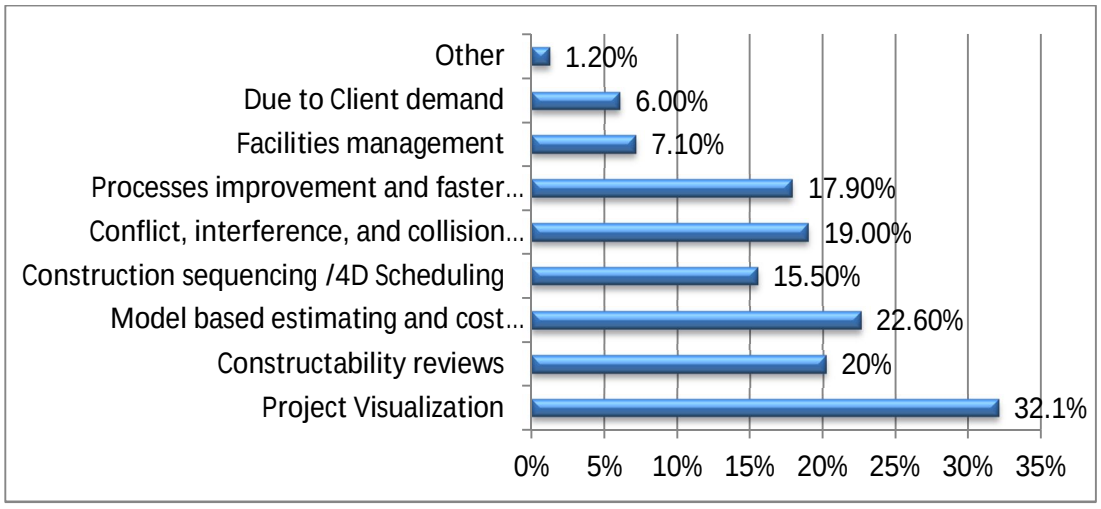

Figure 4.25: Purpose of utilization of BIM in respondent's firms

4.9.3.4 Benefits of BIM implementations: Frequency analysis

The percentage of benefits achieved due to BIM applications being used in the respondent's firm/organization were given in Table 4.42 and Figure 4.27. These were 32.1% identify and resolve design clashes, 10.7% decrease the number of RFIs and change orders, 21.4% accelerate project schedules, 10.7% project completion within budget, 19% increase in cost estimation accuracy,26.2% enhanced project quality, 19% enhanced project safety, 17.9% improved coordination b/w contractor, consultant and designer and 1.2% other.

Table 4.42: Benefits achieved due to BIM

Achievement achieved due to BIM applications	**Frequency**	**Percent**
Identified and resolved design clashes	27	32.1%
Decrease in number of RFIs and change orders	9	10.7%
Accelerated project schedules	18	21.4%
Project completion within budget	9	10.7%
Increased in cost estimation accuracy	16	19%
Enhanced project quality	22	26.2%
Enhanced project safety	16	19%
Improved coordination among contractor, consultant & designer	15	17.9%
Other	1	1.2%

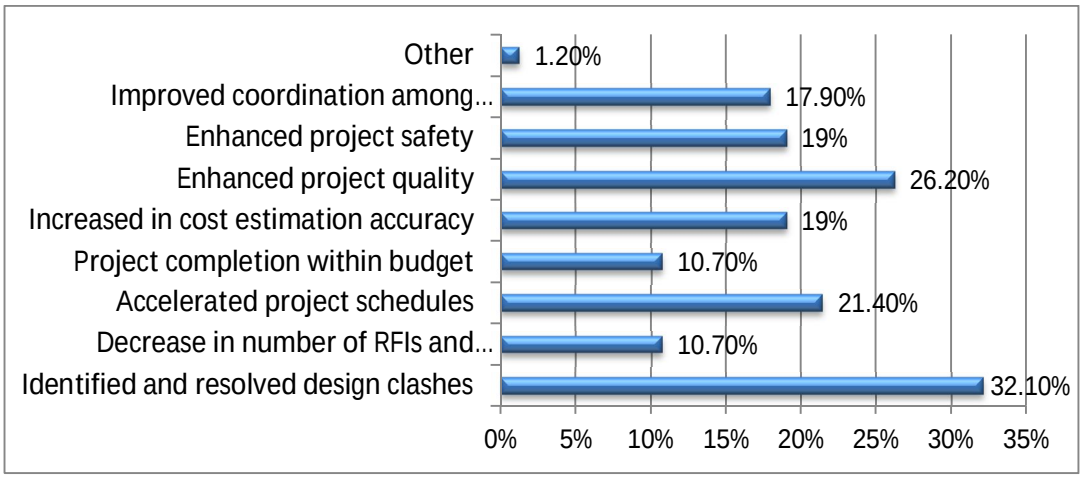

Figure 4.26: Benefits achieved after implementations of BIM in respondent's firms

4.9.3.5 BIM skills essential for CE&M students: Frequency analysis

According to responses of AEC firms/organizations following BIM skills as shown in Table 4.43 and Figure 4.28 are essential for CE&M students and should be developed in CE&M students before they enter into construction industry.

Table 4.43: BIM skills required in construction industry

BIM skills required in construction industry	Frequency	Percent
Drawing reading	35	41.7%
Cost estimation from drawing	39	46.4%
Software configuration	32	38.1%
System understanding	38	45.2%
Modeling and analysis of model	62	73.8%
None of the them	2	2.4%
other	2	2.4%

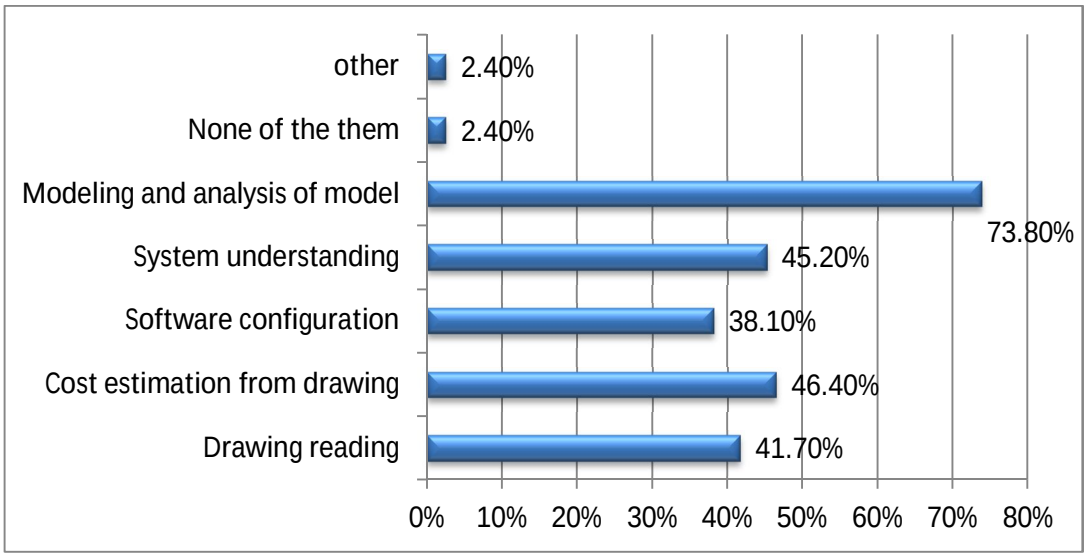

Figure 4.27: BIM skills required in construction industry

4.9.3.6 BIM contents essential for CE&M students: Frequency analysis

Table 4.44 and Figure 4.29 indicates the AEC firms/organizations member responses related to the BIM contents which should be taught to CE&M students before they enter into construction industry.

Table 4.44: Contents of BIM essential for CE&M students

Contents of BIM essential for CE&M students	Frequency	Percent
BIM theory and literature	44	52.4%
Applications of BIM software for model creation and detailing	52	61.9%
Applications of BIM software for model analysis	42	50%
BIM and integrated project delivery system	34	40.5%
Don't know	5	6%

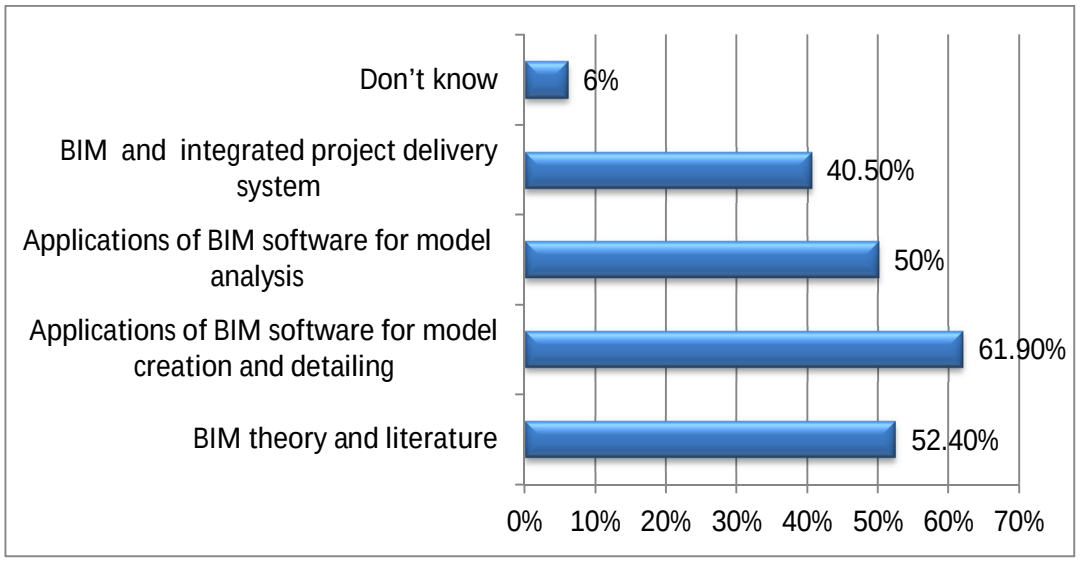

Figure 4.28: Contents of BIM essential for CE&M students

4.9.3.7 Time required for BIM adoption in AEC firms: Frequency analysis

The percentage of time required that might take AEC firms/organizations for integration of BIM applications are shown in Table 4.45 Figure 4.30. Most of the AEC firms/organizations 40.54 might take might take more than 5 years for complete BIM adoption in their construction projects.

Table 4.45: Time required for BIM adoption in AEC firms

Time required for BIM adoption in AEC Firms	Frequency	Percent
Firm already using BIM	14	18.91%
Adoption in less than 1 year	5	6.75%
Adoption in 1-3 years	25	33.78%
Adoption in 3-5 years	22	29.72%
Adoption in more than 5 years	30	40.54%
Never want to see	4	4.50%

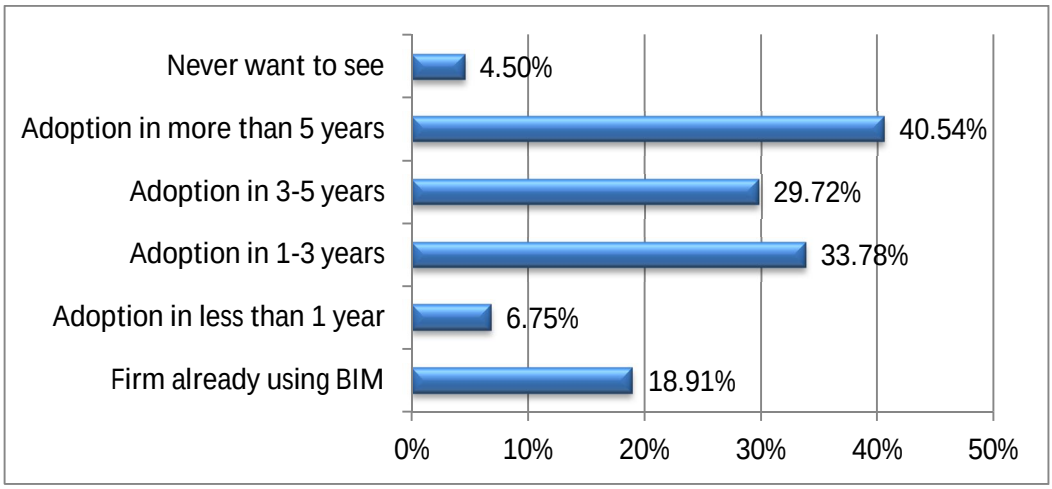

Figure 4.29: Time required for BIM adoption in AEC Firms

4.9.3.8 Expectations from current and future CE&M students: Frequency analysis

The percentage of BIM knowledge areas which might essential for current and future CE&M graduate is shown in Table 4.46 and Figure 4.31. These were 61.9% conceptual understanding of BIM tools and process, 56% proficient skills with BIM software, 8.3% none of them.

Table 4.46: Respondents expectations from current and future CE&M students

Expectations from current and future CE&M students	**Frequency**	**Percent**
Theoretical knowledge of BIM	52	61.9%
BIM software skills required	47	56%
None of the above	7	8.3%

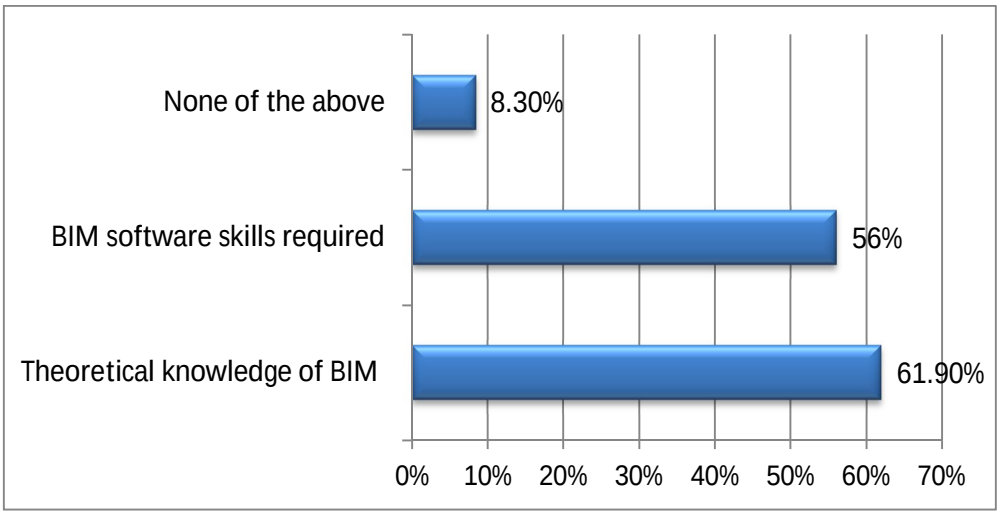

Figure 4.30: Respondent BIM expectations from current and future CE&M students

4.9.3.9 Pakistani industry expectations: Frequency analysis

The percentages of AEC industry requirements form CE&M students as shown in Table 4.47.

Table 4.47: Frequency analysis of Pakistani Industry requirements

Sr. No	Research Variables	Responses	Frequency	Percent	Cumulative Percent
1.	BIM is important for AEC industry of Pakistan	Yes	70	94.6%	94.6%
		No	0	0%	94.6%
		Don't Know	4	5.4%	100%
2.	Respondents' level of formal education of BIM	Very Low	15	20.3%	20.3%
		Low	17	23%	43.3%
		Medium	34	45.9%	89.2%
		High	7	9.4%	98.6%
		V .High	1	1.4%	100%
3.	BIM usage would be a positive addition to AEC firms	Very Low	2	2.7	2.7
		Low	2	2.7	5.4
		Medium	19	25.7	31.1
		High	32	43.2	74.3
		V .High	19	25.7	100
4.	A class or course on BIM in a university curriculum would be beneficial to	Very Low	0	0%	0%
		Low	2	2.7%	2.7%
		Medium	10	13.5%	16.2%

	CE&M students	High	23	31.1%	47.3%
		V .High	38	51.3%	98.6%
		Don't Know	1	1.4%	100%
5.	Use of BIM in the Pakistani construction industry will increase in coming five years	Very Low	2	2.7	2.7%
		Low	13	17.6	20.3
		Medium	25	33.8	54.1
		High	27	36.5	90.6
		V .High	5	6.7	97.3
		Don't Know	2	2.7	100
6.	Having BIM knowledge would make someone a more desirable candidate in your firm	Very Low	2	2.7	2.7
		Low	13	17.6	20.3
		Medium	25	33.8	54.1
		High	27	36.5	90.6
		V .High	5	6.7	97.3
		Don't Know	2	2.7	100

4.9.3.10 Barriers to integrating BIM in Construction industry: Frequency analysis

There were number of barriers that affect the successful integration of BIM in Pakistani AEC firms/organizations. Most of the respondents 65.5% consider lack of BIM skills personnel and 59.5% consider traditional contact system are the two main barriers in integrating BIM in Pakistani construction industry. The others significant barriers are shown in Table 4.48 and Figure 4.32.

Table 4.48: Frequency Analysis of barriers to integrating BIM in construction industry

Sr. No	Research Variables	Frequency	Percent
1	Traditional contract system	50	59.5%
2	Lack of BIM skills personnel	55	65.5%
3	BIM requires advanced ICT equipment	21	25%
4	Inadequate top management support to adopt BIM	37	44%

5	Not all stakeholders are using BIM	33	39.3%
6	High cost of BIM implementation	12	14.3%
7	BIM is a complex methodology to understand	16	19%
8	Client does not demand	37	44%
9	Unwillingness to change the traditional way	44	52.4%
10	Don't see its benefit	2	2.4%
11	Significant changes in workflow, roles and responsibilities	17	20.2%
12	Lack of its standardized tools	14	16.7%
13	Other	2	2.4%

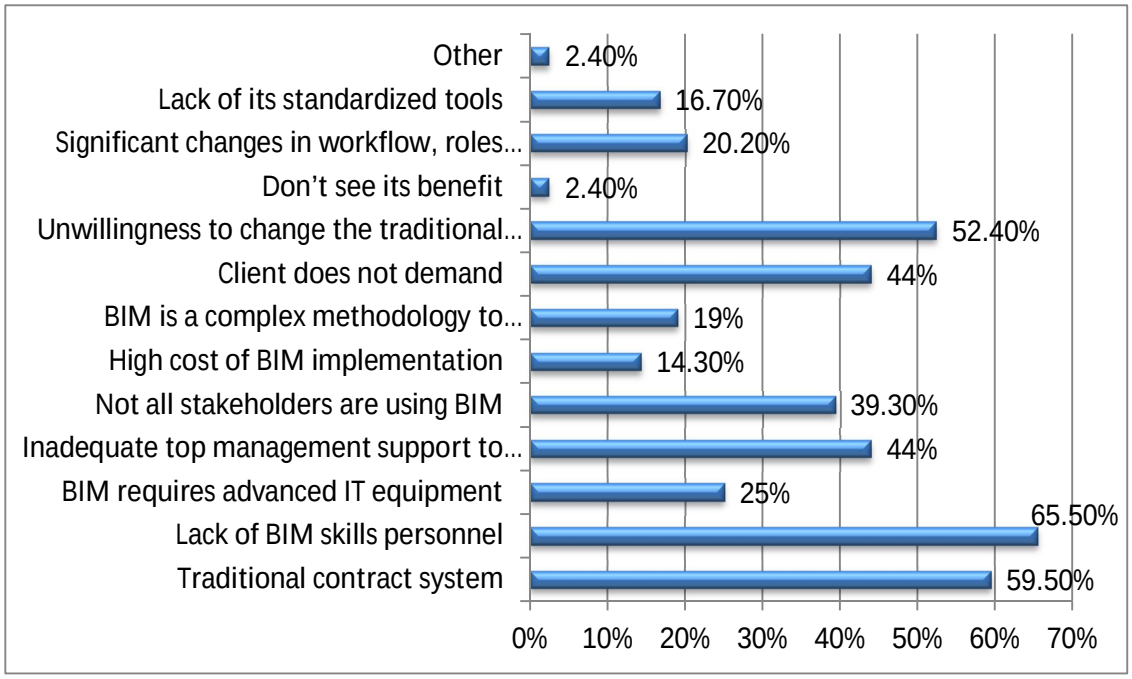

Figure 4.31: Barriers to integrating BIM in construction industry

4.9.4 Hypothesis Testing

To analyze the data, which were obtained by the construction industry survey, hypothesis t- test were applied for the determination of Firms/Organizations exposure to BIM. Results are shown in the Table 4.49.

To assess formal education of AEC professional's respondents; a null hypothesis was established that "formal education of respondents is very low to medium level". This statement can also be expressed as "$\mu \leq 3$". Here "μ" is the test value of population mean. The t value from the Table was found to be 1.664 at the significance level of 95%, but the calculated value was -4.40, which is less than the value obtained from the t Table. This means that the null hypothesis has not to be rejected, so it can be said that the formal education of BIM of most of AEC professional working in construction industry is "very low to medium level".

Similarly to check the use of BIM in AEC Firms a null hypothesis was established that "Use of BIM in the Pakistani construction industry is very low to medium level will increase in coming years". The t value from the t Table chart was found to be 1.664 at the significance level of 95%, but the calculated value was 1.79, which is less than the value obtained from the t Table. This means that the null hypothesis has to be rejected, so it can be said that the use of BIM is not very low to medium level will increase in Pakistani construction Firms/Organizations. All other variable has testing in the same way.

Table 4.49: Hypothesis Testing

Null Hypothesis	**tobs**	**tcalc**	**Result**	**Outcome**
H1: Formal education of BIM of most of the professional working in construction firm is very low to medium level i.e. $\mu \leq 3$	1.664	-4.20	Zobs> Zcalc	Do not Reject H1
H2: BIM usage would be a beneficial in construction industry is very low to medium level in Pakistan i.e. $\mu \leq 3$	1.664	9.92	Zobs < Zcal	Reject H2
H3: A class or course on BIM in a	1.664	11.44	Zobs < Zcalc	Reject H3

university curriculum can be beneficial to CE&M students is very low to medium level i.e. $\mu \leq 3$				
H4: Use of BIM in the Pakistani construction industry is very low to medium level will increase in coming years i.e. $\mu \leq 3$	1.664	1.79	Zobs < Zcalc	Reject H4
H5: Having BIM knowledge CM students is very low to medium level attractive candidate in Pakistani construction industry i.e. $\mu \leq 3$	1.664	13.36	Zobs < Zcalc	Reject H5

4.10 SUMMARY

In this chapter, the information which was received by the construction industry and academia was analyzed. To analyze the data correctly and accurately, statistical analysis was applied on the data. Different tests such as validity, reliability, frequency and hypothetical analyses were carried out on the data through statistical analysis.

Based on the results obtained by this analysis draft BIM curriculum is developed and it was more refined by the US BIM experts. The feedback obtained from US BIM experts is shown in appendix D. In the next chapter, conclusions and recommendations will be discussed in detail.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

The following major findings can be drawn from the university based data analysis.

- The current status of most of the AEC universities of Pakistan have low level of BIM academic implementation and 54.8% are not teaching or discussing BIM concept in their architecture, civil engineering and construction management related programs.
- 45.2% of the AEC universities in Pakistan are teaching or discuss BIM concept at under graduate, graduate and PhD levels and out of these 60.71% have included separate 1-2 BIM course, 7.14% have included 3-5 course and 39.28% haven not included any courses but they discuss BIM concept with their students by workshops/presentation or by BIM specific projects.
- These universities desire that the BIM skills should be developed in the CE&M students before they enter into local and international construction industry, i.e. 82.14% recommend modeling and analysis and 75% recommend drawing reading skills as the top two skills.

- It is very alarming situation that most of Pakistani universities (61.3%) are not interested to research about BIM. Only 38.7% AEC faculty members research involving BIM at their universities.
- Most of the universities (69.3%) might take 3-5 years of time for complete BIM adoption in their AEC programs.
- Most of the universities (80.6%) agree with BIM based education and believe that a class or course in university curriculum can be beneficial to CE&M students.
- Different strategies were highlighted for integration of BIM in CE&M programs among these 69.35% suggested arranging BIM workshops/presentations and 62.9% suggested teaching standalone BIM as the best strategies for integration of BIM.
- Most of the faculty members (20.9%) agree from high to very high levels that BIM education offered in Pakistani universities will prepare the CE&M students for job in local construction industry.
- Most of the faculty members (53.3%) agree from high to very high levels that BIM education offered in Pakistani universities will prepare the CE&M students for job in international construction industry.
- There are number of factors that affect the successful integration of BIM in CE&M programs but 95.16% is the lack of professionally trained BIM faculty and 58.06% is the traditional CE&M curriculum structures as the

most significant barriers in integrating BIM in Pakistani engineering universities.

The following major finding can be drawn from the AEC industry based data analysis.

- Very few (10.8%) Pakistani AEC firms use BIM applications for most of their projects, (32.4%) use BIM for some of their projects and (56.8%) AEC firms do not use BIM applications as yet.
- Within these AEC firms, most commonly used BIM application is (43.24%) Autodesk® Revit, while some other applications in use include Autodesk® Navisworks. , Graphisoft ®ArchiCAD, Synchro, and Autodesk® 3D.
- These AEC firms were utilized BIM for (32.1%) project visualization and (22.6%) for model based estimation and cost controls purpose.
- Majority of AEC firms indicates that after implementations of BIM in their construction projects two main benefits were achieved, i.e. 32.2% easily identify design clashes and 26.2% enhanced project quality.
- These firms desire that the BIM contents should be taught to CE&M students before they enter into construction industry, i.e. 52.4% recommend BIM theory and literature and 61.9% recommend applications of BIM software for model creation and detailing purpose.
- These firms also desire that the BIM skills should be developed in the CE&M students before they enter into local and international construction

industry, i.e. 73.8% recommend modeling and analysis and 46.4% recommend cost estimation from drawing as the top two skills.

- Most of AEC professionals (70.25%) were in favor of implementing BIM in Pakistani construction industry but this implementation might take 3-5 years of time for complete BIM adoption in their industries.
- Most of the AEC industry professionals (43.2%) agree from high to very high level that use of BIM in Pakistani construction industry will increase in coming five years.
- There are number of factors that affect the successful integration of BIM in Pakistani construction industry but 65.5% is the lack of BIM skills professionals and 59.5% is the traditional contract system as the most significant barriers in integrating BIM in AEC industries.

5.2 RECOMMENDATIONS

The following recommendations can be draw in the light of this research work:

Recommendation # 01

- Main reason of integrating BIM in academia and industry is the lack of BIM skilled personnel so workshops/conferences should be arranged in academia this not only provides knowledge and skills to CE&M students but also to the faculty members. The following proposal can be used for organizing 20 hour workshop on BIM.

Total Hour: 20

Number of Hour of Lectures per week: 10

Learning Outcomes

- ✓ Develop architectural, structural and MEP BIM Models.
- ✓ Perform Analyses such as Clash Detection, Energy Analysis, Solar Study, Lighting Analysis, Quantity Take Off, 4D Scheduling using BIM tools
- ✓ Project Documentation for design, execution and facility management operations using BIM tools.
- ✓ Collaborate and Co-ordinate with multiple disciplines involved in a construction project using BIM tools.

Course Contents

Lecture #	Duration	Course Content
1	3 hours	Lecture on Introduction to BIM + Introduction to Autodesk Revit User Interface
2	3 hours	Architectural Modeling
3	3 hours	Architectural Modeling + Structural Modeling
4	3 hours	Structural Modeling + MEP (Mechanical , Electrical , Plumbing) Modeling
5	3 hours	Project Documentation + Quantity Take Off + Sheet Generation
6	3 hours	Introduction to Autodesk Navisworks + Clash Detection + 4D Scheduling + QTO
7	2 hours	Energy Analysis

Recommendation # 02

- It is extremely important to implement BIM rich concept in CE&M curricula so there is a need to make new course for it .The following BIM course

"BIM in construction management" is purposed for postgraduate level that can be used as a separate 3 credit hour course work in CE&M programs.

New Course :

Elective Course for Construction Management
Proposed subject title: BIM in Construction Management
Degree Program: MS Construction Engineering & Management
NIT-SCEE, Islamabad

1. Educational Objectives

The purpose of this course is to enable the students to understand and implement Building Information Modeling (BIM) in construction management framework. It will also enable students to creatively think of construction related problems and arrive at solutions of complex and risk prone projects by using the state of the art nD technology available in form of BIM applications.

2. Input Obtained from Industry/Corporate Sector

Information and Communication Technology (ICT) is an extremely important topic of 21st century. ICT systems are used today in construction industry and academia comprising of BIM tools among many other applications. Most of AEC professionals in Pakistan are in favor of implementing BIM on construction projects. BIM education offered at postgraduate level can provide the opportunity to construction engineering and management (CE&M) students to develop their

knowledge and skills up to the current BIM based local and international construction industry requirements. Moreover, being a new perspective in the field, knowledge of BIM can also open many doors to research areas.

3. International Practice

Courses with the core learning of understanding and implementation of BIM in construction management process are being offered in postgraduate as well as undergraduate programs of Construction Engineering in a number of universities world over. Some universities with such courses are mentioned as follows:

a. University of Washington, USA.
b. Purdue University, USA.
c. Polytechnic Institute of NYU, USA.
d. Oklahoma State University, USA.
e. Auburn University, USA.
f. Brigham Young University, USA.
g. University of New South Wales, Australia

4. Proposed Timeframe of Commencement

Fall – 2015

5. Total Credit Hour: 03

Number of Hour of Lectures per week: 01

Number of Hours of Labs per week: 02

6. Learning Outcome:

By the end of this course students will be able to understand the concept and functions of BIM and its tools including:

a. Understand the basic knowledge of BIM in construction management framework
b. Develop architectural, structural and MEP BIM models.
c. Understand construction industry challenges and can perform analyses such as clash detection, energy Analysis, quantity take off, 4D scheduling
d. Develop project documentation for design, execution and facility management operations

7. Course Contents

- ✓ BIM introduction
- ✓ BIM and integrated project delivery system
- ✓ Preparation of BIM implementation plan
- ✓ Project visualization and constructability review
- ✓ Cost estimation (5D) and Scheduling (4D)
- ✓ Conflict, interference, and collision detection
- ✓ Site logistics and communication
- ✓ Basics of BIM and sustainability (Energy Modeling)
- ✓ BIM based facility management

8. Examinations and Assessments

Type	Frequency	Weightage
Quiz	5	10
Term project	1	20
Mid-term exam	2	30
Final exam	1	40
Total	**9**	**100**

Relative Grading system will be used

More than 75% class attendance is mandatory to appear in the final exam

9. Term Project

Prepare a Bid proposal of any given project with the help of using Autodesk's Revit software, Naviswork Manage and other applicable software. It may include 3D modeling, cost estimation, scheduling, site logistics, constructability analysis and energy analysis of given project. All other details of the project will be developed as the class progresses.

10. Teaching Methodology

The course is delivered through a combination of:

- Lectures
- Guest speaker
- Video session / Discussion sessions
- Workshops

- Visit of AEC industry
- Case study of projects

11. Faculty

Professional BIM trained faculty will be required.

12. Laboratories

Computer Lab work is required.

13. Required Software

Autodesk Revit 2015, Autodesk Navisworks Manage 2015, Google Sketchup

14. Library

Relevant Books:-

a. BIM and Construction Management: Proven Tools, Methods, and Workflows by Brad Hardin
b. BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors by Chuck Eastman, Paul Teicholz, Rafael Sacks, Kathleen Liston, 2nd Edition
c. Design Integration Using Autodesk Revit 2014, By Daniel John
d. Building Information Modeling: BIM in Current and Future Practice by Karen Kensek, Douglas Noble, 2014

15. Proposed Research Areas / Benefit(s) to the Society

Construction industry of Pakistan as a whole can benefit from such training of students. The agents of change in the form of latest BIM knowledge and skills, students will be instrumental to fill the gaps in professional management practice. The contribution of knowledge and skills of BIM will be the ease in plan reading, cost estimation and solving analytical problems. Such knowledge of BIM will enable postgraduates to get good jobs in local and international environment and facilitate society by providing latest ICT based solutions as a bright side of civil engineering.

Recommendation # 03

- Continuous research practices should be done to find out the best option to integrating BIM in academia and according to the change in requirements in local and international construction industry.

Recommendation # 04

- HEC should develop a policy plan for create awareness related to BIM in engineering universities and use a separate funding for training the faculty members of AEC according to the latest ICT based knowledge because educating the teacher means educating the students and ultimately educating and strengthening the construction industry as a whole. The following BIM education policy plan can use for this purpose.

National Policy:

Government of Pakistan through HEC has stressed on development of new curriculum through "Module III: Curriculum Development, Assessment and Evaluation" developed by National Academy of Higher Education (NAHE).

Vision:

To provide the latest ICT based education in civil engineering, construction engineering and management (CE&M), architectural engineering programs of all Pakistani engineering universities.

Implications of BIM Curriculum:

Currently most construction education programs in Pakistan are focused on teaching traditional management techniques which are insufficient to handle construction projects efficiently. The problem is that traditional construction education provides well-structured programs and knowledge that barely cater real ICT based solutions.

The input and feedback from the Pakistani construction industry and academia indicates that the significance of adopting additional skills and subjects such as BIM must be incorporated into CE&M education.

In world BIM education is at different levels of implementation across the globe. Some countries have successfully implemented this integration in their construction programs while the others are in process.

This integration of latest ICT based knowledge in the curriculum can provide great opportunity that can enhance skills and capabilities of student coherence with current local and international construction industry requirements.

Forward:

This is a policy document, which invites all the AEC stake holders, particularly HEC and PEC to develop their action plan, using this policy as a base document and submit to National Academy of Higher Education (NAHE) Islamabad for review and approval.

It is intended that the BIM curriculum outlined here should be approved by the HEC and PEC in order to enhance the CE&M student knowledge and skills by providing latest ICT based solutions as a bright side of civil Engineering.

Introduction:

Building Information Modeling, or BIM is a parametric, 3D digital model-based process that is used to generate plans, sections, elevations, perspectives, details, schedules- all of the necessary components to document the design of a building and is also used for performing design analyses such as structural analysis, energy analysis etc. This model also serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life cycle from inception onward. BIM brings better resolved solutions, reduced waste both in time and materials, faster project delivery, reduced risk, enhanced sustainability, better whole-life performance and improved facility operation and maintenance. This

approach saves time and money and is being used in buildings, infrastructure, industry and other sectors involving construction activity.

BIM's extraordinary abilities and the consequent benefits have sparked waves of change across the construction industry paradigm. At present, Due to this fast growing awareness and adoption of BIM applications in AEC industry, several CE&M programs around the globe are in different stages of implementation of BIM course for their CE&M students Courses with the core learning of understanding and implementation of BIM in construction management process are being offered in postgraduate as well as under graduate programs of Construction Engineering in a number of universities world over. Some universities with such courses are mentioned as follows:

a) University of Washington, USA.
b) Purdue University, USA.
c) Polytechnic Institute of NYU, USA.
d) Oklahoma State University, USA.
e) Auburn University, USA.

Policies and their Implementation Strategies:

Current Status:

The imperative requirement of BIM education in CE&M programs has been aptly stressed globally and cannot be ignored. However, in Pakistan, BIM education from academic perspective is quite uncommon. BIM education is lacking in formal and

informal settings. Universities across the country are facing a lack of focus on CE&M skills and education.

BIM education Awareness:

Policy Statement:

The PEC and universities will make increased efforts to promote awareness about significance of BIM in CE&M education

Strategies to Implement Policy:

Awareness will create by organizing workshops in different AEC universities that produce some audio-visual material. Further, effectively engage with academia and industry and set-up a dedicated knowledge center for BIM education and awareness on PEC website.

Introduction of BIM in Curriculum structures

Policy Statement:

The HEC will include BIM Education in CE&M curriculum of all government owned as well as private universities.

Strategies to Implement Policy:

Education expert committee will be formed which can formulate detail clear guidelines for introduction of BIM in curriculum structures. Further, provision of some incentive to those AEC universities who integrate lasted ICT based knowledge according to local and integrate construction industry demands.

Curriculum Law Enforcement:

Policy Statement:

The HEC will ensure appropriate measures to improve the quality of education. It will take appropriate measures to enforce all universities to include BIM contents in their university curriculum according to local and international industry requirements.

Strategies to Implement Policy:

Introducing universities performance evaluations standards and establish a monitoring and evaluation system to ensure continuous improvements. Further, penalty should impose to all those universities who not integrate the latest contents into their AEC programs**.**

BIM Education Faculty Training program

Policy Statement:

The HEC and PEC will include BIM Education to the CE&M curriculum of all government owned universities as well as private universities. Teachers will be given particular training regarding BIM education.

Strategies to Implement Policy:

Professional Competency Enhancement Program for Teachers (PCEPT) will start in all AEC universities and provide some funding to AEC universities in this regard. Further short term foreign faculty hiring program will start and scholarships provide to our local faculty so that they get the latest ICT based knowledge from foreign universities

Collaboration with industry stakeholders

Policy Statement:

The HEC and PEC will collaborate to the construction industry stakeholder and use all possible resource to minimize the gap between the construction industry and academia.

Strategies to Implement Policy:

HEC and PEC should formulate the education expert committee which consists of education expert and industry professionals. This committee will held once meeting in a month and present different solution for this purpose.

Implementation and Coordination Committee:

A committee comprising of representatives from all stakeholders should be constituted as a result of approval of above policies. The main functions of this committee would include preparation of implementation strategy for their respective departments. The committee will also play as coordinator to solve the inter department issues and to ensure smooth data flow. This committee will define the funding mechanism and work towards establishing BIM education training Fund.

The key participants of this committee would include the Director / Deputy Director of education department and CEO of different recognized AEC firms, from all provinces. The committee members will meet to discuss barriers during the integration of BIM in universities and provide some solution for this purpose.

Additional meetings will be conducted on need basis. Director of education department will also act as convener for the meeting

5.3RECOMMENDATIONS FOR FUTURE RESEARCH

Following are recommendations suggested for future research study.

- A research can be conducted to investigate other alternative strategies that can be best fit to integrating BIM in CE&M education.

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APPENDICES

APPENDICE A

ACADEMIA SURVEY FORM

Integration of Building Information Modeling into Construction Management Curriculum: Lesson Learnt From Developed Countries

INTRODUCTION

I am an MS student of Construction Engineering & Management (CE&M) at the School of Civil & Environmental Engineering (SCEE), National University of Sciences & Technology (NUST), Islamabad. As part of my education, a research is being carried out to examine the integration of Building Information Modeling (BIM) in the curriculum of CE&M in engineering universities of Pakistan.

BIM is an emerging technology/process to virtually construct a building prior to its physical construction in order to work out the potential problems as well as simulate and analyze potential impacts.

This questionnaire is designed for AEC (Architecture, Engineering and Construction) related faculty in engineering universities of Pakistan and its aim is to capture the current state of CE&M curriculum with regards to BIM and identify the barriers to integrating BIM into CE&M curriculum.

It'll take around 5 minutes of your precious time. You, being an honorable member of (AEC) faculty in Pakistani engineering universities, are requested to participate in this survey. I would be very grateful for the valuable time you will spend to complete this questionnaire.

Please be reminded that the data will be used STRICTLY for educational purposes and NO personal information will be disclosed at any forum.

Thanks again. Your response is highly appreciated.

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SECTION I: RESPONDENT INFORMATION

NAME OF RESPONDENT:
_____

EMAIL: _____

CONTACT NO (OPTIONAL):_____

DESIGNATION:
_____

QUALIFICATION:

□ Bachelor Degree □ Master Degree (MS/M Phil) □ Doctorate (PhD)

PROFESSIONAL TEACHING EXPERIENCE:

□ Less than 1 year □ 1-3 years □ 3-5 years □ More than 5 years

BIM SOFTWARE EXPERIENCE (Professional/Non-professional):

□ No Experience □ Less than 2 year □ 2-5 years □ More than 5 years

LEVEL OF THEORITICAL KNOWLEDGE OF BIM:
□ Little □ General □ Working □ Expert

SECTION II: UNIVERSITY DETAILS

UNIVERSITY NAME: _____

DEPARTMENT: _____

LOCATION OF UNIVERSITY:

□ Sindh, City _____ □ Punjab, City _____ □ Khyber Pakhtunkhwa, City _____ □Balochistan, City _____ □ Gilgit–Baltistan, City _____ □ Azad Kashmir, City_____

SECTION III: BIM AND UNIVERSITY CURRICULAM

1. **Do you teach or discuss BIM in your AEC (Architecture, Engineering and Construction) curriculum program?**

□Yes □No

If yes*, please proceed to Question 2. If no, please proceed to Question 9*

2. **If yes, then which of the following apply?**

□ Mention of BIM concept in the courses
□ Expect from students to learn BIM skills by themselves
□ BIM specific course included in curriculum
□ Combine BIM concepts into traditional courses
□ Give BIM specific research projects to students
□ Offer BIM in a workshop
□ Other, Please Specify: ----------

3. **In which level you teach or discuss BIM in your AEC curriculum program?**

□ Undergraduate level □ Graduate level □ PhD level

4. **Since how long BIM has become part of the program in your university?**

□ Earlier than 2008 □ 2008-2012 □ 2013-14 □ Not included yet

5. **How many BIM related courses have been included in the AEC curriculum?**

□ 0 □ 1-2 □ 3-5 □ More than 6 □ Don't know

6. **Which BIM software's are currently being used in the AEC (Architecture, Engineering and Construction) curricula at your university?**

□ Autodesk Revit (Arch, Structure, MEP)
□ Autodesk Navisworks
□ Graphisoft ArchiCAD

□ VICO (Constructor)
□ Bentley (Arch, Structure, MEP)
□ Vector Works
□ TEKLA Structures
□ Other, Please Specify: ----------

7. In which of the following areas your BIM courses focus on?

□ Introduction to BIM
□ Product visualization
□ Constructability reviews
□ Model based estimation and cost controls
□ Construction sequencing / 4D Scheduling
□ Cost estimation and control
□ Conflict, interference, and collision detection
□ Facilities management
□ Other, Please Specify: ----------

8. What BIM skills should be developed in CE&M students before they enter into construction industry?

□Drawing reading
□ Cost estimation from drawing
□Software configuration
□System understanding
□Modeling and analysis of model
□Other, Please Specify: ----------

9. As per your knowledge is/are there faculty member(s) researching on BIM at your university?

□ Yes □ No □ Don't know

10. How confident are you in your knowledge and skills of BIM?

□ Confident □ In between □ Not confident

11. Indicate your level of satisfaction with the current status of BIM education within the AEC curriculum in your university?

□ Very Low □ Low □ Medium □ High □ Very High □ Don't know

12. As per your knowledge of other Pakistani engineering universities, indicate your level of satisfaction with the current status of BIM education within their AEC curriculum?

□ Very Low □ Low □ Medium □ High □ Very High □ Don't know

13. **In what time you see BIM completely adopted in the AEC programs?**

□ We currently use BIM
□ In one year's time
□ In three years' time
□ In five years' time
□ Don't know

14. Your level of belief that a class or course on BIM in a university curriculum can be beneficial to CE&M students?

□ Very Low □ Low □ Medium □ High □ Very High □ Don't know

15. **What contents of BIM should be taught to the CE&M students that might fulfill the construction industry requirements?**

□ BIM concept and literature
□ Applications of BIM software for model creation and detailing
□ Applications of BIM software for model analysis and configuration
□ BIM for integrated project delivery
□ Other, Please Specify: ----------

16. **What strategies should be used to integrate BIM into CE&M curriculum in Pakistani engineering universities?**

□ Teach standalone BIM course
□ Incorporate BIM in conventional courses
□ Arrange BIM workshops/presentations
□ Restructure the existing CE&M curriculum to include BIM
□ Expect our students to learn BIM skills by themselves
□ Other, Please Specify: ----------

17. How better the BIM education offered in the Pakistani engineering universities in CE&M programs prepares the students for jobs in the local construction industry?

□ Very Low □ Low □ Medium □ High □ Very High □ Don't know

18. How better the BIM education offered in the Pakistani Engineering universities in CE&M program prepares the students for jobs in the international construction industry?

□ Very Low □ Low □ Medium □ High □ Very High □ Don't know

19. Do you believe the use of BIM in the Pakistani construction industry will continue to increase in coming years?

□ Very Low □ Low □ Medium □ High □ Very High □ Don't know

20. Do you believe the demand of students with BIM knowledge in the AEC industry of Pakistan will increase in coming years?

□ Very Low □ Low □ Medium □ High □ Very High □ Don't know

21. Do you believe the demand of students with BIM knowledge in the international AEC industry will continue to increase in coming years?

□ Very Low □ Low □ Medium □ High □ Very High □ Don't know

SECTION IV: BARRIERS TO INEGRATING BIM IN CE&M CURRICULUM

22. **What are the barriers to integrating BIM into CE&M curriculum in Pakistani engineering universities?**

□ Lack of professional trained BIM faculty
□ Disagreement over BIM concept
□ Inadequate funding
□ Traditional CM program structures
□ Need for strong fundamental knowledge
□ Need for industry involvement
□ Unwillingness to change the existing curriculum
□ Faculty time and resources required to develop a new course
□ Lack of BIM handbooks and other training materials
□ Lack of student demand
□ Professional accreditation issues
□ Other, Please Specify: ----------

Thank You for Your Precious Time and Valuable Input

APPENDICE B

INDUSTRY SURVEY FORM

Integration of Building Information Modeling Into Construction Management Curriculum: Lesson Learnt From Developed Countries

INTRODUCTION

I am an MS student of Construction Engineering & Management (CE&M) at the School of Civil & Environmental Engineering (SCEE), National University of Sciences & Technology (NUST), Islamabad. As part of my education, a research is being carried out to examine the requirements of Pakistani construction industry within the area of Building Information Modeling (BIM) from the CE&M students.

BIM is an emerging technology/process to virtually construct a building prior to its physical construction in order to work out the potential problems as well as simulate and analyze potential impacts.

This questionnaire is designed for AEC (Architecture, Engineering and Construction) related professional of Pakistani construction industry and its aim is to capture the current requirements of Pakistani construction industry from CM students within the area of BIM.

It'll take around 5 minutes of your precious time. You, being an honorable member of (AEC) professional in Pakistani construction industry, are requested to participate in this survey. I would be very grateful for the valuable time you will spend to complete this questionnaire.

Please be reminded that the data will be used STRICTLY for educational purposes and NO personal information will be disclosed at any forum.

Thanks again. Your response is highly appreciated.

For more details, please contact:
Engr. Ali Abbas

MS Construction Engineering & Management,
NIT-SCEE, NUST, Islamabad,
Tel: 92-344-2275433
E-mail: aliabbas.cem5@nit.nust.edu.pk

SECTION I: RESPONDENT INFORMATION

NAME OF RESPONDENT (OPTIONAL):_____

EMAIL: _____

CONTACT NO (OPTIONAL):_____

DESIGNATION: _____

QUALIFICATION:

□ Bachelor Degree □ Master Degree (MS/M Phil) □ Doctorate (PhD)

Profession:

□ Architect / Designer □Engineer / MEP Consultant□General / Specialty Contractors □ Developers / Facility owners

PROFESSIONAL EXPERIENCE:

□ No Experience □ less than 2 years □ 2-5 years □5-10 years □ More than 10 years

SECTION II: FIRM / ORGANIZATION DETAILS

NAME: _____

LOCATION OF FIRM/ORGINIZATION:

□ Sindh, City _____ □ Punjab, City _____ □ Khyber Pakhtunkhwa, City _____ □Balochistan, City _____ □ Gilgit–Baltistan, City _____ □ Azad Kashmir, City_____

Which of the following best describe your organization?

□ Architect □ Consultant/Engineer □ General Contractor □ Trade/Specialist Contractor

□ Design Builder/Project Management □ Other, Please Specify: _____

SECTION III: FIRM / ORGANIZATION EXPOSURE TO BIM

1. **Within your firm, have you adopted BIM for your projects?**

□ Yes, for most projects
□ Yes, for a few projects
□ No

If yes, please proceed to Question 3. If no, please proceed to Question 7

2. **Indicate the BIM application which is currently being used in your firm?**

□ Autodesk Revit Arch, Structure, MEP
□ Autodesk Navisworks
□ Graphisoft ArchiCAD
□ VICO (Constructor)
□ Bentley Arch, Structure, MEP
□ TEKLA Structures
□ Other, Please Specify: ----------

3. **For what purpose you utilize BIM in your firm?**

□ Product Visualization
□ Constructability reviews
□ Model based estimating and cost controls
□ Construction sequencing / 4D Scheduling
□ Conflict, interference, and collision detection
□ Competitors using it
□ Processes improvement and faster documentation
□ Facilities management
□ Due to Client demand
□ Other, Please Specify: ----------

4. **Of the following benefits, which did you achieve (along with the %age) after using BIM application?**

□ Product visualization _____
□ Constructability reviews _____

- □ Faster and more effective processes _____
- □ Improvement in communication between all parties _____
- □ Cost estimating and cost controls _____
- □ Construction sequencing / 4D scheduling _____
- □ Conflict, interference, and collision detection _____
- □ Better production quality _____
- □ Other, Please Specify: _____

5. After using BIM in construction project what success did you achieve?

- □ Identify and resolve design clashes
- □ Decrease the number of RFIs and change orders
- □ Accelerate project schedules
- □ Project completion within budget
- □ Increase in cost estimation accuracy
- □ Enhanced project quality
- □ Enhanced project safety
- □ Improved coordination b/w contractor and consultant & designer

6. Your level of formal education of BIM?

□ Very Low □ Low □ Medium □ High □ Very High

7. Do you think BIM is important for (Architect, Engineering and Construction) AEC industry of Pakistan?

□ Yes □ No □ Don't know

***8.* Do you feel like BIM usage would be a beneficial addition to your company?**

□ Very Low □ Low □ Medium □ High □ Very High

SECTION IV: INDUSTRY REQUIREMENTS

9. Do you believe a class or course on BIM in a university curriculum would be helpful to CE&M students?

□ Very Low □ Low □ Medium □ High □ Very High □ Don't know

***10.* What contents of BIM should be taught to the university students that might fulfill the construction industry requirements?**

□ BIM theory and literature
□ Applications BIM software for model formation and detailing
□ Applications of BIM software for model investigation and configuration
□ BIM for integrated project delivery
□ Don't know
□ Other, Please Specify: ----------

11. What BIM skills you require from CE&M students before you hire them?

□ Drawing reading
□ Cost estimation from drawing
□ Software configuration
□ System understanding
□ Modeling and analysis of model
□ None of the above
□ Other, Please Specify: ----------

***12.* In what time you see BIM completely adopted in your firm?**

□My firm already using BIM □ Less than 1 year □ 1-3 years □ 3-5 years □ More than 5 years □ Never want to see

13. What's your expectation regarding BIM knowledge from the current / future CE&M students?

□ Theoretical knowledge of BIM tools and process
□ Expert skills with BIM software
□ None of the above
□ Other, Please Specify: ----------

14. Do you believe the use of BIM in the Pakistani construction industry will increase in coming five years?

□ Very Low □ Low □ Medium □ High □ Very High □ Don't know

15. Having BIM awareness would make someone a more attractive applicant in your firm?

□ Very Low □ Low □ Medium □ High □ Very High □ Don't know

SECTION IV: BARRIERS TO INEGRATING BIM IN CONSTRUCTION INDUSTRY

16. What are the main barriers for the integration of BIM into Pakistani construction industry?

- Traditional contract system
- Lack of BIM skills personnel
- BIM requires advanced IT equipment
- Inadequate top management support to adopt BIM
- Not all stakeholders are using BIM
- High cost of BIM implementation
- BIM is a complex methodology to understand
- Client does not demand
- Unwillingness to change the traditional way
- Don't see its benefit
- Significant changes in workflow, roles and responsibilities
- Lack of its standardized tools
- Other, Please Specify: ----------

Thank You for Your Precious Time and Valuable Input

APPENDICE C

US EXPERTS FEEDBACK COLLECTION SURVEY FORM

Integration of BIM in construction management curriculum: BIM course development for postgraduate students

Dear Respondent,

The team of Construction Engineering & Management (CE&M) at, National University of Sciences & Technology (NUST), Islamabad, Pakistan is trying to incorporate Building Information Modeling (BIM) in construction management education. With an international scope, we are currently trying to develop a postgraduate level BIM curriculum for (CE&M) students which can fulfill the latest international construction industry requirements.

The objectives of this course are to enable the students to understand and implement Building Information Modeling (BIM) in construction management framework. It will also enable students to creatively think of construction related problems and arrive at solutions of complex and risk prone projects by using the state of the art nD technology available in form of BIM applications.

It will take around 10 minutes of your precious time. You, being an accomplished professional of Architecture, Engineering and Construction (AEC) in US, are requested to participate in this survey. Our team will be very grateful for the valuable time you will spend to complete this survey.

Please be reminded that the survey findings will be used STRICTLY for educational purposes and NO personal information will be disclosed at any forum.

Thanks again. Your response is highly appreciated.

For more details, please contact:
Engr. Ali Abbas
NIT-SCEE, NUST, Islamabad
E-mail: E-mail: aliabbas.cem5@nit.nust.edu.pk

Organization / Individual Introduction

Name *

Please state your name: _____

Your organization *

Please state the name of your organization: _____

Experience *

Please state your experience relating BIM (Years): _____

Position/Designation *: _____

BIM CE&M CURRICULUM

1. Course Contents of proposed BIM curriculum *

Please prioritize the course content according to relevance for construction management studies. 1 is the highest assignable priority and 9 is lowest assignable priority.

	1	2	3	4	5	6	7	8	9
BIM introduction	○	○	○	○	○	○	○	○	○
BIM and integrated project delivery system	○	○	○	○	○	○	○	○	○
Preparation of BIM implementation plan	○	○	○	○	○	○	○	○	○
BIM based project visualization and constructability review	○	○	○	○	○	○	○	○	○
BIM based cost estimation	○	○	○	○	○	○	○	○	○

	1	2	3	4	5	6	7	8	9
(5D) and Scheduling (4D)									
BIM based conflict, interference, and collision detection	○	○	○	○	○	○	○	○	○
BIM based site logistics and communication	○	○	○	○	○	○	○	○	○
Basics of BIM and sustainability (Energy Modeling)	○	○	○	○	○	○	○	○	○
BIM based facility management	○	○	○	○	○	○	○	○	○

Any comments / suggestions regarding the course contents:

_____
_____
_____
_____

2. Required Software for CE&M student *

Please indicate the BIM applications which should be included in CE&M curriculum

☐ Autodesk Revit

☐ Autodesk Navisworks Manage

☐ Google SketchUp

☐ Ecotect

☐ Autodesk QTO

☐ Autodesk 3D

☐ Grahisoft ArchiCAD

☐ Other

Any comments / suggestions regarding the softwares:

_____
_____
_____
_____

3. Term Project

The following term project is proposed for CE&M students to increase their knowledge relating BIM. Please state your agreement about such an arrangement. * Preparing a Bid proposal of any given project while using Autodesk's Revit , Naviswork Manage and other relevant softwares. It may include 3D modeling, cost estimation, constructability analysis and energy analysis of given project.

	1	2	3	4	5	
1 (agree)	○	○	○	○	○	5 (disagree)

Any comments / suggestions regarding the term project:

_____
_____
_____
_____

4. Term Project LEARNING OUTCOMES

Please state your agreement about the learning outcomes of BIM related course. * Major learning outcomes of this course is that, CE&M students can understand the concept and functions of BIM and its tools including understanding of basic BIM

knowledge in construction management framework; understanding roles and responsibilities of AEC stakeholders in the BIM process; developing architectural, structural and MEP BIM models; performing analyses such as clash detection, energy analysis, quantity take off and 4D scheduling using BIM tools

	1	2	3	4	5	
(Agree)	○	○	○	○	○	Disagree)

Any comments / suggestions regarding the learning outcomes of this course:
_____
_____
_____
_____

5. Teaching Methodology *

Please prioritize the teaching methodology to be used in BIM course. 1 is the highest assignable priority and 6 is lowest assignable priority.

	1	2	3	4	5	6
Lectures	○	○	○	○	○	○
Guest speaker	○	○	○	○	○	○
Video session / Discussion sessions	○	○	○	○	○	○
Workshops	○	○	○	○	○	○
Visit of AEC industry	○	○	○	○	○	○
Case Studies	○	○	○	○	○	○

Any comments / suggestions for improvement in teaching methodology of BIM course as stated above**:**

_____
_____
_____
_____

6. Examinations and Assessments *

Please assign weights so that the cumulative weight is 100

	10	20	30	40	50	60	70	80	90	100
Quiz/s	○	○	○	○	○	○	○	○	○	○
Term project/s	○	○	○	○	○	○	○	○	○	○
Mid term exam/s	○	○	○	○	○	○	○	○	○	○
Final exam/s	○	○	○	○	○	○	○	○	○	○

7. Relevant Library *

Please prioritize BIM related books that you find relevant for CE&M course.1 is the highest assignable priority and 4 is lowest assignable priority.

	1	2	3	4
BIM and Construction Management: Proven Tools, Methods, and Workflows (Brad Hardin)	○	○	○	○
BIM Handbook: A Guide to	○	○	○	○

	1	2	3	4
Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors (Eastman et. al.)				
Design Integration Using Autodesk Revit 2014 (Daniel)				
Building Information Modeling: BIM in Current and Future Practice (Kensek and Noble, 2014)				

Any suggestions and comments regarding BIM relevant books:

_____
_____
_____
_____

8. Comments and Suggestions

Please provide your recommendations in regards of BIM curriculum components proposed for Construction Management studies:

_____
_____
_____

APPENDICE D

US BIM Expert's Comments Regarding BIM Curriculum

Expert	University	Designation	Academic BIM Experience in years	Comments
Expert 1	Purdue University	Associate Professor	15	• Include site logistics as well as scheduling in term project. • Introduce other software including Autodesk QTO, Bluebeam. • Workshops, site visits and guest speakers on case studies help students the most with BIM.
Expert 2	Auburn University	Associate Professor	8	• Lab hours should be more than lecture hours (BIM course work). • Include brief details about term project.
Expert 3	Georgia Institute of Tech.	Assistant Professor	4	• Term project should be 50 marks. • Autodesk Revit, Autodesk Navisworks Manage should be included in CE&M curriculum.
Expert 4	Arizona State University	Research Associate	4	• Course is useful. However, more time is required for teaching BIM applications. • This course should be such that it has one contact hour for lectures and 3-4 contact hours for lab work. • Include the preparation of BIM implementation plan as course content.
Expert 5	Georgia Institute of Tech.	Research Associate	2	• The basic concept of BIM is the most important thing, which should come from the book, literature view and lectures by researchers. • The second important thing is to learn the challenges and current practice in industry, such as concept of IPD. • The last thing is to learn how to use some BIM software and this is actually the easiest thing to learn, compared with the former two content.