BUILDING INFORMATION MODELING (BIM): ADVANTAGES, RISKS AND APPLICATIONS ASSOCIATED WITH ITS ADOPTION IN ARCHITECTURE, ENGINEERING AND CONSTRUCTION (AEC) INDUSTRY OF PAKISTAN

by

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(2010 – NUST – MS – CE&M –09)

A thesis submitted in partial fulfillment of
the requirements for the degree of

Master of Science
in
Construction Engineering & Management

Department of Construction Engineering & Management
National Institute of Transportation
School of Civil & Environmental Engineering
National University of Sciences & Technology
Islamabad, Pakistan

(2012)

This is to certify that the
thesis titled

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submitted by

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has been accepted towards the partial fulfillment
of the requirements for the degree
of
Master of Science in Construction Engineering & Management

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DEDICATED

TO

MY DECEASED GRAND FATHER

(RAI NAZAR MUHAMMAD KHARAL)

ACKNOWLEDGEMENTS

I am thankful to Almighty Allah, who gave me strength to complete my research. I would like to pay debt of gratitude to my advisor Dr. Muhammad Babar Khan, for his fathomless guidance, valuable time and encouragement, to complete my research work. I am also extremely grateful to the committee members, Dr. Muhammad Rafiq Muhammad Choudhry, Dr. Hamza Farooq Gabriel, Engr. Mansoor A. Malik, Engr. Zia Ud Din and Engr. Mateen Mazher for their sincere guidance to complete my research work. I owe my special thanks to the Dr. Salman Azhar, Dr. Faisal Arian and Engr. Muhammad Tariq (a Ph.D. scholar in the field of BIM) for their support and guidance to complete my thesis work. In the end, I pay my earnest gratitude with sincere sense of respect to my father, mother, uncle Riaz and all family members for their unending support, encouragement, prayers and patience.

ABSTRACT

Building Information Modeling (BIM) has gained attention in the Architectural, Engineering and Construction (AEC) industry. BIM envisage the use of virtual n-dimensional (n-D) models generated in computers to simulate the design, construction, planning and operation of a facility. It allows the engineers, architects and constructors to visualize what is to be built in virtual environment and to identify potential conflicts in design, construction or operational of the facility. Along-with many advantages there are certain barriers associated with BIM adoption which hinders the implementation of BIM in AEC industry. This research aims to rank the advantages, barriers and potential fields of application of BIM in AEC industry of Pakistan.

This research quantifies the difference in perception of AEC professionals regarding the advantages, risks and potential applications of BIM. Furthermore, the research will bench mark the current state of BIM adoption and also predicts the future of BIM in Pakistan. The study is undertaken via a questionnaire based survey comprising of 7 advantages, 12 barriers and 12 application of BIM. A pilot study was conducted that involved three local architects, two academia professionals, one contractor and one engineering consultant to establish the adequacy and appropriateness of the identified advantages, risks and potential applications. The questionnaire was modified based on the results of the pilot study and an open ended question requiring suggestions for making BIM popular in Pakistan was incorporated. Data collected from 102 respondents, (that includes architects, engineering consultants, contractors, sub contractors / suppliers, research and development professionals) form 50 organizations varying from small to very large in size and working across the Pakistan and is analyzed using SPSS.

Analysis of data collected from 102 AEC professionals showed that the current state of BIM adoption is very low, i.e., 73% organizations have neither adopted BIM nor involved in BIM adoption process in any capacity. Furthermore, 39% respondents consider the there is very low level of “Buzz” about BIM is present in AEC industry of Pakistan and 22% consider no “Buzz” about BIM. BIM is a faster and more effective method for designing and construction management, it improves quality of the design and construction and it reduces rework during construction are the top thee advantages according to the perception of AEC professionals of Pakistan. BIM has least impact on reduction of cost, time and human resources. Sub-consultants are unaware of BIM, lack

of knowledgeable and experienced partners and lack of institutional education are top three barriers in BIM adoption in Pakistani environment. Respondents of this survey consider that technology advancement in the form of BIM is necessary to optimize the performance of the industry. AEC professionals' faces a lot of problems related to clash detection and inter services coordination; therefore, they ranked 3D coordination as the best application of BIM for Pakistani industry. Lighting analysis and 4D scheduling are ranked at second and third position amongst the potential application of BIM. Use of BIM in prefabrication is ranked least amongst the listed application of BIM. AEC professionals want to learn BIM and 96% among them are in favour of implementing BIM in AEC industry of Pakistan. Therefore, they suggested to spread BIM awareness by conducting seminars, workshops and training sessions. BIM shall be included in the courses of architectural engineering, civil engineering and architecture. Clients can make their part by including BIM in contract documents.

The survey results concluded that the AEC professionals of Pakistan have an instinct to shift to BIM because they consider current technology is not enough to tackle the problem in the area of 3D coordination, lighting analysis and 4D simulation scheduling. BIM adoption will help improve the quality of work, reduces rework during construction. Furthermore, it is a faster and more effective method for designing and for construction planning, scheduling and simulation. BIM is a relative popular approach within the architects but sub-consultants are unaware about BIM due to lack of experienced partners and lack of institutional education that results in low rate of BIM adoption in Pakistan.

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LIST OF ACRONYMS

AEC	Architecture, Engineering and Construction
BIM	Building Information Modeling
CAD	Computer aided design
GSA	General Services administration, America
HEC	Higher Education Commission
IAP	Institute of Architects Pakistan
IBC	Institute for BIM in Canada
IPD	Integrated Project Delivery
MEP	Mechanical, Electrical and Plumbing
PCATP	Pakistan Council of Architects and Town Planners
PEC	Pakistan Engineering Council
P & D	Planning and Development
R & D	Research and Development
RFI	Request for information
RII	Relative Importance Index
SPSS	Statistical Package for Social Sciences
VDC	Virtual design and construction

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Chapter 1

INTRODUCTION

1.1 STUDY BACKGROUND

The architecture, engineering and construction (AEC) industry is experiencing a ongoing decrease in its productivity of construction labour since the early 1960s. Meanwhile, the process industries such as the manufacturing industry have raised their labor productivity. The decline of labor productivity in the AEC industry requires more labor hours per contractual dollar amount. This indicates that AEC industry is deficient of development for labor economy ideas. Figure 1.1 depicts the gap between the process and AEC industry labor productivity.

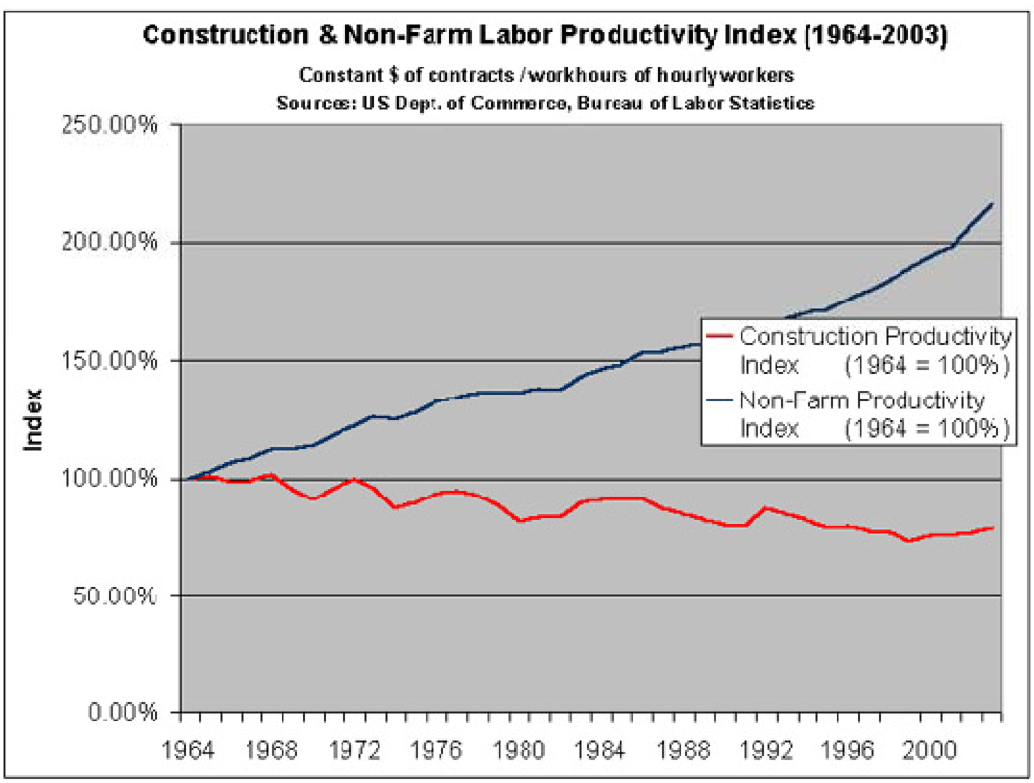

Figure 1.1: AEC and Process Industry Labor Productivity Index (Teicholz, 2004)

The main causes of the decrease in labor productivity in the AEC industry are related to

- The fragmented nature of AEC industry due to traditional project delivery methods,
- Use of traditional 2D Computer Aided Drafting (CAD) technology and
- The size of AEC firms (Teicholz, 2004).

At first, the traditional project delivery approach for construction projects, Design-Bid-Build, fragments the functions of stakeholders during design and construction phases. In other words, it hinders the joint involvement of the construction contractor or the project manager throughout conceptual and designing of the building. Secondly, use of general and conventional two dimensional CAD drawings does not support a true collaborative approach. Architects and engineering consultants produce their own fragmented CAD design drawings / documents to relay theirs designs to owners and contractors. These drawings are not integrated and usually pose clash of information which result in inadequacy in labor productivity. The estimators need to calculate and produce their own quantity take offs based on the CAD documents produced by consultants. Moreover, the 2D CAD approach does not endorse the integration of the drawings with schedule and cost. Lastly, due to unpredictable demand and unique site requirements the construction companies are very small specialized and regional firms.

Furthermore, the workers of AEC industry on the average are paid lower wages than the process industry. Therefore, firms do not have as much of an incentive or the resources to invest money in research and development of technology because of its high risks and costs. When the advance methods and technologies are used, they are applied per project basis and are not adapted quickly in the construction industry.

One of the first steps towards the use of 3D technology in the construction industry was initiated as a 3D solid modeling in late 1970s. During this time, manufacturing industry carried out product design, analysis, and simulation of 3D products. Three dimensional modeling in the construction industry was hindered “by the cost of computing power and later by the successful widespread adoption of CAD” (Eastman, 2008). The process industry realized, spent more capital in technology and seized the “potential benefits of integrated analysis capabilities, reduction of errors, and the move toward factory automation”. They worked jointly with modeling tool providers to trim down and eliminate the technological software hinders.

AEC industry has recognized the basis of object-oriented building modeling in 1990s. Initially, certain market sectors such as prefabricated structural steel employed the parametric 3D modeling. Now, a variety of BIM tools became readily accessible throughout the AEC industry. This is a reward of AEC industry's commitment to Building Information Modeling (BIM) for the last 20 years (Eastman, 2008). AEC industry has come to a position to realize the true advantages of technological advancement. The labor effectiveness gap can be closed via the Building Information Modeling processes.

The intent of this research to study BIM and to establish benefits, risks and potential applications of BIM particularly for AEC industry of Pakistan, as AEC industry of Pakistan is also in front of analogous problems even with more intensity like design and construction coordination, construction of 3D building with 2D drawings, clash detection, lake of experienced BIM professionals and coordination of architectural drawings with engineering drawings. In this research, the benefits, risks and potential applications of BIM are discussed and analyzed in detail to help the industry to recognize the advantages, problems and constraints of BIM adoption. The research concluded that although BIM tools do pose some shortcomings such as sub consultants are unaware of BIM however use of BIM can still be very beneficial to the owners, consultants, contractors, construction managers and suppliers / fabricators, as BIM supports collaborative efforts from all stakeholders to reduce the overall input of each individual stakeholder and also to optimize design and construction processes. AEC professionals of Pakistan, who have adopted BIM, have suggested some ways to improve BIM adoption rate in AEC industry like inclusion of BIM as a subject in graduation and master degrees in architecture and civil engineering.

1.2 OVERVIEW OF BIM PROCESS

Primarily, the Building Information Model is a three dimensional digital demonstration of a building with its intrinsic components and characteristics. It is made of intelligent building components which comprises of data attributes and parametric rules for each object. For example, a window of certain material and dimension is parametrically associated and hosted by a wall. Moreover, BIM offers consistent and coordinated views and demonstration of the digital model together with reliable data for each view. This reduces a lot of designer's time as each view is coordinated through the built-in intelligence of the BIM model. According to the National BIM Standard, Building Information Model is “a computerized representation of physical and functional characteristics of a building and a shared knowledge resource for data about a facility forming a reliable basis for decisions during the project life-cycle; defined as existing from earliest conception to demolition” ("About the National BIM Standard-United States", 2010).

Building Information Modeling (BIM) is the process and practice of virtual design and construction (VDC) through its entire lifecycle. It is a platform to share knowledge, data and communicate between project participants. In other words, Building Information Modeling is the process of developing the Building Information Model.

High quality 3D rendered images of a building can be generated from Building Information Models. If the contractor only uses the model to better communicate the BIM concept in 3D and does not further use the built-up information in the Building information Model, then this is called as “Hollywood” BIM. Contractors might use the “Hollywood” BIM to win contracts. However, they do not confiscate the full possible value of Building Information Modeling.

BIM software offers many advantages for general building design. State-of-the-art BIM software uses a centralized, parametric model—where all the plans and sections, the quantity takeoffs, and other related documentation are “live” views of the model and are digitally coordinated by the software. This integrated set of deliverables has an unambiguous connection to each other and to the model, resulting in improved coordinated construction documents that reduce errors and omissions (Robert E Middlebrooks, 2006)

1.3 RESEARCH OBJECTIVES

The main objectives of the research study are;

a. To look at the current state of BIM adoption in Pakistan.
b. To study, explore and rank the advantages, risks and applications associated with the adoption of BIM.
c. To compare the perception of different stake holders of AEC industry of Pakistan about the adoption of BIM.
d. To predict the future of BIM in Pakistan.

1.4 SCOPE OF RESEARCH

The scope of this study is limited to AEC industry of Pakistan and mainly covers the perception of key stakeholders i.e. clients, consultants, contractors, subcontractors and suppliers / fabricators about advantages, risks and potential application associated with the adoption of BIM. An effort has been made to include as many types of project stakeholders as possible in the survey. Data is collected through questionnaire based survey form 102 respondents belonging from 50 organizations, working across the Pakistan. The major limitation being faced is the lack of research in this area and non availability of BIM experienced professionals.

1.5 ORGANIZATION OF THESIS

The thesis is prearranged into five chapters with chapter 1 covering problem statement, introduction to BIM, scope and objectives of the research and chapter 2 wrappers literature review of BIM, its advantages that have been explored in other parts of the world, bottle necks that can be faced during the BIM adoption process and also introduces with the potential application. Chapter 2 also presents the efforts, which previously have been made, to in the field of BIM. Chapter 3 exposes the reader to the methodology used in the research including information about the statistical test used in the research to achieve the objectives. Chapter 4 depicts the data gathering processes, data analysis and the results archived. The final chapter 5 presents the conclusions inferred from results of data analysis and it also recommends a route to make BIM popular in Pakistan.

Chapter 2

LITERATURE REVIEW

2.1 BACKGROUND

In 1974 a paper was presented by Chuck Eastman (now professor at Georgia Institute of Technology) and five other authors. It explained problems with the principal means of communications in the building design and construction process; those means were drawings, including notes and specifications. Some of the problems they pointed out were:

- 2D drawings are basically redundant, because to illustrate a three dimensional room with two dimensional drawings you need at least two drawings, thus shows one dimension twice. 2D drawings are also redundant in the aspect that many items are presented on different drawings at different scale. All this means that design change in any of drawing will lead to changes in a whole set of drawings.
- Large efforts are required to keep design up-to-date. But even with a large effort there is a great chance that information somewhere is obsolete or non-consistent. This might result in designers making judgment on faulty information.
- Information required for analysis of the construction must be taken manually from the drawings. This is labor rigorous.

They proposed a solution to this problem that was to construct a computer system that could store and control design information at great detail allowing design, constructional, and operational analysis. This computer system was called Building Description System, (BDS). (Eastman et. al 1974).

Now, the problems identified by Eastman et al more than 38 years ago still exist may be to a minor degree but they are still very much a part of the building process; it is disjointed and communication is mainly done by paper - and errors in these paper documents often delays the process and we have to incur unanticipated field cost (Eastman et al). And even more and today's solutions to these problems look a lot like the solutions designed by Eastman et al, regardless if it is presented as Virtual Design and Construction (VDC), Integrated Project Delivery (IPD), or Building Information Modeling (BIM). However, over the past years BIM has become the best choice for many institutions and departments (GSA, AIA, NIBS, (Bell et al 2007)), as well as for the major developers of modeling software (Autodesk, Tekla, Bentley).

Even if the concept, or a concept similar to BIM, was presented 35 years ago it never really took off in the AEC industry. Instead of taking up computer modeling in similar ways as the aeronautical industry – which used it for design, tests and optimizations, the AEC industry opted to more or less just to digitize 2D drawings. However, this is about to change. As of late some major institutions and big owners, e.g. the GSA (USA) and Senate Properties (Finland), have started to specify the use of BIM when they procure the services for construction and design (Bell et al 2007).It is said that BIM will have a most important impact in the AEC industry, and many of the problems being faced by the industry will be solved b adoption of BIM, among others it is said that:

- With BIM you will be able to create drawings of any set of objects at any time in the project directly from the model thus greatly reducing time spent on generating drawings manually. You will be able to do cost estimation and quantity take offs promptly and easily.
- The model will make easy the work of detecting clashes before mobilization into the construction phase.
- Impact of proposed design changes will be shown in the model directly and automatically on other parts of the structure.
- Lean production methods will be more simply implemented since they require careful harmonization which BIM facilitates.

In the 21st century, every development in technology has been achieved with progress in computer science. The result of each development is to provide more information to achieve objectives easily. This technical evolution is also depicted in the Architecture, Engineering, and Construction (AEC) Industry. In the past 10 years, design tools in the AEC industry have been enhanced from 2D modeling to 3D modeling. Today, some software companies like Autodesk claim that they have developed new design software based on the concept of BIM (Han Yan and Peter Damian, 2007).

2.2 DEFINITIONS OF BIM FROM LITERATURE

Building Information Modeling (BIM) stands for the process of development and implementation of a computer generated model to integrate the planning, design, construction and operation of a facility. The resulting Building Information Model is a data-rich, intelligent, object-oriented and parametric digital representation of the building, from which drawings and data appropriate to various users' needs can be extorted and analyzed to produce information that can be used in decisions making and to improve the project delivery process (AGC, 2005).

A building information model portrays the geometry, geographic information spatial relationships, quantities and characteristics of building elements, material inventories, cost estimates and schedule of performance. This model can be used to express the entire building life cycle (Bazjanac, 2006). As a result, quantities and shared properties of materials can be easily extracted. Scopes of work can be easily isolated and defined. Systems, sequences and assemblies can be shown in a relative scale with the whole facility or group of facilities. The construction documents such as the drawings, submittal processes, procurement details and other specifications can be easily interrelated (Khemlani et al., 2006).

The principal difference among BIM and 2D CAD is that the latter explains a building by isolated 2D views such as plans, sections and elevations. Variation in one of these views requires that all other views must also be checked and updated accordingly, an error-prone process that is one of the major causes of poor documentation. In addition, data in these 2D drawings comprise of graphical entities only, such as lines, arcs and circles, in contrast to the intelligent background semantic of BIM models, where objects are defined in terms of building elements and systems such as spaces, walls, beams and columns (CRC Construction Innovation, 2007).

A BIM model carries all required information related to the building, including its aesthetic and functional propertiess and project life cycle information, in a combination of “smart objects”. For example, an air conditioning unit within a BIM would also contain data related to its supplier, operation and maintenance procedures, flow rates and clearance requirements (CRC Construction Innovation, 2007).

BIM processes are for development and use of computer generated n-dimensional (n-D) models to simulate the planning, design, construction and operation of a facility. It is helpful for architects, engineers and constructors to visualize what is to be built in virtual environment and to identify potential design, construction or operational clashes and problems (Slaman Azhar at el, 2007).

Mortenson (M. A. Mortenson Company) consider VDC “an intelligent simulation of architecture,” it has to display 6 important features (Campbell, 2007).

1. 3 Dimensional representation, to enhance representation of complex structure conditions than 2 Dimensional design Drawings.
2. Automation – simulating of design and construction.
3. Computable – one can utilize BIM information, because BIM model is dimension-able, quantifiable and query-able, something more than illustration.
4. Accessible – data made accessible to the whole project team through interoperable and instinctive interface, including architects, engineers, contractors, fabricators, owners, facility maintenance, and users.
5. Durable – data that depicts as-built conditions and remains serviceable through all phases of a facility’s life, including design and planning, fabrication and construction, and operations and maintenance.
6. Comprehensive – summarizing and communicating design intent, constructability, building performance, and sequential and financial aspects of construction and design means and methods.

The Building Information Model is a three dimensional digital representation of a building and its inherent characteristics. It is made of intelligent building parts which includes data attributes and parametric rules for each object. For instance, a door of certain material and dimension is parametrically linked and hosted by a wall. Furthermore, BIM provides reliable and coordinated views and representations of the digital model including reliable data for each view. This saves a lot of designer’s time since each view is coordinated through the built-in intelligence of the model. According to the National BIM Standard, Building Information Model is “a digital representation of physical and functional characteristics of a facility and 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” ("About the National BIM Standard-United States", 2010).

BIM is an integrated process which is used to ease the exchange of design and construction data to project stakeholders. It is the act of gathering and of using dependable, reliable and sufficient information to support any desired activity along the construction lifecycle. The modeling process is built upon the demonstration of this information in digital formats, which support the exchange of data in an instantly recognizable and reusable fashion by construction practitioners (IBC, 2011)

2.3 ADVANTAGES OF BIM

The advantages of design building by using BIM processes are considered self evident by many who consider that the only way to ensure that all the drawings of a building were geometrically consistent was to extracted them directly from a virtual three-dimensional model. (Hernandez, 97) (Peltz, 97) In addition, it is considered that, since architects are in the business of designing and visualizing three-dimensional environments, the three-dimensional model was a more suitable design medium than two-dimensional drawings. Indeed, the three-dimensional model would ultimately become the construction documentation.

2.3.1 Reduce Construction Cost

According to AIA (2007), BIM reduces Construction Cost (Bottom Line Benefit).

- Provide analysis of variations
- Improved material pricing
- Reduction in RFIs
- Increase Construction speed
- Analysis Value Engineering Impacts

On the Camino Project (a project where BIM model was used), the MEP subs have reduced their cost downwards in finalizing their contracts due to the increased productivity that has resulted from a highly accurate bill of materials generated using BIM model and increased pre-fabrication on the project. We believe that this has resulted in a much improved cost control for the subs performing the work on the project. On the Sequus Project, cost control was a key distress for the owner. Typical cost escalation on projects of this complexity range from 2% - 10%, with 2% considered extremely doing well, according to the Sequus project manager. The cost escalation on the Sequus Project averaged 1% for the MEP subcontractors, which was typically due to owner initiated design modifications (Sheryl Staub & Atul Khanzode, 2007).

2.3.2 Reduce Construction Time

Use of BIM reduces construction time due to improvement of following processes and applications.

- Improves preconstruction planning
- Improves construction scheduling
- Improves project design coordination
- Improves construction quality (BIM Handbook by Kymmell W.)

2.3.3 Improve Quality

BIM advances the quality of the building project by optimizing project life cycle costs.

- Design: Optimize Space, Equipment Size, Energy Consumption
- Construction: Optimize Cost, Schedule
- Facilities Management: Optimize building operation (AIA, 2007)

BIM creates design of better quality as project proposals can be thoroughly analyzed, simulations can be done quickly and performance benchmarked, enabling improved and creative solutions (Salman Azhar at el, 2008).

2.3.4 Reduce Human Resource

According to Yan, H., and Damien, P., in the operation phase, Building Information Modeling generates obtainable concurrent information before and during performance of the project; and the economic aspects of the project. BIM leaves a digital document trail consequential from transformations and developments during operation. An Autodesk publication claims that: “BIM speeds up the adaptation of standard building prototypes to site business conditions, such as retail, that require the building of similar buildings in many different sites.” From the questionnaire, most BIM users believe that BIM can reduce human resource during the entire operation phase (Yan, H., and Damien, P., 2008).

2.3.5 Reduce Contingencies

BIM will curtail change orders, rework during construction and design coordination issues, and will also decrease the initial project cost. Hence, contractors will sharpen their pencils and will offer pricing per known factors, the number of unknowns, pricing for contingencies and site coordination efforts are reduced (Patrick C. Suermann and Raja R.A. Issa, 2009).

2.3.6 Faster & More Effective method

BIM processes are faster and more effective processes because information is and data can be shared more easily, can be value-added and it can also be reused (Azhar, S. at el, 2008).

2.3.7 Reduce Rework during Construction

The MEP design management and coordination processes eradicate most of the design conflicts prior to commencement of construction. Typically, many clashes / conflicts go undetected until they come upon during installation, often resulting in costly rework. On the Sequus Project (a project where BIM model was used), the only rework that was required happened between trades that did not model their scope of work in 3D. In fact, the superintendent for the civil contractor noted the "seamless" installation process for the 3D work. On the Camino project (another project where BIM model was used), after 250,000 square feet had been erected, there was not a single field conflict throughout the installation of the MEP work. According to the Superintendent, he has never experienced this level of correctness of field installation before in his 35 years of experience and estimates that he is spending much less time resolving field issues compared to previous projects. He estimates that on previous projects he used to spend 2 to 3 hours per day for with these issues, and on Camino he has spent a total of 10-15 hours over a period eight month after the MEP installation began (Sheryl Staub & Atul Khanzode, 2007).

2.4 BARRIERS IN ADOPTION OF BIM

The following are the barriers, which AEC industries in the other parts of the word are facing. These barriers hinder the professionals to adopt BIM process for design and construction.

2.4.1 Lack of Experienced Partners

According to BIM handbook by Kymmell W., (year) Projects are built by people. Research into successful projects has shown that there are several significant keys to success:

1. A knowledgeable, dependable, and decisive project owner/developer;
2. A team with appropriate experience and chemistry assembled as early as possible, but certainly before 25% of the project design is complete; and
3. A contract that supports and rewards firms for behaving as a team.

These three points do appear like common sense when they are applied to a sport team or a music band; but it seems far-fetched to apply this to the AEC industry. The existing system is strongly embedded in the history of the professions, and nothing short of a civilizing or psychological revolution will likely change this in a noteworthy way. Necessity, however, is forcing the AEC industry into this direction, and it will behoove all the players on a team to recognize that they are part of a team and learn to behave consequently. Coordinated and collaborating project teams will be a requirement for survival in the industry in the not too distant future.

2.4.2 Views regarding Current Technology

Computers have transformed the way documents are generated. Similarly, information technology is bound to reform the way people exchange information and documents. Information technology (IT) is defined as “the use of electronic machinery and programs for the processing, storage, transfer and presentation of information”. IT includes many technologies such as computers, software, networks and even telephones and fax machines. The purpose of IT is to make easy the exchange and management of information and has a lot of potentials for the information process component of the AEC industry. These recent technologies will certainly have a profound impact on how organizations operate on a daily basis (Rivards H, 2000).

The major difference between BIM and conventional 3D CAD is that the latter explains a building by independent 3D views such as plans, sections and elevations. Editing one of these views requires that all other views must be checked and updated, an error-prone process that is one of the major causes of poor documentation. In addition, data in these 3D drawings are graphical entities only, such as lines, arcs and circles, in contrast to the intelligent contextual semantic of BIM models, where objects are defined in terms of building elements and systems such as spaces, walls, beams and columns (Azhar at el, 2008).

2.4.3 Cost of Implementing BIM

As a universal rule, No one generally wants to start over, because it seems like a waste of time and effort (BIM Handbook by Kymmell W.). This research will find out, is this a reason for not adoption of BIM in Pakistan.

According to McGraw Construction, smart market report, cost of implementation include

- BIM training
- New / upgraded of hardware
- Develop collaborative BIM process with external links
- Developing custom 3D libraries

2.4.4 Limited adoption in our Industry

BIM adoption is limited in AEC, due to following factors

- Lack of information
- Resistance to change
- Up front cost
- Interoperability (Pike Research, 2012)

2.4.5 Direct Advantages are not for Designer

The reward a client and a contractor attain from BIM can easily be accepted. Application of BIM model permits for lesser design mistakes, lesser construction mistakes, design optimization, and lesser design integration problems which eventually lead to less clashes and claims. At finishing point of the building, the client can utlize as-built BIM model for facility management. On other hand, the monetary advantages of BIM are less instantaneous for the designing consultants. BIM essentially produces noteworthy realistic obstacles to the design professionals. We can say that the consultants should switch to advance tools, provide training to peoples, and title holder the use of BIM to be spirited in relevant designing department. On the whole, it is evident that no monetary advantages are present for the designers so they have less motivation to entirely switch to BIM tools, as it may increase their possible professional liability. Only for the reason that they can get huge information from the BIM model, it may not essentially mean that designers will be satisfied for the information. The designing consultants are presently encountering unbalanced rewards for BIM (too much liability without any return) (Leon L. Foster, 2008).

2.4.6 Need for BIM Specific Contract Documents

The requirement of customary contract and bidding documents to tackle BIM is hindering its adoption. BIM specific contract and bidding documents carry out following three purposes: firstly, supplies arrangement for project; secondly set up agreement allowance of responsibilities and an incorporated affiliation among risks assumed, dispute resolution, and indemnity; and thirdly decrease manual input in certifying the risks, duties and liabilities of the stakeholders involved in the project. As design liability insurances do not obstruct a joint BIM atmosphere, industry standard agreements appear to do so. Present standard contracts visibly divide, identify, and assign roles and liabilities between project parties. Present contracts stands on a legal system that distinguishes designer, as a consultant, and civil works, as a legal, contractual and agreement compulsion. Typical contracts imagine the incorporation of designing data into tools of consultancy. These are provided to the owner for use by the contractor. Owner is required to stand for the sufficiency of the documents. More and more data is swapped by electronic means, however the distinction between consultants and contractors continues. Althrough the electronic exchange of consultancy data, the “hard copy” is pointed to as the scheming data. For a “joint information and joint risk” condition, this present conduct is seen as useless and deficient. While BIM conduct paying attention on utilizing BIM tools by a combined panel, the capability to depend upon the data restricted in the BIM library is necessary. Contracts lacking information on the allocation of liability and the aptitude to depend upon the common catalog cannot be applied for project to promote BIM adoption. With the development of BIM adoption, legal and contractual advancement is also required to fix due and collective liability for the gang of design data, permit justified dependence on the data, allocate the liability of sharing, revising and finalizing the information, and sharing profit according to the liability of information provided into BIM model. Several essential required for successful delivery of project change with the adoption of BIM. It will take time to develop Contracts that allocate risk, responsibility and profit according to input required from each of the stakeholder. Unluckily, according to author’s thoughts, conclusive of his interviews with the techno-legal division of the AEC that typical AIA bidding documents with BIM incorporation are not seen to be devolved in near future. Some more years will be required to do so, even after the finalization of roles and responbilities of the parties. (Leon L. Foster, 2008).

2.4.7 New Form of Business

At present in America, the AEC professionals are not ready to completely utilize the rewards VDC modeling. EPC and design-built firm are only present BIM users. In rest of the word, different designing and construction entities make joint ventures and consortiums among themselves with joint exposures and rewards. In America, on the other hand, business relations that would permit joint liabilities share and working motivations are young. This type of teamwork cannot be easily attained by organizations having conflicting backgrounds and financial benefits, in anticipation of its occurs, designing organizations will carry on to obtain a advantage that is excessively small in comparison to their input. (Leon L. Foster, 2008).

2.4.8 Risk Allocation

Leon L. Foster (2008) explain this issue, the use of BIM considerably changes the associations between project parties and intermingles their risks and responsibilities. Our legal system, nevertheless, assumes a less joint environment with clearer explanation of liability. As we move forward with BIM projects, risks will need to be to be paid sensibly, based on the profit a party will be getting from BIM, the skill of the party to through the risks, and the aptitude to absorb the risks through insurance cover or some other means.

As confirmed in the start, BIM is a instrument. Modern progresses in technology have made BIM easy to get to and applicable to the work of all stakeholders of a project team. The utilization of BIM will inevitably change the ways projects are envisaged, designed, coordinated, communicated, erected and constructed. On the other hand, the middle responsibilities of the affiliates of the project players will not change.

Whether the design is delivered in the shape of 2D printed documents or a 3D digital medium or in blend of both, the roles of the members of the project team remain unchanged. It is very significant to recognize the difference between design and coordination. Creation of a compound (coordination) model does not require or succeed a design that is expressed in 2D printed form. When a contractor or construction manager develops a “3D coordination” model, the BIM instrument is completely similar to a light table used in the past to overlay mechanical and electrical drawings. Recognizing the soundness and worth of the information in any BIM is the liability of every project team player that operates it.

Contractors and construction managers require understanding that coordination, whether through BIM technology or a light table, is their core service to the project. It is a fact, based on consequences from Sprint Center Arena case study, BIM coordination enhanced communication, which decreased construction cost and time, thus reduced overall risk. As the leaders of construction coordination, contractors and construction managers have the responsibility to give confidence and facilitate the sharing and distribution of BIM technology on a project. Appropriate contract language will guide the open sharing of information between team members. In addition, the design teams must also identify the benefits of sharing all available electronic information with the whole project team. Subcontractors are still accountable for fully conveying their interpretation of the design intent to the design team. They also must synchronize their work with that of other subcontractors by sharing electronic information they have developed in file formats that can be used and combined with the work of others (Leon L. Foster, 2008).

According to Zijia Liu (2010) two major obstacles had blocked the implementation of BIM. The first obstacle is that the legal responsibilities among project participants in which BIM practice have not been grown-up enough. Users favor to use BIM internally for the first a number of BIM projects or they develop a lonely BIM before they have the potential to handle an integrated environment. The second difficulty lies with the training costs related to use these programs. BIM tools are complex and require professional teaching to master the realistic jobs.

2.4.9 Concerns about software limitations or complexity

Digital architectural data must contain sufficient information to cover a buildings whole life cycle, from design to analysis, construction, inspection and facilities management. This would need the development and acceptance of complete standards for many types of data; however some observers are hopeful enough to propose that such complete standards will eventually exist (International Association for Interoperability, 98).

The lack of interoperability whole standards and the resultant loss of efficiency in the process industry had been considered in the billions of dollars every year and in the end drove members to build up and accept the Standard for the swap over of Product Model Data (STEP) (Stumpf, Ganeshan, and, Lui, 96). Such sufferers from the un-standardized character of AEC computer practice are understood. It is predict that the exact nature of the standards will turn into less important than the simple need for their survival.

The processes industry concerns with BIM cannot be completely understood without discussion on the idea of interoperability. According to a research by the Structural Engineering Institute of ACSE and the Structural Engineers Association of Texas, the chief criticism is broke interoperability of different suppliers' parametric modeling (BIM) tools. Interoperability is the capacity to manage and communicate digital product and project information among project stakeholder firms. The capacity of different software tools to use, edit, coordinate, supplement, and swap over information depends upon universal standards for telling construction elements and systems. According to The National Institute of Standards and Technology estimates that $15.8 billion is worn out yearly due to inadequate interoperability (Gallaher and O'Connor, 2004). As revealed in Figure 2.1 the concept of BIM interoperability and integrated process for data exchange across the AEC industry is a best approach to reduce the waste at present experienced in the U.S. AEC Industry (Leon L. Foster, 2008).

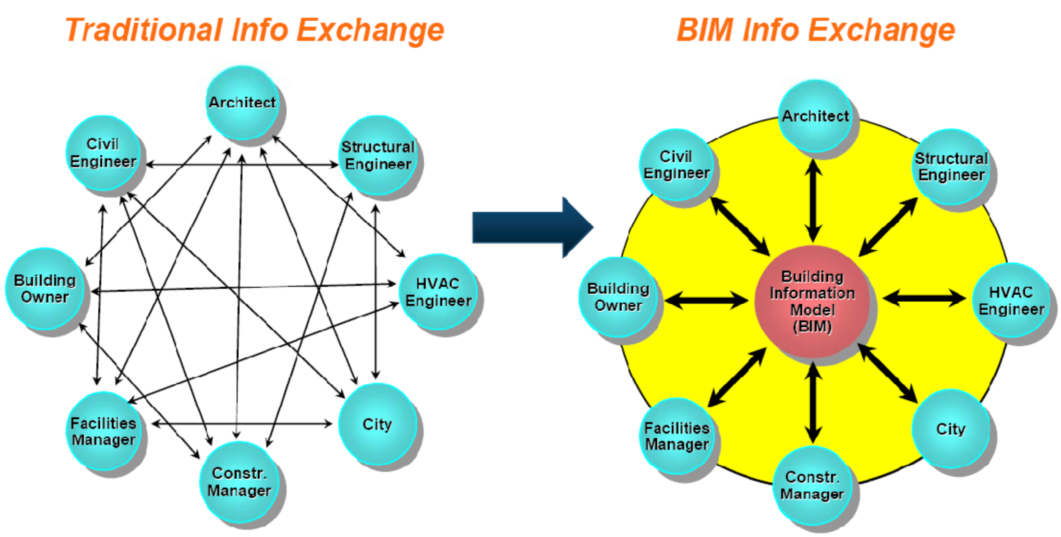

Figure 2.1: BIM, Interoperability and Integrated Processes (Young, 2007)

2.4.10 Institutional Education

Dean (2007) carried out a research study to scrutinize if BIM should be taught as a subject to the construction management students. He conduct two questionnaire surveys targeted at general contractors and ASC construction management programs in the Southeast. Based on the collected data, he concluded in general that construction management programs should teach BIM to their students. The major reasons behind this conclusion were:

Approximately 70% of the industry stakeholders indicated that they are either using or bearing in mind to use BIM in their groups. This trend indicates that the BIM deployment in the construction industry is going to increase.

About 75% of survey participants think employment candidates with BIM skills to have an advantage over candidates who lack BIM knowledge.

In another study, Woo (2006) pointed out that properly structured BIM courses would provide industry-required familiarity to prepare students for flourishing careers in the AEC industry. Instead of teaching a separate course, he recommended to reconfigure the existing construction courses to incorporate BIM into the course contents (Azhar at el, 2008).

2.4.11 Aesthetic Considerations

Design consultants will be reluctant to use the computer as is it likely that insufficient expertise in its use, will reduce their design diversity. The attentiveness among construction designers, that the computer inflicts an obstacle to creativity, has been borne out by the responses of the respondents in this research (Leon L. Foster, 2008).

2.4.12 Sub Consultants are unaware of BIM

Out of all engineers the Mechanical and Structural Engineers are the most likely to recognize modeling in BIM format. Although Engineers are also likely to see the lack of incentive for implementing the BIM process into their firms. Like Architects, Engineers will use less time documenting the project and more time dedicated to design.

Real Designs will work with you to help decide all BIM design issues within the project. BIM/IPD can really help organize the design and where issues will be once the building is being set in place. It is great for help with simulation and analysis of different parts of the project as well as reducing the confront of losing intellectual property and liability issues. Using BIM can definitely help decrease the amount of project design errors which therefore speed up the productivity in the field and get the job done more professionally.

2.5 APPLICATION OF BIM

BIM processes are readily being adopted in the countries of first world order and second word order like Sweden, USA, UK and Canada. Following are the applications for which BIM has been adopted in different parts of the world by different stakeholders to optimize their profitability and performance.

2.5.1 3D Coordination

BIM models are produced, to scale, in 3D space; all major systems can be visually checked for interferences. This process can confirm that piping does not overlap with steel beams, ducts or walls (Azhar at el, 2008).

After all building systems are created in 3D and incorporated into BIM, these systems are then merged. All utensils, fixtures, furniture's, pipes, conduits, structural members, cable trays and other building machinery are checked through "clash detection" tools to find out and resolve clashes before systems are constructed in the building. Some early cases have shown an 80% decrease in field-related questions and clashes due to this exact use of BIM. As shown in Figure 2.2 all mechanical, electrical, plumbing, fire protection, structural, and architectural systems are integrated before they are made-up and fitted in field (Leon L. Foster, 2008).

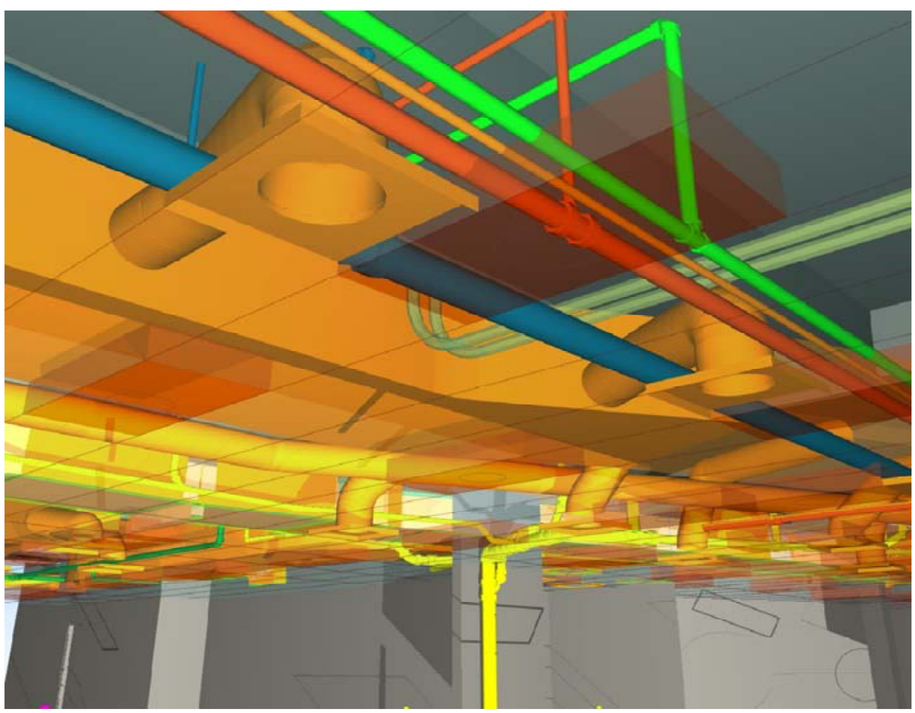

Figure 2.2: Systems Coordination (*Mortenson 3D Image*)

Teamwork of the construction team with the architect, engineer and the owner is favored to be started on early stages of design phase. At that time, the Building Information Modeling shall directly be implemented. If the architect is only providing 2D drawings, then the construction manager should translate the 2D drawings to 3D intelligent models. When the specialty contractors, particularly the MEP contractors and the steel fabricators are concerned, they need to spatially integrate their work. The 3D coordination can be started right after the model is created to make sure that any same space interference (hard clash) or clearance clash (soft clash) conflicts are resolved. On the whole, the coordination efforts of construction manager and specialty contractors in advance of construction assist to decrease design errors tremendously and to better understand ahead of time the work to be done. For example, Research 2 Tower Project for Colorado Denver Health Science Center renowned itself with the implementation of BIM in comparison to Research 1 Tower project which had major complex mechanical system problems. The BIM usage for Research Tower 2 incorporated 3D MEP coordination as shown in figure 6, work planning for concrete placement, and assembly instruction models. The benefits for Research 2 project included 37% decrease in coordination RFIs, and 32% decrease in coordination change orders (Young, 2009).

Figure 2.3: Layers of Complex Systems at Research 2 Tower Vivarium (Young, 2009)

2.5.2 Design and Constructability Reviews

Constructors use BIM as a method to provide support to the design team and to offer "built ability review" in which a diversity of means and techniques are examined and veteran to make sure the design can be constructed at site and meet end schedule and cost. Frequently, BIM points out errors and oversights in the planning and design, and can assist with probable alternate solutions while shielding the original design intent (Leon L. Foster, 2008). Figure 2.4 shows the design visualization of structural components.

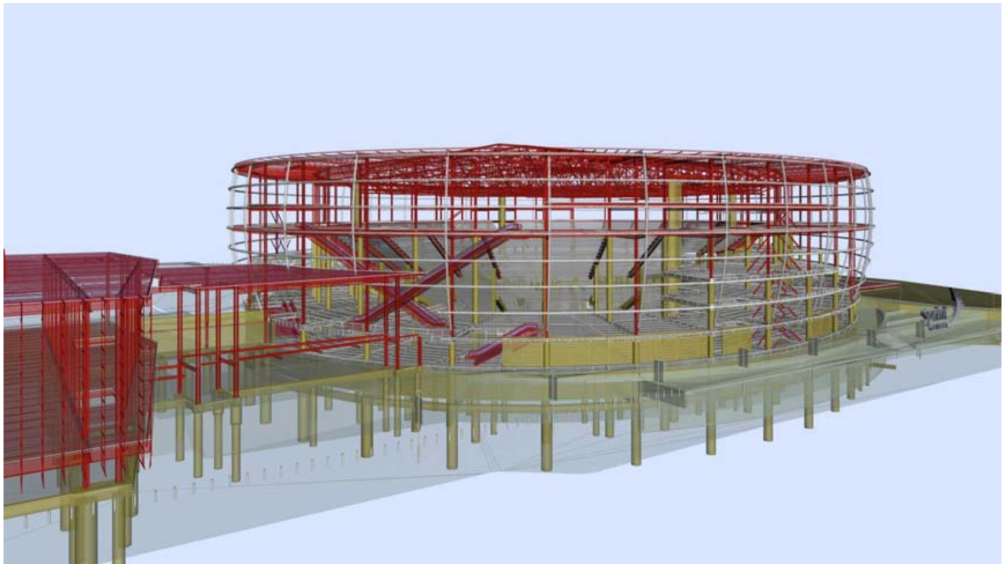

Figure 2.4: Design Visualization of Structural Components (*Mortenson 3D Image*)

2.5.3 4D" Scheduling and Sequencing

Andreas Winberg and Erik (2010), narrates that conventionally the construction phase time plan has been envisaged by a Gantt chart which has linked the diverse activities to each other. In a big project there are thousands of different activities that are connected to each other in different ways. As the number of activities increase the understanding of the construction phase time plan will decrease. This in turn can lead complexities to see which collision a certain work task has on the project. When using BIM it is possible to connect the construction phase time plan to the BIM model. The different construction components will have different internal pecking order. You cannot do a certain activity before others, and e.g. you cannot cast concrete before excavation, building formwork and installed the reinforcement. The information in the 4-D model can be visualized in a simple and intuitive way. This in turn will increase the understanding of the construction phase time plan and which impacts a deviation from the time plan will cause on the project. The 4-D model also has benefits when it comes to:

- Communication, the planer can with the aid of the model visualize different phases in the execution. This can be convayed to the construction site work teams but also to other stakeholders in the project. It will also be likely to use the model to visualize how a difficult activity ought to be constructed.

- Multiple stakeholders, the model can be used to aid the communication between the project crew and laypersons e.g. what impact the execution will have on the access to different key institutions.
- Site logistics, the 4-D model can be used to incorporate temporary construction components. E.g. lay-down areas, lodging roads or places were to store large equipments as a screen.
- Trade coordination, a 4-D model may understand information about expected time and space flow of trades on the construction site. This in turn facilitates planers to see possible bottlenecks.
- analyze the working progress, by using an up-dated 4-D model the planer can simply check whether the execution of the project is running on schedule or behind (Andreas Winberg and Erik 2010)

2.5.4 "5D" Cost Estimating

BIM software(s) have built-in cost estimating features. Material quantities are extracted automatically and changed when any changes are entered in the model (Salman Azhar at el, 2008).

A BIM model can also be directly linked to an estimation program, i.e. an aid software / program for the BIM modeling program that is described on estimation tasks. By using this type of program the planers will be able to relate the constructions components and its assemblage with the resources that is required for execution, e.g. a cast of a specific concrete slab requires three skilled workers, a concrete truck with its accommodation road, eight square meters of formwork, quality check on concrete etcetera. By using this instrument the planer will be able to evaluate different construction set-ups. This in turn opens up the possibility to optimize the production phase, e.g. through assemble adequate size of a work crew, co-operating material flow or planning the work so the heavy machinery, such as wheel loaders, will be utilized as much as possible (Andreas Winberg and Erik 2010).

Mehmet F. Hergunsel (2011) explains use of cost estimating in BIM, The two main rudiments of a cost estimate are quantity take-off and pricing. Quantities from a Building Information Model can be exported to a cost database or an excel file. However, pricing cannot be extracted from the model. Cost estimating needs the skill of the cost estimator to examine the components of a material and how they get installed. If the pricing for a certain activity is not obtainable in the database, cost estimator may need a additional breakdown of the element for more accurate pricing. For instance, if a concrete pour activity is taking place, the model may report for the level of detail for the rebar, wire mesh, pour stop, formwork, concrete etc., but not include it as part of the quantity take-off extraction. Cost estimator may need this level of detail from the model to figure out the unit price which comprise of the unit material cost, unit labor cost, overhead and profit. The unit labor cost is driven by the mobilization and execution durations, and the labor wage while the unit material cost is the amount of the material costs used for the activity per unit. Once the unit price is reached, the cost of the whole activity can be attained by multiplication of the total quantity extracted from BIM and unit price.

In Building Information Model, the data output is as accurate as the data input. It is considerably important to have the contractor and the designer to agree on component definitions. For instance, if an architect is showing concrete slab to show the roof for modeling intentions, the roof quantity information will not be accurately accounted for quantity extraction purposes in the model. In general, the BIM expertise is a great tool to optimize the efficiency of the estimators through quantity extraction from the model particularly if the construction and design team work collaboratively (Mehmet F. Hergunsel, 2011).

2.5.5 Integration of Subcontractor and Supplier Data ("6D" Procurement)

The greater part of complete data that is included into BIM comes from fabricators, subcontractors, suppliers, and vendors who usually would supply "shop drawings" that detail accurately how they would carry out the design intent in manufacture and fitting. At the present with the use of BIM, there is barely ever one Model. Typically many models are shaped by several line contractors. As mentioned before, the model manager would be legally responsible to offer a platform to join multiple models shaped in different design softwares into one file, to be viewed as one integrated BIM model. This is where the initial advantages of visualization, coordination,conflict detection, and specific trades' scope separation and examination are found (Leon L. Foster, 2008).

According to chapter seven of The BIM Handbook, when using BIM, as discussed in 2.5.2 Designers, the designers will enhance the quality of the design documents. This will facilitate more prefabrication off-site because the BIM model contains all the vital details of every element in the construction. There are three different kinds of prefabricated building components:

- Made-to-stock, e.g. reinforcement bars, standardized pipes of different types and other building elements that has its own standard.
- Made-to-order, e.g. ventilating fans and other building elements that is made for a extensive market segment.
- Engineered-to-order, e.g. pre-cast concrete pieces and other building components that is specially made by a subcontractor to fulfill a specific function.

The first two types of prefabrications will not be effected by BIM in the same degree that the third; Engineered-to-order (ETO). The subcontractors and fabricators that provide ETO elements will have an motivation to begin their work with BIM; by working with BIM they can expand their business (The BIM Handbook).

2.5.6 Prefabrication

Andreas Winberg and Erik (2010), narrates that to construct prefabricated construction components there are explicit demands on the design documents, as well as it needs complete planning and coordination between the all stakeholders. Some of the rewards of using prefabricated construction components are:

- Reduce risk; prefabrication is favored with regards to the large risk of shortcomings in an onsite fabrication relative to prefabrication.
- Time optimization; the construction components may be fabricated in advance and be delivered to the construction site just in time for the installation of the prefabricated component.

Furthermore a fault in an offsite fabrication, contrast to an onsite fabrication, will have lesser impact on the construction time which is linked to the construction cost. When using a BIM model in the design phase the accuracy in the design documents will increase, this in turn will direct to:

- Increased contribution, the experience and information from the fabricators can be used in initial phase to confirm and validate the model. Particularly, when it comes to particular construction components that can be prefabricated.

- Enable prefabrication in bigger extent, since an precise model does not omit any sections, the constructor knows how every construction element shall be constructed Andreas Winberg and Erik 2010).

Pipe manufacturing company could use BIM to collect coordinated piping locations, lengths and sizes for its fabrication software as long as the interoperability is achievable. This allows in-wall drops together with hot, cold, drain/vent, vacuum, etc. to be prefabricated. The drops usually stick out a foot from the wall to provide connects to the horizontal branches over the ceiling. Additionally, if a pipe requires to be weld, they must come at convenient sections. Pipes normally come to jobsite 5 to 10 feet sections. Welding small sections of black iron pipe with four inches or bigger diameter would be possible to weld offsite whereas two 10 foot sections welded offsite would not be convenient. Also, offsets and joints would prefer to be prefabricated. Overall, it is idyllic to prefabricate all the small pieces in a controlled environment with readily available apparatus which would yield more professional, higher quality, and less costly products (LeBlanc, 2010).

Difficult steel joints generate in Building Information Model can be welded offsite. The welding of these small intricate elements in advance of steel erection can save time and capital. Furthermore, BIM helps to appropriate modify designs to eradicate or reduce use of beam penetrations that may result from MEP clashes. A few beam penetrations may become inevitable for complex project. A good coordination of these penetrations with BIM technology supports determining the beam penetration positions and prefabricate offsite. Prefabricated beam penetrations would set aside tremendous time, money and effort in contrast to onsite beam penetrations. Furthermore, roof penetrations for concrete rooftops shall be sleeved prior to concrete pour at the roof level. Supplemental steel for each penetration may be desired. These penetrations can be synchronized with BIM when the specialty contractors are on board (LeBlanc, 2010).

Walls, rooms, and houses can be digitally designed and constructed with Building Information Model. These walls, rooms and houses can be prefabricated with roughed mechanical, electrical, plumbing (MEP) components. Final MEP connections can be prepared once the prefabricated components are assembled onsite (Mehmet F. Hergunsel, 2011).

2.5.7 Structural Analysis

Parag S. Kulkarni (2007), elaborates the use of BIM model for structural analysis and constraints linked with the such use, as following.

Since the last five years, BIM (Building Information Modeling) is in the glare of publicity in the architectural ring and is also building headway into the structural designer's territory. Several BIM uses for structural engineering are accessible, including Revit Structure, Bentley Structures, and Tekla Structural. Since architects and designers are the ones at the top in the construction food chain and they gain the most from BIM, down-the-line structural engineering companies are almost force into adapting this new technology. If the building project has to be made easily exchangeable among the architect/ designer and the structural engineer, it has to be on an interoperable platform for flawless information exchange.

Going through the latest software versions existing today, I find that flawless BIM software integration with structural analytical software is part hype and part essential. Let us see how. In the current circumstances, BIM rests at the heart of the process, and in which structural analysis is an offshoot of the larger method But on the other hand, for structural engineers, structural integrity is the most vital aspect of all the project aspects that can be dealt with by using BIM.

Conceptually, the architect develops the model with the help of BIM software, passes it on to structural engineer who runs it in an "external analytical engine." The model is "updated" and sent back to BIM, which is then utlized to take the project until completion. But there are limitations in the process. The incorporation of BIM with analysis tools does not run as smoothly, or in some cases, it simply does not run at all. In order to identify potential errors, one has to be aware of the inward-outward file sharing among the BIM application and analysis instrument and vice versa. When information is transferred from a BIM application to an analysis tool, it is done by means of "bridging" software. But a BIM model at any phase has numerous entities that are not accepted as they are not required in analysis. For example, masonry walls present in a BIM model but they are neither accepted by the analysis tool nor are they necessary to be modeled, as in most cases, masonry walls are plain line loads on the structural member.

In addition to elements not being accepted, distortions can also occur, such as the one given in the Figure 2.5 below. The top image depicts a Revit Structure model, which comes from one of the tutorials built-in with the application. The lower image displays the model distortion that takes place when the model is opened in ETABS. The distortion can be corrected, but is a distortion none the less. Perhaps as in medicinal commercial that contain warnings and cautionary notes, we also need to mandate warnings from our software vendors about the shortcomings in their applications. Any error that has gone ignored, particularly in a building structure, can put public safety at a larger risk (Parag S. Kulkarni, 2007).

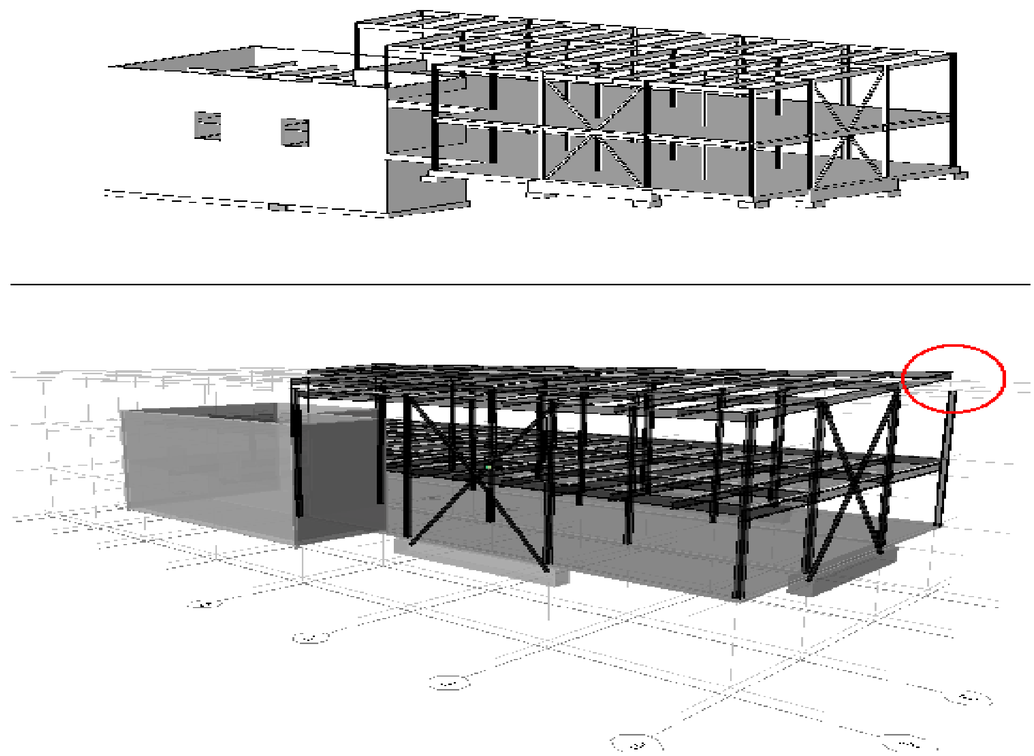

Figure 2.5: Distortion in structural elements

2.5.8 Lighting Analysis

A process in which systematic modeling software, utilizes the BIM design to, decide the performance of a given lighting system. This can also take account of artificial (indoor and outdoor) and natural (day lighting and solar shading) lighting. Based on this analysis, further improvement and refinement of the lighting design takes place to create effective, efficient, ambient and constructible lighting systems. The use of this analysis instrument allows for performance simulations that can significantly enhance the design and performance of the facility's lighting over its lifecycle. It also enhances the quality of the design analyses and reduces the cycle time and cost of the design analyses (http://bim.psu.edu/Uses/Lighting_Analysis.aspx).

2.5.9 Mechanical (HVAC Analysis)

BIM can actually reduce errors made by designing team as well as the contractor team (including Subcontractors) by permitting the use of conflict detection where the computer really enlightens team members about parts of the building in clash or clashing, and through complete automated visualization of each part in relation to the entire project. BIM also offers enough information for building performance examination and evaluation, which is of huge importance for sustainable building design. BIM also offers precise and very dependable data about the building, faced, the structure, the materials used including sustainable aspects such as green building design and day lighting simulation (Leon L. Foster, 2008).

2.5.10 Energy Analysis

With BIM, much of the data desirable for supporting performance analysis is captured naturally as design on the project proceeds. By using a building information model, designers can analyze how a building will perform, even in the very early stages of design and armed with this information, they can quickly assess design alternatives and make improved decisions to iterate on a green design. By reforming the design and analysis functions, BIM helps the necessary calculations wanted to enhance building performance. BIM and its dependence on a digital building model rationalizes the design and analysis functions, leting designers to quickly appraise design alternatives and make better decisions to iterate on a greener design. (Robert E Middlebrooks, 2006).

It is found that the majority of professionals who are implementing BIM-based sustainability analyses are mainly architects and contractors. The analyses types with the most common use are energy analysis, delighting, orientation analysis, solar analysis, building, massing analysis and site analysis. Most of these professionals realized some-to-significant time and costs savings as compared to the conventional methods. The software types which seem to have the most common use are Autodesk Ecotect TM, Virtual Environment (VE)TM Autodesk Green Building Studio (GBS)TM, and Integrated Environmental Solutions (IES)1 (Azhar and Brown, 2009).

2.5.11 “7D” Operations and Maintenance

Facilities management departments can also use BIM for renovations, repairs, restorations, space planning, and operations maintenance (Salman Azhar, 2008).

Project Managers can provide a record Building Information Model to the owner after the completion of a project. The model comprises the incorporation of the as-built drawings from the subcontractors. In addition, each object property in the model can also take account of links to submittals, operations and maintenance, and warranty information. Centralized software database can help the facilities management department to find information easier. Record model can be used for security management and safety information such as emergency lighting, emergency power, egress, fire extinguishers, fire alarm, smoke detector and sprinkler systems (Liu, 2010).

Generation of Building Information Model as a record model is an area in the process of growth. The interoperability of the record model with various software could potentially be a challenge. In addition, the owner needs to be willing to allocate budget to train employees, update and maintain the record Building Information Model (Keegan, 2010).

Furthermore, the facility management team can analyze energy efficiency of a virtually / digitally built model. In addition to that, facilities management team can plan with record model to maintain, track and renovate buildings by using spatial (3D) information such as furniture, equipment, and MEP (mechanical, electrical, and plumbing) connections. Finally, the facilities management department can use the model to produce cost and schedule impacts for maintenance and renovation projects. Overall, a record model can be used for optimization of time, cost and quality for facility management and maintenance (Mehmet F. Hergunsel, 2011).

As the benefits of the record model are recognized, the owners will be more demanding of the record BIM Model. A precise record model that contains the scope of the project and the needs of the facilities management department can help the owner manage and maintain the building tremendously. This can leave a long lasting positive impression of the project manager to the owner of the project (Mehmet F. Hergunsel, 2011).

2.6 BIM IN PAKISTAN

Building Information Modeling has not taken roots as a designing approach in Pakistan. Building models are used only for presentations and, to some extent for architectural design review and do not contain any data / information beyond spatial relationships, colours, materiality and textures etc. Few architectural firms (examples are

Ahed Associates, Khatri Associates, Schematics, Icon) have adopted BIM for architectural design and many other firms are in process to adopt the BIM. The main obstacle is the lack of engagement of other consultants (MEP, Structural etc.) in the BIM process (Zain Mankani, 2010).

CHAPTER 3

RESEARCH METHODOLOGY

3.1 INTRODUCTION

The research methodology adopted for this study is discussed and presented in this chapter. Research strategy shows how the researchers are going to carry out their study to achieve and answering research objectives (Saunders *et al.,* 2007). The core technique for collecting and producing research data is the questionnaire survey. This research is carried out as an exploratory study to measure the present state of implementation of Building Information Modeling (BIM) in Pakistan, advantages, risks, potential application / uses associated with its adoption and also to predict the future of BIM in AEC industry of Pakistan. Schematic layout of the research methodology used in this research is given in Figure 3.1. After the preliminary study, detailed literature review is carried out and a number of already developed questionnaires and some case studies are examined. Seven (7) advantages, twelve (12) barriers and twelve (12) potential uses / application are after extensive literature review.

A likert scale consisting of five points, with 1 being is lowest and 5 is highest, is utilized to judge the respondent's perception about the question. The sample for this investigation is chosen from population of AEC industry of Pakistan. All the stakeholders of AEC including Architects, Consultants / Engineers, General Contractors, Trade / Specialist Contractor, Design Builder / Project Management and Academics / Research are made part of this survey.

Google documents are used to create online questionnaire form. The link of the questionnaire was sent to stake holders of AEC through email; their emails are acquired from following resources;

1. PEC's (Pakistan Engineering Council) website
2. IAP's (Institute of Architects Pakistan) website
3. Participants of 1st International BIM workshop in NED University Karachi
4. Personal / professional relations

Out of 150 questionnaires sent out, 104 are received. Two incomplete questionnaires are excluded so final analysis is carried out basing on 102 questionnaires.

Respondents to this survey include 14 architects,24 Consultants / Engineers, 18 General Contractors, 8 Trade / Specialist Contractor,16 Design Builder / Project Management and 22Academics / Research.

The collected data is analyzed using MS excel and Statistical Package for the Social Sciences (SPSS-18). Two tests are applied to measure the internal consistency (reliability) of the questionnaire. The 1st test is Cronbach's Coefficient Alpha method. The Shapiro-Wilk Normality Test is performed to check whether data is para-metric or non para-metric i.e. is it normally distributed or otherwise. Sampling error is calculated using descriptive statistics. Kruskal-Wallis test is performed to check the differences or similarities in the perception of all stakeholders about advantages, risks and potential applications. A 5% significance level is considered to characterize statistically significant relationships in the data. Advantages, barriers and potential application are assessed and ranked using relative importance index (RII) method.

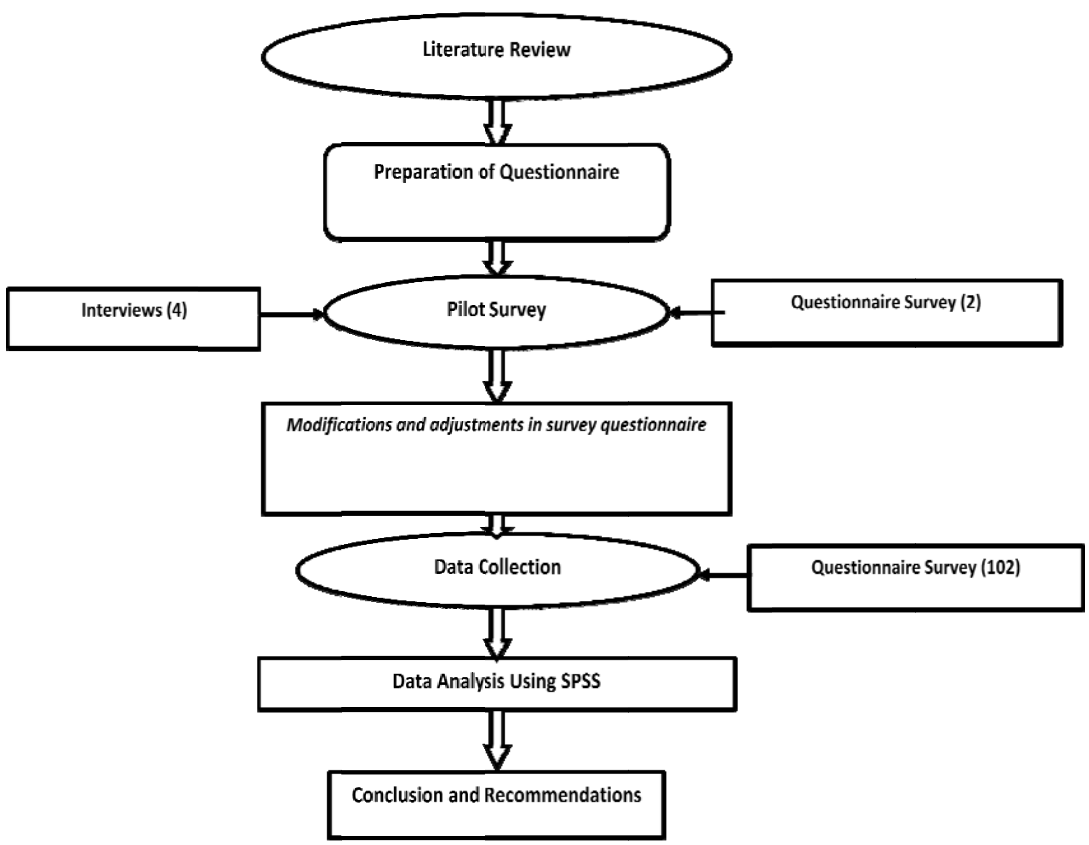

Figure 3.1: Research Methodology

3.2 RESEARCH DESIGN

The research intent has been recognized in the 1st chapter. The rout for achieving the intent is discussed here in an appropriate manner. The research techniques used in social sciences are surveys, experiments, analysis, histories and case studies. Furthermore, technique adopted for a specific research depends on the level of research, nature of the research operation (what, how, why), research aim and control over variables (Yin J., 2006). While selecting a suitable technique for research, it is obligatory to consider the relations between data collection and data analysis, as well as the main intent to be addressed, and the outcomes. Consequently, when proceeding on a research, the research questions, the data collection and analysis approach and the variety of data should be considered.

For the design of questionnaire, no one particular questionnaire was referred, many research papers and thesises are referred simultaneously. However the concept of this type of questionnaire for BIM is taken from Han Yan and Peter Damian's research paper, this research was conducted in 2007 in UK and USA to rank advantages and barriers associated with BIM adoption. The only 6 advantages and 5 barriers were expressed Han Yan and Peter Damian's research. I have increased the advantages to 7 and barriers to 12 and another section regarding potential application / uses of BIM in AEC industry of Pakistan was also added in the survey. A 5 point likert scale is used, to explore the complete range of possible replies between "Strongly Agree" and "Strongly Disagree" (Fellow and Liu, 2003). The principal consideration for using likert scale is to determine the extent to which respondents agree or disagree with a particular statement or view (Cormack, 2000). The responses to each statement/question are then used to calculate RII ranging from 0 to 1. RII method has the limitation that it may capitalize on skewed data thus inflating the relative weight for a certain factor.

$$\text{Relative Improtance Index (RII)} = \frac{\sum w}{(\text{A} \times \text{N})} \quad (3.1)$$

$$\text{RII} = \frac{(1n_1 + 2n_2 + 3n_3 + 4n_4 + 5n_5)}{(A * N)}$$

Where;

w = weighting assigned to each factor by the respondents having range from 1 to 5

n_1 = number of respondents for very low performance of safety practice

n_2 = number of respondents for low performance of safety practice

n_3 = number of respondents for moderate performance of safety practice

n_4 = number of respondents for high performance of safety practice

n_5 = number of respondents for very high performance of safety practice

A= highest weight is 5

N = sample size or number of samples is taken as 102

Data is analyzed using MS excel and SPSS-18, to have frequency analysis, reliability analysis and SPI analysis. Kruskal-Wallis test is performed to check the differences in perception of all stakeholders about safety performance level. The selection of these statistical techniques will be established in relevant chapters.

3.3 SURVEY SAMPLE

The course of actions and statistical methods adopted to choose the sample size from the whole population of AEC industry of Pakistan are descried hereunder. Entire population includes architects, consulting engineers, contractors, suppliers, fabricator, construction management firms and project management units.

3.3.1 Sample Selection

The aim of statistics is to summarize the measure about some characteristics of the population through sampling in a nutshell. For high-quality results sampling should be a true representative of entire population. There are numerous ways of sampling depending on the characteristics of the population. These are random, non-random and judgmental samplings (Francis and Hoban, 2002). In judgmental method of sampling, sample is selected on the basis of researcher′s judgment, without use of statistical sampling techniques. Judgmental sampling can be bias prone, so grounds for using it should be undoubtedly mentioned. Random sampling method is used when structure of the population has no considerable variation. Either random number table or software programmes are used for the medley of random samples with each of the members having equal probability of selection. Techniques used in non random sampling are:

- Systematic Sampling
- Stratified Sampling
- Cluster Sampling

The sample for this research is selected from a population of AEC industry of Pakistan. According to PEC data, the figure of building and civil engineering companies registered with PEC before Feb 2012, are 30000 but not all of them are executing construction projects so we can consider architects in them also. It is reasonably a large population and the sample selection will symbolize various AEC professionals consisting of Architects, Consultants / Engineers, General Contractors, Trade / Specialist Contractor, Design Builder / Project Management and Academics / Research. Evidently, surveying all the companies in the whole AEC industry would give up the most representative results though scarcely practicable due to amount of work and time implicated.

Therefore, the web link of an online prepared questionnaire was emailed to 150 randomly chosen potential respondents, who have at least some knowhow of BIM, working with 50 construction companies/organizations with in Pakistan. These construction companies/organizations vary in size i.e. 14 small (less than 10 employees), 18 medium (10 to 100 employees), 32 large (100 to 500 employees) and 38 large (over 500 employees). These construction companies / organizations works in all parts of the Pakistan i.e. 70 works in Punjab and Islamabad, 22 in KPK (Khyber Pakhtunkhwa), 34 in Sindh, 16 in Baluchistan, 26 in Kashmir and 14 in Gilgit Baldistan. 28 out of 102 construction companies / organization are using BIM or involved in BIM adoption process in any capacity.

3.3.2 Sample Size

The following factors should be taken into account for determining suitable sample size:

a. Sampling error
b. Population size
c. Confidence level

Equation (3-2) gives the formula which can be used to calculate the sample sizes (Dillman, 2000):

$$N_s = \frac{\left[(N_p)(P)(1-P)\right]}{\left[(N_p-1)(B/C)^2+(P)(1-P)\right]} \tag{3.2}$$

where,

N_p = population size i.e. 30000

N_s = sample size for the desired level of precision

P = percentage of the population that is anticipated to choose one of the reply categories (yes/no); P = 0.5

B = an acceptable sampling error; (±10% or ±0.10)

C = Z statistic associated with the confidence level (1.96 corresponds to 95% confidence level)

Acceptable sample sizes for various populations with different sampling errors for 95% confidence level are given in Table 3.1. These sample sizes can also be calculated using the formula given in equation (3-2).

Table 3.1: True Sample Size *(Dillman, 2000)*

Completed sample size needed for various population sizes and characteristics at three levels of precision						
Sample size for 95% confidence level						
	± 10% Sampling Error		**± 5% Sampling Error**		**± 3% Sampling Error**	
Population Size	**50/50 Split**	**80/20 Split**	**50/50 Split**	**80/20 Split**	**50/50 Split**	**80/20 Split**
100	49	38	80	71	92	87
200	65	47	132	111	162	155
400	78	53	196	153	291	253
600	83	56	234	175	384	320
800	86	57	260	188	458	369
1000	88	58	278	198	517	406
2000	92	60	322	219	696	509
4000	94	61	351	232	843	584
6000	95	61	361	236	906	613
8000	95	61	367	239	942	629
10000	95	61	370	240	965	640
20000	96	61	377	243	1013	661
40000	96	61	381	244	1040	672
100000	96	61	383	245	1056	679
1000000	96	61	384	246	1066	683
1000000000	96	61	384	246	1067	683

Sample size that represents the targeted population can also be determined by using equation (3-3) (Shash and Abdul-Hadi, 1993):

$$n = n' \Big/ \left[1 + \left(n'/N\right)\right] \qquad (3\text{-}3)$$

where;

n = sample size from finite population

N = overall population

n′ = sample size from infinite population, which can be calculated as $n' = S^2 / V^2$

S^2 = standard error variance of population elements = P (1-P); maximum at P=0.5

V = standard error of sample population = 0.05 for confidence level 95%

There were 102 valid responses out of 150 depicting an overall response rate of 68%. In the AEC industry, a fine response rate is around 30% (Black *et al.*, 2000). Consequently, the response rate in this study is acceptable. The sample size is 102 for this study, on the other hand to know whether or not this sample size really stands for the population, Table 3.1 is utilized which shows sample sizes requirement for various population sizes and features at three level of precision. These values can be confirmed using the formulae specified in equations (3-2) and (3-3).

Before Feb 2012, more than 30000 building and civil engineering companies have been registered with PEC. This figure can be used as the population size. Confidence level is chosen as 95%. It is also considered that the answers will be consistent and will set the p value to 0.5 (means that probability of occurrence is 50%). Utilizing a fifty-fifty split maximizes the issue variance, which requires the biggest possible sample to control for the dissimilarity between the response options. By putting these values in equations (3-2) and/or (3-3), the sample size comes out to be 96 with a sampling error of ±10%. Investigation of the collected data by SPSS, gives maximum sampling error as ±9.40% which is lower than ±10% so any sample over 96 is fairly acceptable for a sampling error of ±10%. Therefore a sample consisting of 102 respondents is quite dependable for further analysis.

3.4 DESIGN OF SURVEYS

Various related previous studies were reviewed an integrated with respect to our local AEC industry requirements, so the relevant responses must be accomplished for data analysis.

3.4.1 Review of Previous Studies

The importance of questionnaire design for an pushing survey has been tinted by many researchers (Kim, 2010;Lingard *et al.*, 2010). Consequently, a well planned questionnaire includes questions that respondents can tackle and answer without putting in much of the attempt, which maintains their attention, and at the same time does not put away much of their time. Rate of response is influenced by several factors, such as the questionnaire's size and dimensions, type and color of paper used, cover pages, questions order, as well as the stamps and packet used to mail the questionnaire (Memili *et al.,* 2011). Moreover, researchers are in support of mixed-mode survey in order to obtain a improved response rate. In this survay, mixed mode survey was taken on, some respondents replied to the online form of the questionnaire and others were surveyed by mailed questionnaire. To accomplish a high response rate combined survey method is highly suggested (Mbachu, 2008). Technological developments have also given rise to self-administering surveys such as web and electronic mails. Tailored Design Method devised by Dillman (2000) assists to reduce survey error and to boost response rates.

There are lots of ways to make sense of increased rewards, decrease social costs for being a survey respondent, and build the respondents′ confidence (Dillman, 2000). Stipulation of rewards to respondents can be made by financial or material incentives, ask for suggestion, make the questionnaire attractive, inform respondents that opportunities to respond are rare, and offer a result summary.

3.4.2 Tailored Design Method

Tailored Design Method is implemented for survey in this thesis. Points which are taken care throughout the survey are:

Providing rewards

a. Use of flattering phrases, such as "thank you for finishing this questionnaire".
b. Respondents are given significance by exhibiting them that they are ingredient of a carefully selected sample as per their experience and professionalism in the AEC.
c. The importance of the study and its significance and relevance to the respondent's firm are also articulated in the covering letter of the questionnaire.

Reducing the cost for being a respondent

a. Questionnaire form is having five point likert scale questions which require lesser time to answer as compare to open ended questions. Moreover it also reduces the mental attempt of respondents while selecting the answer from a choice of responses.
b. The organization of questionnaire is providing a upright flow to the respondents while answering questions and all questions are grouped under various sections.

c. On the basis of availability of the addresses, questionnaires are also sent via mail/email to the respondents for getting their responses.

Establishing trust

a. The entire address, email and other contact information pertaining to the researcher are also provided on the covering letter.

b. Respondents are also guaranteed that their confidentiality would be preserved and use of data would be restricted to the current study only.

According to Dillman (2000) , follow-up alerts have fabulous effects on response rates. He also stated that without follow-up, the response rates would be much lesser, no matter how inspirational the mail package or motivating the questionnaire is. Researchers have to have a poise of the time and cost while implementing the follow-up (McGuinness, 2008). In current survey, two follow ups are conducted after two and four weeks of the first mailing. Specimen of the online questionnaire, used in this research for survey, is exhibited in Appendix-I.

3.4.3 Reliability and Validity of Survey

The reliability and validity of a study determine that the research mechanism fulfills its intended function. "*Reliability* refers to the consistency of a calculation and to the probability of obtaining alike results if the measure is to be duplicated" (Oppenheim, 1992). Reliability can be calculated in a variety of ways however most commonly used method in researches is internal consistency. *"Validity* establishes whether the score or question can measure what it is supposed to measure" (Oppenheim, 1992). To establish the reliability and validity of a questionnaire, researchers use several methods. As such, some will refer to the research mechanism used in previous studies already been proven valid and reliable.

Same approach is taken on in this study. Before selecting the questionnaire, a widespread literature review is conducted and a questionnaire is drafted.. It ultimately improved the reliability and validity of questionnaire. The data is analyzed using MS excel and SPSS-18 with the application of frequency analysis, reliability analysis, normality test and Kruskal-Wallis test for non parametric data to find out the significant difference between the opinion of client, consultant and contractors on any particular aspect of question asked.

3.5 STATISTICAL TERMINOLOGIES

The statistical terminologies used in this research are adopted from Choudhry and Kamal (2008) and are explained below:-

3.5.1 Hypothesis Testing and Statistical Hypothesis

It is a extremely important part of statistical inference and is a practice which enables to decide on the basis of information obtained from sample data whether to recognize or reject a statement/assumption about the value of a population factor. Such a statement or assumption which may be or may not be true is called statistical hypothesis. The hypothesis is acknowledged as being true, when it is supported by the sample data and is rejected when the sample data fails to support it.

3.5.2 Null Hypothesis and Alternative Hypothesis

Null hypothesis is the one which is to be experienced for possible rejection under the supposition that it is true and is denoted by Ho. Any other hypothesis which is acknowledged when the null hypothesis is rejected, is known as alternative hypothesis.

3.5.3 Significance Level and Test of Significance

Significance level is the probability used as a normal for rejecting a null hypothesis Ho, when Ho is assumed to be true. Test of Significance is a rule or method by which sample outcomes are used to decide whether to accept or reject null hypothesis.

3.6 DATA ANALYSIS TECHNIQUES

MS excel and SPSS-18 are utilized to analyze the data. The research follows usual level of significance i.e. $\alpha = 0.05$. Following statistical techniques are used for analysis.

3.6.1 Test for Normality

An assessment of the data normality is a pre-requisite for the use of various statistical tests. It is performed to know whether data is normally distributed or not, i.e. is the data parametric or non-parametric in character A more thorough test of normality suitable for data sets of about two thousands (2000) elements or less is presented by the Shapiro-Wilk test. To count as adequately normal, the Significance (Sig.) value should be non significant (i.e. it should be larger than 0.05). For the data set more than 2,000 values Kolmogorov-Smirnov test, also known as K-S Lilliefors, is more appropriate. Consequently in this study Shapiro-Wilk test is used to ensure the normality due to the limitation of sample size.

3.6.2 Kruskal-Wallis Test and one way ANOVA

The Kruskal-Wallis test along with one-way analysis-of-variance are utilized to establish whether three or more independent groups are identical or varied on some variable of attention. It is more suitable for finding statistical proof of *inconsistency* or differences in perception, using mean values or indices of the a variety of groups. The Kruskal-Wallis test is used for non parametric data while one way ANOVA is used for parametric data. As the collected data did not pass the normality test so the Kruskal-Wallis test is utilized for further analysis. It is much less susceptible to outliers. The null hypothesis (Ho) for the test is that the means of variables are equal and is rejected if the result is significant. The results are veteran against the obstacle of significance of 0.05. If significance value is greater than 0.05 then it implies that all the stakeholders have similar perception about the question and vice versa.

3.7 SUMMARY

The research study utilized multiple or mixed research method. Questionnaire survey is taken on as the main research tool for data collection from respondents, goggle documents is used develop an online questionnaire form. In this chapter design of survey questionnaire, rout to carry out the research, sampling methods, statistical tests for used for data analysis and use to MS Excel and SPSS for to attain conclude able results are discussed in detail. Above discourse provides a clear understanding of the research methodology used.

Chapter 4

DATA ANALYSIS, RESULTS & DISCUSSIONS

4.1 INTRODUCTION

BIM adoption in the AEC industry is not satisfactory. Architects want to invest in BIM but they are unable to it without the support of sub consultants i.e. HVAC consultant, electrical consultant, Pluming and firefighting consultant. For a successful application of BIM model all stakeholders are required to give their input. Sub consultants also want to invest in BIM but their concern is lack of experienced and knowledge partners. It is need of the hour to teach BIM at graduation level in Civil Engineering, Building and Architectural Engineering and Architecture, so that its awareness can be increased.

However, some architectural firm in Karachi like Ahed Associative, Khatri Associates etc have started to use BIM for creating architectural model of the building, design review, clash detection, lighting analysis. Certain universities like UET Lahore, NUST Islamabad and NED Karachi have taken first step and have started to organize seminars and workshops regarding BIM. BIM research work has also been started in the above mentioned universities.

Data is collected through questionnaire based survey is analyzed using MS excel and SPSS-18. Results of the survey are discussed in the subsequent paragraphs.

4.2 CHARACTERISTICS OF RESPONDENTS AND THEIR ORGANIZATIONS

The aim of the first part of the questionnaire was to record the characteristics of the respondents and their organization. Its purpose was to establish that the responses are from respondents with good qualification and experience and also belongs from reputed organizations.

4.2.1 Grouping of the Respondents

There are 102 valid responses out of 150, showing a response rate of 68%. Response by Architects is 14%, Consultants / Engineers is 24%, General Contractors is 18%, Trade / Specialist Contractor is 8%, Design Builder / Project Management is 16%

and Academics / Research is 22%. Grouping and percentages of respondents are shown in Table 4.1 and Figure 4.1.

Table 4.1: Grouping of Respondents

Type of Organizations	Frequency of Respondents	Percentage of Each Group
Architects	14	14
Consultants / Engineers	24	24
General Contractors	18	18
Trade Specialist Contractor	8	8
Design Builder / Project Management	16	16
Academic Research	22	22
Total	102	

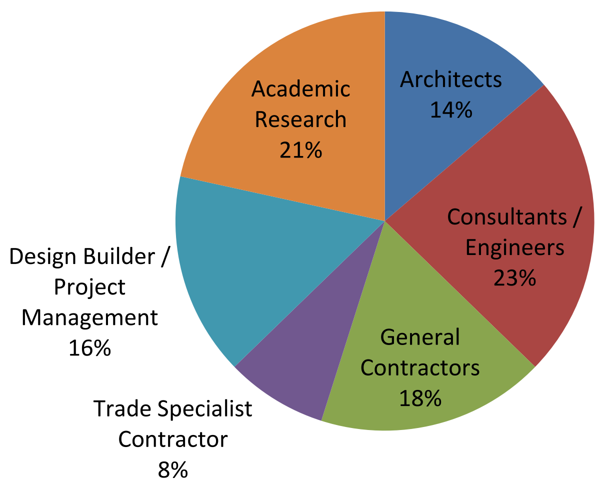

Figure 4.1: Grouping of the Respondents

4.2.2 Professional Experience of the Stakeholders in the AEC Industry

Respondents are having varied experience in the AEC as shown in Table 4.2 and Figure 4.2. Approximately 41% (42) of the respondents have accumulated over 10 years of professional experience, 21.6% (22) have 6 to 10 years of construction experience, whereas 37.3% (38) have 1 to 5 years of construction experience (professional graduated after 2005 have more exposure to BIM). Therefore, the information provided by these professionals can be considered authentic and reliable.

Table 4.2: Experience of Respondents in AEC Industry

Experience of Respondents	Frequency	Percentage
More than 1year to5years	38	37.3
6-10 years	22	21.6
11-15 years	18	17.6
16-20 years	14	13.7
20+ years	10	9.8
Total	102	100

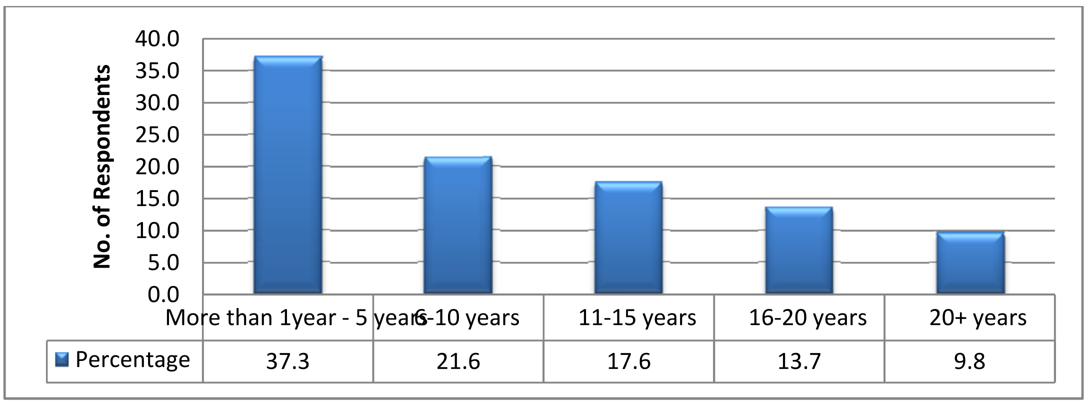

Figure 4.2: Percentage of Respondents basing on Industry Experience

4.2.3 BIM Experience of the Respondents

Table 4.3 and Figure 4.3 show BIM Experience of stakeholders holders who responded to this survey. Approximately 54.9% (56) respondents have no professional experience related to BIM but having some knowhow of BIM, 25.5% (26) have one year or less BIM experience, 11.8% (12) have 1 to 3 years BIM experience and only 7.8% (8) having 3 to 5 years of BIM experience.

Table 4.3: BIM Experience of Respondents

BIM Experience of Respondents	Frequency of Respondents	Percentage
Nil (But Having Basic Knowhow of BIM)	56	54.9
0 - 1 Year	26	25.5
1 - 3 Year	12	11.8
3 - 5 Year	8	7.8
Total	102	100.0

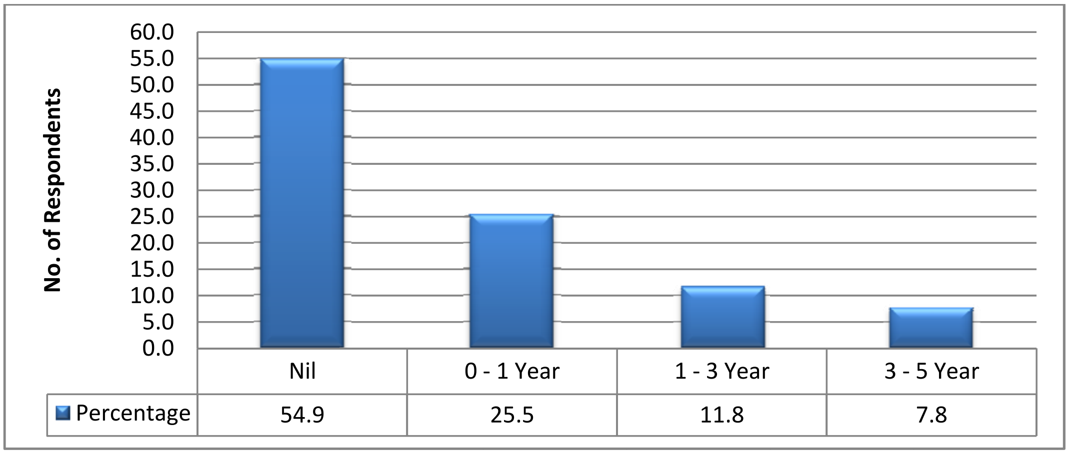

Figure 4.3: BIM Experience of Respondents

4.2.4 Size of Respondents' Organizations

Respondents to this study are working in different construction companies on various projects. Distribution of the respondents basing on size of their organizations is given in Table 4.4 and Figure 4.4. 13.7% (14) respondents belong to very small organizations, 17.6% (18) to small organizations. Cumulatively 68.7% (70) respondents belong to either large or very large organizations.

Table 4.4: Frequency of Respondents basing Size of Organizations

Size of Respondents' Organizations	Frequency	Percentage
Very Small (Below 10 employees)	14	13.7
Small (10-25 employees)	18	17.6
Large (100-500 employees)	32	31.4
Very large (over 500 employees)	38	37.3
Total	102	100

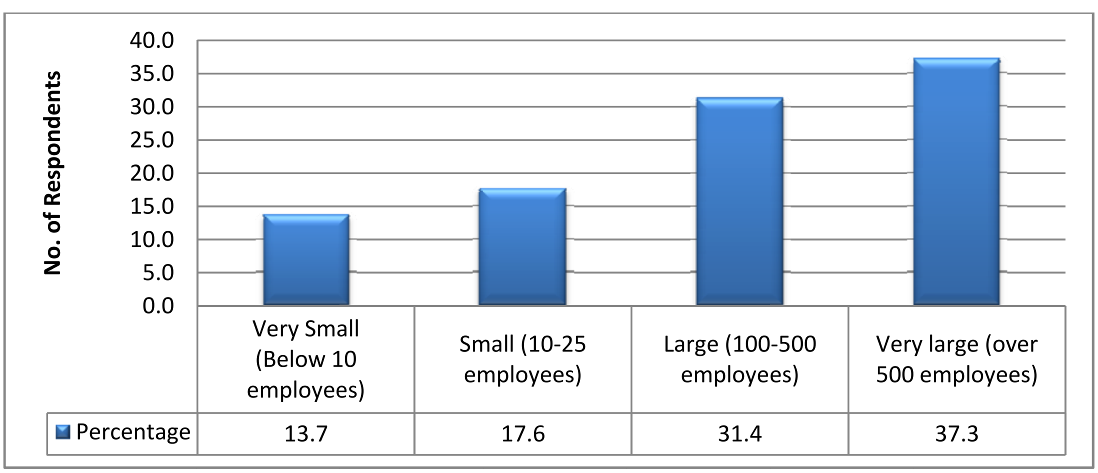

Figure 4.4: Frequency of Respondents basing Size of Organizations

4.2.5 Working Regions of Respondent's Organizations

Respondents' organizations have working experience in all areas of Pakistan. Distribution of the respondents basing on their working areas is given in Table 4.5 and Figure 4.5. 69 % organizations have their business in Punjab, 33 % having in Sindh, 25% in Kashmir, 22% KPK, 16% Baluchistan and 14% in Gilgit Baldistan.

Note: Total Frequencies exceeds 102 and total percentage exceeds 100 because, respondents can select more than one option related to this question.

Table 4.5: Working Regions of Respondents' Organizations

Working Regions	Frequencies	Total	Percentage
Punjab	70	102	69
KPK	22	102	22
Sindh	34	102	33
Baluchistan	16	102	16
Kashmir	26	102	25
Gilgit Baldistan	14	102	14
Total	182		178

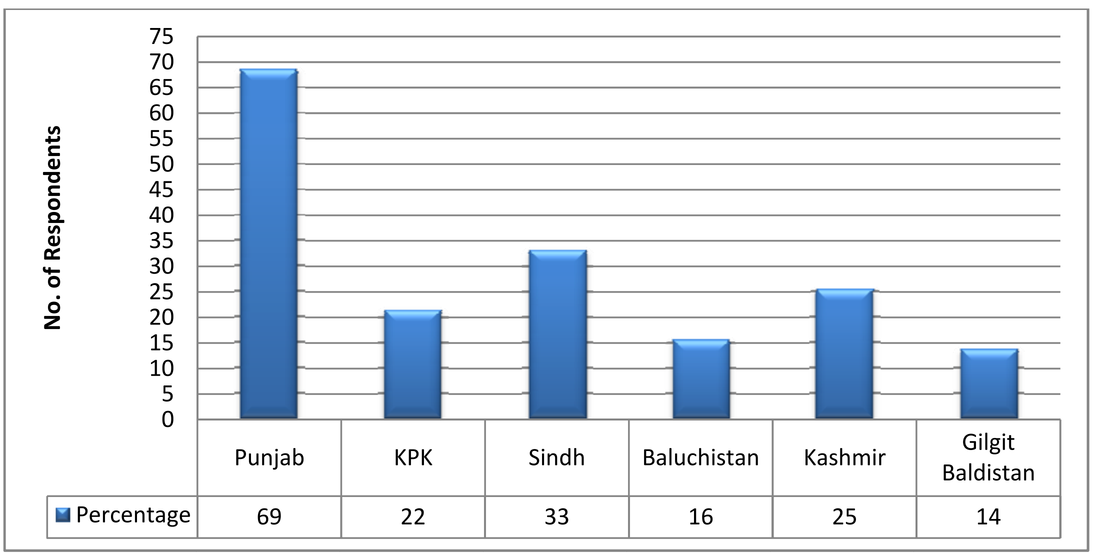

Figure 4.5: Working Regions of Respondents' Organizations

4.2.6 Type of AEC Organizations Included in the Survey

The survey comprises of respondents from 50 companies / organizations, names of them are listed below in Table 4.6 under their respective head. However there are 5 respondents, who have not shown their company's identity (as question was not mandatory) but replied all the other questions, so there response was counted as valid response.

Table 4.6: AEC Organizations Included in the Survey

Type of Organizations	No of Respond ents	Type of Organizations	No of Responde nts
Architectural Organizations		**General Contractors**	
NESPAK (Architecture and Planning Division)	2	Frontier Works Organization	4
Al Imam Enterprises Lahore	3	DESCON	4
SRDW Lahore *	2	Paragon Constructors	2
Ahed Associates Karachi	1	SCOPE Karachi	1
Dimension Associates Lahore	1	Izhar Group	1
Artmid Islamabad	1	MEC Engineering Islamabad	1
Kashif Aslam Associative, Lahore	1	SKB Engineering & Construction	1
Khatari Associative Karachi	1	Build Fast, Islamabad	1
PEPAC Islamabad	1	SAMBU	1
Archifact Design Group Lahore	1	Bahria Town	1
Design Builder Project Management		MAAKSONS	1
PMU-FSA, Lahore *	1	Mughal Pakistan	1
P & D Department, Lahore	2	**Consultants / Engineers**	
MES	3	National Industrial Parks Development and Management Company	1
DHA Lahore	2	Naizi Design System, Lahore	3
ERRA-PMU	2	Finite Engineering, Islamabad	1
Academics / Research		NESPAK (structural Engg.	3

		Div & Construction Management Div .)	
Urban Unit Lahore	3	Suhail Ahmed Associates, Lahore	1
NUST	4	Arif Associates, Lahore	1
Architectural Engineering & Design Dept, UET Lahore	3	ECON, Lahore	1
School of Architecture & Design, UET Lahore	1	ACS Engineering Concern	1
Civil Engineering Dept, UET Lahore	1	ACE Lahore	1
MUST Mirpur	1	**Trade / Specialist Contractors**	
NESCOM	1	Professional resource associates	1
Wah Engineering Collage,	1	Wateen Telecom	1
NED Karachi	1	Solutions Engineering (Pvt) Ltd.	1
University of Lahore	1	Philips Electrical Industries of Pakistan	1

∗ SRDW: Saad Rashid Design Work
PMU-FSA: Project Management Unit – Forensic Science Agency
MES: Military Engineering Services

4.3 CURRENT STATE AND FUTURE BIM IN PAKISTAN

The second part of the questionnaire included questions regarding the current state of BIM in Pakistani AEC industry and future of BIM in Pakistan.

4.3.1 General Level Buzz about BIM in AEC Industry of Pakistan

It is clear from Table 4.7 and Figure 4.6 that most of the professionals consider that there is low (39.2%) or medium (25.5%) level of buzz about BIM is present in the Pakistani AEC market. 21.6% considers, no buzz about BIM. 11.8% responses that there is a high buzz and only 2% considers very high buzz.

Table 4.7: Buzz about BIM

Level of Buzz	Frequency of Responses	Percentage
None	22	21.6
Low	40	39.2
Medium	26	25.5
High	12	11.8
Very High	2	2.0

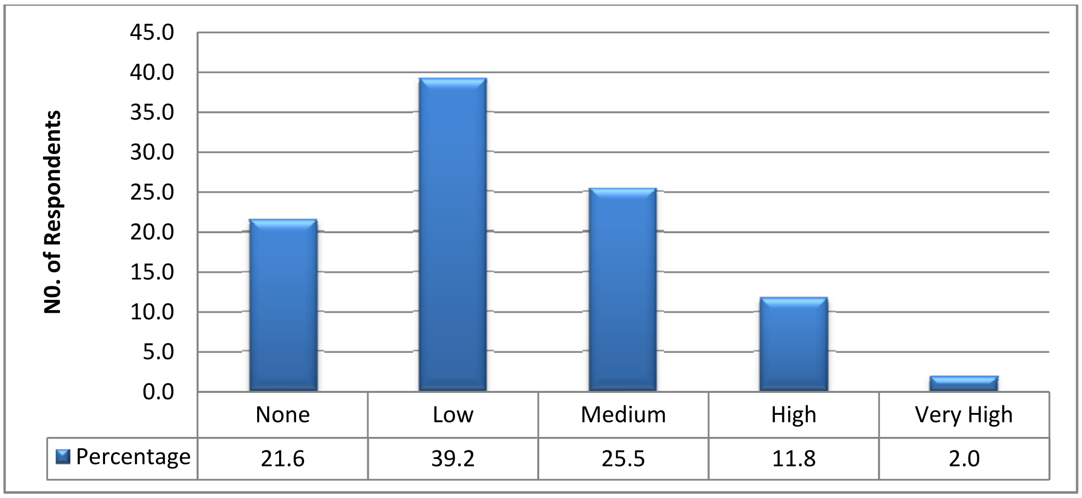

Figure 4.6: Buzz about BIM

4.3.2 Knowledge level of BIM

Respondents were asked, to rank their level of knowledge related to BIM. There response is shown in Table 4.8 and Figure 4.7. 80% of respondent have either little, fair or experts level knowledge of BIM. Only 20% responded considers that they have no knowledge related to BIM.

Table 4.8: BIM; Level of Knowledge

BIM Level of Knowledge	Frequency of Responses	Percentage
Nothing	20	19.6
Little	48	47.1
Fair	32	31.4
Experts	2	2

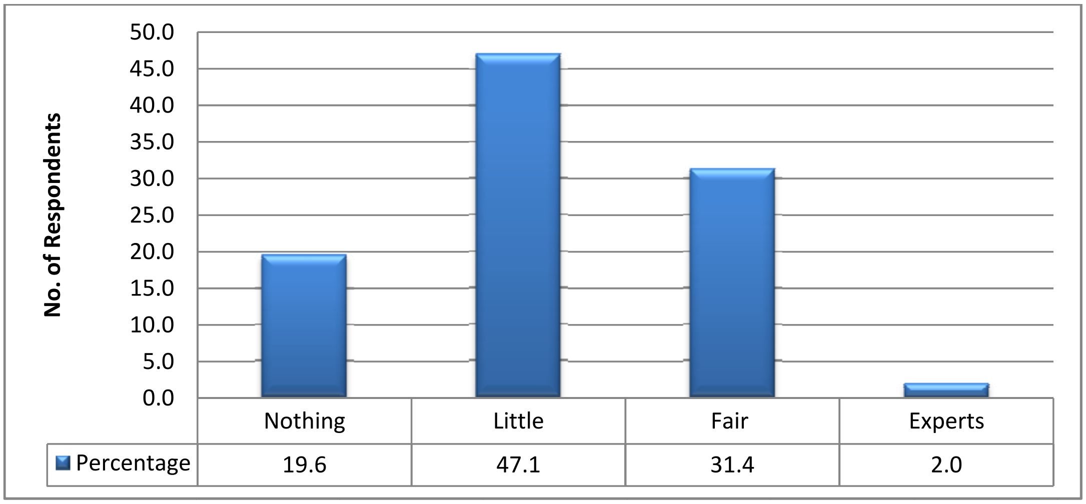

Figure 4.7: BIM; Level of Knowledge

4.3.3 Organization using BIM

It is established in this survey that only 27% organization are using BIM or involved in BIM adoption process in any capacity whereas 73% organization are neither using BIM nor involved in BIM adoption process in any capacity, same is depicted in the Figure 4.8.

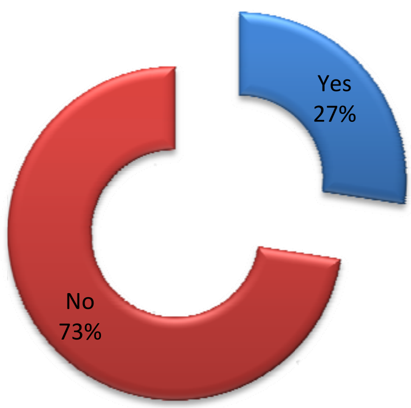

Figure 4.8: Organizations Using BIM

4.3.4 Future of BIM in Pakistan

The positive point is that most of AEC professional are very optimistic about the future of the BIM. Figure 4.9 shows that 96% professionals are in favor of implementing BIM in the Pakistani market.

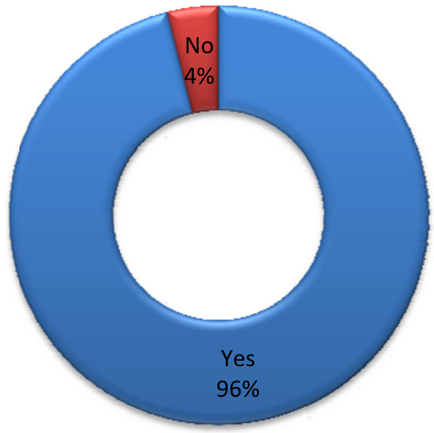

Figure 4.9: Are you in Favor of BIM Implementation in Pakistan

Same is being depicted from the results of another question, related to future of BIM, shown in Table 4.9 & Figure 4.10. 52.9% respondents say "definitely yes" for the future of BIM whereas only 2% respondents consider no future of BIM in Pakistan.

Table 4.9: Future of BIM

Future of BIM	Frequency of Responses	Percentage
Definitely No	2	2
May be No	2	2
No Idea	8	7.8
May be Yes	36	35.3
Definitely Yes	54	52.9

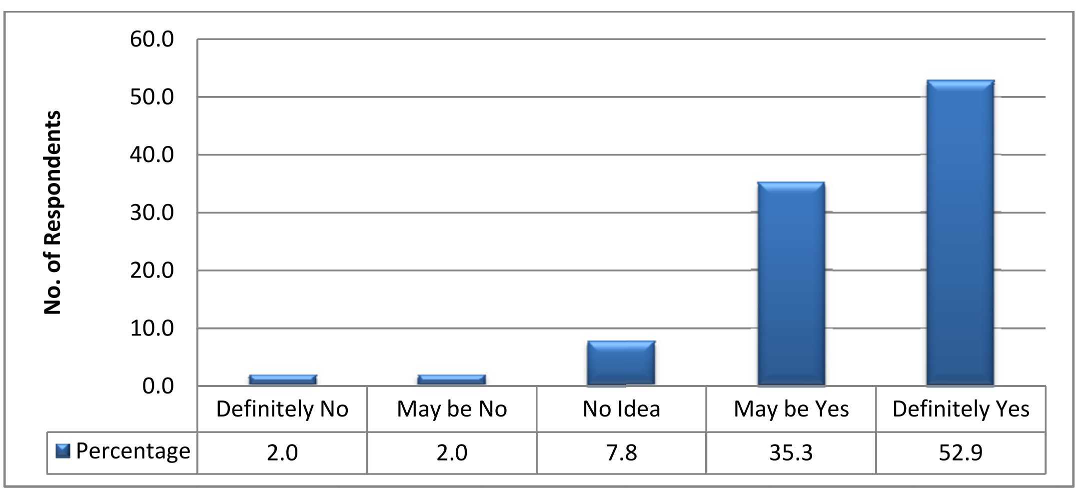

Figure 4.10: Future of BIM

4.4 STATISTICAL ANALYSIS

Following statistical test are applied to the data collected from the questionnaire to check the reliability of data as well as to achieve the research objectives.

4.4.1 Reliability of the Sample

4.4.1.1 Cronbach's Coefficient Alpha Method

Cronbach's Coefficient Alpha method is the most common measure of internal consistency (reliability). It is most commonly used to check the reliability of scale when questions are asked on likert scale. If Cronbach's Coefficient Alpha value is higher than 0.7, this means that the data is reliable for analysis (Li, 2007). In our case, its value is calculated as 0.828 for advantages of BIM, 0.796 for barriers and 0.952 for application, using SPSS, as given in Table 4.10. Its higher value indicates that the data is consistent and reliable for analysis.

Table 4.10: Reliability Statistics

Case Processing Summary for Advantages				Cronbach's Alpha	0.828
		N	%		
Cases	Valid	102	100.0		
	Excluded[a]	0	.0		
	Total	102	100.0	Number of Items	7
Case Processing Summary for Barriers				Cronbach's Alpha	0.796
		N	%		
Cases	Valid	102	100.0		
	Excluded[a]	0	.0	Number of Items	12
	Total	102	100.0		
Case Processing Summary for Applications				Cronbach's Alpha	0.952
		N	%		
Cases	Valid	102	100.0		
	Excluded[a]	0	.0	Number of Items	12
	Total	102	100.0		

a. Listwise deletion based on all variables in the procedure.

4.4.2 Normality Test

To check the normality of the collected data, ‘Shapiro Wilk normality test’ is conducted because sample size is less than 2000. It is performed to know whether the data is normally distributed or not, i.e. is the data 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). Therefore, data is not normally distributed and non parametric tests are required for further analysis. Table 4.12 shows the data regarding test of normality by Shapiro Wilk test.

Table 4.12 (a): Tests of Normality (advantages) - Shapiro Wilk Test

Advantages	Shapiro-Wilk		
	Statistic	**df**	**Sig.**
Reduce Construction Cost	.885	102	.000
Reduce Construction Time	.816	102	.000
Improve Quality	.823	102	.000
Reduce Human Resource	.878	102	.000
Reduce Contingencies	.850	102	.000
Faster & More Effective method	.825	102	.000
Reduce Rework During Construction	.839	102	.000

Table 4.12 (b): Tests of Normality (Barriers) - Shapiro Wilk Test

Barriers	Shapiro-Wilk		
	Statistic	**df**	**Sig.**
Lack of Knowledgeable & Experienced Partners	.786	102	.000
Current Technology is Enough	.862	102	.000
Cost of implementing	.885	102	.000
Limited Adoption in our Market	.835	102	.000
Immediate Benefit do not accrue to the Key Adopter	.847	102	.000
Absence of slandered BIM Contract document	.874	102	.000
Need for a New Business Model	.872	102	.000
Risk Allocation (Collaboration Vs Responsibility)	.864	102	.000
Concerns about software Limitations and complexity	.864	102	.000
Institution Education	.835	102	.000

Aesthetic Considerations	.901	102	.000
Sub Consultants are Unaware of BIM	.746	102	.000

Table 4.12 (c): Tests of Normality (Applications) - Shapiro Wilk Test

Applications	Shapiro-Wilk		
	Statistic	**df**	**Sig.**
3D Coordination	.794	102	.000
Design and Constructability Review	.872	102	.000
4D Scheduling and Sequencing	.837	102	.000
5D Cost Estimating	.879	102	.000
Integration of Subcontractors and Suppliers Data	.859	102	.000
Prefabrication	.865	102	.000
Structural Analysis	.846	102	.000
Lighting Analysis	.849	102	.000
Mechanical Analysis	.875	102	.000
Energy Analysis	.872	102	.000
Other Engineering Analysis	.866	102	.000
Operations and Maintenance	.853	102	.000

4.4.3 Kruskal Wallis Test for BIM Advantages

As the collected data is non para-metric so Kruskal Wallis test is performed to check whether all stakeholders including architects, Consultants / Engineers, General Contractors, Trade / Specialist Contractor, Design Builder / Project Management and Academics / Research, have similar perception regarding the advantages, barriers and potential application or otherwise. Table 4.13 explains that all stakeholders have similar perception about advantages associated with the adoption of BIM except ‘reduce construction cost’, and ‘reduce construction time’. Significance value of these three BIM advantages is less than 0.05, which means that stakeholders have given different ranking to these BIM advantages. So these three BIM advantages are further analyzed.

Table 4.13: Kruskal Wallis Test[a,b] for Advantages of BIM

S. No	Advantages of BIM	Significance
1	Reduce Construction Cost	**0.015**
2	Reduce Construction Time	**0.031**
3	Improve Quality	0.097
4	Reduce Human Resource	0.528
5	Reduce Contingencies	0.908
6	Faster & More Effective method	0.082
7	Reduce Rework During Construction	0.094

a. Kruskal Wallis Test
b. Grouping Variable: Stakeholders (Architects, Engineers, General Contractors, Specialist Contractors, Project Managers & Academics)

4.4.3.1 Difference in Perception on “Reduce Construction Cost”

Table 4.14 clarifies that significance value of “Reduce construction cost” is less than 0.05 because of difference in opinion of Design Builders and Specialist contractors. Design builder / Project management firm rates “reduces construction cost” at 87.5% because their profit is directly proportional to reduction in the construction cost of the project while trade / specialist contractors are least concerned with the reduction in the cost of the project, they are only concerned with their part of work, so they rated this Advantage as low as 60%. The resulted RII values for other stakeholders depict the concern of each of stakeholder for cost reduction.

Table 4.14: Stakeholder’s RII Difference for “Reduce Construction Cost”

S. No.	Stakeholder	RII
1	Architects	0.7142
2	Consultants / Engineers	0.6666
3	General Contractors	0.7555
4	Trade / Specialist Contractor	**0.6000**
5	Design Builder / Project Management	**0.8750**
6	Academic / Research	0.6363

4.4.3.2 Difference in Perception on "Reduce Construction Time"

Table 4.15 shows the difference of stakeholder's perception regarding "reduce construction time" as an advantage of BIM adoption. All the stakeholders rate it high as an advantage, design builder / project management professional's rates highest at 90%. Academic / Research professional's rate lowest to reduce its significance in Kruskal Wallis test. Academic / research people are not involved in real time construction, so it is impossible for them to know the importance of "time reduction". Lesser is the time of construction lesser will be overhead expenses.

Table 4.15: Stakeholder's RII Difference for "Reduce Construction Time"

S. No.	Stakeholder	RII
1	Architects	0.8000
2	Consultants / Engineers	0.7166
3	General Contractors	0.8666
4	Trade / Specialist Contractor	0.7500
5	Design Builder / Project Management	**0.9000**
6	Academic / Research	**0.6545**

4.4.4 Kruskal Wallis Test for Barriers in Adoption of BIM

Kruskal Wallis test is also applied to Barriers in adoption f BIM. Table 4.16 explains that stake holders differ in perception about barriers to BIM adoption in most of the factors. Significance value for "cost of implementing", "absence of standard contract documents", "risk allocation", "concerns about software limitations and complexity, "institutional education", "aesthetic considerations" and "sub-consultant are unaware of BIM" is less 0.05, which indicates the difference in perception of stake holders about these factors. This establishes that AEC stakeholders have more assorted perception about the barrier of BIM adoption as compare to advantages and application.

Table 4.16: Kruskal Wallis Test[a,b] for Barriers in Adoption of BIM

S. No	Barriers in Adoption of BIM	Significance
1	Lack of Knowledgeable & Experienced Partners	0.492
2	Current Technology is Enough	0.080
3	Cost of implementing	**0.029**
4	Limited Adoption in our Market	0.332

5	Immediate Benefit do not accrue to the Key Adopter	0.119
6	Absence of slandered BIM Contract document	**0.010**
7	Need for a New Business Model	0.080
8	Risk Allocation (Collaboration Vs Responsibility)	**0.007**
9	Concerns about software Limitations and complexity	**0.000**
10	Institution Education	**0.005**
11	Aesthetic Considerations	**0.000**
12	Sub Consultants are Unaware of BIM	**0.017**

a. Kruskal Wallis Test
b. Grouping Variable: Stakeholders (Architects, Engineers, General Contractors, Specialist Contractors, Project Managers & Academics)

4.4.4.1 Difference in Perception on "Cost of Implementation"

Table 4.17 indicate that architects and Engineering consultants rate this factor very high at 78% and 71% respectively while Design builders / Project management firm rates it as low as 60%. The reason behind this is very straight forward; architectural and engineering consultants are basic producer of the BIM models while contractors, suppliers and project managements firm just have to use the model only for their part of work. Therefore, architectural and engineering consultants have to invest a lot on training, equipment and softwares as compared to rest of the stakeholders.

Table 4.17: Stakeholder's RII Difference for "Cost of Implementation"

S. No.	Stakeholder	RII
1	Architects	**0.7142**
2	Consultants / Engineers	**0.7833**
3	General Contractors	0.6666
4	Trade / Specialist Contractor	0.7000
5	Design Builder / Project Management	**0.6000**
6	Academic / Research	0.6545

4.4.4.2 Difference in Perception on "Absence of BIM Contract Documents"

Table 4.18 explains that this factor has low level of significance because General Contractor rates it as high as 87% and Architects rates it as low as 60%. Contractor's liabilities are very much dependent of the contract documents; he rates the risks and contingencies according to the terms of the contract documents. Architectural consultants just have to ensure the contract compliance on the behalf of client but their fee is not dependent upon the type and terms of the construction contract documents.

Table 4.18: Stakeholder's RII Difference for "Absence of BIM Contract Document"

S. No.	Stakeholder	RII
1	Architects	**0.600**
2	Consultants / Engineers	0.7500
3	General Contractors	**0.8666**
4	Trade / Specialist Contractor	0.7500
5	Design Builder / Project Management	0.8250
6	Academic / Research	0.7454

4.4.4.3 Difference in Perception on "Risk Allocation"

Table 4.19 indicates that the difference in perception for this particular factor is because of very low rating given by Specialist Contractors. Trade contractors just have to deal with the risk involved in their part of work while contractor and consultants have deal with whole project. For example, architectural and engineering consultants have to provide professional liability insurance for whole of the project. Similarly contractor have also to ensure all the risks with many insurance policies, he has also to provide back to back insurances to client for trade contractor's work but trade contractor may or may not have to provide insurance only for his part of work.

Table 4.19: Stakeholder's RII Difference for "Risk Allocation"

S. No.	Stakeholder	RII
1	Architects	0.7714
2	Consultants / Engineers	0.7833
3	General Contractors	0.7777
4	Trade / Specialist Contractor	**0.5500**
5	Design Builder / Project Management	0.7250
6	Academic / Research	0.6727

4.4.4.4 Difference in Perception on "Concerns about software Limitations and complexity"

Table 4.20 indicates that the difference in perception for this particular factor is because of very low rating given by Specialist Contractors. In Pakistan, suppliers are worse than worst in BIM adoption. Mostly they just provide the input data to architect and architects further incorporates the data into the design / model. Therefore suppliers and trade contractors have to interface BIM softwares rarely so they perceive rare concerns about softwares.

Table 4.20: Stakeholder's RII Difference for "Concerns about software Limitations and Complexity"

S. No.	Stakeholder	RII
1	Architects	0.8571
2	Consultants / Engineers	0.8500
3	General Contractors	0.8000
4	Trade / Specialist Contractor	**0.5000**
5	Design Builder / Project Management	0.7000
6	Academic / Research	0.6545

4.4.4.5 Difference in Perception on "Institutional Education"

Table 4.21 indicates that the difference in perception for this particular factor is because of General Contractor, who rates it very high at 91%. It is because BIM is not a part of Civil Engineering curriculum.

Table 4.21: Stakeholder's RII Difference for "Institutional Education"

S. No.	Stakeholder	RII
1	Architects	0.8000
2	Consultants / Engineers	0.7666
3	General Contractors	**0.9111**
4	Trade / Specialist Contractor	0.7000
5	Design Builder / Project Management	0.8250
6	Academic / Research	0.6727

4.4.4.6 Difference in Perception on "Aesthetic Considerations"

Table 4.22 indicates that the difference in perception for this particular factor is because of vast difference between Architects' RII (77%) and Specialist Contractors' RII (35%). Architects rates it high because aesthetics is the theme of their profession while Specialist Contractors are least concerned with aesthetics. Architects are the ones, who have to deal with aesthetics to deliver a master piece to the client and also for his popularity. Their survival is dependent upon aesthetic and BIM softwares have many limitations in terms of aesthetics. BIM softwares like Revit Architecture use default shapes of building elements, which are available in the software library or from internet library. If an architect wants create a unique building element, it would be extremely difficult on Revit architecture.

Table 4.22: Stakeholder's RII Difference for "Aesthetic Considerations"

S. No.	Stakeholder	RII
1	Architects	**0.7714**
2	Consultants / Engineers	0.6000
3	General Contractors	0.7555
4	Trade / Specialist Contractor	**0.3500**
5	Design Builder / Project Management	0.6000
6	Academic / Research	0.5818

4.4.4.7 Difference in Perception on "Sub Consultants are Unaware of BIM"

Table 4.23 indicates that the difference in perception for this particular factor is due to the fact that all the stake holders except Consultants / Engineers (Sub Consultants) consider this factor as an extreme barrier in adoption of BIM in Pakistani AEC. In Pakistani AEC industry, BIM is only known to architect and they just use BIM to create 3D images, nothing more than that. BIM proper use and adoption can only be enhances, if sub-consultants are well enough educated and trained in BIM.

Table 4.23: Stakeholder's RII Difference for "Sub Consultants are Unaware of BIM"

S. No.	Stakeholder	RII
1	Architects	0.8857
2	Consultants / Engineers	**0.7833**
3	General Contractors	**0.9556**
4	Trade / Specialist Contractor	0.8000
5	Design Builder / Project Management	0.8500
6	Academic / Research	0.8000

4.4.5 Kruskal Wallis Test for Uses / Application of BIM

Lastly, Kruskal Wallis test is also applied to potential uses / application of BIM to check the difference in stakeholder's perception. Table 4.24 indicates that all the stakeholders have similar perception for all potential applications except "Design & Constructability Review", "5D Cost Estimating" and "Operation and Maintenance".

Table 4.24: Kruskal Wallis Test[a,b] for Application of BIM

S. No	Application of BIM	Significance
1	3D Coordination	0.105
2	Design and Constructability Review	**0.015**
3	4D Scheduling and Sequencing	0.136
4	5D Cost Estimating	**0.002**
5	Integration of Subcontractors and Suppliers Data	0.199
6	Prefabrication	0.333
7	Structural Analysis	0.304
8	Lighting Analysis	0.166
9	Mechanical Analysis	0.400
10	Energy Analysis	0.465
11	Other Engineering Analysis	0.271
12	Operations and Maintenance	**0.026**

a. Kruskal Wallis Test
b. Grouping Variable: Stakeholders (Architects, Engineers, General Contractors, Specialist Contractors, Project Managers & Academics)

4.4.5.1 Difference in Perception on “Design and Constructability Review”

Table 4.25 indicates that the difference in perception for this particular factor is due to the fact that there is a vast difference of RII between Architects (67%) and Academic and Research professionals (87%). This is application is very use full for project management firms and also for contractors to find optimized ways for construction by visualizing 3D and model also by visualizing construction simulation of design.

Table 4.25: Stakeholder’s RII Difference for “Design and Constructability Review”

S. No.	Stakeholder	RII
1	Architects	**0.6667**
2	Consultants / Engineers	0.7167
3	General Contractors	0.7333
4	Trade / Specialist Contractor	0.7500
5	Design Builder / Project Management	0.8000
6	Academic / Research	**0.8727**

4.4.5.2 Difference in Perception on “5D Cost Estimating”

Table 4.26 indicates that the difference in perception for this particular factor is due to the fact that there is a vast difference of RII between Architects (63%) and Academic and Research professionals (89%). Architects can produces many elements other than standard building elements (available in Revit Architecture Library), but there is a problems with these self generated elements that cost data cannot be linked with them, their presence in the model is just for aesthetic purpose.

Table 4.26: Stakeholder’s RII Difference for “5D Cost Estimating”

S. No.	Stakeholder	RII
1	Architects	**0.6333**
2	Consultants / Engineers	0.7167
3	General Contractors	0.7500
4	Trade / Specialist Contractor	0.6500
5	Design Builder / Project Management	0.7000
6	Academic / Research	**0.8909**

4.4.5.3 Difference in Perception on "Operations and Maintenance"

Table 4.27 indicates that the difference in perception for this particular factor is due to the fact that there is a vast difference of RII between Design Builders / Project Management firm (57%) and Specialist Contractors (85%). Design builders / project management firm are least concerned with BMS "Building Management Services" or facility management but trade / specialist contractors have to provide their services throughout the life cycle of the building. A BIM can make facility management easier for trade and specialist contractors.

Table 4.26: Stakeholder's RII Difference for "5D Cost Estimating"

S. No.	Stakeholder	RII
1	Architects	0.7000
2	Consultants / Engineers	0.8333
3	General Contractors	0.7250
4	Trade / Specialist Contractor	**0.8500**
5	Design Builder / Project Management	**0.5750**
6	Academic / Research	0.8000

4.5 RANKING OF BIM ADVANTAGES

BIM advantages are recorded according to over all perception recorded from all the stakeholders of AEC industry of Pakistan. An illustration is also provided, which depicts perceptions recorded against advantage from each type of respondents.

4.5.1 Overall Ranking of BIM Advantages by Mean and RIIs

The questionnaire comprises of seven BIM advantages to assess and rank them according to the respondents' replies. The data collected through 102 respondents is analyzed using MS excel and SPSS-18. Means, percentages, relative importance indexes (RIIs) and ranking of seven BIM advantages is calculated which is given in Table 4.27. Out of seven BIM advantages, "Faster and more effective method" has the highest value of RII (0.8118) whereas "Reduce Construction Cost" has the lowest value of RII (0.7098). It implies that AEC professionals don't consider BIM as a cost reduction tool, followed by "Reduce Human Resources" and Reduce Construction Time". On the other hand the factor of "Faster and more Effective Method" is the better perceived BIM advantage in AEC industry of Pakistan, followed by "Improve Quality" and "Reduce Rework during Construction".

Table 4.27: Mean, Percentage, RIIs and Ranking of BIM Advantages

S. No	BIM Advantages (7)	Mean	Percentage (%)	RIIs	Overall Ranking
1	**Reduce Construction Cost**	**3.5490**	**70.9804**	**0.7098**	**07**
2	Reduce Construction Time	3.8627	77.2549	0.7725	05
3	Improve Quality	4.0196	80.3922	0.8039	02
4	Reduce Human Resource	3.6667	73.3333	0.7333	06
5	Reduce Contingencies	3.9020	78.0392	0.7804	04
6	**Faster & More Effective method**	**4.0588**	**81.1765**	**0.8118**	**01**
7	Reduce Rework During Construction	3.9216	78.4314	0.7843	03
	Total	3.8543	77.09	0.7709	-

Figure 4.11 shows the overall ranking of all seven BIM advantages by AEC professionals of Pakistan based upon RIIs.

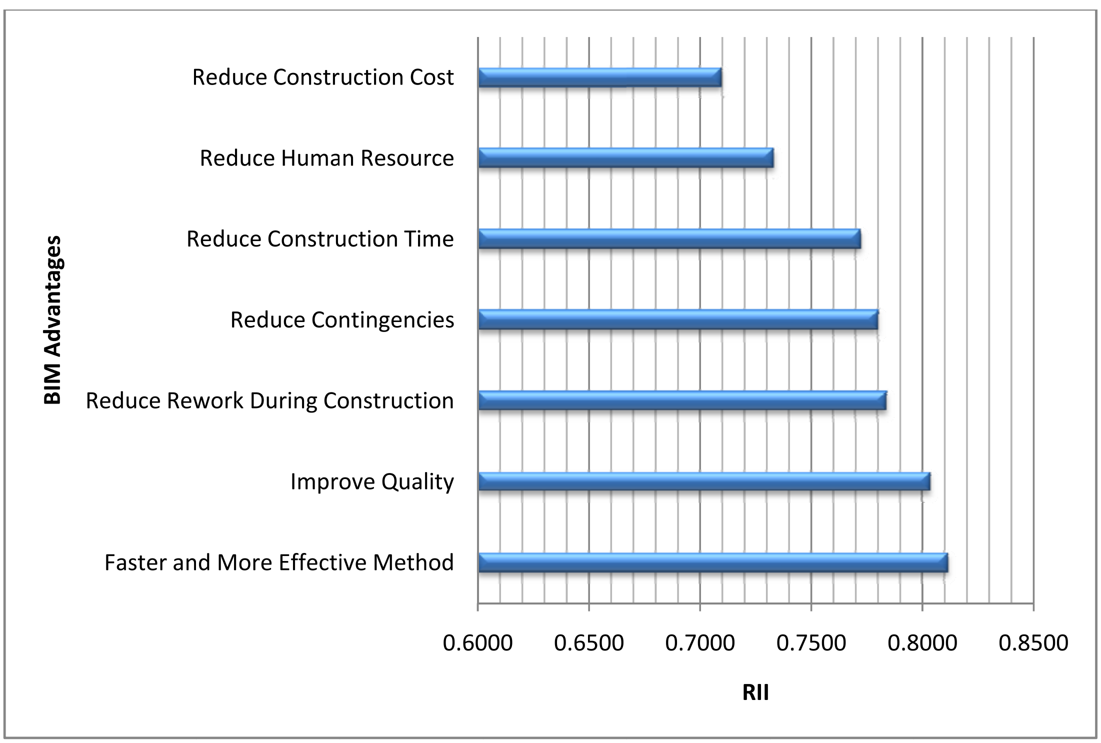

Figure 4.11: Ranking of BIM Advantages in AEC of Pakistan (basing on RIIs)

4.5.2 BIM Advantages – Inter Profession Comparison

To note the difference in perception of different stakeholders for advantages of BIM, which AEC industry may get by the adoption of BIM, Figure 4.12 depicts the RIIs given by each type of professional respondents to each of the advantage. It is clear from the Figure 4.12, Design builders / Project management firm rates RIIs for each advantage highest relative to professional belonging from other type of organizations. Specialist contractors are the one, who rates “Reduce Construction Cost” at 0.6000 (RII), which is the lowest rating given by any type of professionals to this advantage. Lowest ranting for “Reduce Construction Time” is given by professionals from Academics and Research. All professionals rates “Improve quality” more than 0.8000 (RII) except Academics and Research professional, who rate it round about 0.7000 (RII). Lowest rating for “Reduce Human Resources” comes from Architectural professionals. Again, Academics and Research professional’s gives lowest rating to “Reduce Contingencies”. “Reduce Rework during Construction” is lowest rated by Specialist contractors. “Faster and more Effective Method” is best rated by most of the professionals except Architectural professionals and its overall rank is 1.

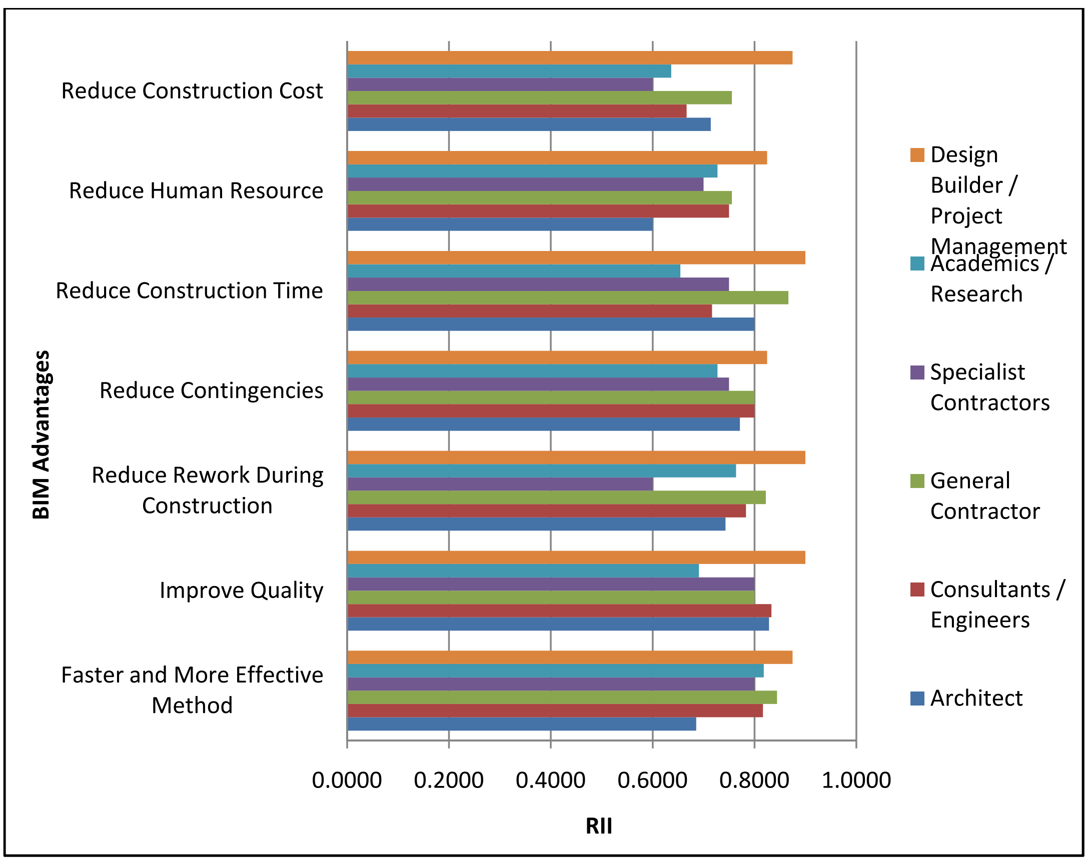

Figure 4.12: BIM Advantages – Inter Profession Comparison

4.6 RANKING OF BARRIERS TO BIM ADOPTION

Barriers to BIM adoption are recorded according to over all perception recorded from all the stakeholders of AEC industry of Pakistan. An illustration is also provided, which depicts perceptions recorded against barrier form each type of respondents.

4.6.1 Overall Ranking of Barriers by Mean and RIIs

Twelve Barriers were listed in the questionnaire to access and rank them according to the respondents' replies. The data collected through 102 respondents is analyzed using MS excel and SPSS-18. Means, percentages, relative importance indexes (RIIs) and ranking of twelve Barriers are calculated which is given in Table 4.28. Out of twelve Barriers listed in the questionnaire, "Sub Consultants are unaware of BIM" is the top ranked risk with RII value of 0.8431 whereas "Current Technology is enough" is the least ranked risk with RII value of 0.5216. AEC professionals of Pakistan "Current technology is enough" is least ranked risk in BIM adoption, followed by "Aesthetic considerations", "Cost of implementing" and "Immediate benefit do not accrue to key adopter". Top ranked risk is "Sub consultants are unaware of BIM" followed by "Lack of knowledgeable and experience partners", "Institutional education" and "Limited adoption in our industry".

Table 4.28: Mean, Percentage, RIIs and Ranking of Barriers to BIM Adoption

S. No	Barriers(12)	Mean	Percentage (%)	RIIs	Overall Ranking
1	Lack of knowledgeable and experience partners	4.1961	83.9216	0.8392	02
2	**Current technology is enough**	**2.6078**	**52.1569**	**0.5216**	**12**
3	Cost of implementing	3.4510	69.0196	0.6902	10
4	Limited adoption in our market	3.8431	76.8627	0.7686	04
5	Immediate benefits do not accrue to key adopters	3.5098	70.1961	0.7020	09
6	Absence of standard BIM contract documents	3.8039	76.0784	0.7608	05

7	Need for a New Business Model	3.7059	74.1176	0.7412	07
8	Risk Allocation (Collaboration Vs Responsibility)	3.6471	72.9412	0.7294	08
9	Concerns about software Limitations and complexity	3.7451	74.9020	0.7490	06
10	Institution Education	3.9020	78.0392	0.7804	03
11	Aesthetic Considerations	3.1373	62.7451	0.6275	11
12	**Sub Consultants are Unaware of BIM**	**4.2157**	**84.3137**	**0.8431**	**01**
	Total	3.6471	72.94	0.7294	-

Figure 4.13 shows the overall ranking of all 12 Barriers in BIM adoption by AEC professionals of Pakistan based upon RIIs.

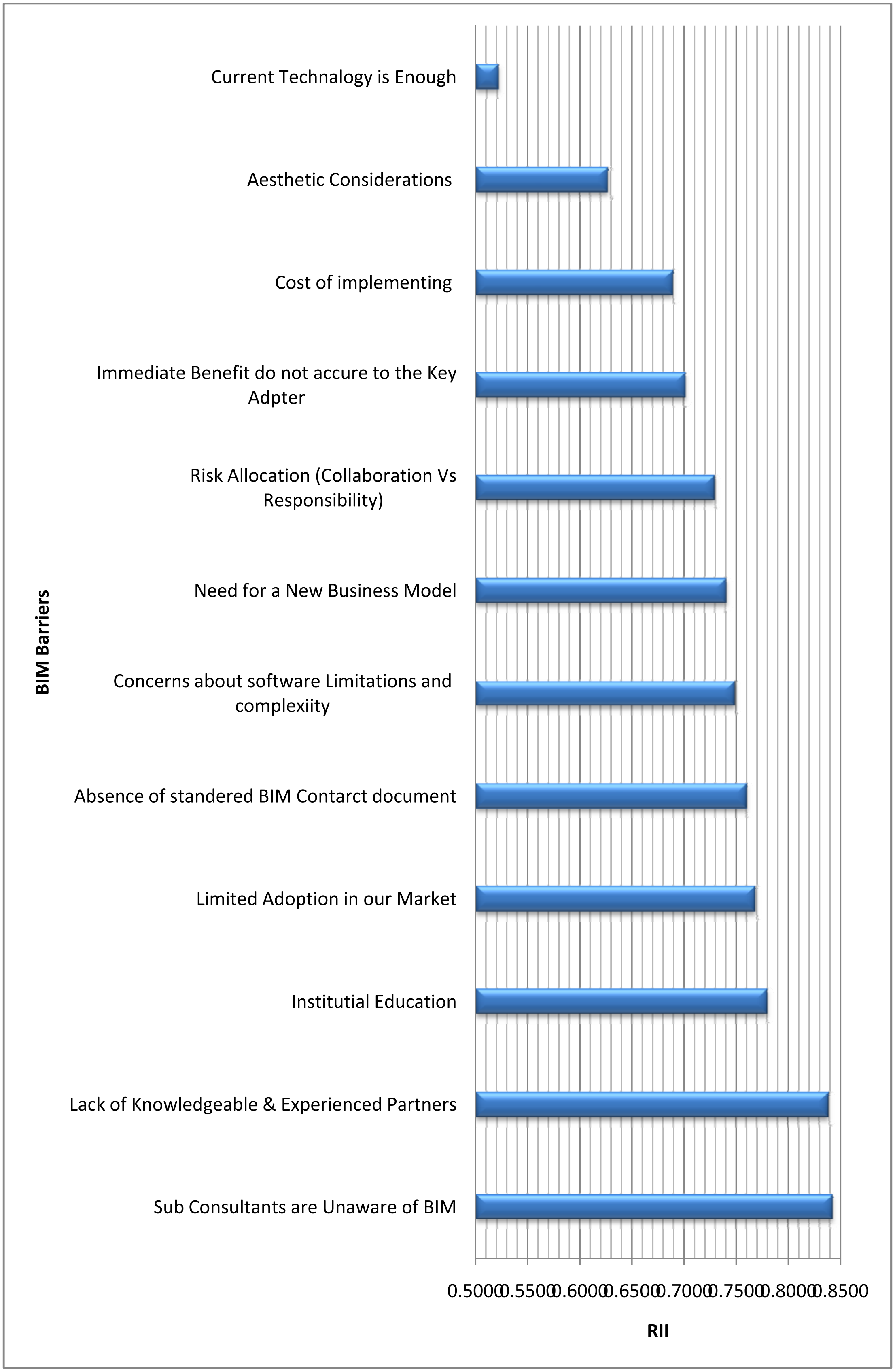

Figure 4.13: Barriers in BIM Adoption

4.6.2 Barriers to BIM adoption - Inter Profession Comparison

Figure 4.14 depicts the difference of perception of each of the stakeholders of AEC industry of Pakistan against each of the risk / barrier. Overall ranking for "Current technology is enough" is 12 because professionals form all type of organizations ranks it below 0.6000 (RII) except specialist contractors, who rank it at 0.6000. As expected, "Aesthetic consideration" as a barrier in BIM adoption got its best RII (0.7714) from Architectural professionals but it has been rated very low by all other AEC professionals, specially by specialist contractors by a RII value of 0.3500. "Cost of Implementation" got its highest RII (0.7833) from consultants / engineers and lowest (0.6000) from design builders. "Immediate benefits do not accrue to key adopter" has been rated more than 0.7000 RII by all the stake holders except Architects who rate it at 0.6000 RII. "Risk Allocation" has be worst (0.5500) rated by specialist contractors while all other professionals have rated it more than 06500 RII. "Need for a new business model has been highly rated by Consultants (0.7833) and worst (0.5500) rated by specialist contractors. "Concerns about software limitations and complexity" has been rated very high (0.8571) by architects, specialist contractors have reduced its overall ranking by giving it 0.5000 RII. "Absence of standard BIM contract documents" has been best rated (0.867) by general contractors and architects give a very low RII of 0.6000 to this barrier in adoption of BIM. "Limited adoption in our market" has been rated to 0.8000 or more by contractors, specialist contractors and consultants while architects rate it at 0.7143. "Institution education" has been rated highly (0.9111) by general contractors while academia give it low RII of 0.6727. "Lack of knowledgeable and experienced parterres" has been highly rated (more than 0.8000) by all he stakeholders especially by Project management (0.8750) and consulting organizations / firm (0.8833). "Sub Consultants are unaware of BIM" got overall no. 1 ranking because of extremely high RII (0.9556) given by general contractors.

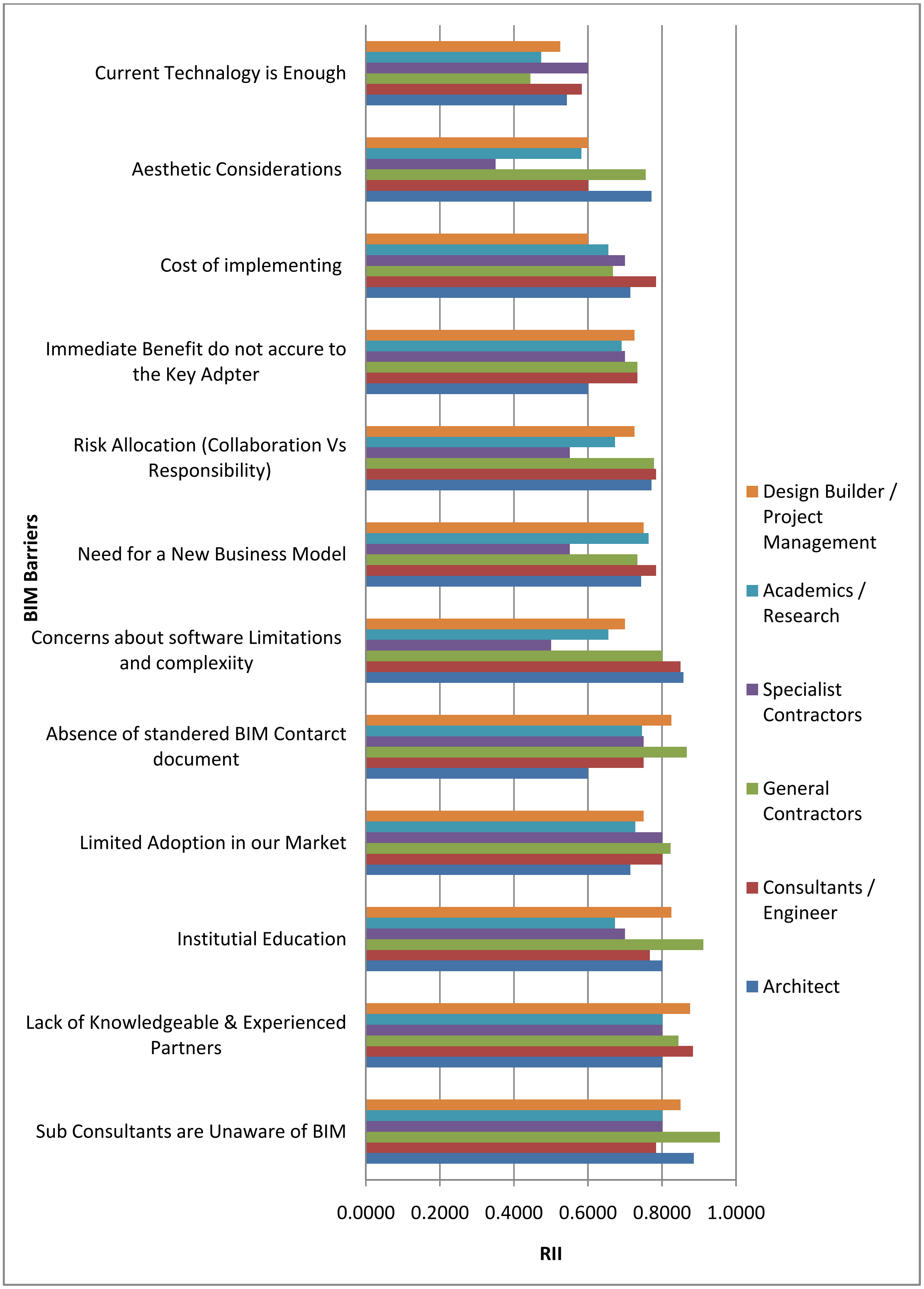

Figure 4.14: Barriers in BIM Adoption – Inter Profession Comparison

4.7 RANKING POTENTIAL APPLICATION OF BIM IN PAKISTAN

BIM Application are recorded according to over all perception recorded from all the stakeholders of AEC industry of Pakistan. An illustration is also provided, which depicts perceptions recorded against advantage form each type of respondents.

4.7.1 Overall Ranking of Application of BIM by Mean and RIIs

Twelve applications were listed in the questionnaire to access and rank them according to the respondents' replies. The data collected through 102 respondents is analyzed using MS excel and SPSS-18. Means, percentages, relative importance indexes (RIIs) and ranking of twelve application are calculated which is given in Table 4.29. Out of twelve Barriers listed in the questionnaire, "3D Coordination" is the top ranked potential application of BIM for AEC industry of Pakistan with RII value of 0.8157 whereas "Prefabrication" is the least ranked risk with RII value of 0.7335. "3D Coordination", "Lighting Analysis","4D scheduling and sequencing" and "Design and constructability review" are ranked at top four positions respectively. "Prefabrication", is least ranked application, followed by "Other engineering analysis", "5D cost estimating" and "Energy analysis".

Table 4.29: Mean, Percentage, RIIs and Ranking of Application of BIM

S. No	Barriers(12)	Mean	Percentage (%)	RIIs	Overall Ranking
1	**3D Coordination**	**4.0784**	**81.57**	**0.8157**	**01**
2	Design and Constructability Review	3.8105	76.21	0.7621	04
3	4D Scheduling and Sequencing	3.8382	76.76	0.7676	03
4	5D Cost Estimating	3.7042	74.08	0.7408	10
5	Integration of Subcontractors and Suppliers Data	3.7377	74.75	0.7475	08
6	**Prefabrication**	**3.6675**	**73.35**	**0.7335**	**12**
7	Structural Analysis	3.7851	75.70	0.7570	05
8	Lighting Analysis	3.8766	77.53	0.7753	02

9	Mechanical Analysis	3.7418	74.84	0.7484	07
10	Energy Analysis	3.7345	74.69	0.7469	09
11	Other Engineering Analysis	3.6748	73.50	0.7350	11
12	Operations and Maintenance	3.7475	74.95	0.7495	06
	Total	3.7831	75.66	0.7566	-

Figure 4.15 shows the overall ranking of all twelve potential applications of BIM, ranked by AEC professionals of Pakistan based upon RIIs.

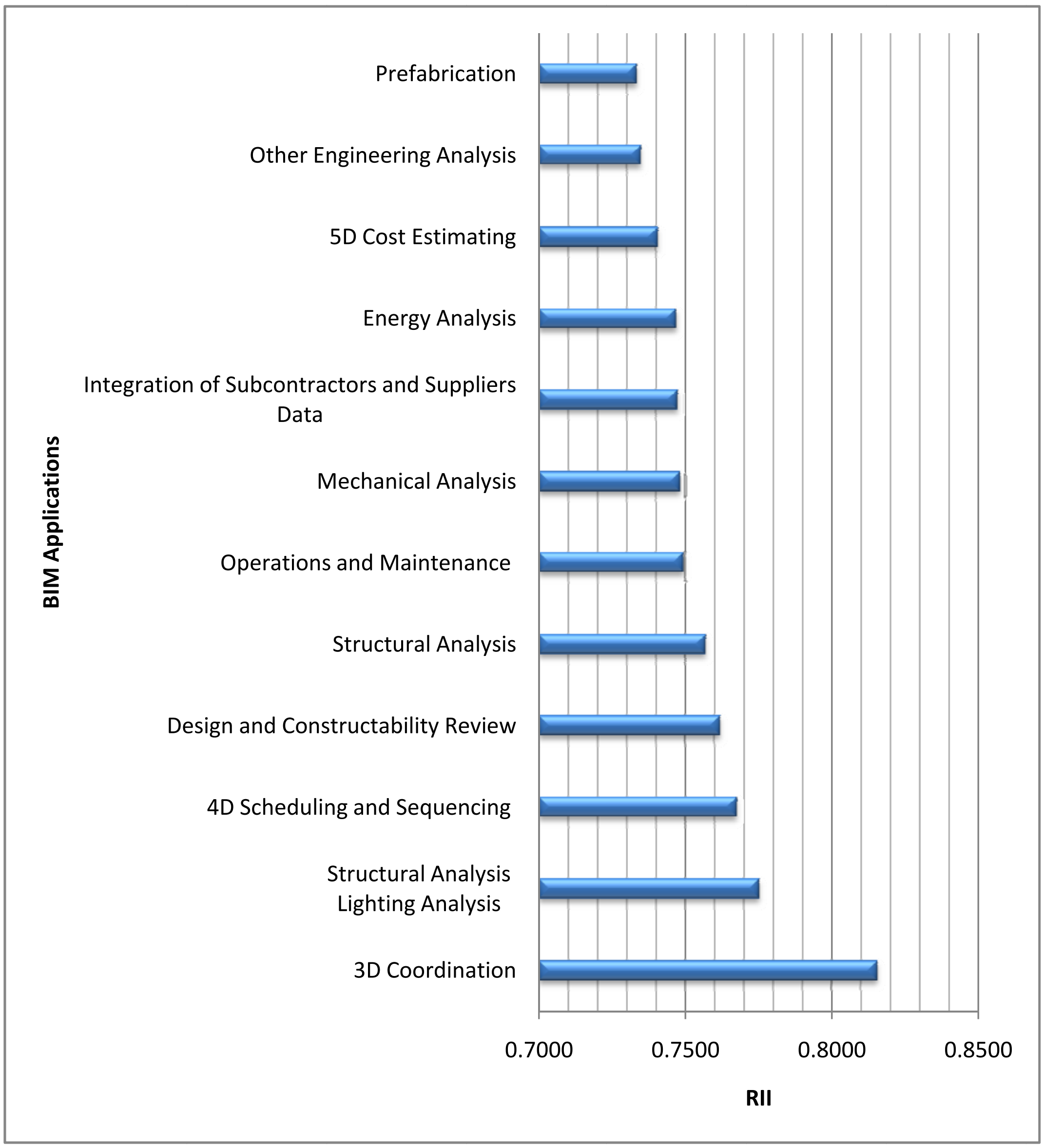

Figure 4.15: Application of BIM

4.7.2 Applications of BIM - Inter Profession Comparison

Figure 4.14 depicts the difference of perception of each of the stakeholders of AEC industry of Pakistan against each of current / potential application of BIM. “Prefabrication” is least ranked application of BIM, because of low RII value of 0.600 by specialist contractors even though it RII value given by project management professionals is 0.8250. Architects rate “Other engineering analysis” as low as 0.6190. Academic / Research professionals rated “5D Cost estimating” an RII of 0.8909 but still on the overall scale it ranks 10 (3rd last) because all other professionals rated its RII less than or equal to 0.7500. Nest is “Energy Analysis” with an overall ranking of 9 because of low RII (0.6524) given by architects. “Integration of subcontractors and suppliers data” and “Mechanical analysis” have also been rated low by architects with RIIs of 0.6000 and 0.6667 respectively. “Operations and Maintenance” got high RII of 0.8500 and 0.8333 from specialist contractors and consultants respectively. “Structural analysis” and “Design and constructability review” got highest RII of 0.8000 and 0.8427 from academia lowest from architects 0.6333 and 0.6667 but still got ranked 5 and 4 respectively. “4D Scheduling and Sequencing” got ranked at no. 3 by getting highest RII of 0.8727 from academia. “Lighting analysis” got ranked at no. 2, due to high RIIs of 0.8364 and 0.8167 by academia and consultants respectively. As expected, “3D Coordination” got an overall rank of 1 because it got RIIs more than or equal to 0.8000 from professionals from all type of organizations except from consultants (0.75000).

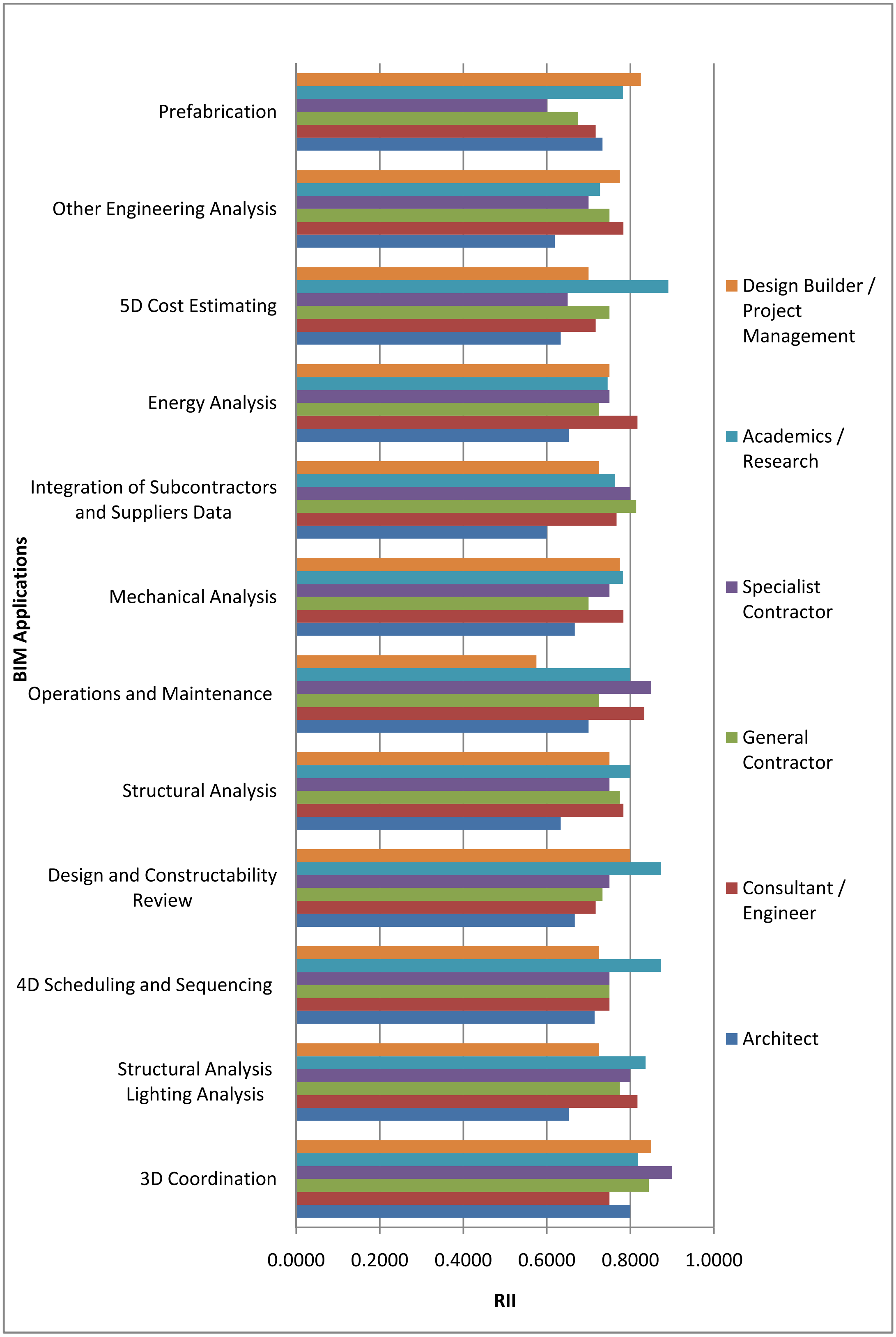

Figure 4.16: Applications of BIM – Inter Profession Comparison

4.8 MAKING BIM POPULAR IN PAKISTAN

At the end of the questionnaire, there was an open ended, requiring the suggestions of the respondents to make BIM popular in Pakistan. Suggestions given by various respondents are following

- By making BIM part of syllabus at undergraduate and post graduate level for civil engineering students. (Zahoor Ahmed, FWO)
- Make society for the promotion if BIM (Rizwan Cheema, Al Imam Enterprises, Lahore)
- There is a supreme need to use BIM technology in construction filed. Awareness can be highlighted by arranging seminars or by practicing it as a part of course in engineering studies. Once the designer will be familiar, it would be a core need for consultant and contractor to learn/use the technology. (Shazad Mirza, ERRA-PMU-RCDP, Kashmir)
- Contractual obligation for consultants and Contractors (Rehan Masood, University of Lahore)
- By Government showing interest in implementation of design standards requiring strict BIM check.(Shama Ambrine , UET Lahore)
- By starting BIM awareness workshops to familiarize the industry professionals, especially Architects, Architectural and Construction related Engineers. (Shama Ambrine , UET Lahore)
- By introducing BIM as a module at undergraduate level (Shama Ambrine , UET Lahore)
- To take up necessary regulatory actions. To make policy to implement BIM systems in all mega building projects as well as multistory buildings. Since it has high operational and maintenance cost, therefore, this aspect should be cater for.(Dr. Sajjad Mubee, P & D Department, Govt. of Punjab)
- By making any pilot project successful and replicate that project in other areas.(H. M. Qasim, Urban Unit, Govt. of Punjab)
- By introducing a separate course at BSc level and by giving training to MS students for one week at least.(Amnah Amir, A & P Division, NESPAK Lahore)
- Seminars, lectures and introduction in institutes (Ar. Azib Bajwa, Sefam Enterprises)

- Well practically the only way which seems to be practical is to redefine our way of contracting. It should be in project specifications and a reasonable sum should be allotted to parties who have are going to make it happen (contractor, consultant etc). Moreover, way of official dealing should be online which have a provision for BIM in reports, submittal/transmittal and correspondences e.g, Constructware from Autodesk and Acconex etc (Qasim Raza, Descon)
- First, there is a need to introduce & implement Construction Engineering & Management concept in Pakistan. Secondly, to implement BIM in Pakistan, we have to take all stakeholders like client, contractor, engineer, designer & architect on Board. Special convincing effort will be required for Client & Contractor. These two stakeholders are always reluctant to a change. Thirdly, a project as an example may be passed through BIM till its completion.(Mehmood Ur Rehman, Karachi.

Mr. Furqan Ahmed, Principal Architect, Khatri Associates, Karachi gave detailed response and proposed following procedure to make BIM popular in Pakistan.

We need to make strong body to fill the Gap b/w AEC, who make awareness and importance of BIM, the body like Link with association like PCATP, IAP, PEC, ABAD, APCA, HEC etc

Step 1: Document the workflow conventional methodology of AEC as individual in context of Pakistan.

Step 2: Old and young generation needs to integrated, for that we need to document the Generations in our industry (like Baby boomer, X, Y Z). As same we need to categorize in the context of AEC. After that we can plan to focus the generation who will adopt BIM.

Step 3: We need to create the road map for implement the BIM in curriculum of all Institutions related to AEC. And the outline need to in the context of Step-1 & 2.

Finally I will suggest we need to make the online forum page. And also publish the small E-Magazine for awareness of BIM in AEC. In which can publish articles and Project done with BIM applications.

4.9 SUMMARY

In this chapter statistical analysis has been discussed. 7 advantages of BIM, 12 barriers in BIM adoption and 12 current / potential applications are analyzed and ranked using SPSS-18 and MS Excel, so as to assess the current state of BIM adoption in AEC of Pakistan. Furthermore respondent's replies were also analyzed to predict the future of BIM in Pakistan. Data was collected from PEC registered construction companies, PCATP registered architects, renowned suppliers, Government organizations (Project Management) working across the Pakistan.

Cronbach's Coefficient Alpha values for advantages (0.828), risks (0.796) and applications (0.952) proved that the data is quite reliable for analysis. Shapiro Wilk normality test confirmed that data is not normally distributed so non para-metric test (Kruskal Wallis test) is applied to judge the differences in perception of all stakeholders, about advantages, risks and applications of BIM in AEC Industry of Pakistan.

"Faster and more effective method" is ranked as best perceived BIM advantage in AEC industry of Pakistan, followed by "Improved Quality" at no. 2 and " Reduces rework during construction" at no. 3. According to the respondents BIM is least effective in cost reduction so "Reduce Construction cost" is ranked at no. 7 (last).

In this chapter, 12 Barriersin adoption of BIM are also ranked. "Sub consultants are unaware of BIM is the highest rated risk and ranked at no. 1, followed by "Lack of knowledgeable and experienced partners" at no. 2 and "Institutional Education" at no. 3. "Current technology is enough" is the least rated risk and ranked at no. 12.

Ranking of BIM uses / application for Pakistani AEC Industry according to respondent's replies is also depicted in this chapter. "3D Coordination" is ranked as no. 1 BIM application for Pakistan, followed by "Lighting analysis" at no. 2 and "4D scheduling and sequencing" at no. 3. "Prefabrication" is least ranked BIM application for Pakistan.

Finally, this chapter also records the respondent's suggestions for making BIM popular in Pakistan.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 REVIEW OF RESEARCH OBJECTIVES

The sub-objectives of this study are:

a. To explore the current state of BIM adoption in Pakistan.

b. To study and explore and rank the advantages, risks and applications associated with the adoption of BIM.

c. To compare the perception of different stake holders of AEC industry of Pakistan about the adoption of BIM.

d. To predict the future of BIM in Pakistan.

The first objective is met by collecting and presenting respondents perception and responses against the questions like general level of buzz about BIM in Pakistani market, respondents know how about BIM and BIM adoption in Pakistani organizations. The second objective is met by exploring 7 advantages, 12 risks and 12 application from literature review and then recording respondents perception on a five point likert scale through a questionnaire survey from 102 construction projects in working across the Pakistan and then analyzing the collected data using SPSS-18 and measuring RIIs for each advantage, risk and application. Third objective is achieved by finding out difference in perception of stakeholders through kruskal wallis test and finally the fourth objective is attained by suggesting measures to make BIM popular in Pakistan and also by presenting future trends of BIM as per respondents perception.

5.2 CONCLUSIONS

The major findings of the study are:

a. Current state of BIM adoption is not satisfactory in Pakistan. Only 27% of AEC organizations are using BIM or involve if BIM adoption process in any capacity. 73% organizations are neither using BIM nor involved in BIM adoption process in any capacity.

b. It is good to note that average RIIs for advantages (0.7709), application (0.7566) is higher than and are relatively closer to 1 than average RII value of barriers (0.7294). It indicates that barriers are being shattered due to increasing awareness about BIM advantages and application.
c. BIM and BIM adoption is more popular in architectural professionals relative to other AEC professionals.
d. AEC professionals graduated after 2005 have more knowledge of BIM as compare to old graduates.
e. BIM adoption rate in Karachi is higher than rest of Pakistan. Firms like Ahed Associates, Khatri Associates have shifted to BIM and utilizing its application like “3D coordination”, “Lighting analysis”, “design review” and “4D Scheduling”.
f. 78.5% of professionals consider that there is some level of “BUZZ” about BIM is present in Pakistani market, “BUZZ” level ranges from low to very high.
g. 80.5 % of the respondents have knowledge of BIM, ranging from little knowledge, fair knowledge and expert type of knowledge.
h. BIM is a faster and more effective method for designing and construction management, it improves quality of the design and construction and it reduces rework during construction are the top thee advantages according to the perception of AEC professionals of Pakistan and BIM has least impact on reduction of cost, time and human resources.
i. Sub consultants are unaware of BIM, lack of knowledgeable and experienced partners and lack of institutional education are top three barriers in BIM adoption in Pakistani environment.
j. Current technology is enough is not regarded as an barrier in BIM adoption and is ranked least, so technology advancement in the form of BIM are needed by the improvement of Pakistani AEC industry.
k. AEC professionals have faces a lot of problems related to clash detection and inter services coordination therefore they ranked 3D coordination as the best application of BIM for Pakistani industry. Lighting analysis and 4D scheduling are ranked at second and third position amongst the potential

application of BIM. Use of BIM in prefabrication is ranked least amongst the listed application of BIM.

l. 96% of AEC professionals are in the favour of implementing BIM in Pakistan. Professionals are willing to implement BIM only awareness and education is need.

5.3 RECOMMENDATIONS FOR MAKING BIM POPULAR IN PAKISTAN

Following are recommendations suggested by the respondents or inferred from the data analysis

a. PCATP, PEC and Universities should play their part in promotion of BIM by organization seminars, lectures and workshops on BIM.
b. Engineering universities should make BIM as a part of syllabus at undergraduate and post graduate level for architectural engineering, civil engineering, architecture discipline (recommended by most of the respondents).
c. BIM users shall make a society for BIM promotion.
d. Clients shall make it as a contractual obligation for consultants and contractors, as client or project owner is the end beneficiary of BIM use.
e. By Government showing interest in implementation of design standards requiring strict BIM check.
f. By making any pilot project successful and replicate that project in other areas.

5.4 KNOWLEDGE CONTRIBUTION

This research study is the pioneer effort to find out the current state of BIM adoption in AEC industry of Pakistan. It will definitely help the stakeholders of AEC to find the weaknesses in their current designing and construction practices in comparison to BIM. This effort will definitely fuel the evolutionary process of changing the mindset of all stakeholders to invest in BIM training and adoption.

5.5 RECOMMENDATIONS FOR FUTURE RESEARCH

a) Design of a Pilot Project with the aid of BIM tools to highlight BIM advantages in comparison to traditional design approach.
b) Study of “Contractual and legal risks” associated with BIM adoption in AEC industry.
c) Study of BIM for sustainable analysis.
d) Challenges in cost estimating with Building Information Modeling.

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APPENDIX-I
SURVEY QUESTIONNAIRE

National University of Sciences and Technology, Islamabad

MS Research Thesis Questionnaire-Survey Form

Topic: ***Building information modeling (BIM), Issues, problems & advantages associated with the adoption of BIM in AEC industry.***

Section 1: Brief Introduction Of BIM
Building Information Modeling is an emerging technology/process/methodology to manage the essential building design and project data in digital format throughout the building life-cycle.
Section 1: Respondents Personal Details
Name
Organization's / Firm's Name
Qualification
Professional Experience (Years)
BIM Experience (Years)
Position
Cell No. (Optional)
Email address

Section 2: General

1. In which region of Pakistan does your organization work? (Tick all appropriate options)
    - Punjab
    - KPK
    - Sindh
    - Baluchistan
    - Kashmir
    - Gilgit Baldistan
2. Which of following best describes your organization?
    - Architect
    - Consultant / Engineer
    - General Contractor
    - Trade /Specialist Contractor
    - Design Builder / Project Management
    - Academic / Research
3. How do you characterize the size of your organization?
    - Small (Below 10 Employees)
    - Small (10 - 25 Employees)

- Large (100 – 500 Employees)
- Very Large (Over 500 Employees)

4. BIM is a hot topic in AEC industry, what is general level of Buzz (know how) about BIM in your working industry?
    - None
    - Low
    - Medium
    - High
    - Very High
5. How do you consider your knowledge about BIM?
    - Nothing
    - Little
    - Fair
    - Expert
6. Is your organization using BIM or involved in BIM adoption process in any capacity?
    - Yes
    - No
7. Are you in favor of implementing BIM in the AEC industry of Pakistan
    - Yes
    - No
8. The future of BIM in AEC industry of Pakistan?
    - Definitely No
    - May be No
    - No Idea
    - May be Yes
    - Definitely Yes

Section 3: Advantages Associated With Adoption of BIM

	Description	Please first go through all mentioned statement and mark **(√)** in the box under one of the five categories which applies.					
		Strongly Disagree	Disagree	Average	Agree	Strongly Agree	Any Comment
1.	Reduce construction cost						
2.	Reduce construction time						
3.	Improve Quality						
4.	Reduce Human Resource						

5.	Reduce contingencies						
6.	Faster and more effective						
7.	Reduce rework during construction						
Any other advantage							

Section 4: Barriers in Adoption of BIM							
	Description	Please first go through all mentioned statement and mark **(√)** in the box under one of the five categories which applies.					
		Strongly Disagree	Disagree	Average	Agree	Strongly Agree	Any Comment
1.	Lack of knowledgeable and experience partners						
2.	Current Technology is enough						
3.	Cost of Implementing						
4.	Limited adoption in our markets						
5.	Immediate benefits do not accrue to key adopter						
6.	Absence of standard BIM contract documents						
7.	Need for a new business model						
8.	Risk allocation (collaboration Vs responsibility)						
9.	Concerns about						

	software limitations or complexity						
10.	Institutional education						
11.	Aesthetic considerations						
12.	Sub-consultants are unaware of BIM						
Any other barrier							

Section 5: Potential Application of BIM							
Description		Please first go through all mentioned statement and mark **(√)** in the box under one of the five categories which applies.					
		Strongly Disagree	Disagree	Average	Agree	Strongly Agree	Any Comment
1.	3D coordination						
2.	Design and constructability reviews						
3.	4D scheduling and sequencing						
4.	5D cost estimation						
5.	Integration of subcontractors and suppliers data						
6.	Prefabrication						
7.	Structural analysis						
8.	Lighting analysis						
9.	Mechanical analysis						
10.	Energy analysis						
11.	Operation and maintenance						
Any other Application							

How we can make BIM popular in Pakistan? (Your suggestions will be highly appreciated)

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APPENDIX-II

RALIABIALITY ANALYSIS

SPSS Reliability Analysis Results

Advantages of BIM

Case Processing Summary

		N	%
Cases	Valid	102	100.0
	Excluded[a]	0	.0
	Total	102	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.828	7

Risks Associated with Use of BIM

Case Processing Summary

		N	%
Cases	Valid	102	100.0
	Excluded[a]	0	.0
	Total	102	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.796	12

Applications of BIM

Case Processing Summary

		N	%
Cases	Valid	102	100.0
	Excluded[a]	0	.0
	Total	102	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.952	12

Advantages of BIM

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Advan.1	.245	102	.000	.885	102	.000
Advan.2	.271	102	.000	.816	102	.000
Advan.3	.249	102	.000	.823	102	.000
Advan.4	.207	102	.000	.878	102	.000
Advan.5	.265	102	.000	.850	102	.000
Advan.6	.240	102	.000	.825	102	.000
Advan.7	.235	102	.000	.839	102	.000

a. Lilliefors Significance Correction

Risks Associated with BIM

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Risk 1	.248	102	.000	.786	102	.000
Risk 2	.263	102	.000	.862	102	.000
Risk 3	.240	102	.000	.885	102	.000
Risk 4	.281	102	.000	.835	102	.000
Risk 5	.246	102	.000	.847	102	.000
Risk 6	.225	102	.000	.874	102	.000
Risk 7	.253	102	.000	.872	102	.000
Risk 8	.227	102	.000	.864	102	.000
Risk 9	.258	102	.000	.864	102	.000
Risk 10	.265	102	.000	.835	102	.000
Risk 11	.197	102	.000	.901	102	.000
Risk 12	.273	102	.000	.746	102	.000

a. Lilliefors Significance Correction

Applications of BIM

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Application 1	.253	102	.000	.794	102	.000
Application 2	.228	102	.000	.872	102	.000
Application 3	.288	102	.000	.837	102	.000
Application 4	.196	102	.000	.879	102	.000
Application 5	.288	102	.000	.859	102	.000
Application 6	.288	102	.000	.865	102	.000
Application 7	.290	102	.000	.846	102	.000
Application 8	.276	102	.000	.849	102	.000
Application 9	.253	102	.000	.875	102	.000
Application 10	.204	102	.000	.872	102	.000
Application 11	.223	102	.000	.866	102	.000
Application 12	.251	102	.000	.853	102	.000

a. Lilliefors Significance Correction

ADVANTAGES - Kruskal-Wallis Test

Ranks

	GROUP	N	Mean Rank
FAC 1	1	14	50.21
	2	24	43.33
	3	18	55.39
	4	16	73.75
	5	8	42.75
	6	22	45.05
	Total	102	
FAC 2	1	14	50.50
	2	24	43.42
	3	18	63.28
	4	16	65.00
	5	8	54.25
	6	22	40.50
	Total	102	
FAC 3	1	14	51.57
	2	24	55.17
	3	18	48.83
	4	16	66.75
	5	8	47.00
	6	22	40.18
	Total	102	
FAC 4	1	14	44.07
	2	24	50.50
	3	18	52.94
	4	16	62.13
	5	8	42.50
	6	22	51.68
	Total	102	
FAC 5	1	14	50.36
	2	24	54.00
	3	18	51.83
	4	16	56.63

Name	**Group #**
Ar-Resp	1
En-Resp	2
GC-Resp	3
DB-Resp	4
SC-Resp	5
R&D-Resp	6

	5	8	48.75
	6	22	46.50
	Total	102	
FAC 6	1	14	31.93
	2	24	52.58
	3	18	55.39
	4	16	59.13
	5	8	44.50
	6	22	56.59
	Total	102	
FAC 7	1	14	44.93
	2	24	51.33
	3	18	54.28
	4	16	66.50
	5	8	32.00
	6	22	49.77
	Total	102	

Test Statistics[a,b]

	FAC1	FAC2	FAC3	FAC4	FAC5	FAC6	FAC7
Chi-Square	14.127	12.310	9.306	4.150	1.544	9.779	9.412
df	5	5	5	5	5	5	5
Asymp. Sig.	.015	.031	.097	.528	.908	.082	.094

a. Kruskal Wallis Test

b. Grouping Variable: QUES

RISKS - Kruskal-Wallis Test

Ranks

	GROUP	N	Mean Rank
FACR1	1	14	47.64
	2	24	57.25
	3	18	51.17
	4	16	58.00
	5	8	38.50
	6	22	47.95
	Total	102	
FACR2	1	14	54.07
	2	24	61.17
	3	18	39.50
	4	16	49.75
	5	8	66.00
	6	22	45.14
	Total	102	
FACR3	1	14	55.07
	2	24	66.08
	3	18	47.39
	4	16	36.25
	5	8	52.00
	6	22	47.59
	Total	102	
FACR4	1	14	39.79
	2	24	55.75
	3	18	59.83
	4	16	46.38
	5	8	55.75
	6	22	49.68
	Total	102	
FACR5	1	14	32.07
	2	24	56.67
	3	18	56.17
	4	16	51.88
	5	8	51.00
	6	22	54.32

	Total	102	
FACR6	1	14	29.93
	2	24	48.92
	3	18	66.72
	4	16	60.00
	5	8	47.75
	6	22	50.77
	Total	102	
FACR7	1	14	50.36
	2	24	55.92
	3	18	51.17
	4	16	53.63
	5	8	22.50
	6	22	56.68
	Total	102	
FACR8	1	14	56.64
	2	24	59.42
	3	18	59.83
	4	16	51.50
	5	8	20.25
	6	22	44.14
	Total	102	
FACR9	1	14	68.36
	2	24	63.42
	3	18	55.61
	4	16	44.13
	5	8	23.25
	6	22	40.05
	Total	102	
FACR10	1	14	54.79
	2	24	48.08
	3	18	71.06
	4	16	56.38
	5	8	34.50
	6	22	39.77
	Total	102	
FACR11	1	14	70.07
	2	24	45.50
	3	18	67.83

	4	16	50.38
	5	8	19.00
	6	22	45.50
	Total	102	
FACR12	1	14	53.50
	2	24	38.33
	3	18	68.17
	4	16	57.63
	5	8	49.00
	6	22	47.41
	Total	102	

Test Statistics[a,b]

	FACR1	FACR2	FACR3	FACR4	FACR5	FACR6	FACR7	FACR8	FACR9	FACR10	FACR11	FACR12
Chi-Square	4.410	9.845	12.468	5.745	8.760	15.209	9.847	15.841	22.335	16.788	24.343	13.859
df	5	5	5	5	5	5	5	5	5	5	5	5
Asymp. Sig.	.492	.080	.029	.332	.119	.010	.080	.007	.000	.005	.000	.017

a. Kruskal Wallis Test

b. Grouping Variable: QUES

ADVANTAGES - Kruskal-Wallis Test

Ranks			
	GROUP	N	Mean Rank
AP1	1	14	53.93
	2	24	37.50
	3	18	52.72
	4	16	59.38
	5	8	62.50
	6	22	54.50
	Total	102	
AP2	1	14	38.79
	2	24	43.58
	3	18	46.94
	4	16	58.25
	5	8	48.00
	6	22	68.32
	Total	102	
AP3	1	14	46.50
	2	24	46.67
	3	18	47.94
	4	16	50.38
	5	8	44.25
	6	22	66.32
	Total	102	
AP4	1	14	37.07
	2	24	46.42
	3	18	52.83
	4	16	50.25
	5	8	35.25
	6	22	71.95
	Total	102	
AP5	1	14	35.21
	2	24	52.67
	3	18	60.83
	4	16	49.38
	5	8	56.50

	6	22	52.68
	Total	102	
AP6	1	14	57.64
	2	24	49.08
	3	18	39.06
	4	16	64.63
	5	8	34.50
	6	22	57.05
	Total	102	
AP7	1	14	36.21
	2	24	52.50
	3	18	53.39
	4	16	56.13
	5	8	46.25
	6	22	57.14
	Total	102	
AP8	1	14	35.93
	2	24	56.08
	3	18	51.39
	4	16	46.13
	5	8	52.50
	6	22	60.05
	Total	102	
AP9	1	14	40.07
	2	24	56.58
	3	18	44.94
	4	16	55.63
	5	8	49.75
	6	22	56.23
	Total	102	
AP10	1	14	40.36
	2	24	59.83
	3	18	48.28
	4	16	50.88
	5	8	49.50
	6	22	53.32
	Total	102	
AP11	1	14	37.50
	2	24	58.17

	3	18	54.28
	4	16	57.38
	5	8	45.00
	6	22	48.95
	Total	102	
AP12	1	14	47.64
	2	24	60.67
	3	18	46.72
	4	16	32.63
	5	8	63.00
	6	22	57.41
	Total	102	

Test Statistics[a,b]

	AP1	AP2	AP3	AP4	AP5	AP6	AP7	AP8	AP9	AP10	AP11	AP12
Chi-Square	9.095	14.166	8.381	18.459	7.301	12.157	6.020	7.831	5.131	4.614	6.375	12.774
df	5	5	5	5	5	5	5	5	5	5	5	5
Asymp. Sig.	.105	.015	.136	.002	.199	.033	.304	.166	.400	.465	.271	.026

a. Kruskal Wallis Test

b. Grouping Variable: QUES