IMPLEMENTING BUILDING INFORMATION MODELING (BIM) AT AEC FIRMS IN INDIA

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The Supervisory Committee certifies that this ***disquisition*** complies with North Dakota State University's regulations and meets the accepted standards for the degree of

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ABSTRACT

The Indian Architecture, Engineering, and Construction (AEC) industry is still at the very infancy stage with the adoption of Building Information Modeling (BIM) to improve the design, construction, and facility management of construction projects. Therefore, several issues about data acquisition and management arise during the design creation and development of a construction project due to the complexity, ambiguity, and fragmented nature of the Indian construction industry. This paper suggests a strategy for India's AEC firms to successfully implement BIM in their current working processes. The research method involves studying the current state of BIM knowledge in the Indian construction industry along with the online survey used for data collection regarding the problems faced by the Indian AEC firms. These data were analyzed using inferential statistics to discover effective ways to introduce BIM by India's AEC firms. Based on the analysis, a roadmap for the transitioning steps is developed for use.

ACKNOWLEDGEMENTS

This paper regarding the subject of BIM implementation at AEC firms in India is the final part of my Master of Science in Construction Management study in the Department of Construction Management and Engineering at North Dakota State University (NDSU). My ambition with this master's paper is to develop my understanding of the BIM status in India and, in return, to contribute my knowledge to the improving the construction industry.

There are many people who have greatly supported the writing of this paper. I would like to thank all the people/AEC firms who participated in the online survey and Dr. Gang Shen for his guidance with the statistical analysis; without them, it would be impossible to present this paper. In particular, I want to present my gratitude to my adviser, Dr. Zhili (Jerry) Gao, for supervising the work in this master's paper and for providing guidance and feedback during the progress of my research. I also wish to extent gratitude to committee members, Dr. Eric Asa and Dr. Jun Kong for their assistance and time devoted to my education.

Last and most importantly, I want to thank my husband, Pavan Dabade; my parents; and my friend, Anusha Pyata, for encouraging and motivating me with my progress in paper work.

DEDICATION

I dedicate this paper to my loving, caring, and supportive husband for his motivation towards my education.

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LIST OF ABBREVIATIONS

2D	……	Two dimensions: x, y
3D	……	Three dimensions: x, y, and z
4D	……	3D + Time
5D	……	4D + Cost
AEC	……	Architecture, Engineering, and Construction
AECFM	…….....	Architecture, Engineering, Construction, and Facility Management
AGC	……	Associated General Contractors
AIA	……	American Institute of Architects
BIM	……	Building Information Modeling
CAD	……	Computer Aided Design
GDP	……	Gross Domestic Product
HVAC	……	Heating, Ventilation, and Air Conditioning
I T	……	Information Technology
IPD	……	Integrated Project Database
MEP	……	Mechanical, Electrical, and Plumbing
NBIMS	……	National Building Information Modeling Standard
RFI	……	Request for Information
ROI	……	Return on Investment
UK	……	United Kingdom
USA	……	United States of America
VDC	……	Virtual Design and Construction

LIST OF SYMBOLS

$	……	Dollar
₹	……	Indian Rupees
%	……	Percent
<	……	Less than
≥	……	Greater than or equal to
=	……	Equal to
H_0	……	Null hypothesis
H_a	……	Alternative hypothesis
N	……	Number of survey respondents
$\bar{p}$	……	Sample proportion
$\mu_{\bar{p}}$	……	Mean of sample proportion
$\sigma_{\bar{p}}$	……	Standard deviation of sample proportion
p_{H_0}	……	Population proportion
μ_{H_0}	……	Mean of population
σ_{H_0}	……	Standard deviation of population

1. INTRODUCTION

1.1. Background

A multi-dimensional tool, Building Information Modeling (BIM) is process that supports virtual design and construction methodologies putting all team members together throughout the entire design and construction process and beyond to the operations in maintenance of the building, during its working life. Typically, BIM is one holistic process using real-time, intellectual modeling software effectively working in 3D, 4D (3D + time), and 5D (4D + cost) to improve productivity, to save money and time in the design and construction phases, and to reduce operating costs after construction (Micheal, 2013).

Designers all over the world are implementing BIM as a new technology for their firms. According to a recent McGraw-Hill Construction Report (2012), BIM adoption in the USA expanded from 49% in 2009 to over 71% in 2012. In the UK, the government introduced a progressive program for mandated use of fully collaborative BIM for government projects by 2016 to reduce project delays and cost overruns as part of the overall economic development (UK Government, 2011). In Singapore, the government provides BIM funds to promote a broader usage of BIM technology (Singapore Government, 2013). In contrast, the Indian construction industry is not tapping the true potential of BIM tools. A majority of the architectural and engineering firms in India still rely on two-dimensional Computer-Aided Design (CAD) drawings. This usage of traditional methods neither implies that the Indian designers are ignorant of BIM and its ability, nor does it exhibit a paucity of skilled BIM users in the Indian AEC industry. In fact, there is lot of outsourcing for a full range of BIM services by development centers in India, delivering built environments for projects designed in the USA, the UK, and European countries. These international firms utilize the advantage of the cost-

effective production, and the proficiency that India has developed in past few years of experience (PRLOG, 2007).

Among Indian architects, engineers, and contractors, there is a need for directed development, integration of information technology and business processes for simulation, coordination, communication, and knowledge sharing to support design and construction. Currently, there is no clear consistency about the process of implementing or using BIM for AEC firms in India. Even the Associated General Contractors (AGC) of America realizes that there is an absence of a single document that instructs BIM application for firms. This fact creates the need to standardize and create guidelines for the implementation of a BIM process in the construction industry.

This paper focuses on the following questions facing the Indian construction industry in regards to BIM applications:

- What are the considerations of AEC firms in India about the choice of whether to use BIM?
- What strategy should Indian AEC firms apply when implementing and transitioning to BIM?

The significance of these questions lies in the fact that it would provide us with the current status of BIM knowledge among Indian architects, engineers, and contractors as well as the problems they are facing with incorporating technologically advanced changes in their current work process. Following are a few potential advantages of BIM that the Indian AEC industry is not tapping into: visual coordination, accuracy and consistency of data, collaboration, easy quantity take-offs, scheduling, etc. Taking a step further, BIM in conjunction with cloud computing facilitates project team members to update construction project data instantaneously,

helping project team members to discuss design changes; to combine various models (i.e., architectural, structural and MEP (Mechanical, Electrical, and Plumbing) models); and to purge conflicts—all in the initial conceptual and design phases. With the aid of BIM cloud computing, architects, engineers, contractors, and extended team members can work together effortlessly and in a timely manner (Yoders, 2013). To summarize briefly, the above-mentioned advantages are just a few of the deliverable features which Indian AEC firms are not utilizing optimally to their benefit.

1.2. Problem Statement and Research Motivation

1.2.1. Problem Statement

As per a research conducted by Kumar and Mukherjee (2009), the main reasons for BIM not being implemented in the Indian construction industry are as follows:

- The lack of technical expertise,
- The unawareness of BIM and its methodology among the industry professionals,
- The complicatedness involved in using BIM software,
- The passive approach of industry professionals towards exploring latest technology,
- The absence of demand from clients and contractors,
- The unwillingness to transition from the traditional practices to latest technology,
- The ambiguity concerning the BIM implementation in the country.

According to a report created by Kumar and Mukherjee (2009), 23% of Indian AEC professionals were exclusively using BIM for their practices; of the remaining 77%, only 9% were actively utilizing BIM applications and solutions. In the advanced countries such as the USA, the percentage of companies employing BIM increased from 49% in 2009 to 71% in 2012.

Hence, implementing BIM effectively for Indian AEC firms requires substantial changes in the way construction businesses work in India. Therefore, transitioning to BIM requires a thorough assessment of how to reorganize offices, how to identify possible alterations in workflow due to BIM, and how to choose the correct proficient team to those new advanced processes.

The author believes that incorporating these technologies with the proper guidance for the transition is particularly relevant for developing countries such as India which have large construction industries. The author wishes to demonstrate how the implementation and transition to BIM applications and solutions can result in significant benefits for the Indian construction industry.

1.2.2. Motivation for This Study

India is a developing country; there is a need for every kind of infrastructure. Unlike in developed countries such as the USA and the UK, the Indian government does not create initiatives to promote the usage of BIM in the AEC industry. The decision is left to the private companies to incorporate BIM and to promote its use. The Indian government can easily fund the promotion of new technology advancements, but instead, no initiative is being taken, leaving the responsibility to the private AEC firms to initiate usage of new tools.

A majority of the people working in the AEC disciplines are not convinced about the value and necessity of using BIM in India because of the following rampant myths:

- BIM practice imposes individual to learn 2D drafting before learning BIM.
- BIM obstructs creativity of the AEC users.
- BIM merely creates 3D models.
- BIM is simply a drafting tool.

- BIM is advantageous only for larger projects.
- BIM is expensive
- BIM is complicated to be taught.
- BIM is a latest and an underdeveloped technology (Rajvir, 2013).

India has a large and inexpensive labor resource which significantly reduces the value of the BIM deliverables. A lower cost for workers has discouraged efforts to replace field labor with automated solutions (Rundell & AIA, 2005). The fact that should not be overlooked here is what tremendous benefits BIM offers: time and cost savings, a high return on investment (ROI), and a competitive advantage.

There is a need for a guidance-centered BIM implementation process in India, viewing all buildings as a product of the constantly evolving process, rather than having a closed opinion about the design and working culture which is very common in India. BIM helps design/construction projects be successful on various fronts. Hence, AEC firms should aim to engage and materialize the paradigm shift towards BIM technology.

1.3. Objectives

The purpose of this paper is to investigate a strategy to achieve successful ways of implementing BIM at AEC firms in India. The objectives are as follows:

- To study potential advantages/benefits of transitioning the Indian AEC industry from 2D CAD to BIM.
- To assess the impediments and driving factors those prohibit the implementation of BIM in India.
- To propose successful implementation strategy for BIM at AEC firms in India.

Indian AEC workers who are content with using the current traditional practices should look beyond CAD applications to achieve success with BIM. Furthermore, the obstacle faced by Indian AEC firms is as follows: after the decision of transitioning to BIM, they now face a new problem with a new software technology that has a combination of old working processes which restricts the optimal usage of BIM, leading to the Indian AEC firms not being able to perform efficiently.

1.4. Organization of the Paper

The organization of this paper is briefly described below.

- Chapter 1. Introduction: This chapter provides a concise background about the research topic and its need for study; this chapter also clearly states the research problem, motivation, and purpose and objectives of this research paper.
- Chapter 2. Methodology: This chapter provides an explanation with a detailed flow chart for the process involved with the research study; literature review; data collection (conducting an online survey); and data analysis, including an explanation of inferential statistics and how the recommendations to implement BIM were made.
- Chapter 3. Literature Review: This chapter studies the existing knowledge of BIM by reviewing other authors' and experts' point of view for the subject. This chapter provides the following details: an overview of the current Indian construction industry, an overview of BIM implementation in the Indian AEC sector, the understanding of BIM and its benefits, and the impediments of BIM implementation in India.
- Chapter 4. Survey Data Analysis: This chapter presents the findings of the online survey conducted using descriptive statistics and hypothesis testing using inferential statistics, and summarizes the literature review and survey analysis.

- Chapter 5. Recommendations for Implementation: Based on the summary of the literature review and the survey analysis, this chapter proposes strategies for successful BIM implementation at Indian AEC firms.
- Chapter 6. Conclusion: This chapter discusses the study assumptions and limitations, identifies the scope for future directions of study, provides the conclusion of study, and finishes the paper with the summary of the author's contribution for suggesting that the Indian AEC industry embrace technological advancement for better efficiency and productivity.

2. METHODOLOGY

The core intention of this study was to measure how many architects, engineers, and contractors in India use or tap the true potential of BIM at their firms (in comparison to technologically advanced countries such as the USA). The focus was also to assess the barriers for slow BIM adoption in India. Figure 1 illustrates the methodology adopted during the study of this paper.

This study tries to apply the existing theoretical knowledge of BIM in the construction industry to a particular problem, i.e., Indian AEC firms struggling with the issues of transition from traditional methods to BIM. Potential advantages of BIM over CAD were studied. This study was in the category of exploratory research which is undertaken to investigate an area where little is known or to consider the possibilities of undertaking a particular research study, i.e., factors affecting as potential barriers for implementing BIM in the Indian construction industry. In order to collect the essential data, the author reviewed scholarly articles and journals to enhance the theoretical knowledge of BIM and its significance in the Indian AEC industry.

The questions in the survey focused primarily on gauging the respondent's awareness about the following areas pertaining to BIM: familiarity, general knowledge level and its specific application to projects, existing work practices and experience, inhibitions to adopt, perception of commercial drivers and potential benefits, management's inclination or appetite to adopt, technical capability, and skills to use BIM tools. A total of 43 respondents from the Indian construction industry were randomly selected as participants. The online survey was the research instrument used for data collection. The inferential statistics method was utilized to project the findings of the survey to reflect the Indian AEC industry, based on the sample group, and to support the empirical data received via the online survey.

Based on the findings of the statistical analysis of the survey, conclusions, which aligned with the problems faced by the Indian AEC industry when implementing BIM, were drawn. Based on the inferential statistical analysis, implementation strategies to overcome those barriers were suggested.

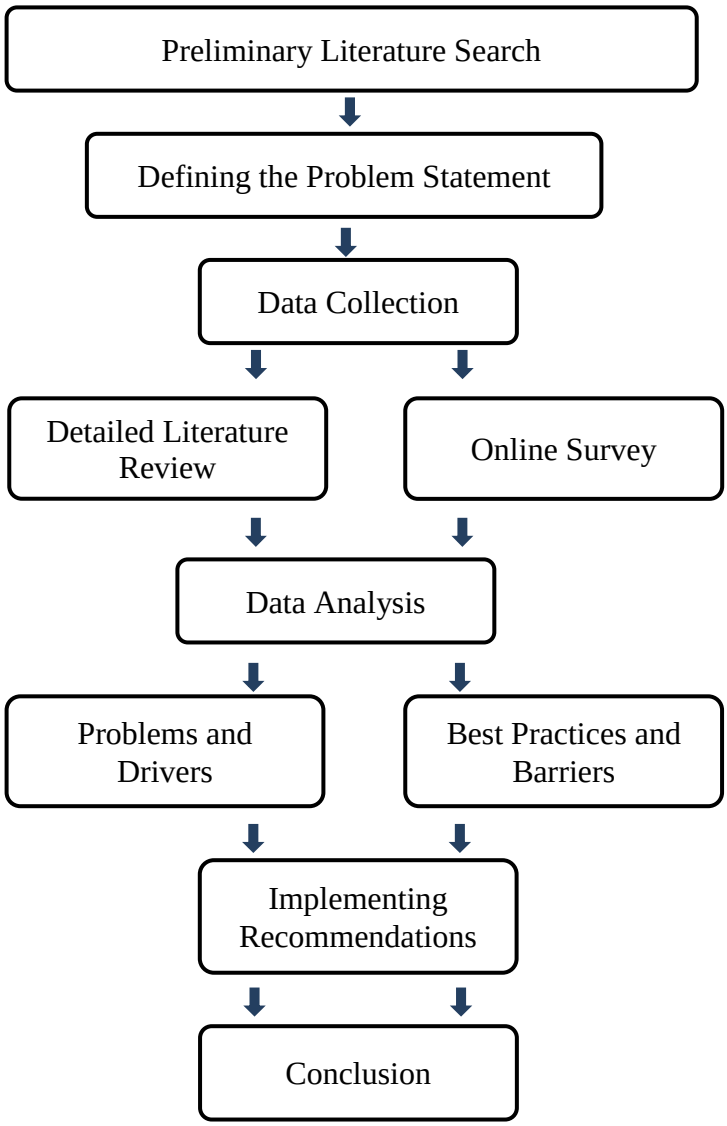

Figure 1. Flow Chart for the Research Methodology.

2.1. Literature Review

The sources for the Literature Review consisted, for the most part, of journals and articles about the challenges faced by the Indian AEC industry when implementing BIM. Other sources

were websites about the background of BIM, BIM definitions, benefits of BIM, current industry trends in western countries, barriers of BIM in India, and related research books.

The majority of the articles and journals were accessed from the online libraries of North Dakota State University and the Science Direct Journal articles. Attention was paid to the authenticity of the sources and academic contents, in respect to articles and websites referred during the literature study. Information posted on the website was only used if the information were related to the kind of information required. The details of the Literature Review are described in Chapter 3.

2.2. Online Survey

Asking questions and assessing the obtained responses is the most fundamental form of inductive research. Therefore, a survey was used as the primary data-collection tool. The study anonymously surveyed AEC firms in India about the impediments they have faced or are facing on the path of BIM implementation. Various Indian AEC firms that were not currently using BIM were also surveyed to learn about their inhibitions in the process and their myths regarding the BIM usage. The main purpose of this inductive approach was to empirically verify the hypotheses identified in the Literature Review, i.e., to discover the extent to which the BIM applications and solutions are being used by the Indian AEC firms as well as what possible barriers or resistance exist in deploying BIM for these firms. The survey was taken by construction industry personnel from all over India, so it can be assumed that the results obtained represent a homogeneous group of AEC personnel who are currently active in the Indian construction industry. Some construction professionals in India helped the author develop a list of firms to contact for data collection. The questionnaire was developed and approved by the Institutional Review Board (IRB; IRB approval can be found in Appendix A.) at North Dakota

State University (NDSU). The questionnaire was managed online through the NDSU Group Decision Center (GDC). Then, selected companies' employees were asked to complete surveys via the internet. Confidentiality of the proprietary information was strictly controlled. Fairly even balances among the different company types were maintained.

The questionnaire had 25 close-ended questions (a type of question, whose answer or answers must be selected from a set of responses) to gauge the current "status check" on BIM implementation in India. Participants were asked to answer the questionnaire based on a 6-point agree-disagree scale. In addition, participants were also asked to mention any additional important comments that were not stated in the questionnaire. The questions were divided into three parts: (1) Part I: Information Sheet, (2) Part II: Respondent's Background and Knowledge of BIM, and (3) BIM Usage. Part I provided the objectives of the survey, and frequently asked questions and answers about the survey. Question #1 was to verify if the participants read the information sheet and to measure their willingness to participate in the survey. Part II consisted of 11 questions that were used to identify the respondent's industry experience and knowledge about BIM technology and processes. These questions asked information about (a) roles, (b) years of experience, (c) number of employees, (d) levels of understanding about BIM, and (e) reasons for adopting or not adopting BIM for their construction projects. Part III consisted of 13 questions that were used to identify how BIM is used by gathering (a) years of application, (b) BIM software, (c) BIM project size, (d) pilot projects, (e) related CAD software, (f) client satisfaction, (g) strengths of using BIM, (h) obstacles of using BIM, (i) success factors of BIM implementation, and (j) implementation procedures. The complete questionnaire can be found in Appendix B.

The survey was sent to 60 Indian architectural and construction firms, of which 43 firms responded to the survey. Because the survey contained a certain set of questions to be answered only by BIM users, the survey was 100% completed by 9 firms.

2.3. Data Analysis

The data collected with the survey were analyzed using the inferential statistics that are used for drawing conclusions of the population by studying a sample group. In any research, the fundamental use of inferential statistics is to test hypotheses, and a point to be noted here is that inferential statistics does not fix for sample bias (Korb, 2013).

2.3.1. Explanation of the Inferential Statistics Used in the Survey Analysis

With educational research involving large group or populations, it is not feasible to test all the individuals about whom the conclusions need to be made. For example, the purpose of this research study was to ascertain that how many percent of Indian AEC firms use BIM in comparison to the developed country such as the USA. However, it would be impractical to test all AEC firms in India because of the management of resources, time period, and other logistical aspects. As an alternative, the author randomly selected a sample from the larger group to conduct a study. The author does not intend to limit findings to the small group of AEC firms in India who participated in the study. Instead, the intention was to express that, because there were less percent of BIM users in the sample group, it is also the case with the entire AEC population in India and suggesting strategies to implement BIM at AEC firms would enhance the organization's productivity and increase business benefits, ultimately improving the current state of project delivery system in the country. Thus, the author aims to make inferences, about the entire population based on the responses obtained from the sample group via survey (Korb, 2013).

The possibility of generalizing the data, obtained via survey undertaken by sample group, to the entire population, can be determined using inferential statistics. In inferential statistics, to state whether the results are considerable, the difference between the two groups in the sample is supposed to be substantial. Then only, the inferences can be generalized to the entire population. Alternatively, if the difference between the groups is very low, then the results are not considerable and, are merely the outcome of chance (Korb, 2013).

When using inferential statistics, "z-test is a statistical test where normal distribution is applied and is basically used for dealing with problems relating to large samples when $n \geq 30$" (Explorable.com, 2009). As per the central-limit theorem, not all, but most of the test statistics are based on normal distribution. The z-test locates, how many standard deviations away the z-score is, as expected under the null hypothesis. If the probability value obtained via z-test is less than 5% i.e., significance level, then the null hypothesis is rejected, as there is less than 5% chance of accepting it (Luen, 2008).

2.3.2. Analysis Procedure

The data that were gathered using the online survey during this research, were used to draw inferences for the general population of the Indian AEC industry using the inferential statistics method explained above (showing that the z-test score is less than the critical value based on the significance level of 5%, therefore rejecting the null hypothesis that the usage of BIM in Indian AEC firms is more than or equal to 35.5%), thus proving that the survey results had very little chance of error and actually reflected the entire population of the Indian AEC industry.

The research hypothesis used during the analysis was as follows: The proportion of Indian AEC firms using BIM is less than 35.5%. The value of 35.5% was based on the

assumption that the percent of Indian AEC firms that utilize BIM are 50% less than the percentage of BIM users in developed country such as USA. The null hypothesis used during the hypothesis testing was as follows: The proportion of Indian AEC firms using BIM is equal to or more than 35.5%. The following steps were used for testing hypotheses in the analysis chapter:

- Using descriptive statistics, describe the data associated with the survey responses.
- Using inferential statistics, make inferences about the Indian AEC industry from the survey observations.
- Find the z-test score using hypothesis testing with a one-sample, one-tailed method.
- Based on the z-test score, significance level, and critical z-value, accept or reject the null hypothesis (H_0)
- Draw and analyze conclusions based on the z-statistics.

2.4. Implementing Recommendations

Finally, based on the Literature Review and survey analysis results, a successful BIM implementation plan for Indian AEC firms is suggested. The study uses a quantitative method approach which is supported by statistical analysis, yielding results that are factual and unbiased, thus enhancing credibility.

3. LITERATURE REVIEW

3.1. Overview of the Current Indian Construction Industry

India's construction industry creates enormous employment opportunities across various sectors related to it and is an important indicator of development. The national Gross Domestic Product (GDP) increased by ₹6,708 billion (₹, Indian Rupees) in the year 2011-12 (approximately 8% growth in GDP) (Indian Mirror, 2012). Even though the Indian construction industry is pretty big in size, the majority of it is fragmented into small and medium-sized companies which carry out the contracting and sub-contracting work with labor-intensive techniques that are done by about 35 million people in the unskilled labor force who depend on the work for their daily wages (AnythingResearch India, 2014).

With the current government's emphasis on constructing new infrastructure, substantial investment is planned for the future of construction sector in India. The Indian Planning Commission has estimated that it requires about ₹45 lakh crore or $1 trillion worth of investment just for building new infrastructure, in course of the 12th Five-Year Plan (Government of India Planning Commission, 2014).

The new infrastructure requirement is of an immense magnitude. Better construction management practices are required for optimizing resources and maximizing productivity and efficiency. Experts believe that, once the phase of global financial volatility passes, the construction sector in India could be among the fastest growing in the country (Sharma, 2013). This scenario creates a crucial need among the Indian AEC industry for proper project coordination and to ensure efficiency.

3.2. Overview of BIM Implementation in the Indian AEC Sector

This section presents India's status for implementing BIM within the AEC sector. The rate of adoption for BIM technology in the developed world is more than what is seen in developing countries. Contrary to the present scenario, the need for BIM adoption in developing countries is more than in the developed countries. The recognition of BIM technology in India is in absolute contrast to status in developed countries.

According to the article posted by CAD Services (2012) on BIM implementation in India, the architects and engineers face many obstacles before fully adopting BIM applications and solutions. The major concern is the cost of implementing any new BIM software as well as the added cost of upgrading the hardware and educating the employees for BIM usage on the construction projects. Moreover, in India, the choice of implementing a costly technology looks unappealing to the AEC industry professionals, especially considering the fact that, the skilled and unskilled labor is inexpensive, abundant and readily available.

BIM is still in its infancy stage in India. Although its adoption rate has seen an upward trend in the past 3 to 4 years, it still has not reached a stage where users can boast about the cost savings for a project due to BIM implementation because a majority of BIM users in India have not seen a full cycle of BIM implementation for their projects. Organizations remain skeptical about BIM implementation and its perceived benefits. Where it stands now with respect to adopting BIM in the AEC industry, India can have a significant impact for the educational and research fields via collaboration between the government and the construction industry by drawing parallels across emerging economies to develop BIM implementation strategies (Sawhney & Singhal, 2013; CAD Services, 2012).

3.3. Impediments of BIM Implementation in India

The Indian AEC industry has inertia towards adopting new technology. In a fragmented AEC industry such as the one in India, change cannot be implemented on a uniform scale. The potential benefits of implementing BIM are well known to the Indian AEC industry, but the industry is skeptical about it due to the high cost of implementation. For BIM to be adopted successfully to improve productivity there is a need to change the traditional work processes prevalent in India. The stratified industry is a problem; this change cannot be adopted by an individual but must be embraced by the industry as a whole (Sawhney & Singhal, 2013).

In India the implementation of Virtual Design and Construction (VDC), a synonym to BIM and widely acknowledged across the country, confronts many hurdles. Half knowledge about the subject or lack of trusted source to validate the information of BIM within the Indian AEC industry deters the potential AEC firms, clients and project owners from using it, which ultimately amplifies the resistance to implement BIM (Avsatthi, 2013; Wallett, 2013). The following sections show a few major reasons for barriers with BIM implementation for Indian AEC firms.

3.3.1. Cost of Software and Hardware Upgrade

Many people believe that the cost of implementing BIM is too prohibitive; way beyond their project's budget. The exorbitant prices for various BIM software packages are the prevailing barrier to BIM acceptance in the Indian construction domain. The costs of BIM software packages are more expensive compared to CAD software packages which are available on the market at a fraction of the cost of BIM software. Besides the initial cost of the software package, the price to keep the subscription updated is astronomically high by Indian standards (Khemlani, 2012).

3.3.2. Disruption in Workflow

The implementation and use of BIM compels the AEC firms to modify the current conventional design workflows in order to effectively adopt BIM. The fluster and variation in conventional workflow is an unavoidable phase of BIM exploitation. Thinking back on disruptions, this situation was exactly the case when 2D CAD systems were introduced in the 1980s. The present AEC industry in India is so satisfied with and used to 2D CAD systems that it resists getting outside the comfort zone (Davidson, 2009).

3.3.3. Training Employees

Adequate training required for the firms' staff is one of the biggest obstacles to BIM adoption. Because most of India's AEC firms still use 2D drafting software such as Autodesk AutoCAD, they are not keen on investing time to train staff or investing money in new technologies for the BIM culture that stimulates a new way of thinking about building design in the industry. A big dilemma faced by Indian AEC firms planning to adopt BIM applications and solutions is to train the technicians, engineers, or architects for BIM usage (Davidson, 2009).

3.3.4. Inexpensive and Abundant Labor Resources

India has relatively inexpensive and abundantly available skilled and unskilled labor. The average hourly rate for unskilled labor in the construction industry is USA $0.28. This inexpensive labor rate is often used by the Indian AEC companies as a means of avoiding the high cost of implementing BIM software at the cost of exploiting the construction workers (Autodesk, 2005; Kerry, 2013).

3.3.5. Resistance for Accepting New Changes

In the AEC industry, most work is performed at sites. During earlier days, even the architects, designers, and other professionals went to the site for planning, designing, etc. The

BIM process has brought facilities to perform these tasks to a computer using several advanced software programs. Now, it is not necessary for designers to visit sites regularly. Architects, designers, engineers, etc. can perform their work from any computer at any location, resulting in limited site visits. These changes brought by BIM process have introduced a restriction in AEC industry conventional work style (Tesla, 2014).

3.3.6. Slow Adoption of Technology

The potential benefits of BIM are well known and documented. However, the BIM implementation rate is still growing at a very sluggish pace. One of the reasons for this crawling BIM adaptation rate in the Indian AEC industry is the fragmented nature of the industry itself (Architectural Evangelist, 2013).

3.4. Understanding BIM

To facilitate the struggling phase experienced during BIM implementation by AEC professionals, understanding BIM definition proves to be essential. Many different organizations have tried to define BIM, but there is a lack of consensus. Then what is BIM? If this question is asked to various people working in the AEC industry, we get very different answers because BIM is a tool to achieve goals and because, depending on what goals need to be achieved, the tool is used in different ways.

The BIM acronym has been used so often without due care and attention that the term is almost akin to 3D modeling. In simple terms, 3D modeling is defined as modeling a drawing in 3D via specialized software, and the product is called a 3D model. To merely form shapes and create a three-dimensional model does not mean that one is using BIM. This case is particularly true if these 3D models have no intelligence built into them and are neither parametric nor have any advanced details. This misunderstanding is the one that the author believes most Indian AEC

firms have about BIM. Just because a person generates 3D models does not mean that he/she is taking advantage of all that BIM has to offer. A few BIM definitions are as follows:

The American Institute of Architects (AIA) defines BIM as "a model-based technology linked with a database of project information, and this reflects the general reliance on database technology as the foundation. It is identified as one of the most powerful tools to support Integrated Project Database (IPD). Because BIM can combine, among other things, the design, fabrication information, erection instructions, and project management logistics in one database, it provides a platform for collaboration throughout the project's design and construction phase" (AIA National; AIA California Council, 2007, p. 10).

The Associated General Contractors (AGC) of America generally defines BIM as "the process of generating and managing building information model through the use of three–dimensional, intelligent design information" (The Associated General Contractors (AGC) of America, 2014, pp. 1-1).

According to Hardin B. (2009, pp. 3-4), "BIM is not just software. BIM is a process and software." He also states, "As a company integrates this technology, it begins to see other processes start to change. Certain processes that have made perfect sense for CAD-type technology now do not seem to be as efficient. As the technology changes, so do the practices and functions of the people using the technology."

Furthermore, the National Building Information Modeling Standard (National BIM Standard (NBIMS), 2014, pp. 1-1) describes BIM as "A BIM is a digital representation of physical and functional characteristics of a facility. As such it serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its lifecycle from inception onward."

3.5. Potential Benefits of Using BIM

The possible economic benefits and improvement of productivity with successful BIM implementation is well acknowledged and gradually better understood within the AEC industry (Bernstein & Pittman, 2004). BIM applications and solutions is one of the most challenging technological progresses in recent years for the architecture, engineering, construction, and facility management (AECFM) industry. Its lucrative deliverables is attracting majority of the construction companies, who aim to offer high quality product for their clients. The integrated database gives the opportunity to every individual involved in an entire construction project (including architects, engineers, contractors, project managers, and owners) to collaborate together, allowing them to view the model in different ways and to share information.

One of the main advantages of implementing BIM applications is the visual coordination and the capability to identify possible conflicts among the various building systems. Furthermore, the instantaneous data updating attribute of BIM along with cloud computing, helps AEC professionals tremendously in saving time, otherwise spent or wasted in exchanging project information. These deliverable products are just a few things that one can expect from this powerful tool which completely transforms the way business is performed (Franklin, 2010).

The advantages and possible benefits of this new technology compared to traditional 2D CAD has been researched intensely in various nations. BIM offers a plethora of benefits, both directly and indirectly, to all members of the AECFM industry. A reduction in conflicts and changes/rework during construction, low levels of risks and improved estimate of long lead resources , overall reduction construction wastage and the whole-life costs of built assets, better-performing completed infrastructure, and improved overall project quality are among the

advantages that can be experienced with appropriate usage of BIM applications and solutions. Figure 2 illustrates some of the main benefits for using BIM (Lindblad, 2013).

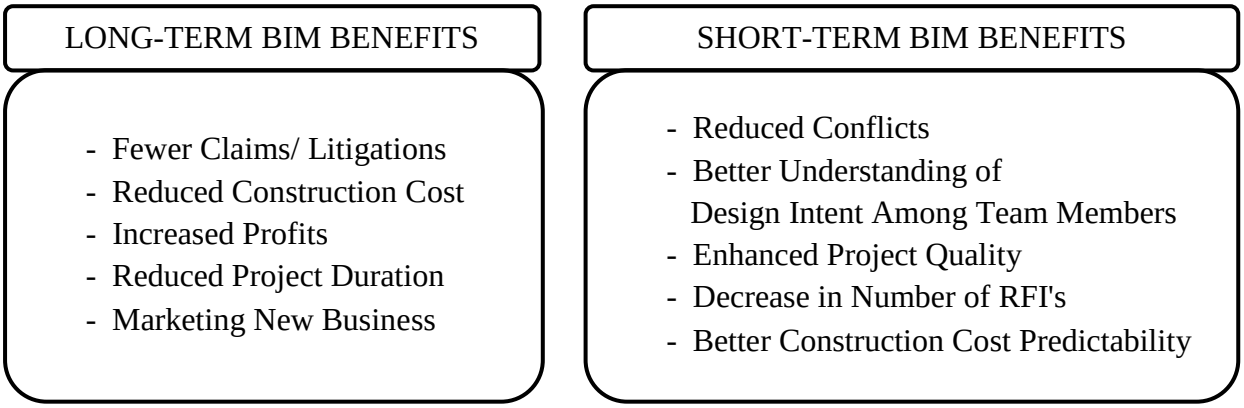

Figure 2. BIM Benefits. (McGraw Hill Construction, 2012)

3.5.1. Visualization

The ability to create, visualize, and present architectural and engineering documents is one of the direct benefits for a 3D model. Many individuals have difficulty understanding overloaded 2D drawings even after intently studying the drawings. However, a 3D model, even with relatively few details, clearly represents the building project and allows better visualizations for many of its features. These building elements are not only represented as 3D objects; instead, they are also associated with accurate and relevant information, thus reducing errors and requests for information (RFI), creating fewer change orders, and saving valuable time (Kame & Ukrande, 2013).

3.5.2. Accuracy and Reliability of Data

BIM applications and solutions make certain that all of the data extracted from the various models of a particular project are faultless. This consistent of data eliminates the suspicion thought of error between various sets of drawings. This reliability indicates that whichever design alteration is made in a particular view will be automatically be modified throughout all other views for that project (Smith, 2009; Birx, 2005).

3.5.3. Collaboration

BIM proves to be very beneficial for sharing a single database among multiple team members. The AECFM industry is tightly bound together, and the challenge to synchronize among these professionals seems to be achievable because of BIM. It has been demonstrated repeatedly that collaboration among teams at initial stages of construction project has great rewards for planning and scheduling. Therefore, by developing BIM models at initial stages of a project, AEC firms can totally ensure in-depth collaboration among the extended project team, on almost all of the construction issues. Thus leading to improved productivity, communication, and quality control (Haron, Marshall, & Aouad, 2012; Autodesk, 2011).

3.5.4. Ease of Quantity and Cost Estimation

When the construction and design team is working collaboratively using BIM, many benefits can be experienced; for example, quantity take-offs and cost estimation are just few among many of them. BIM's trait of estimation from the model helps the estimator prepare the material/resources estimation faster, easier, and with fewer errors. BIM allows cost estimates to be more accurate and reliable than those prepared using conventional methods which are subjected to manual miscalculations (Hergunsel, 2011).

3.5.5. Energy Efficiency

BIM systems are proficient and aid in delivering projects with optimal sustainable design. BIM's analysis tools help analyze heating and cooling requirements, identify day-lighting opportunities, and choose building equipments those help in reducing overall energy usage. Various attributes (such as, climatic conditions, electrical lines, etc.) can be incorporated, in assessing the energy consumption and carbon emissions of the particular project (Ashcraft, 2006; Autodesk, 2010).

By studying the individual benefits of BIM, potential advantages can be summarized that each attribute is a route for the optimum utilization of resources, i.e., through better designs, improved quality, and reduced cost overruns. Therefore, BIM applications and solutions has the absolute capability in tackling the various inefficiency problems that are present in the Indian AEC industry.

3.6. Current Industry Trends in Western Countries

Many contractors, architects, designers, and engineers in developed countries such as the USA and the UK are practicing this extremely sophisticated technology for better productivity and efficiency with infrastructure projects (UK Government, 2011). This technological advancement and recognition of BIM in India is in absolute contrast to status in developed countries.

Although, India has a rising and expanding construction market, with a great prospective for residential and commercial development, but still the country's architects and engineers work processes are performed using the traditional practices. On the contrary, the western countries or the developed countries have identified and understood the tremendous potential of BIM technology and so, it is being incorporated by increasing number of AEC firms (CAD Services, 2012).

3.7. Summary

BIM is a technology that empowers the user while it is also a business and organizational issue for the firm where it is adopted. With the size, scale, and complexity of projects, increasing the rate of BIM adoption is essential. There needs to be a cultural mind shift for AEC industry personnel's thinking in India.

The fragmented Indian AEC industry does not work collaboratively as yet and this criterion is substantial enough for BIM potential and growth in upcoming years. The construction sector in India still has not completely opened the doors for BIM. The reasons range from shortage of skilled force, to too many design alterations taking place, hence leaving construction industry professional with no time to explore it. The prime reason being, clients are not insisting in using it. Eventually, as the clients would begin assessing the projects for money and delays, architects and engineers will have to become efficient and thorough with their coordination.

According to report by Autodesk and CAD services (2012) "Designers across the world have started implementing BIM technology in their respective construction projects, whereas their Indian counterparts have still not captured the full potential of BIM technology for visualization and walkthrough developments." For example, like many others, the architectural firm of Abhay & Associates (Hyderabad, India) uses AutoCAD 2D drawings for conceptual planning and designing to detail drawing and uses Excel sheets for estimation. While outsource for 3D modeling and walkthrough by sending the 2D plans and elevations to the 3D modeling professional. This outsourcing causes a lot of friction because there are increased RFIs, coordination issues, file-compatibility issues, financial expenses, and further delays.

In a developing country such as India, where skilled and unskilled labor is inexpensive, abundant and readily available, the thought of transitioning to the evidently costly software lacks luster. Furthermore, implementing BIM also indicates incorporation of leaner practices and this amplifies the unemployment among the unskilled labor force. All these factors have discouraged AEC firms from moving to highly developed solutions such as BIM.

The cost and time savings associated with BIM usage needs to be understood by Indian AEC firms. Strategic plan should to be developed to make use of and experience the benefits offered by this technology.

To summarize the Literature Review, it can now be comfortably said that the Indian AEC industry is fully aware of the potential benefits that BIM has to offer over 2D CAD. However, the industry is skeptical to take that leap to implement BIM due to certain impediments. Some hurdles could be summarized as the astronomical cost of procuring and maintaining the software as well as training the staff, and the disruption caused by the stratified nature of the Indian AEC industry. According to Sawhney and Singhal (2013), one strategy to potentially start implementing BIM within the Indian AEC industry requires the entire industry to be integrated and to have a willingness to embrace the BIM culture. As per the recent survey conducted by the author, the biggest reasons for not implementing BIM in the Indian AEC industry are not enough demand from clients and/or other firms/projects (62%), cultural resistance (24%), and disruptions to implement a new process (14%). These responses are good indicators of the non-integrated nature of the Indian AEC industry. These barriers in BIM implementation leads us back to the original problem that this paper wishes to confront: implementing BIM effectively at Indian AEC firms by suggesting successful implementation strategies.

4. SURVEY DATA DISCUSSION AND ANALYSIS

The survey was sent via internet to 60 Indian architectural and construction firms, all over India, of which 43 firms responded to the survey. The survey was 100% completed by 9 firms as it contained a certain set of questions to be answered only by BIM users. The data collected from each respondent were summarized with the help of the Qualtrics survey website which uses descriptive statistics and updates, without human intervention, as respondents participate in a survey. The frequency, or percentage count, is the basic form of descriptive statistical analysis, summarizing the each and every specific variable for a given data set.

4.1. Breakdowns of Survey Data

The data obtained via survey have been discussed in this chapter using central tendency or the mean and percentage frequency. The percentage frequency is the ratio of measure of observed quantitative value to the total number of responses, and it is expressed in percent (%) value. This proportion not only expresses the occurrence of a variable with respect to all occurrences, but also is an effective way to demonstrate the frequency of data (Colwell & Carter, 2012). The mean is the widely used method in central tendency and is usually referred as an average. It is the ratio of total sum of all the numbers in a data set to the total number of data points (Bowerman, O'Connell, Murphree, & Orris, 2012).

In the following sub-sections, the first section is categorized to share basic information of respondent’s role and years of experience in the construction field. Later findings are categorized on the basis of respondent’s perception of BIM on the basis of the awareness, the status, the adoption, the benefits, the barriers and the implementation process.

4.1.1. Respondents' Distribution

This sub-section summarizes the responses received from survey respondents based on their role in their respective organizations and their years of field experience. Also, this segment uses the percentage frequency to indicate the results. As seen in Figure 3, the majority of respondents were senior architects (37%), followed by others (i.e., managing director, principle architect, project coordinator, project manager, consultant, assistant project manager, etc.; 28%), contractor/ construction managers (26%), and engineers (21%). None of the junior architects took part in the survey.

As seen in Figure 4, the majority of respondents had 3-5 years of experience (58%), followed by 6-10 years of experience (26%), and 0-2 years (12%); 4% of respondents had 11 or more years of experience.

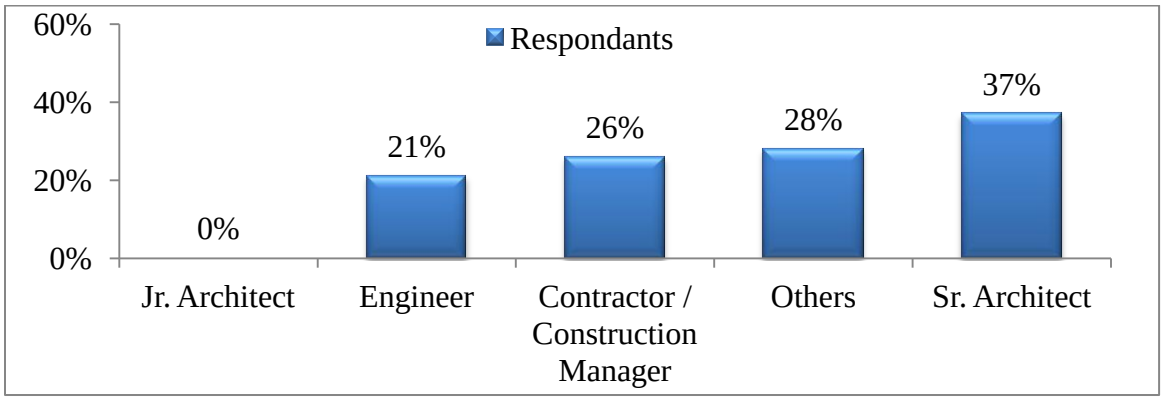

Figure 3. Role of Respondents in Their Organizations.

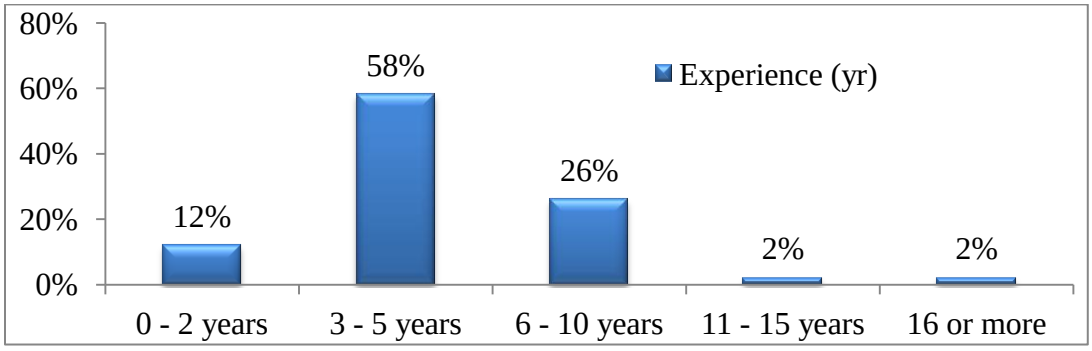

Figure 4. Years of Field Experience for the Respondents.

As seen in Figure 5, the majority of responding organizations had more than 100 employees (49%), followed by organizations that had 10 or fewer employees (30%); 12% of organizations had an employee count between 11 and 50, and 9% of organizations had an employee count between 51 and 100.

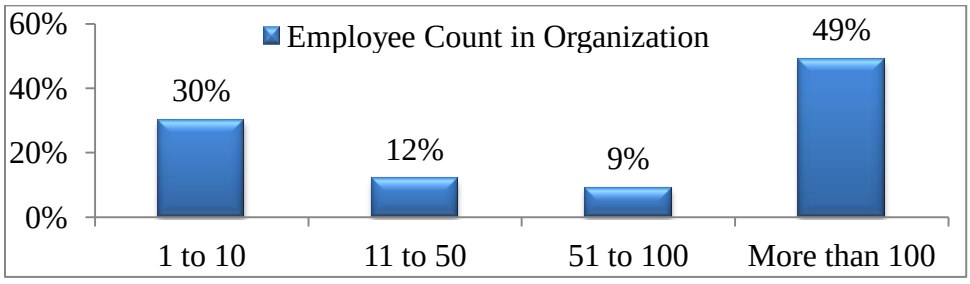

Figure 5. Number of Employees Working in the Organization.

4.1.2. Awareness of BIM

This section summarizes the responses received from survey respondents based on their idea of BIM and level of BIM knowledge among the India construction industry. Also, this segment uses the percentage frequency to indicate the results. As seen in Figure 6, 77% of the survey's respondents have heard of the BIM solution and application, whereas 23% of the respondents were unaware of BIM.

As seen in Figure 7, 62% of the respondents rightly believed that BIM is a process. Whereas, thirty-one percent believed that BIM was a technology; 24% believed that BIM was software; 12% believed that BIM was a philosophy; and the remaining 5% believed it was a clash-detection technique.

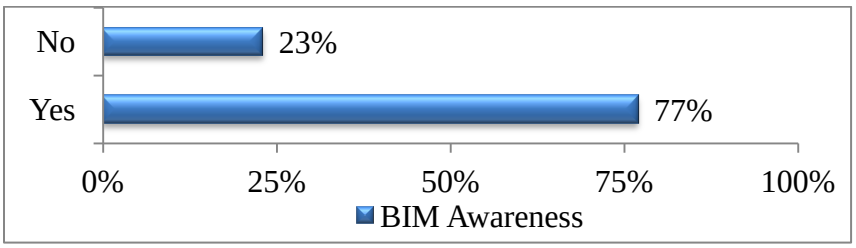

Figure 6. Respondents' BIM Awareness.

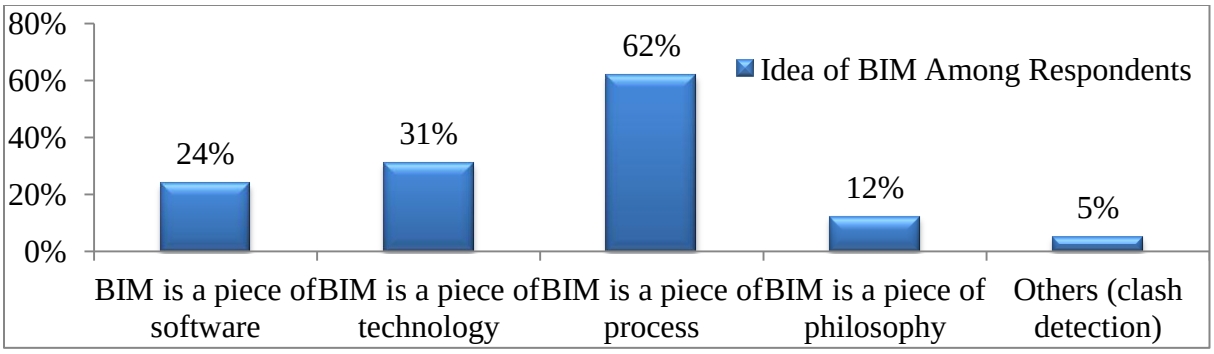

Figure 7. Idea of BIM Among Respondents.

As seen in Figure 8, 60% of the respondents believed that the current knowledge level about BIM among people in India's AEC industry is low. Nineteen percent of the respondents believed it to be medium; 12% believed that the Indian AEC industry is not familiar with BIM; 7% believed that the current knowledge level is high; and the remaining 2% believed it to be very high.

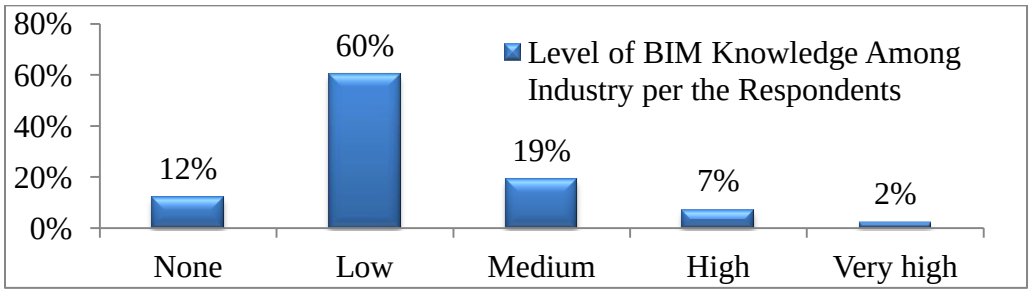

Figure 8. Level of BIM Knowledge Among Construction Industry as per the Respondents.

4.1.3. Status of BIM Applications

This section summarizes the responses received from survey respondents based on the amount BIM usage among Indian AEC organizations. Also, this segment uses the percentage frequency to indicate the results. As seen in Figure 9, only 26% of the respondents had used BIM solutions and applications at least once, and 74% had not yet worked on any projects using BIM. This percent of BIM usage was a very small percentile of the total respondents when compared to the AEC industry for developed countries such as the USA and the UK.

As seen in Figure 10, of the 26% of the respondents who had used BIM at least once, 60% of them still use BIM. The remaining 40% have discontinued using BIM.

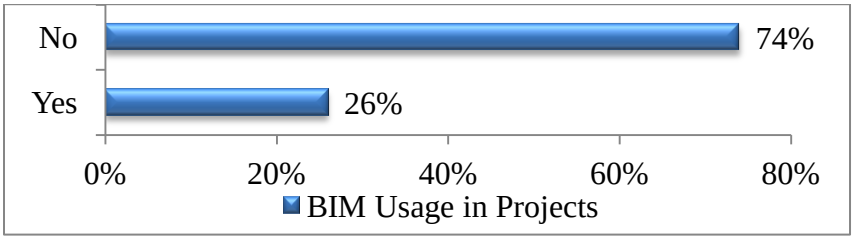

Figure 9. BIM Usage for Projects.

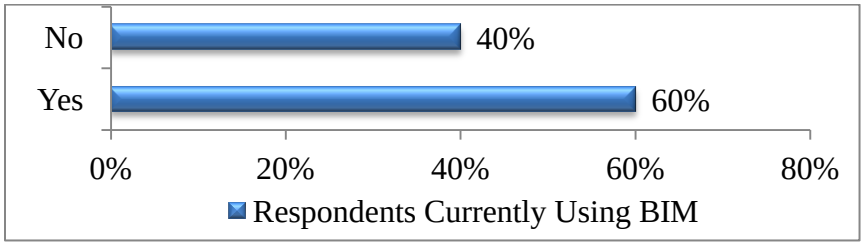

Figure 10. Respondents Currently Using BIM.

4.1.4. Adoption of the BIM Process

This section summarizes the responses received from survey respondents based on BIM acceptance, reasons given by BIM non-users for not adopting BIM, reasons given by BIM users for adopting BIM. Also, this segment uses the percentage frequency to indicate the results. As seen from Figure 11, when asked whether BIM should become a mandatory process in the industry, surprisingly, 52% of the respondents replied "yes," and 45% responded "don't know," revealing ambiguity among the industry. One of the respondents also commented, "It should be included as a subjective course during degree time period as after which an architect has to face many challenges by which he may not focus in depth about BIM…"

One of the respondents also said, "Integration of all the facilities and utilities is a must for the construction world," implying the respondent's positive approach toward BIM implementation and making it a mandatory process.

As seen in Figure 12, the most common reason for respondents to utilize a BIM process was to improve the quality of a project and/or for better 3D visualization (55%). Forty-five percent of the respondents used BIM for easy data management, followed by 18% of respondents utilizing BIM to satisfy the owner's demands.

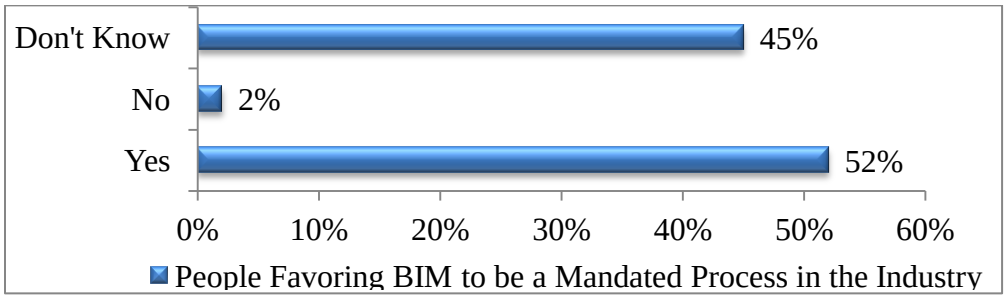

Figure 11. BIM to be a Mandated Process in the Industry.

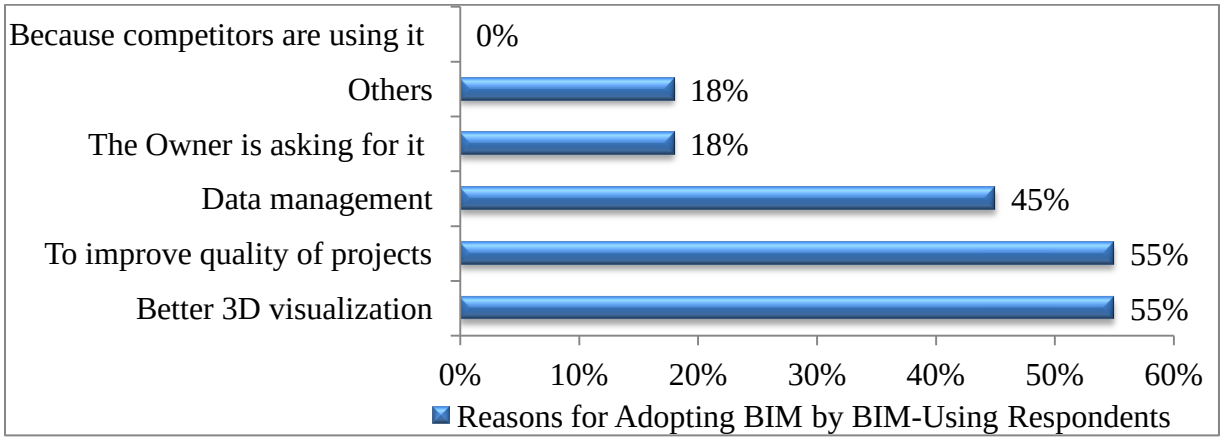

Figure 12. Reasons for Adopting BIM by BIM-Using Respondents.

As seen Figure 13, 62% of BIM non-users said that there was not enough demand from clients to use BIM on projects. Fifty-nine percent said that they did not use BIM because they lacked trained staff. Twenty-eight percent said that either the cost of training for BIM was high or that they did not have enough time to evaluate BIM. Twenty-four percent of BIM non-users did not believe in changing the current work culture. Twenty-one percent said that the high cost of acquiring the software that supports BIM and inexperienced end users were there reason for not using BIM. Fourteen percent of the respondents believed that the cost of hardware upgrades

was too high; they experienced disruptions implementing a new process and/or functionality issues. Ten percent believed that the ROI was too low. Seven percent of the respondents said they did not see a value for BIM use. Three percent believed that the cost of maintaining the BIM software was too high and/or that the software had interoperability issues.

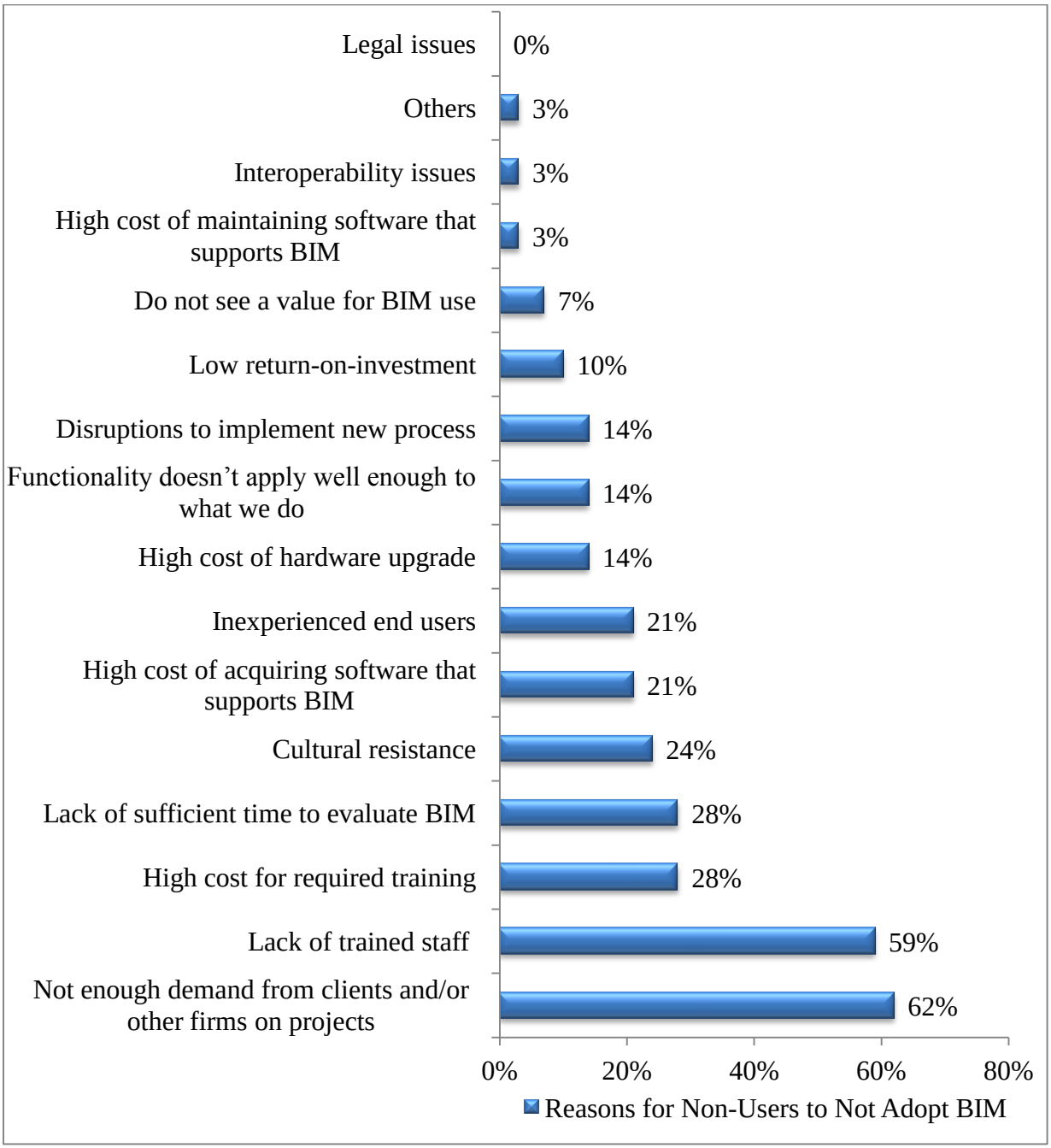

Figure 13. Reasons for Non-Users to Not Adopt BIM.

As seen in Figure 14, 56% of BIM users have been utilizing BIM for the past 2-3 years; 33% of BIM users have just begun utilizing it in the past 1 year; and 11% of BIM users have been utilizing BIM for more than 6 years.

As seen in Figure 15, a majority of the respondents (67%) said they were using the Autodesk Revit software tool to practice BIM at their firms; 33% used Graphisoft ArchiCAD and Google Sketch Up; 22% used Autodesk Navisworks; whereas 11% were using Bentley Micro Station, Vico, and Tekla.

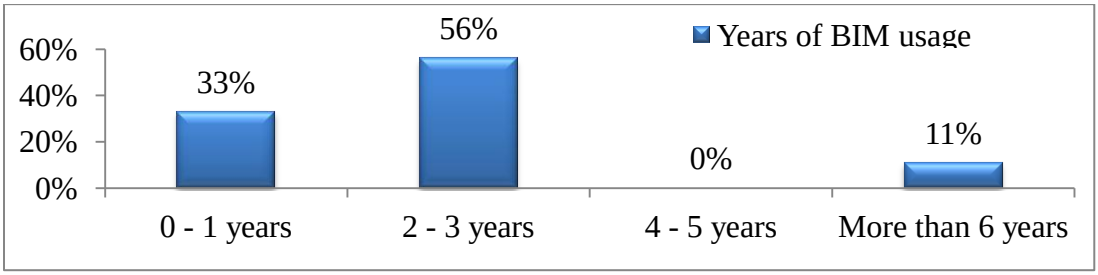

Figure 14. Years of BIM Usage.

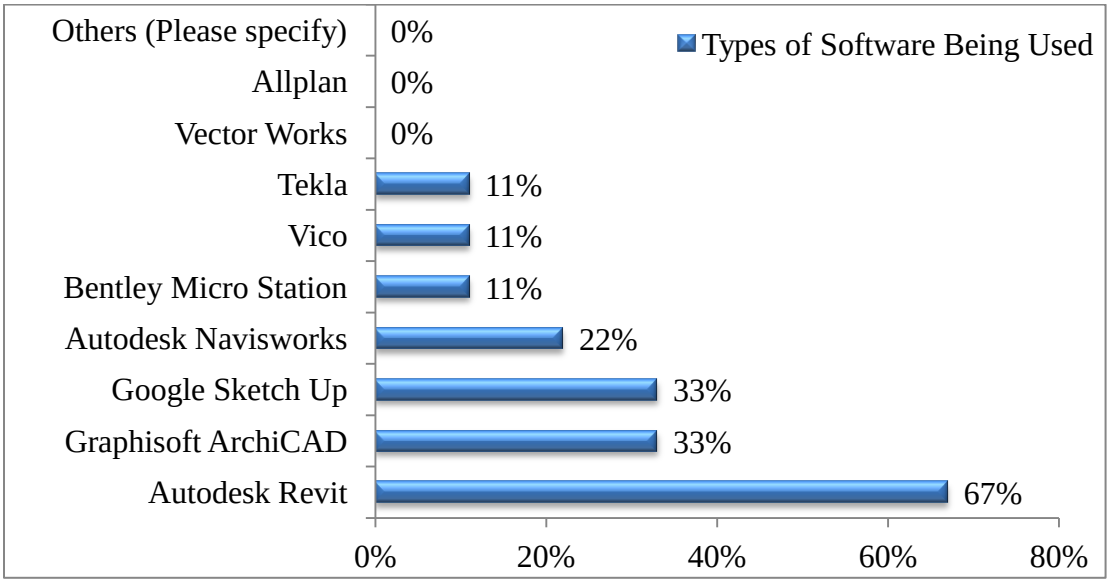

Figure 15. Software Being Used to Practice BIM.

As seen in Figure 16, the majority (78%) of respondents' BIM projects was of large size and valued at more than ₹5 crore (one crore is equal to ten million, as per the Indian numbering

system); 22% of the respondents used BIM for projects valued between ₹1 crore and ₹5 crore Indian rupees; and none of the respondents used BIM for projects that had less than ₹1 crore of value.

As seen in Figure 17, 56% of the respondents did not use a pilot project before they fully adopted BIM, and only 44% of the respondents used a pilot project, taking the appropriate step toward successful BIM implementation.

As seen in Figure 18, 63% of the respondents' pilot BIM project was the first of its kind for their organizations, and only 38% of the respondents replied no.

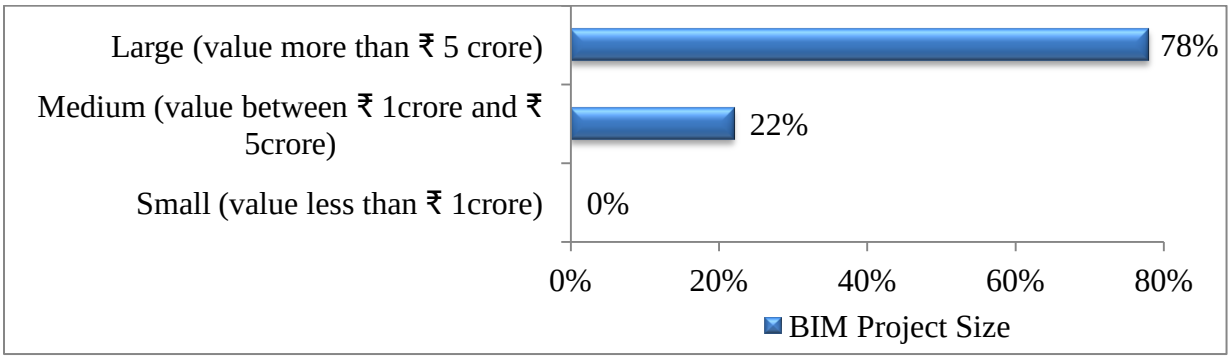

Figure 16. BIM Project Size.

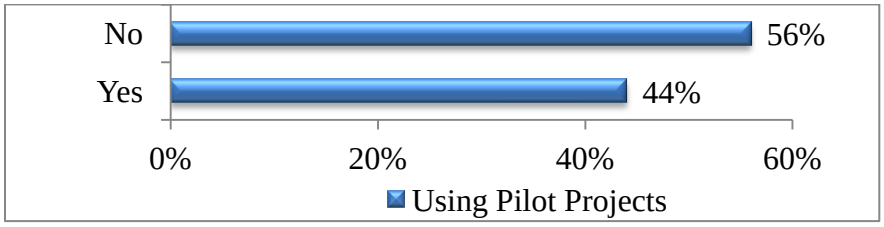

Figure 17. Using Pilot Projects.

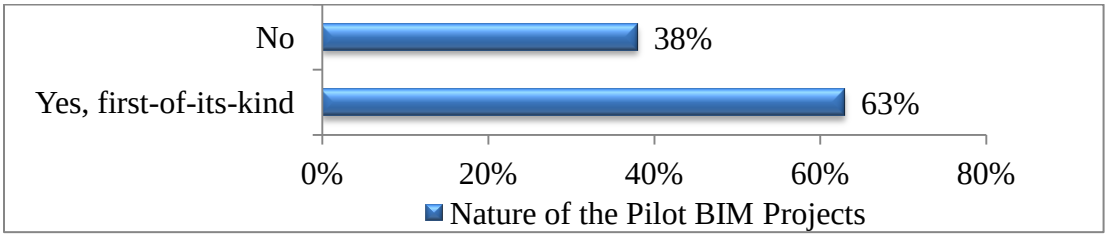

Figure 18. Nature of the Pilot BIM Projects.

As seen in Figure 19, 89% of the respondents use BIM applications and solutions in conjunction with Computer-Aided Design (CAD). This percentage of CAD usage shows that most BIM users have not yet completely eliminated their traditional way of working and are still trying to get accustomed with the new system and technology. Only 11% of the respondents do not use CAD along with BIM applications and solutions.

As seen in Figure 20, 78% of the BIM user respondents are utilizing three-dimensional (3D) CAD, and 22% of the BIM user respondents are utilizing two-dimensional (2D) CAD.

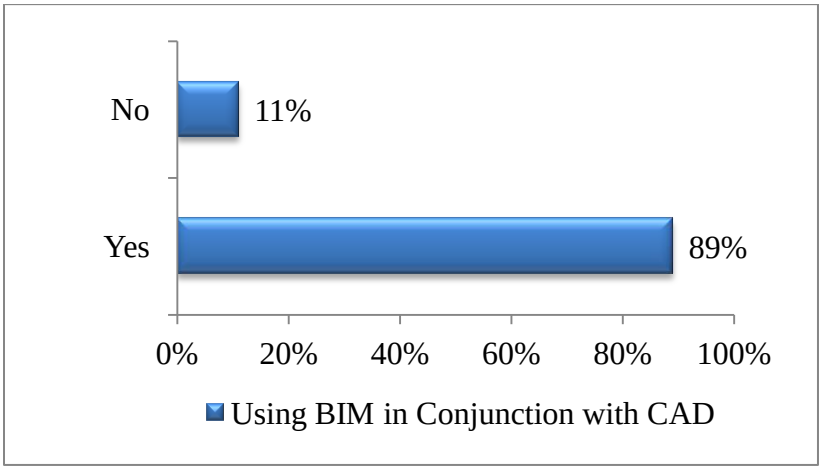

Figure 19. Using BIM in Conjunction with CAD.

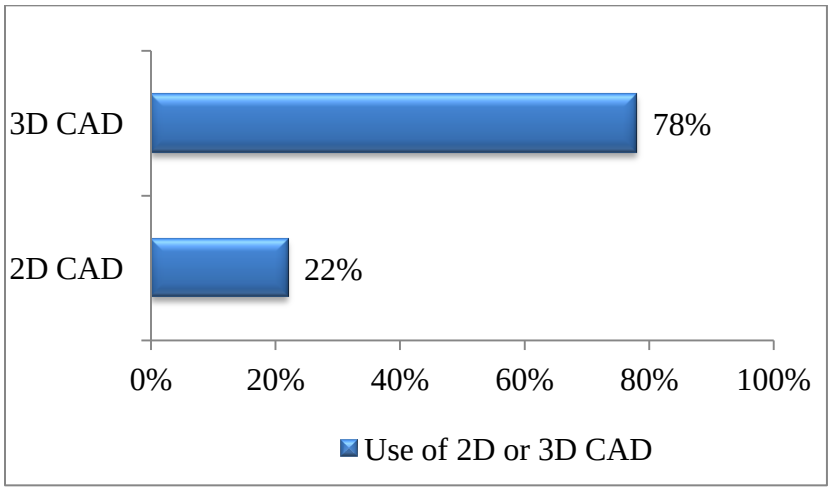

Figure 20. Use of 2D or 3D CAD.

4.1.5. Benefits of Using BIM

Figure 21 is based on a 6-point agree-disagree scale, where zero represents strongly disagree and five represents strongly agree. Also, this segment uses the mean value to indicate the results. Therefore, the mean values in figure 21 indicate the central tendency of all BIM using respondents to each question on a scale ranging from strongly agree or strongly disagree.

As seen in Figure 21, for the "BIM facilitates building lifecycle management (BLM)," "BIM's ability to capture specifications in the model," "BIM's coordinated views and documents eradicate the fear of making last-minute changes," and "BIM efficiency helps save time" statements, the BIM-using respondents replied with an average score, or mean, of 3.89. For the "BIM creates new opportunities in upcoming markets" and "BIM allows better understanding for design" statements, the BIM-using respondents replied with an average score of 4.0. For the "BIM has thoughtful design features," "BIM allows better documentation with less errors," "BIM induces more confidence," "BIM forces designer to think three-dimensionally," and "BIM allows user to work on a single 3D model rather than a multitude of separate 2D files" statements, the BIM-using respondents replied with an average score of 4.11. For the "BIM makes work less tedium" and "BIM's built-in and accurate scheduling capabilities" statements, the BIM-using respondents replied with an average score of 3.78. For the "BIM helps spend more time on design issues, rather than CAD or presentation issues" and "BIM eliminates the divide between designer and 'CAD person'" statements, the BIM-using respondents replied with an average score of 3.67. For the "BIM accuracy helps save time" and "BIM allows better presentation of design concepts to client" statements, the BIM-using respondents replied with an average score of 4.33.

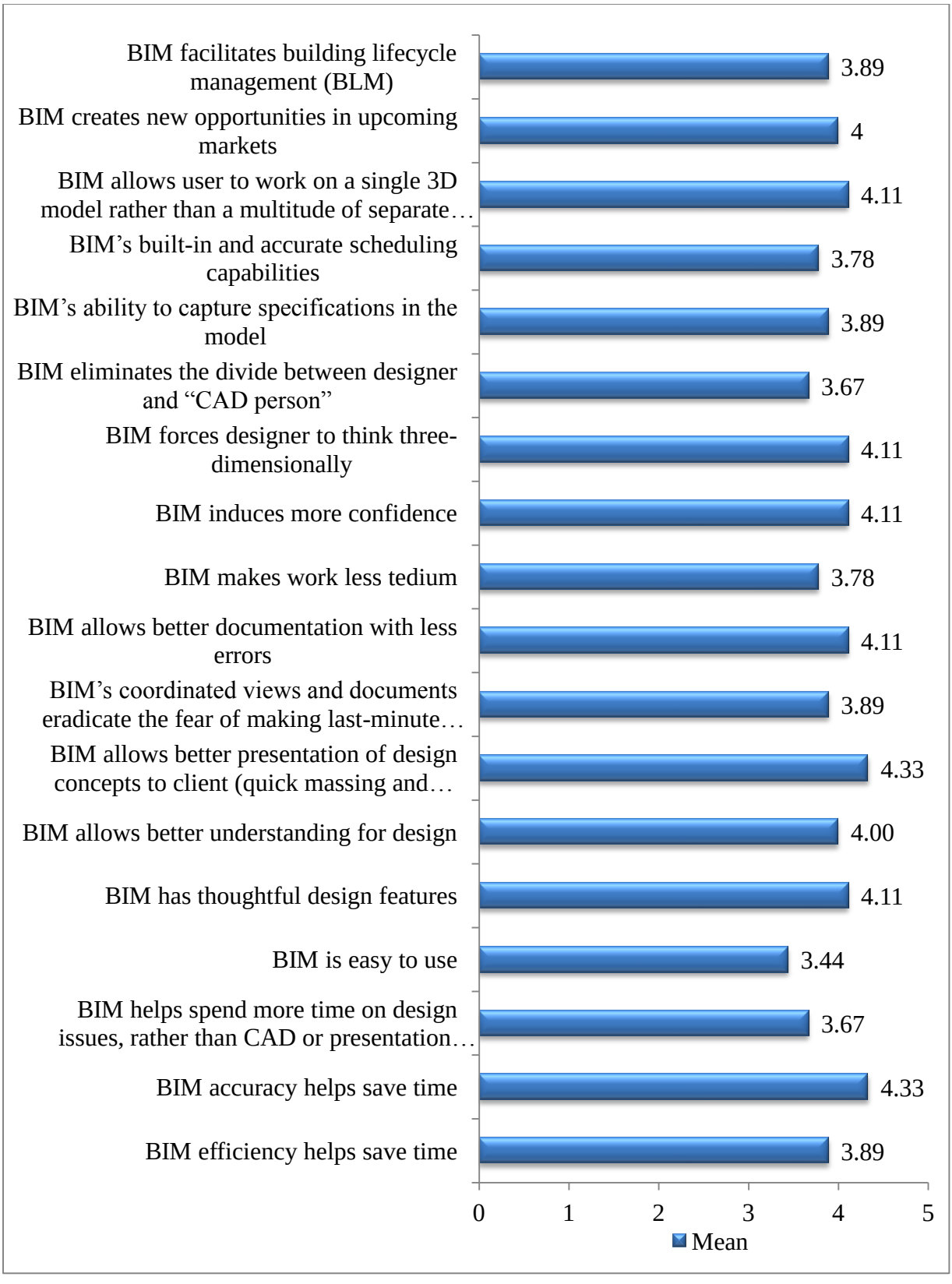

Figure 21. Benefits of Using BIM vs. CAD.

4.1.6. Barriers Encountered

Figure 22 is based on a 6-point agree-disagree scale. The mean has been used to measure the central tendency of the survey respondents. For the "Costly software has to be procured for BIM implementation" statement, the BIM-using respondents replied with an average score of 4.11. For the "Ample amount of time is required to learn application and customize according to company's standards" statement, the BIM-using respondents replied with an average score of 4.0. For the "BIM compels user to work on a single 3D model rather than a multitude of separate 2D files" and "BIM requires lot of communication and collaboration" statements, the BIM-using respondents replied with an average score of 3.89. For the "Costly hardware has to be bought for BIM implementation" and "BIM application faces sluggish performance of software and higher demand of computer resources" statements, the BIM-using respondents replied with average scores of 3.78 and 3.56, respectively. For the "There are incompatibility problems (file formats/standards/ versions) in BIM," "BIM implementation initially affects the productivity," and "BIM faces application programming interface (API) and customization problems" statements, the BIM-using respondents replied with an average score of 3.44. For the "There are indirect costs of organizational/process/workflow changes as a result of BIM implementation," "There is professional resistance to the above changes," and "BIM is a completely different interface than CAD" statements, the BIM-using respondents replied with an average score of 3.33. For the "Cost of training BIM to employees is high" and "BIM has low ability for abstractions, especially during schematic/preliminary/conceptual design stage" statements, the BIM-using respondents replied with an average score of 3.22. For the "BIM imposes resistance to rigor and honesty" and "BIM lacks support for multidisciplinary building design" statements, the BIM-using respondents replied with average scores of 3.11 and 2.89, respectively.

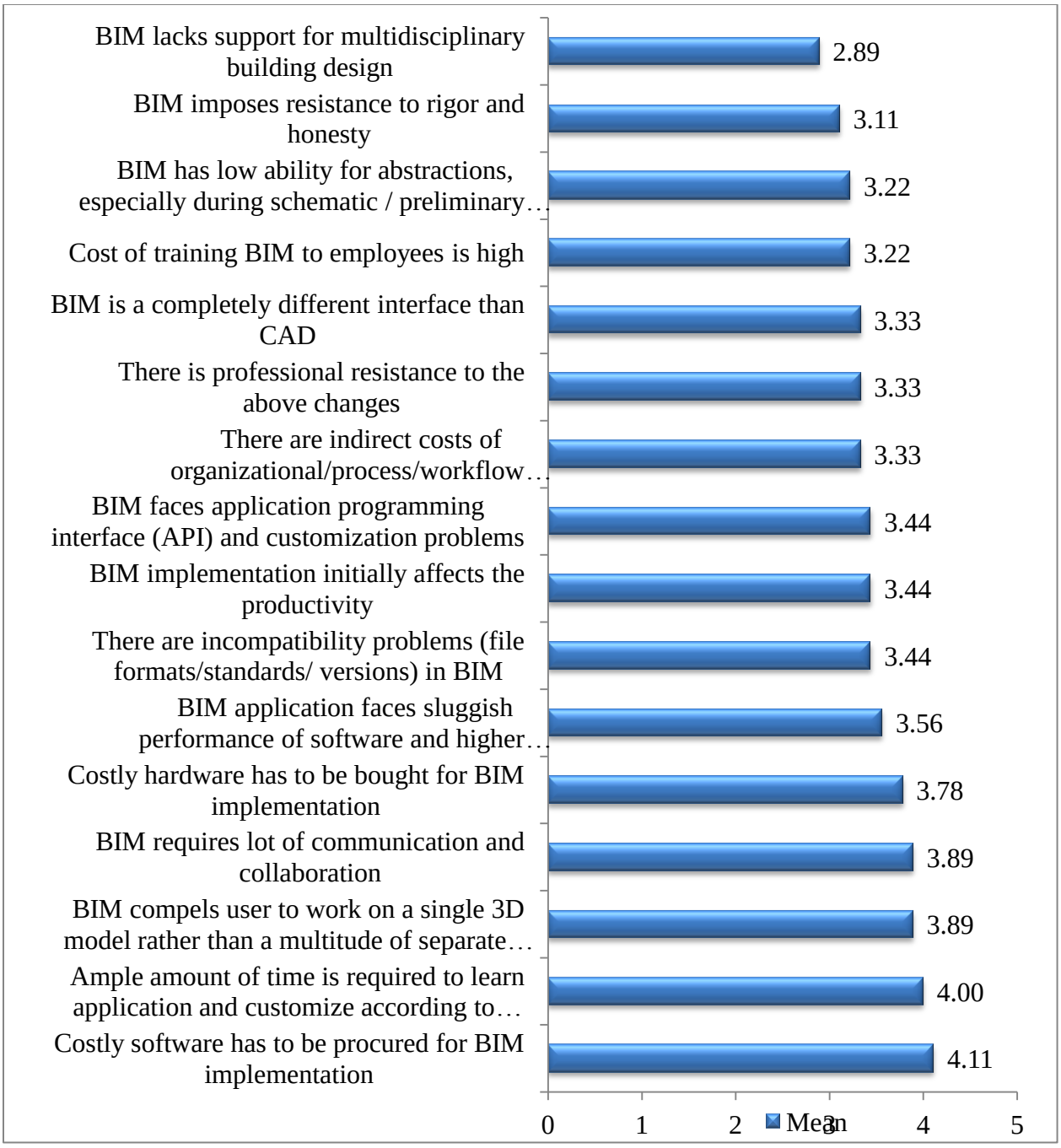

Figure 22. Obstacles for BIM Implementation vs. CAD.

4.1.7. BIM Implementation

Figure 23 is based on a 6-point agree-disagree scale, where zero represents strongly disagree and five represents strongly agree. The mean has been used to measure the central tendency of the survey respondents' answers. For the "BIM is more effective than CAD"

statement, the BIM-using respondents replied with a mean score of 4.22. For the "BIM is more efficient than CAD" statement, the BIM-using respondents replied with a mean score of 3.22. For the "BIM is faster than CAD" statement, the BIM-using respondents replied with a mean score of 3.33. For the statement about the ease of learning BIM, the BIM-using respondents replied with a mean score of 3.33. When asked how satisfied they are with the BIM software's capabilities, the BIM-using respondents replied with a mean score of 3.89. For the "BIM usage increases the level of service, quality and performance of the architectural firm" statement, the BIM-using respondents replied with a mean score of 4.56. For the "BIM is useful for different design and documentation tasks" statement, the BIM-using respondents replied with a mean score of 4.44. When asked about the willingness to pay extra for BIM services and the clients' knowledge of BIM and its various deliverables, the response was an average score of 2.89.

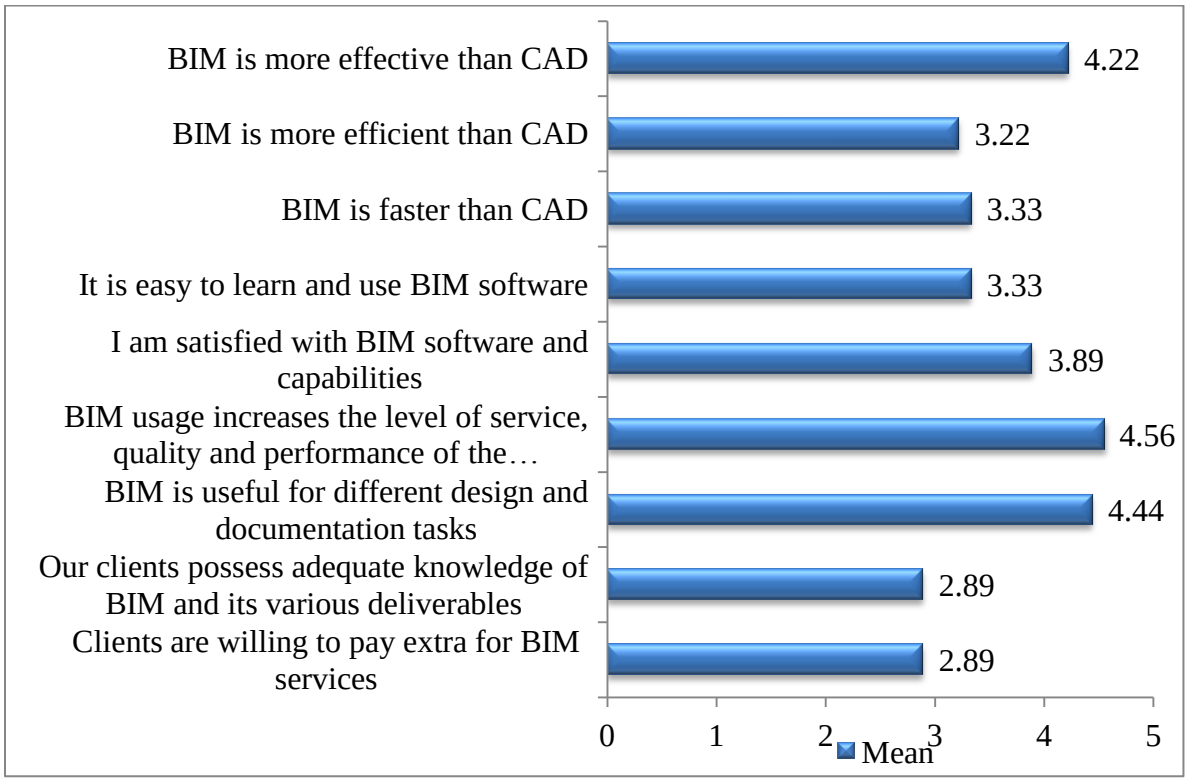

Figure 23. BIM Implementation.

As seen in Figure 24, for the "Start all new projects using the BIM process" statement, the BIM-using respondents replied with an average score of 3.67. For the "Choose a 'Change Champion,'" "Develop an implementation plan," and "Hire a BIM consultant" statements, the BIM-using respondents replied with an average score of 3.89. For the "Commitment from senior managers," "Select a Pilot Project and initial team," "Create a BIM manual," and "Repeat above process on remaining project teams" statements, the BIM-using respondents replied with an average score of 4.00. For the "Develop on-going training program" and "Change vocabulary and perception" statements, the BIM-using respondents replied with average scores of 4.11 and 4.22, respectively. For the "Setup initial formal training" and "Evaluate implementation plan" statements, the BIM-using respondents replied with an average score of 4.33.

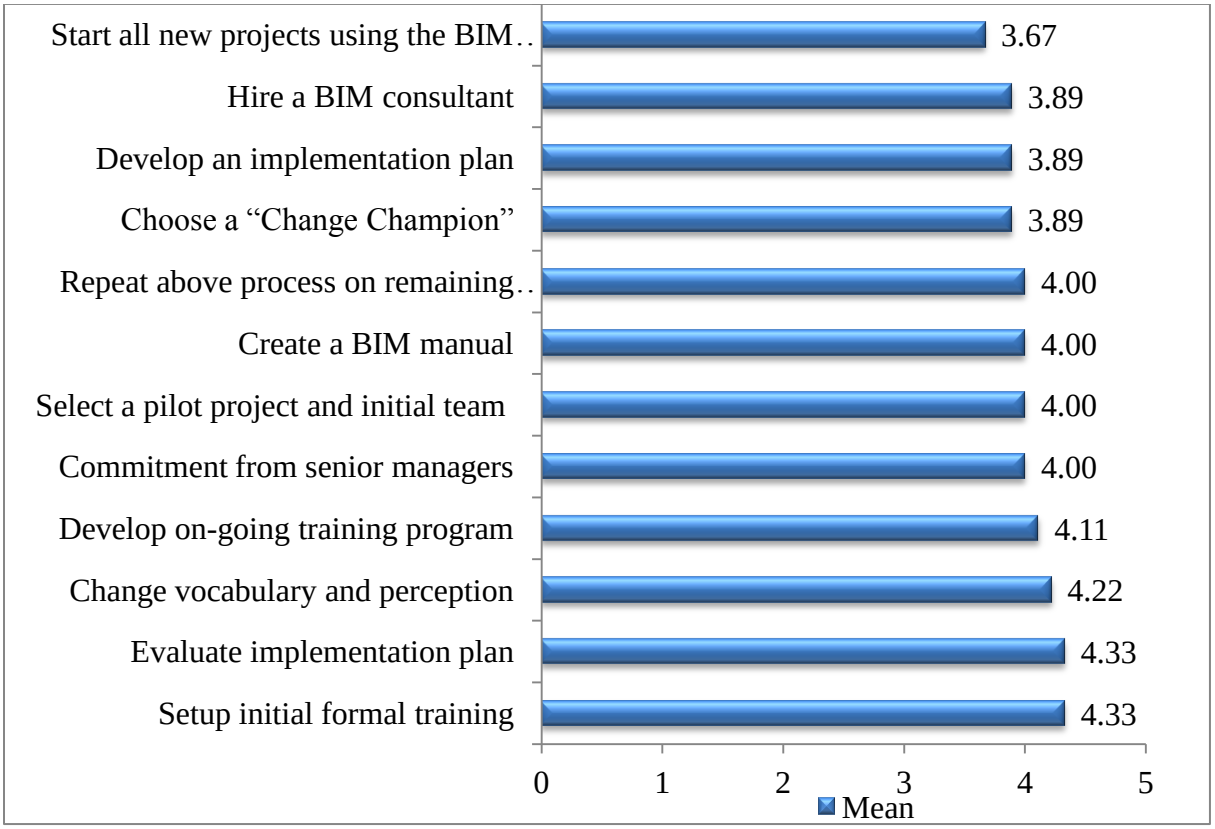

Figure 24. Actions Required for Successful BIM Implementation.

Figure 25 uses the percentage frequency to indicate the results. As seen in Figure 25, 46% of the respondents said they have or would "Inquire about training availability," "Inquire about cost associated with BIM adoption," and "Attend training first then buy software that supports BIM." Forty-three percent of the respondents said they have or would "Inquire about software that supports BIM." Thirty-eight percent of the respondents said they have or would "Hire a BIM consultant before BIM implementation." Twenty-two percent of the respondents said they have or would "Conduct research on Integrated Project Delivery (IPD)." Sixteen percent of the respondents said they have or would "Buy software that supports BIM first then attend training" and "Inquire about legal aspects of BIM practice." Fourteen percent of the respondents said they have or would "Hire a BIM consultant after implementation." Eleven percent of the respondents said they have or would "Developing software add-ons." Eight percent of the respondents said they have or would "Use software that I already have in place."

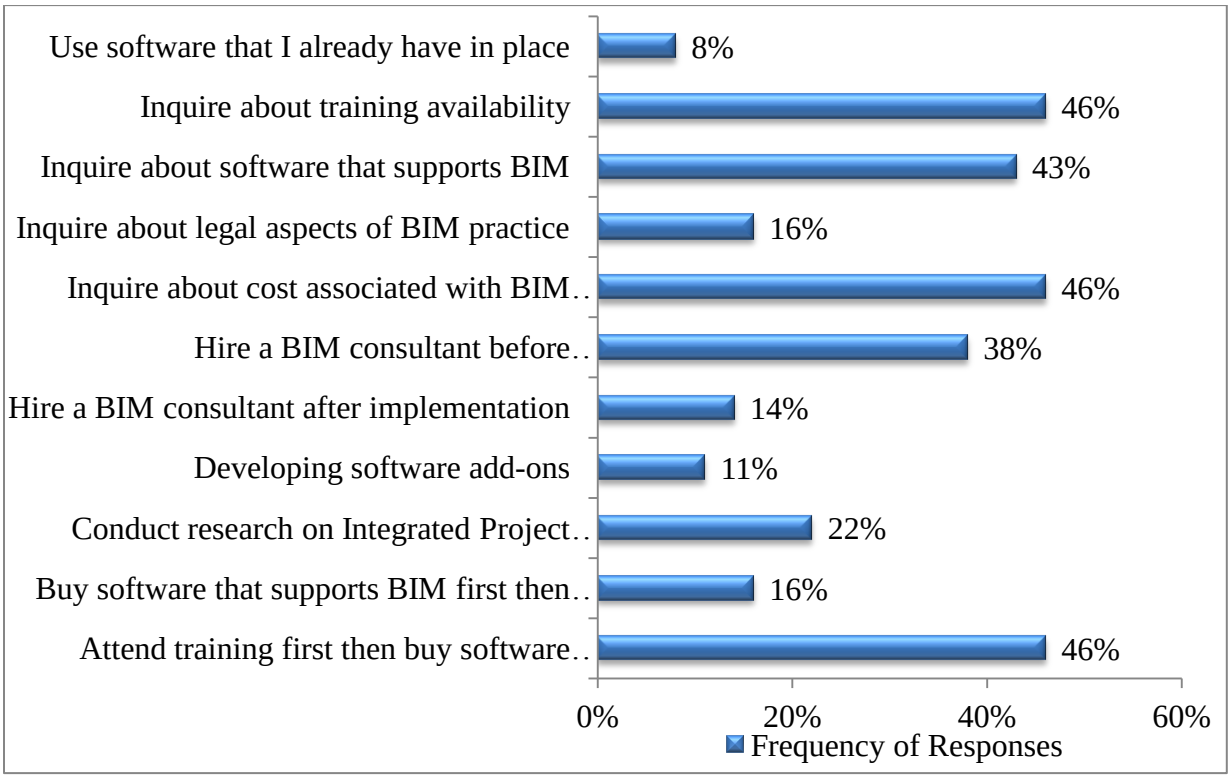

Figure 25. Essential BIM Implementation Aspects.

4.2. Hypothesis Testing

The author needed to test the hypothesis about whether more than 35.5% of Indian AEC firms use BIM; 35.5% (i.e., 50% of 71%) was a fair number to use for analysis, as compared to the percentage of BIM users in the USA (71%), to prove that the results that were received via the online survey are fairly accurate with a significance level of 5%. Via the online survey, the author collected a sample of 43 AEC firms, and it was found that 7 of them are currently using BIM.

To perform hypothesis test, null and alternative hypothesis are needed to be established. Our null hypothesis was that hypothesis which author believed was not correct.

Null hypothesis, H_0: The proportion of Indian AEC firms that use BIM is more than or equal to 35.5%.

H_0: $p \geq 35.5\%$

Alternative hypothesis, H_a: The proportion of Indian AEC firms that use BIM is less than 35.5%.

H_a: $p < 35.5\%$

We are testing the null hypothesis. We need to assume a proportion based on the null hypothesis for the population. Given that assumption, what is the probability that 7 of the 43 respondents (n) actually use BIM services? If that probability is less than the significance level of 5%, then we are going to reject the null hypothesis in the favor of the alternative hypothesis (Trochim, 2006). Assuming the null hypothesis is true for this assumption, we are going to pick a population proportion (i.e., from the Bernoulli distribution) so high so that it maximizes the probability of getting the null hypothesis to be true.

Now, from the survey conducted, we know that 7 of the 43 AEC firms use BIM. Calculating the sample proportion ($\bar{p}$),

$$\bar{p} = \frac{7}{43} = 0.163$$

The highest population that fits our null hypothesis to maximize the probability of accepting the null hypothesis is actually if we are right at 35.5%. If we say our population proportion (p_{H_0}) is 35.5%, then our null hypothesis is true.

$$p_{\mathrm{H}_0} = 0.355$$

If we take the maximum proportion that still satisfies our null hypothesis, we are maximizing the probability that we get ($p_{\mathrm{H}_0} = 0.355$). Assuming our null hypothesis is true, the population mean (μ_{H_0}) is given by the following equation:

$$\mu_{H_0} = 0.355$$

In a normally distributed bell curve, the populations mean (0.355) would be right at the center of the bell curve. As per the binomial theorem, the population's standard deviation (σ_{H_0}) is given by the following equations:

$$\sigma_{H_0} = \sqrt{\mu_{H0} * (1 - \mu_{H0})}$$

$$\sigma_{H_0} = \sqrt{0.355 * (1 - 0.355)}$$

$$\sigma_{H_0} = \sqrt{0.229}$$

$$\sigma_{H_0} = 0.479$$

In order to ensure that we can use a normal distribution, we have to make sure that the sample (n) times sample proportion ($\bar{p}$) OR the sample (n) times one minus sample proportion ($\bar{p}$) is greater than 5.

$$n\bar{p} > 5 \ (or) \ n(1 - \bar{p}) > 5$$

$$(43 * 0.163) = 7.009 > 5 \quad (or) \quad (43 * 0.837) = 35.991 > 5$$

Now, the mean of the sample proportion data ($\mu_{\bar{p}}$) is the same as that of our population mean (μ_{H_0}).

$$\mu_{\bar{p}} = \mu_{H_0} = 0.355$$

As per the central-limit theorem, in our case, the standard deviation of our sample proportion ($\sigma_{\bar{p}}$) is as follows:

$$\sigma_{\bar{p}} = \frac{\sigma_{H_0}}{\sqrt{n}}$$

$$\sigma_{\bar{p}} = \frac{0.479}{\sqrt{43}} = 0.073$$

Now to calculate the probability of having a sample proportion ($\bar{p}$) of 0.163, we have to calculate how many standard deviations it is away from our mean; we essentially calculate a z-statistics for our sample and then calculate whether the probability of obtaining that z-score is more or less than the significance level of 5%.

Calculating how many standard deviations we are away from the mean,

$$z = \frac{\bar{p} - \mu_{\bar{p}}}{\sigma_{\bar{p}}}$$

$$z = \frac{0.163 - 0.355}{0.073}$$

$$z = -2.63$$

Because z is a negative value, we need to find, from the z table, the critical z-value in the lower tail to the left of the mean. Any z-value that is smaller than the critical z-value has less than a 5% probability of occurring and, for us, would be the validation to reject the null hypothesis.

From the standard normal cumulative probability table (attached as Appendix C), the critical z-value at the 5% significance level is -1.64. Therefore, the probability that the obtained z-score is less than the critical z-value (-1.64) or that, in any normal distribution, the probability of the obtained z-score being less than critical z-value is going to be less than 5%.

The z-score for our actual sample is -2.63; i.e., this value is to the left of the critical z-value. Therefore, the probability of this calculated z-score (-2.63) is definitely less than 5%.

Hence, we reject our null hypothesis that usage of BIM at Indian AEC firms is more than 35.5%, and we accept the alternate hypothesis that usage of BIM at Indian AEC firms is less than 35.5% and that there is a need to suggest a successful BIM implementation strategy for these AEC firms.

Finally, from the above hypothesis test using one-sample, one-tail z-statistics, it is evident that the survey results or the frequency of responses obtained from the online survey can be applied not only to the sample group, but also to the entire Indian AEC industry. Hence, all the previously discussed survey data (Section 4.1) depict the current situation of the entire Indian AEC industry regarding the awareness, status, adoption, benefits, and barriers encountered for BIM implementation within the respective firms and the industry as a whole.

4.3. Survey and Literature Data Combination

4.3.1. Current Level of BIM Adoption in India

From the survey data, BIM is gaining acceptance at a very gradual pace in India. However, the data showed that the majority of the study participants are grappling with the issues of the transition phase from non-intelligent 2D CAD drawings to powerful BIM solutions. Per our survey, only 77% of the population in the AEC industry is aware of BIM, and a majority (60%) of the AEC industry believes that the industry's prevalent BIM knowledge is very low.

Even though the professionals in the Indian AEC industry believe in the potential benefits that BIM has to offer, a large portion of them are still not willing to change the traditional methods used by the firms because of the multiple reasons, such as the high cost of implementation, the associated training cost, or not enough demand from clients. The same problem was studied in this paper' Literature Review, and one of the causes that surfaced in the Literature Review was that the Indian AEC industry's firms have not yet seen a complete cycle of BIM adoption and benefits, making them skeptical about whether to embrace BIM with confidence because of the astronomical cost involved with its adoption.

4.3.2. Barriers of BIM Implementation in Indian AEC Firms

4.3.2.1. Personnel shortage

Both the Literature Review and survey responses validated that one of the major causes for not adopting BIM is the "lack of trained staff." In the author's perspective, one of the reasons for the lack of trained staff could be a stagnant education system. The course work at Indian architectural and engineering colleges is updated at very large intervals of time, thus leading to new graduates with obsolete knowledge. A similar point of view was expressed by one of the anonymous respondents, "It should be included as a subjective course during degree time period as after which an architect has to face many challenges by which he may not focus in depth about BIM…"

The cause for the scarce availability of trained BIM personnel in the Indian AEC industry that was observed in the Literature Review was the lack of initiative by the Indian firms to impart training to their employees in order to attain BIM proficiency. The main reason was the high cost of training and certification courses (Davidson, 2009).

4.3.2.2. Low client demand

One of the reasons that the survey revealed for not adopting BIM in the Indian AEC industry was the lack of client demand; 62% of the non-BIM users gave the reason that there was not enough client demand to use BIM. In the Literature Review, the reason for low client demand was the lack of a trusted knowledge source to validate the potential benefits of BIM, making it an unappealing choice for clients considering the additional expense they would have to incur (Avsatthi, 2013).

4.3.2.3. High cost of implementation

One of the popular myths in India is that "BIM comes with a big price tag." Per the conducted survey, around 38% of the people believe in this myth; however, in doing so, they overlook the potential benefits that BIM has to offer which, as per the Literature Review, means that they have not seen the complete cycle of BIM: from implementation to the ROI or the profits the company would be able to make after it has mastered BIM implementation to exploit its full potential (Rajvir, 2013; Sawhney & Singhal, 2013; CAD Services, 2012).

4.3.3. Potential Benefits of BIM Implementation in India

The potential benefits of BIM utilization are very well documented in the Literature Review. The author's survey reflects these benefits to a great degree among BIM users in India. Some of the benefits are better 3D visualization (55%), accuracy and consistency of data (90%), impeccable collaboration among different trades involved with the construction industry, convenient quantity estimation, reduced material usage, and wastage.

In addition to the above-mentioned benefits, the author's survey results portray that there are more advantages of adopting BIM, particularly in India, namely:

- The firms can focus more on design issues, making it possible for BIM-proficient people to detect and overcome problems during the initial design phase and making them less dependent on the field workers to tackle problems later in the project field (66%).
- Have a standard communication platform for BIM professionals rather than depending on verbal communications which are more prone to human errors, considering the multiple regional languages used in India (89%).
- The AEC firms can have a better estimation of project-completion dates (78%).
- The AEC firms can have a controlled project cost because, when using BIM, the owner has an exact idea of the material he needs for the project, enabling him to lock in material prices. This cost-control is particularly useful when considering the price-inflation rate in India.

Although some potential barriers lay between the current stagnant Indian AEC industry and BIM implementation, the author feels confident that suggesting strategies to overcome these barriers would definitely help improve Indian AEC firm's performance by leaps and bounds. Looking at the overall picture, it would also help India attain a position as a significant player in the world construction industry. As rightly said by Charles Kettering, "the world hates change, yet it is the only thing that has bought progress" (Kettering, n.d.).

5. RECOMMENDATIONS FOR BIM IMPLEMENTATION

This chapter deals with, suggestions for an elaborate plan of action to overcome the obstacles that are currently faced by the Indian AEC industry, based on the benefits and the barriers in implementing BIM encountered during literature review and survey analysis. There is a paradigm shift in the workflow process for AEC firms across the globe, and in order to sustain and flourish in this competitive market, architects, engineers, and contractors need to understand and take the initiative to surmount this unavoidable hurdle and to befriend this new tool and process that would take them to higher levels of technical and technological success.

Executing BIM at firms is big decision, and to make it successful, AEC firms need to understand what change this new process brings and how they should prepare for it. Considering all the barriers the Indian AEC industry has been facing, the following strategies are deduced from the research to help make a successful transition from the current 2D-CAD dependent industry to a BIM-compliant industry.

5.1. Adoption Process

5.1.1. Senior Authority Buy-In

Implementing BIM requires commitment from every level of the business, but nothing will slay a successful rollout faster than a lack of support from senior management. BIM is not a shoestring budget. A proper financial plan needs to be found; staff members need to be trained; and normal business activities will be disrupted. This disruption in the normal workflow process is for a limited time; however, the advantages would be significant and long lasting. Managers need to be given a realistic view of the changes' impact, as well as the potential benefits, so that, when the going gets challenging, as it certainly will, they are geared up to go the extra mile to make things happen.

In the Indian construction industry, senior architects are considered the primary drivers of BIM use among all building team members, making them the top decision makers. Therefore, taking initiative and backing the team with support is the foremost responsibility of architects aiming to implement BIM which provides a distinct, intuitive, and powerful means for building design.

5.1.2. Set the Aim and Goal

"You get what you plant" applies to BIM implementation as well. Understanding the goals and objectives of adopting, in addition to the required deliverables, is extremely important to ensure maximum efficiencies for the project's client or owner. Also, clear knowledge about how people will cooperate with each other, along with what technologies will be used, needs to be clear and precise. The primary goal of the AEC firms should be to define who will be performing the BIM, outline the respective roles and responsibilities for the team, and clearly identify the deliverables. What and how will the data be shared? How will the progress be measured? Any potential obstruction that is identified can be resolved with skillful planning.

5.1.3. Research and Pilot Study

To avoid the mistakes made by other AEC firms, it is always a good idea to start with your own research on the best BIM implementation practices across the country. There are many cases where companies have struggled with their own processes and software, creating their own method to overcome a problem, so it is really important to try to learn from others, thus making a smaller investment than was planned.

5.1.4. Choosing the Correct Software

Good strategies fail due to choosing an improper tool. The firms' potential can be improved by using the correct software, and the capabilities can be reduced if the company

invests in a software solution which does not serve its BIM needs. Instead of adapting workflows to suit the technology, firms should look for software that allows them to enhance their current workflows. Migrating information production from one platform to another requires a considerable amount of effort, so the most common and basic practice is to look for BIM solutions for the CAD software you are already using rather than investing in a completely new product. When selecting BIM software, one needs to make sure that following criteria are being met: the software requires a relatively low purchase cost; low running, maintaining, and upgrading costs; no requirement to upgrade your present workstations and network; basic training included in the purchase cost; and the availability of active support in your area.

5.1.5. Choosing and Training the Correct Team

Initial stages of BIM implementation are associated with disrupted and low productivity as the transitioning team is trying to learn the new system. Over the period, productivity increases back and rises beyond the point experienced with CAD system, as the new technology takes hold. AEC firms should pay close attention when choosing the transition team. The team should have individuals who are agile, quick learners; who understand the organization's goal; and who will act as a preceptor for BIM. BIM's parametric approach to modeling is the essence of architectural and structural design, so it is advisable to include the organization's best architect and designer on the transition team instead of draftsman. Training staff also means the loss of billable hours and is always a concern for senior management. In these circumstances, the best option would be taking web-based classes and then completing the training by working on an existing project.

5.1.6. Roll-Out Project

Which project should be used to start BIM when every project is equally important? Risk is the synonym for business, and to progress in any business, one has to be a risk taker. What can be done to lower the risk? "Selecting the appropriate project" is where the solution to the above question lies. The roll-out project should be the type of project where the AEC firm has expertise or has handled projects of that type and scale in the past. This selection of right project could help AEC firms in gauging the benefits, because the most important benefits are complicated to measure: time spent on designing rather than drafting, clearer presentation of the design to clients, quick and easy quantity estimation, etc. Collecting these data can help verify the assured ROI for the system.

5.1.7. Work with Project Team Members

In most cases in India, the architect is the owner's representative for the project; he/she has to coordinate among the MEP engineers, contractors, and owner. It was identified via the online survey that the majority of clients are unaware of the BIM topic, and this obstacle is one of the major ones they confront even if they are willing to implement VDC. Hence, it should be noted that, while selecting software (for this new transition), the program needs to be compatible with the software these team members currently use. In the initial stages (especially when other team members are still using old techniques), this compatible software would save a lot of time; otherwise, time is wasted when converting documents to compatible file formats. Eventually, when AEC firms start to experience the benefits of using this parametric modeling approach, they can promote BIM implementation to their team members, too.

5.2. Successful BIM Implementation

To make it profitable and successful in the future, BIM needs to line up with the businesses goals:

- The project's BIM manager needs to be identified and must possess an understanding of project workflows, management, and technicalities required for using BIM. According to Hardin (2009) "BIM doesn't work – people make it work."
- It should be clearly noted that selecting a software package just because everyone is using it does not serve purposes. Significant appraisal ought to be performed to check if investing in this application suits the firm's goals and necessities.
- It is recommended by almost all BIM experts to "start with a small group." In order to reduce the impact on productivity levels, this trick would definitely help with a smooth transition from 2D CAD to BIM.
- The BIM manager or the team leader should be completely aware of the BIM software's ins and outs and should make sure he/she maintains an updated technological knowledge in the office.
- It is good practice to put all information (gained during the training period and practice sessions) in the form of tutorials, standards, and guides/manuals; this data would definitely make working with BIM less complicated.
- Purchasing software and maintaining its annual subscription are costly business matters. AEC firms should adhere to their implementation plan, trying to become more effective and to make more profit. At the same time, AEC firms needs to be flexible and open to adapting to improved alternatives which would help attain goals sooner.

- Analysis and statistical evaluation is of utmost importance. Finding out how BIM has helped or hurt the organization would help guide future progress toward the company's goals and ROI.

With this study, the suggestion is being made, with the help of the above-mentioned strategies, to implement BIM at Indian AEC firms. Even though owners do not possess adequate knowledge about BIM and its various benefits, the survey found that a high percentage of Indian AEC firms assume that the owner will be willing to pay extra for BIM services.

6. CONCLUSION

6.1. Study Limitations

Although this study suggests strategies for successful BIM implementation for the Indian AEC industry, it is based on few assumptions and limitations. It was assumed that, the technicians utilizing BIM are knowledgeable and competent about its usage, BIM utilization plays a significant role from the conceptual design phase to the construction phase, and all the coordinating trades associated with a project are using the same BIM platform. Also, this paper had limitations on the study of AEC firm's return on investment with BIM implementation, the main reason being unavailability of the data, therefore it was not included in the survey analysis to accurately determine or justify potential benefits.

6.2. Future Work

Future studies about encouraging the project owners to exploit the powerful BIM benefits and services may be performed. In a country where there is a huge need and demand for infrastructure, BIM makes sure that more of the investor's capital goes to the proper utilization of costs. The current state of the Indian construction industry demands a massive marketing and promotion campaign to encourage BIM usage. The Indian government, with its substantial resources, could help promote BIM usage for the construction industry.

6.3. Paper Conclusions

With this study involving the Indian AEC firm's consideration of BIM implementation and suggesting strategies based on those factors, the author concludes the paper with the following notes. In Indian AEC industry there are fewer BIM users with low knowledge about BIM. The major reasons for this condition being high cost of software, low demand from the clients and lack of skilled or trained employees. The rampant myths about BIM usage and the

lethargic attitude of professionals toward validating the facts are keeping the firms away from embracing the BIM technology. Moreover, the AEC firms are too comfortable and are not willing to change the current practices.

In this research, it was also noticed that the Indian Government is not involved with initiative to encourage BIM usage in construction industry and there is no initiative from educational institutions either, to introduce new or current global trends related to the construction industry in academics. Therefore strategies suggested by the author would be helpful to promote the usage of BIM in the Indian AEC industry based on the assumption that the firms are proactively involved with implementing BIM.

6.4. Summary of the Author's Contributions

The author believes that the following contributions would be helpful in making a transition from 2D CAD to BIM within the Indian AEC industry:

- Integrated and proactive involvement of the Indian AEC industry toward BIM implementation.
- Active participation of the Indian government and educational institutes to promote and encourage BIM usage in the Indian AEC industry.
- Change in outlook for the Indian AEC firms to focus more on the long-term benefits of BIM rather than the temporary financial setbacks of its implementation.
- Change in the traditional Indian way of thinking, making people more open minded toward adopting new changes for the betterment of the industry as a whole.

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APPENDIX A. IRB APPROVAL

NDSU NORTH DAKOTA STATE UNIVERSITY

January 31, 2014 FederalWide Assurance FWA00002439

Dr. Jerry Gao
Construction Management & Engineering
118F AR/LA

Re: IRB Certification of Exempt Human Subjects Research:
Protocol **#EN14158 , "Implementing BIM in Architectural Firms in India"**

Co-investigator(s) and research team: **Aarti Nanajkar**

Certification Date: 1/31/14 Expiration Date: 1/30/17
Study site(s): **India, various locations**
Funding: **n/a**

The above referenced human subjects research project has been certified as exempt (category # 2) in accordance with federal regulations (Code of Federal Regulations, Title 45, Part 46, *Protection of Human Subjects*). This determination is based on protocol materials (received 1/29/14).

Please also note the following:

- If you wish to continue the research after the expiration, submit a request for recertification several weeks prior to the expiration.
- Conduct the study as described in the approved protocol. If you wish to make changes, obtain approval from the IRB prior to initiating, unless the changes are necessary to eliminate an immediate hazard to subjects.
- Notify the IRB promptly of any adverse events, complaints, or unanticipated problems involving risks to subjects or others related to this project.
- Report any significant new findings that may affect the risks and benefits to the participants and the IRB.
- Research records may be subject to a random or directed audit at any time to verify compliance with IRB standard operating procedures.

Thank you for your cooperation with NDSU IRB procedures. Best wishes for a successful study.
Sincerely,

Kristy Shirley

Kristy Shirley, CIP, Research Compliance Administrator

INSTITUTIONAL REVIEW BOARD
NDSU Dept 4000 | PO Box 6050 | Fargo ND 58108-6050 | 701.231.8995 | Fax 701.231.8098 | ndsu.edu/irb
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APPENDIX B. QUESTIONNAIRE

PART I - INFORMATION SHEET

1. I have read the information sheet and wish to participate in this research. (Please note a negative response will end the survey)
    a. Yes. Please continue the survey on the next page (Part II).
    b. No. Please explain why?

    _____

    _____

PART II – RESPONDENT'S BACKGROUND & KNOWLEDGE OF BIM

This section consists of 10 questions which should identify respondent's industry experience and knowledge of BIM technology and processes.

2. Which of the following most closely describes your role at your organization? (Select all that apply)
    a. Jr. Architect
    b. Sr. Architect
    c. Engineer
    d. Contractor / Construction Manager
    e. Others (Please specify): _____
3. How many years of experience do you have in your field?
    a. 0 -2 years
    b. 3 – 5 years
    c. 6 – 10 years
    d. 11 – 15 years
    e. 16 or more

4. How many employees work in your firm?
    a. 1-10
    b. 11-50
    c. 51-100
    d. More than 100
5. Have you heard of Building Information Modeling (BIM) solutions and applications?
    a. Yes
    b. No
6. How would you describe BIM? (Check one or more)
    a. BIM is a piece of software
    b. BIM is a piece of technology
    c. BIM is a piece of process
    d. BIM is a piece of philosophy
    e. Other, please specify
7. In general, how would you characterize the current knowledge level about BIM among the industry?
    a. None
    b. Low
    c. Medium
    d. High
    e. Very high

8. Do you think BIM should become a mandatory process in the industry? (Please comment your answer)
    a. Yes
    b. No
    c. Don't know
    d. Other, please specify Your comments:
9. Have you used BIM solutions and applications in any of your projects?
    a. Yes: How many projects:
    b. No
10. If the answer to Question #9 is YES, What are your initial reasons for adopting BIM? (Check all that apply)
    a. Because competitors are using it
    b. The Owner is asking for it
    c. Better 3D visualization
    d. Data management
    e. To improve quality of projects
    f. Other, please specify:
11. If the answer to Question #9 is NO, What are the main reasons for not adopting BIM? (Check all that apply)
    a. Low return-on-investment
    b. Do not see a value for BIM use
    c. Legal issues
    d. High cost of acquiring software that supports BIM

e. High cost of hardware upgrade

f. High cost of maintaining software that supports BIM

g. High cost for required training

h. Lack of sufficient time to evaluate BIM

i. Not enough demand from clients and/or other firms on projects

j. Interoperability issues

k. Functionality doesn't apply well enough to what we do

l. Cultural resistance

m. Disruptions to implement new process

n. Inexperienced end users

o. Lack of trained staff

p. Other, please specify

12. If the answer to Question #9 is NO, please skip questions 13-23 and go to question 24 (last question). If YES, are you currently using BIM solutions and applications?

a. Yes

b. No

PART III – BIM USAGE

13. For approximately how many years have you used BIM solutions and applications?

a. 0 – 1 year

b. 2 – 3 years

c. 4 – 5 years

d. More than 6 years

14. Which software vendor(s) do you use/have used for BIM? (Select all that apply)

    a. Autodesk Revit

    b. Graphisoft ArchiCAD

    c. Autodesk Navisworks

    d. Google Sketch Up

    e. Bentley Micro Station

    f. Vector Works

    g. Vico

    h. Tekla

    i. Allplan

    j. Others (Please specify)

15. What were the sizes of your BIM projects?

    a. Small (value less than Rs 1crore)

    b. Medium (value between Rs 1crore and Rs 5crore)

    c. Large (value more than Rs 5 crore)

16. Have you used a pilot project before you fully adopted BIM? (A pilot project refers to an initial roll out of a system)

    a. Yes

    b. No

17. Was the pilot BIM project first-of-its-kind for your firm?

    a. Yes

    b. No

18. Do/did you use BIM software in conjunction with Computer Aided Design (CAD)?

a. Yes

b. No

19. Which of the following CAD applications are you using currently?

a. Two-dimensional (2D) CAD

b. Three-dimensional (3D) CAD

Note: Please answer questions 20-24 below, using appropriate rating numbers.

Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree	Absolutely Disagree
5	4	3	2	1	0

20. Please respond to the following statement:

a. Clients are willing to pay extra for BIM services	
b. Our clients possess adequate knowledge of BIM and its various deliverables	
c. BIM is useful for different design and documentation tasks	
d. BIM usage increases the level of service, quality and performance of the architectural firm	
e. I am satisfied with BIM software and capabilities	
f. It is easy to learn and use BIM software	
g. BIM is faster than CAD	
h. BIM is more efficient than CAD	
i. BIM is more effective than CAD	

21. The following statements list various strengths claimed for BIM and its implementation when compared to traditional methods. Please indicate your agreement with each statement.

a. BIM efficiency helps save time	
b. BIM accuracy helps save time	
c. BIM helps spend more time on design issues, rather than CAD or presentation issues	
d. BIM is easy to use	
e. BIM has thoughtful design features	
f. BIM allows better understanding for design	
g. BIM allows better presentation of design concepts to client (quick massing and rendering visuals)	
h. BIM's coordinated views and documents eradicate the fear of making last minute changes	
i. BIM allows better documentation with less errors	
j. BIM makes work less tedium	
k. BIM induces more confidence	
l. BIM forces designer to think three-dimensionally	
m. BIM eliminates the divide between designer and "CAD person"	
n. BIM's ability to capture specifications in the model	
o. BIM's built-in and accurate scheduling capabilities	
p. BIM allows user to work on a single 3D model rather than a multitude of separate 2D files	
q. BIM creates new opportunities in upcoming markets	

r. BIM facilitates Building Lifecycle Management (BLM)	
s. Other strength. Please specify:_____	

22. The following statements list various obstacles claimed for BIM and its implementation when compared to traditional methods. Please indicate your agreement with each statement.

a. Costly software has to be procured for BIM implementation	
b. Costly hardware has to be bought for BIM implementation	
c. Cost of training BIM to employees is high	
d. There are indirect costs of organizational/process/workflow changes as a result of BIM implementation	
e. There is professional resistance to the above changes	
f. BIM is a completely different interface than CAD	
g. There are incompatibility problems (file formats/standards/ versions) in BIM	
h. BIM implementation initially affects the productivity	
i. Ample amount of time is required to learn application and customize according to company's standards	
j. BIM application faces sluggish performance of software and higher demand of computer resources	
k. BIM compels user to work on a single 3D model rather than a multitude of separate 2D files	
l. BIM requires lot of communication and collaboration	

m. BIM faces application programming interface (API) and customization problems	
n. BIM imposes resistance to rigor and honesty	
o. BIM has low ability for abstractions, especially during schematic / preliminary / conceptual design stage	
p. BIM lacks support for multidisciplinary building design	
q. Other obstacles. Please specify:_____	

23. Please rate how strong or weak are the following actions on the *SUCCESS* of BIM implementation?

a. Commitment from Senior Managers	
b. Choose a "Change Champion"	
c. Develop an Implementation Plan	
d. Select a Pilot Project and initial team	
e. Hire a BIM consultant (Embedded Expert)	
f. Setup initial Formal Training	
g. Change vocabulary and perception	
h. Evaluate Implementation Plan	
i. Create a BIM Manual	
j. Repeat above process on remaining project teams	
k. Start all new projects using the BIM process	
l. Develop on-going training program	
m. Others. Please specify:_____	

24. Which of the following steps has your organization used (or would use) to implement BIM?

(Check all that apply)

a. Inquire about cost associated with BIM adoption	
b. Inquire about software that supports BIM	
c. Inquire about training availability	
d. Buy software that supports BIM first then attend training	
e. Attend training first then buy software that supports BIM	
f. Use software that I already have in place	
g. Developing software add-ons	
h. Inquire about legal aspects of BIM practice	
i. Hire a BIM consultant before implementation	
j. Hire a BIM consultant after implementation	
k. Conduct research on Integrated Project Delivery (IPD)	

25. Please provide your additional comments.

_____

_____

APPENDIX C. STANDARD NORMAL CUMULATIVE PROBABILITY TABLE

Standard Normal Cumulative Probability Table

Cumulative probabilities for NEGATIVE z-values are shown in the following table:

z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
-3.4	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0002
-3.3	0.0005	0.0005	0.0005	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0003
-3.2	0.0007	0.0007	0.0006	0.0006	0.0006	0.0006	0.0006	0.0005	0.0005	0.0005
-3.1	0.0010	0.0009	0.0009	0.0009	0.0008	0.0008	0.0008	0.0008	0.0007	0.0007
-3.0	0.0013	0.0013	0.0013	0.0012	0.0012	0.0011	0.0011	0.0011	0.0010	0.0010
-2.9	0.0019	0.0018	0.0018	0.0017	0.0016	0.0016	0.0015	0.0015	0.0014	0.0014
-2.8	0.0026	0.0025	0.0024	0.0023	0.0023	0.0022	0.0021	0.0021	0.0020	0.0019
-2.7	0.0035	0.0034	0.0033	0.0032	0.0031	0.0030	0.0029	0.0028	0.0027	0.0026
-2.6	0.0047	0.0045	0.0044	0.0043	0.0041	0.0040	0.0039	0.0038	0.0037	0.0036
-2.5	0.0062	0.0060	0.0059	0.0057	0.0055	0.0054	0.0052	0.0051	0.0049	0.0048
-2.4	0.0082	0.0080	0.0078	0.0075	0.0073	0.0071	0.0069	0.0068	0.0066	0.0064
-2.3	0.0107	0.0104	0.0102	0.0099	0.0096	0.0094	0.0091	0.0089	0.0087	0.0084
-2.2	0.0139	0.0136	0.0132	0.0129	0.0125	0.0122	0.0119	0.0116	0.0113	0.0110
-2.1	0.0179	0.0174	0.0170	0.0166	0.0162	0.0158	0.0154	0.0150	0.0146	0.0143
-2.0	0.0228	0.0222	0.0217	0.0212	0.0207	0.0202	0.0197	0.0192	0.0188	0.0183
-1.9	0.0287	0.0281	0.0274	0.0268	0.0262	0.0256	0.0250	0.0244	0.0239	0.0233
-1.8	0.0359	0.0351	0.0344	0.0336	0.0329	0.0322	0.0314	0.0307	0.0301	0.0294
-1.7	0.0446	0.0436	0.0427	0.0418	0.0409	0.0401	0.0392	0.0384	0.0375	0.0367
-1.6	0.0548	0.0537	0.0526	0.0516	0.0505	0.0495	0.0485	0.0475	0.0465	0.0455
-1.5	0.0668	0.0655	0.0643	0.0630	0.0618	0.0606	0.0594	0.0582	0.0571	0.0559
-1.4	0.0808	0.0793	0.0778	0.0764	0.0749	0.0735	0.0721	0.0708	0.0694	0.0681
-1.3	0.0968	0.0951	0.0934	0.0918	0.0901	0.0885	0.0869	0.0853	0.0838	0.0823
-1.2	0.1151	0.1131	0.1112	0.1093	0.1075	0.1056	0.1038	0.1020	0.1003	0.0985
-1.1	0.1357	0.1335	0.1314	0.1292	0.1271	0.1251	0.1230	0.1210	0.1190	0.1170
-1.0	0.1587	0.1562	0.1539	0.1515	0.1492	0.1469	0.1446	0.1423	0.1401	0.1379
-0.9	0.1841	0.1814	0.1788	0.1762	0.1736	0.1711	0.1685	0.1660	0.1635	0.1611
-0.8	0.2119	0.2090	0.2061	0.2033	0.2005	0.1977	0.1949	0.1922	0.1894	0.1867
-0.7	0.2420	0.2389	0.2358	0.2327	0.2296	0.2266	0.2236	0.2206	0.2177	0.2148
-0.6	0.2743	0.2709	0.2676	0.2643	0.2611	0.2578	0.2546	0.2514	0.2483	0.2451
-0.5	0.3085	0.3050	0.3015	0.2981	0.2946	0.2912	0.2877	0.2843	0.2810	0.2776
-0.4	0.3446	0.3409	0.3372	0.3336	0.3300	0.3264	0.3228	0.3192	0.3156	0.3121
-0.3	0.3821	0.3783	0.3745	0.3707	0.3669	0.3632	0.3594	0.3557	0.3520	0.3483
-0.2	0.4207	0.4168	0.4129	0.4090	0.4052	0.4013	0.3974	0.3936	0.3897	0.3859
-0.1	0.4602	0.4562	0.4522	0.4483	0.4443	0.4404	0.4364	0.4325	0.4286	0.4247
0.0	0.5000	0.4960	0.4920	0.4880	0.4840	0.4801	0.4761	0.4721	0.4681	0.4641