

# Application of Building Information Modelling to Integrate Efficiency in Tendering on Infrastructural Development Projects

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**ABSTRACT:** The aim that is addressed in this paper is to assist clients and consultants in improving the predictive ability of the cost estimating of infrastructure projects in India. This study introduces to the fundamental concepts of construction management, with emphasis on increasing the efficiency of the tendering estimates in all infrastructural projects. The conceptual design of a new facility for design and development of infrastructure projects is used as a case study to develop BIM models in this research. Certain key considerations and problems that are faced are highlighted so as to broaden the understanding of the subject. The investigation represents an exercise in performing the essential tasks that constitute a preliminary budget and plan. The conclusions include observations and suggestions that need to be considered while attempting such a job in practice. BIM can provide an efficient way to do sustainability evaluation, which is always a consideration when making decision, especially for public facilities. This research focuses on how BIM can enhance the implementation of tendering assessment for proposed projects at the preliminary stage. The emergence of BIM improves the efficiency of estimating the cost and duration of projects, as BIM enables users to integrate a variety of data into one model, where these data can be shared among, transferred to, and extracted from different tools for cost estimation and schedule planning purposes which in turn will mitigate the errors incurred in tendering processes. The proposed model consists of five modules, including a data collection module, a cost estimation module, a scheduling module, a sustainability evaluation module, and a 5D integrated module. Plug-ins were developed in the model to link BIM tool (i.e., Autodesk Revit) with Microsoft Excel to ensure automatic data transfer among these modules all within a BIM platform so that owners and designers can quickly generate a reliable construction cost estimate, construction schedule, preliminary sustainability evaluation, as well as construction process simulation.

**KEYWORDS:** Pune, construction management, BIM, Construction time, Cost estimates, Tendering.

## I. INTRODUCTION

The Construction industry has a great influence on the economy of all countries. It is one of the parts that provide vital factors for the development of any economy. According to World Bank, the share of construction industry in developing countries is approximately between 6-9% of the Gross Domestic Product (GDP). (Unit, South Asia Sustainable Development, 2007) The construction industry is an important part of the economy and has a considerable impact on the efficiency and output of other industries. It is not possible having extensive investment in manufacturing, agriculture, or service sectors without construction of infrastructure facilities in place. The construction industry, as a traditional industry with a long history, is one of the many industries that influence the economic backbones of many countries. Its progress is always related to the development of society and the advancement of technology. Construction costing and scheduling are essential factors to be considered at the early stages of a construction project because they are of high importance to investors before moving to the detailed design of a proposed project. This is why owners and decision makers are always eager to know the project's cost and duration at the preliminary stage, based on which they can make reliable decisions on the proposed project within a short period.

### ➤ BIM-based automated estimation method

#### 1. Cost estimate module

This module aims to help users obtain the reliable construction cost of their projects quickly at the conceptual stage when the project information is limited. Depending on the conditions and requirements of users, this module provides two methods for calculating the construction cost for both conventional and modular construction. The required

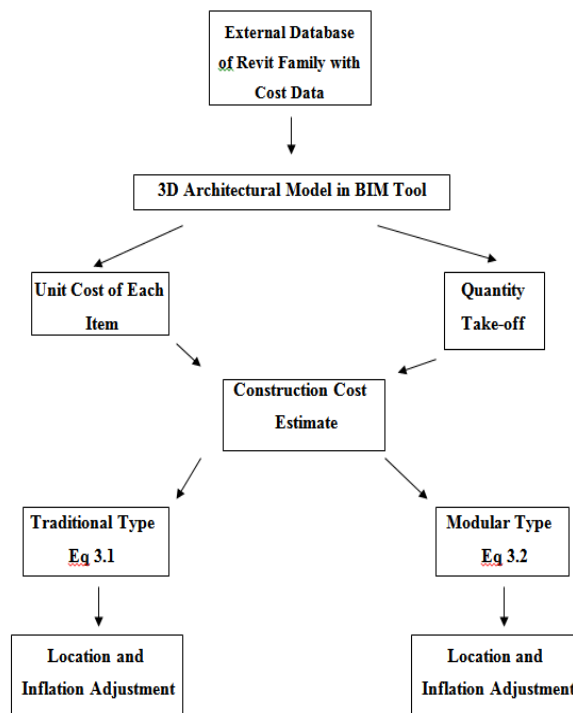
determinants of the cost calculation are unit cost and accurate quantity. Assembly cost data can provide a fast and reasonably accurate way to determine the construction cost, so it is often used during the early stage of the design development to compare the costs of various alternatives on the total building cost. After collecting the cost data, they are inserted into the corresponding properties of the families stored in BIM tool, which means when users review and refer to each type of component, the cost data can be easily obtained from the properties' list.

## 2. Cost estimation for traditional construction

For the traditional type of construction, this model will use the following equation to calculate the direct construction cost:

$$\text{Total Direct Cost Traditional} = \sum (\text{unit cost of item} \times \text{quantity of the item})$$

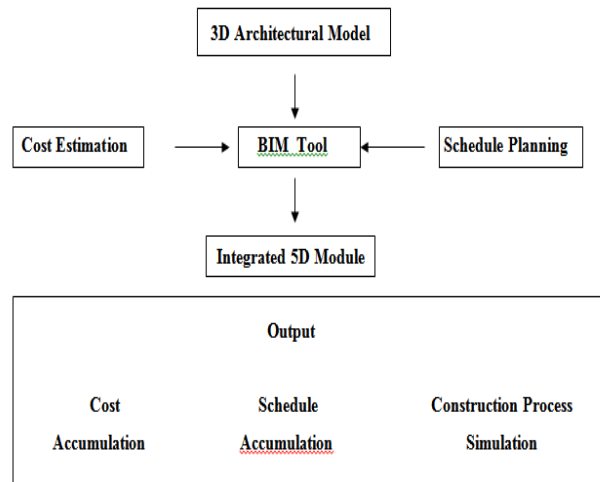
In which unit cost is collected from RS Means Building Construction Cost 2013, which includes material and installation costs, and the quantity is automatically extracted from the 3D architectural BIM model. The total construction cost in this model is direct cost without considering the overhead and profit.



Cost estimation flowchart

## 2. Integrated 5D module

This module illustrates the integration of a 3D BIM model with cost estimation and schedule planning, creating a comprehensive model for owners, designers and contractors to see the construction process before putting the project on site, and to identify the accumulated cost and time that has been used for each construction stage. To achieve this 5D module, the model mainly relies on the automatic data transfer among BIM tools and the developed plug-ins in the cost estimate module, and the scheduling module.



Flowchart of the integrated 5D module

## II. RESEARCH SCOPE AND OBJECTIVES

This research aims at developing a model that integrates BIM with cost estimating, procurement and tendering assessment at a project’s preliminary stage for infrastructural projects  
Therefore, objectives of this research to fulfil the above aim are:

- a) To investigate the errors in existing tendering estimates;
- b) To understand various methodologies that will help in identifying the factors that lead to inaccuracy in pretender estimates through extensive literature survey
- c) To undertake a questionnaire to investigate the existence and the reasons of the factors that influence the pretender cost estimates in infrastructural projects in Pune, India;
- d) To develop a model that integrates BIM with cost estimating, scheduling and sustainability to improve the efficiency on the selected case study site.

## III. PROBLEM STATEMENT

From the schedule B of tender document and the final estimates obtained from the site, there are variations observed in the actual cost and schedule of the targeted planned cost and durations. And through the extensive literature review carried out it can be seen that cost and time overruns are generally observed on all infrastructural sites. Also the efficiency of BIM has been observed by studying the past research papers carried out by various authors. Hence an attempt will be made to apply BIM tools and develop models so that the advantages of using BIM can be achieved to minimise the cost overruns and improve the efficiency of the pre tender cost estimates.

## IV. LITERATURE REVIEW

**Ruoyu Jin, Botao Zhong, Ling Ma, Arman Hashemi, Lieyun Ding (2019) [1]-Integrating BIM with building performance analysis in project life-cycle-** this study performed a holistic review consisting of a bibliometric analysis of existing literature, content analysis of selected studies, as well as follow-up qualitative discussion in BIM.  
**Ayodeji E. Oke, and Clinton O. Aigbavboa, Oriabure T. Ijie, (2017) [2] — Assessment of Qualitative Factors Influencing Contractors Tender and Project Success in an Emerging Economy -** This study examines factors affecting tender prices submitted by contracting firms in Nigeria. The study also assess various variables influencing their successful delivery of construction projects from the point of view of tendering process and procedure within the quest to improving their competitiveness and success rate locally and internationally.  
**Elhag, T. M. S., Boussabaine, A. H., & Ballal, T. M. A. (2005) [2] “Critical determinants of construction tendering costs: Quantity surveyors’ standpoint” -** The main of this study aim was to evaluate and rank cost-

influencing factors of construction projects considered at the pre-tender stage. Factors affecting costs of construction projects were reviewed based upon research work undertaken in different countries.

**Iyer, K. C., & Jha, K. N. (2005) [4] Factors affecting cost performance: evidence from Indian construction projects** - This paper presents the findings of a questionnaire survey conducted on the factors affecting cost performance of Indian construction.

**Chan, D. W. M., Olawumi, T. O., & Ho, A. M. L. (2019) / -Perceived benefits of and barriers to Building Information Modelling (BIM) implementation in construction: The case of Hong Kong-** This study aims to identify and assess the perceived benefits of and barriers to BIM implementation within the Hong Kong housing industry.

**Ali Ghaffarianhoseini, John Tookey, Amirhosein Ghaffarianhoseini, Nicola Naismith, Salman Azhar, Olia Efimova, Kaamran Raahemifar (2016), Building Information Modelling (BIM) uptake: Clear benefits, understanding its implementation, risks and challenges** - This paper aims to debate the truth of BIM, its widespread benefits and current level of uptake.

**Isidro Durazo-Cardenas, Andrew Starr, Christopher J. Turner, Ashutosh Tiwari, Leigh Kirkwood, Maurizio Bevilacqua, Antonios Tsourdos, Essam Shehab, Paul Baguley, Yuchun Xu, Christos Emmanouilidis (2018), -** An autonomous system for maintenance scheduling data-rich complex infrastructure: Fusing the railways' condition, planning and cost - Despite modern developments, the British rail network maintenance intervention planning still employs informed human decision-making, involving the interpretation and contextualization from multiple-sources of information. As demand for new train services increase and the network infrastructure modernizes, planning for an ever increasing number of interventions will be required. This demands systems that not only support the decision making process, but truthfully and cost-effectively schedule the necessary interventions autonomously. An integrated approach

**Xue Li, Jing Xu, Qun Zhang (2017), Research on Construction Schedule Management Based on BIM Technology** - The earliest research on project management in the United States, there are many sufficient theoretical knowledge and a lot of practical experience after a long period of development. With Chain's development of economy and improvement of science and technology continuously, the concept of project management also has been introduced in the field of construction projects. Project management in the progress of management directly affects the economic benefits of the project, so the importance and application value of progress management that one of the three objectives of the project management can't be ignored. At present BIM technology is developing rapidly, the application of BIM technology makes the progress of the efficiency of management, progress management of the content of information.

**Wei-Chih Wang, Shao-Wei Weng , Shih-Hsu Wang , Cheng-Yi Chen (2014), Integrating building information models with construction process simulations for project scheduling support** - This study proposes an interface system that uses the BIMs ability with regard to quantity takeoffs of required materials (such as steel, forms, and concrete) to support site-level operations simulation, ultimately leading to the generation of a project schedule

**Hui-Yu Chou, Pei-Yu Chen (2017), Benefit Evaluation of Implementing BIM in Construction Projects** – This study established a benefit evaluation index and method for the implementation of BIM suitable for contractors in Taiwan.

**Kun-Chi Wang, Wei-Chih Wang, Han-Hsiang Wang, Pei-Yuan Hsu, Wei-Hao Wu, Cheng-Ju Kung (2016), Applying building information modelling to integrate schedule and cost for establishing construction progress curves** - This paper a cost-based progress curve(called S-curve) is often used to control construction project schedules.

**Premjeet Singh, Ayan Sadhu (2019), Multicomponent energy assessment of buildings using building information modelling** - This paper, it is proposed to develop newer strategies to identify critical variables contributing to energy efficiency and design more energy-efficient housing architectures.

**A.D. Britto, Perera B.A.K.S, Illankoon I.M.C.S. (2013), Factors Affecting the Accuracy of Pre-Tender Estimation of Road Construction in Sri Lanka** - This research has been conducted through a literature review of topics related to the cost estimating process, followed by a questionnaire survey.

**Shen XU, Kecheng Liu and Llewellyn C. M. Tang (2013), Cost Estimation in Building Information Model** - This paper introduces a new philosophic stance for cost estimation to address the development of model based cost estimation, addresses the importance of contextual information and the needs of extension of pricing information according to the general process of cost estimation by using the IFC standard. Information requirement as specified in IFC for cost estimation is established and instances of IFC relationship have been identified.

**Daniel W.M. Chan, Timothy O. Olawumi, Alfred M.L. Ho (2019), Perceived benefits of and barriers to Building Information Modelling (BIM) implementation in construction: The case of Hong Kong** - The study adopted a quantitative research design using a structured empirical questionnaire survey. Also, a comparative analysis of the perceptions of the respondents' groupings was conducted.

V. CASE STUDY DETAILS

Jay Malhar Enterprises is a civil and construction company that has built a strong reputation for delivering a quality service on time and at a competitive price which has been remarkable since its formation in year 2006.

They undertake a variety of projects for a wide range of cliental – from small private developments to large Government projects. Their unique and flexible project management systems ensure that a positive outcome is achieved regardless of size or nature of the project.

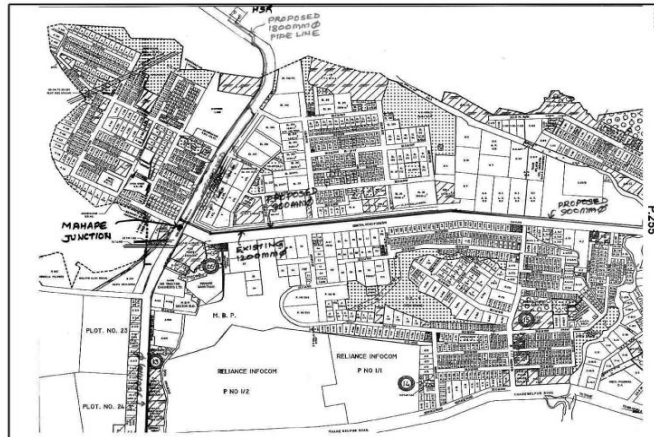


Fig: Case study map

➤ QUESTIONNAIRE DESIGN AND CONTENTS

This research work has implemented survey methodology to uncover the factors affecting the accuracy of pre-tender cost estimation of infrastructure projects in India and the factors affecting BIM implementation in India in the pre design phase as well as during the construction phase. Prior to this survey, literature review and case analysis was carried to find out the above factors.

The questionnaire will start with the questions needing information of the respondent’s job and firm. It will include questions related to the respondent’s job title, type of his organization, no. of employees etc. The next section of the questionnaire will be based on the BIM awareness for respondents and their firm. The questions will be whether his organization is using BIM or not, whether if there is any plan of his organization to use BIM in future, the main function of BIM in a construction project and the number of years his organization using BIM etc.

➤ DATA ANALYSIS TECHNIQUE

**Relative Importance Index (RII)**

The Relative Importance Index technique has been widely used in construction research for measuring attitudes with respect to surveyed variables. Likert scaling was used for ranking questions that have an agreement level. The respondents were required to rate the importance of each factor on a 5-point Likert scale using 1 for not important, 2 for of little importance, 3 for somewhat important, 4 for important and 5 for very important. Then, the relative importance index was computed using the following equation.

$$\text{Relative Importance Index} = \frac{\sum w}{AN} = \frac{5n_5 + 4n_4 + 3n_3 + 2n_2 + 1n_1}{5N}$$

Where W, which is the weight given to each factor by the respondent, ranges from 1 to 5;  
 n1 = the number of respondents for very important;  
 n2 = the number of respondents for of importance;  
 n3 = the number of respondents for somewhat important;  
 n4 = the number of respondents for less important; and  
 n5 = the number of respondents for not important.

A is the highest weight (i.e., 5 in the study) and N is the total number of samples. The Relative Importance Index ranges from 0 to 1 (Tam and Le, 2006).

➤ **DATA COLLECTION RESULT AND ANALYSIS**

1) **Response rate and survey sample**

The survey was sent to all type of professionals in the Indian CI including client, contractor, government authority, architects, structural engineer, interior designers, developers and builders. After one week of opening the questionnaire 45 were received and after sending reminder to those who didn't respond, 12 more responses were received. Finally, 57 complete responses were received with response rate of 64%. Following fig, no 1 shows the response rate of the questionnaire

1) **Response rate of questionnaire**

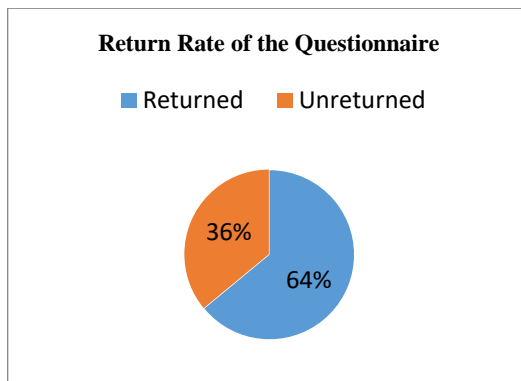


Fig 1 Return Rate of the Questionnaire

2) **Response percentage of each discipline**

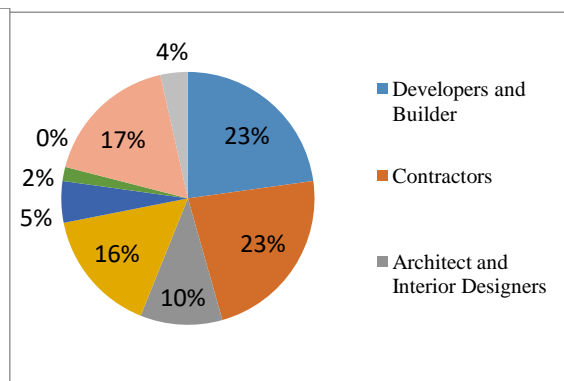


Fig 2 response percentage of each discipline

3) **The nature of respondent's business**

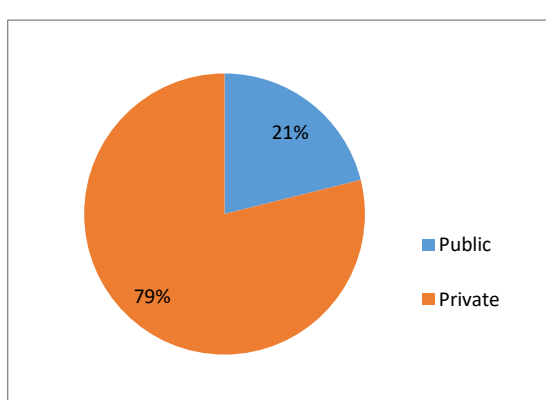


Fig 3 percentage of business nature

4) **Work experience in the CI**

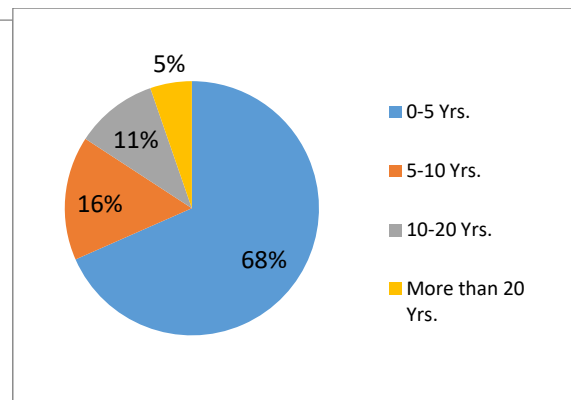


Fig 4 experience percentage of respondents

5) Awareness of BIM

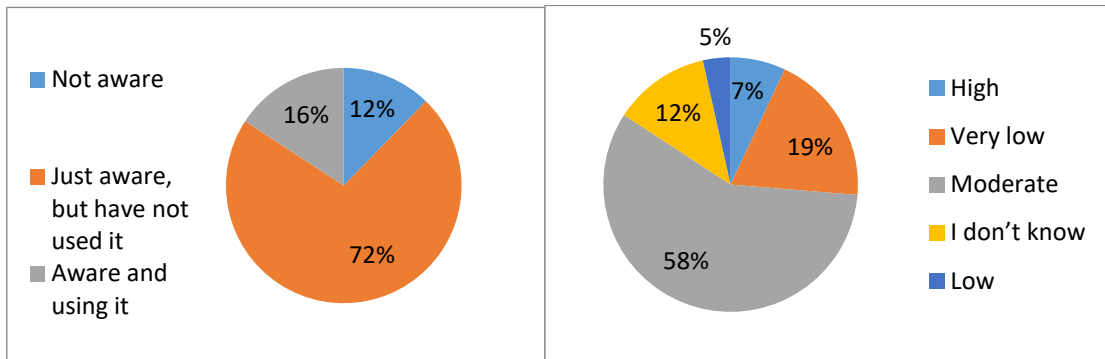


Fig 5 awareness of BIM

Fig 6 level of awareness of BIM

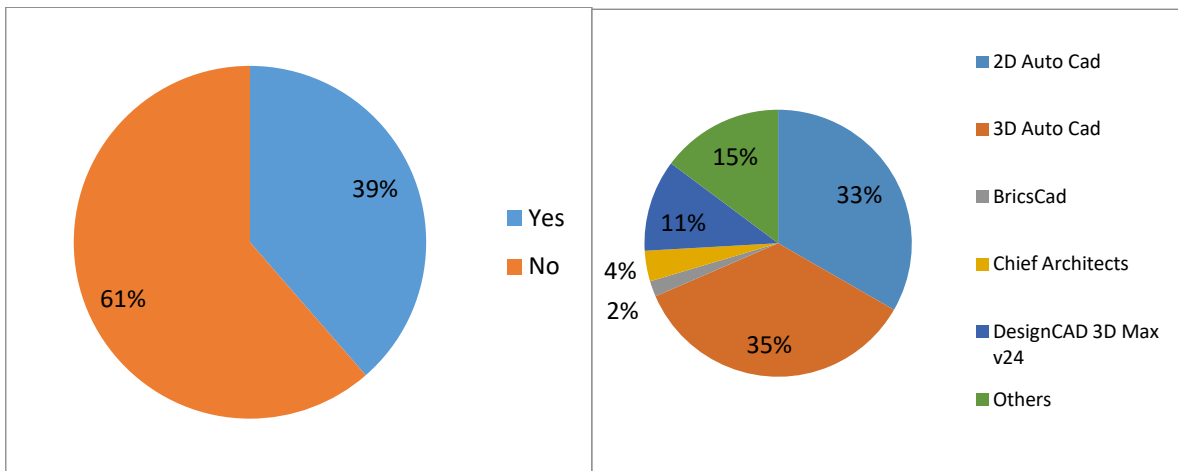


Fig 7 BIM uses in organization

Fig 8 software's that are using instead of BIM

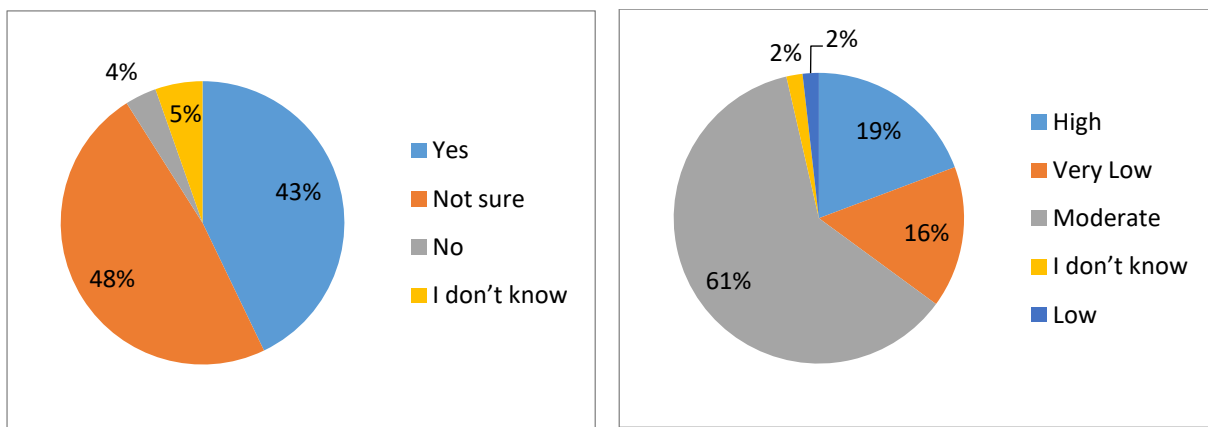


Fig 9 ready to adopt BIM

Fig 10 rate of using new technology

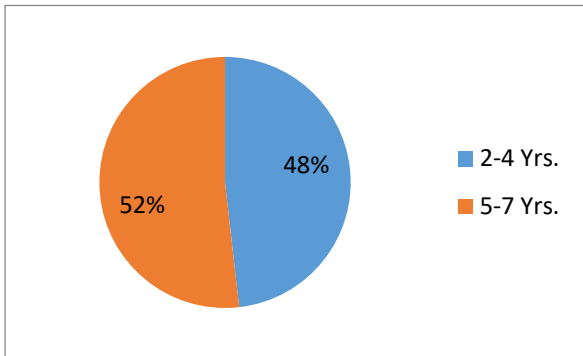


Fig 11 future adoption years of BIM

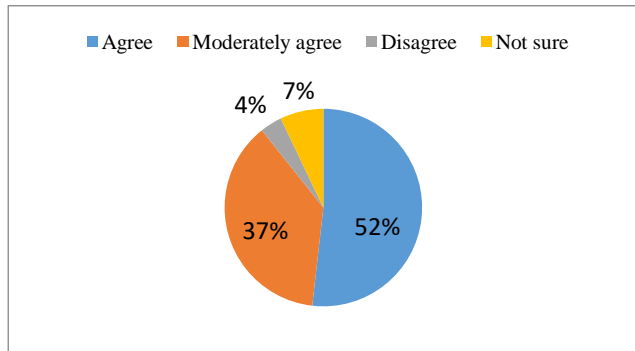


Fig 12 percentage of BIM for overcome challenges

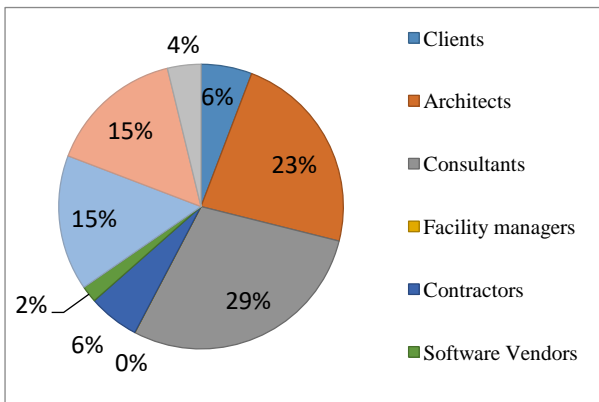


Fig 13 who affects more for BIM implementation in future

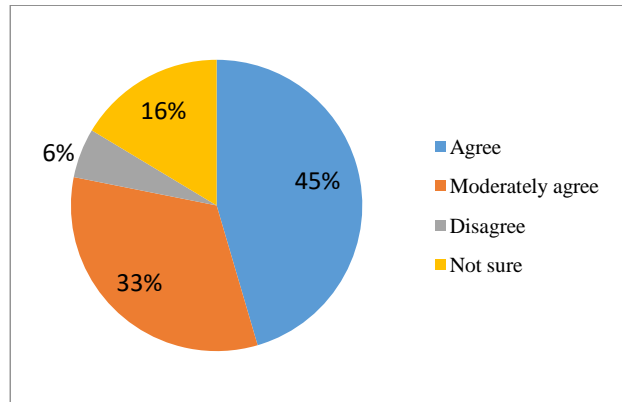
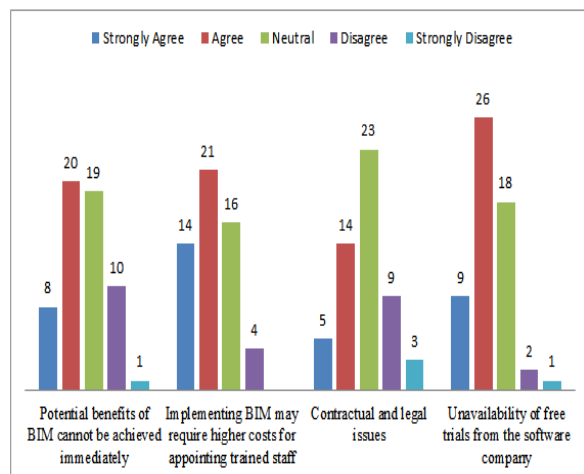
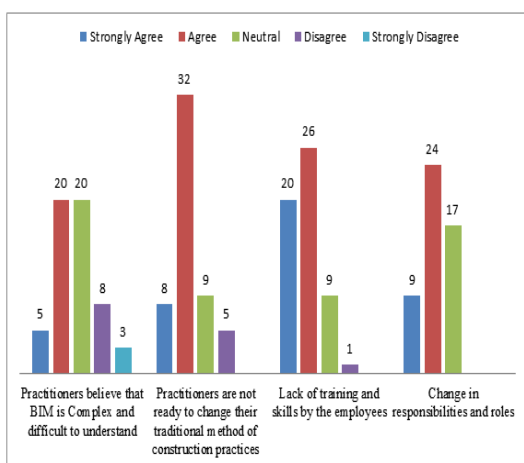
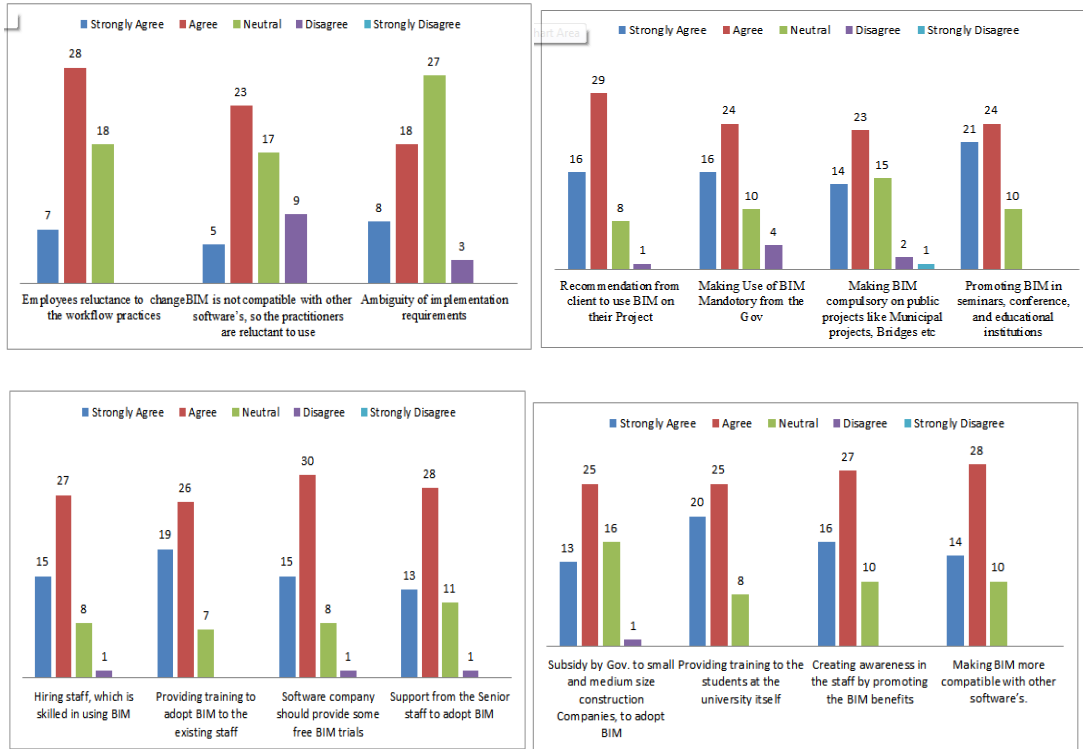


Fig 14 percentage of BIM mandating by municipality

Fig 15 Barriers for the implementation of BIM

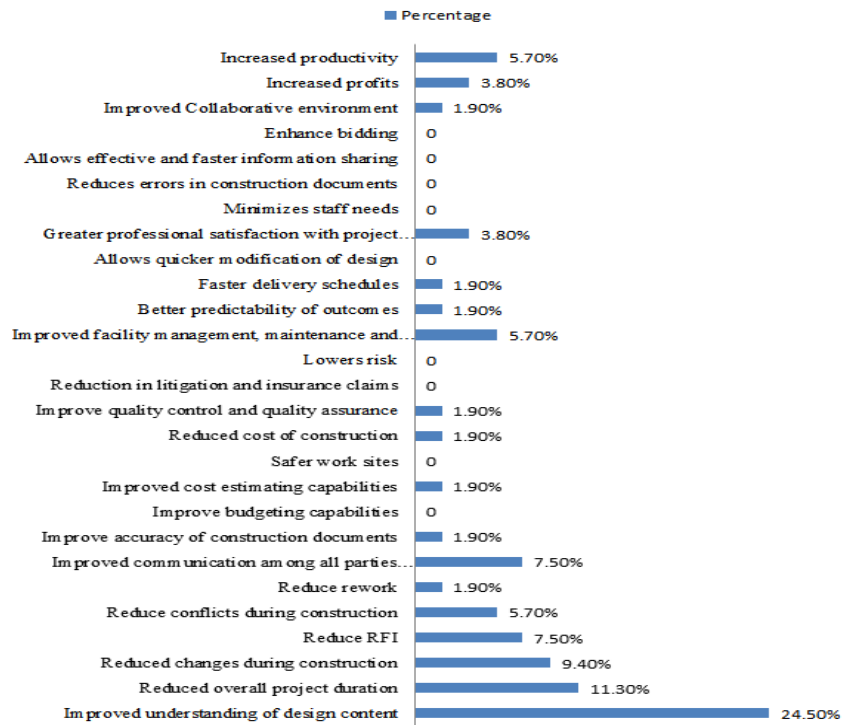






➤ **BENEFITS OF BIM IMPLEMENTATION**

The answer of this question demonstrate that improved understanding of design content is the highest benefit of implementing BIM which contributes to 24.50% in the Indian CI. The reason behind is that BIM offers other benefits as mentioned in the fig below which concludes in increase in productivity of the organization while reduce project duration was ranked as the second top most benefit of BIM implementation which contributes 11.30% in the organization followed by reduce changes during construction which contributed to 9.40% while the other top most benefit which ranked the 4th, 5th, 6th and 7th position are reduce conflicts, improved facility management, increase productivity and greater professional satisfaction respectively.



➤ BIM PROCESS- COST ESTIMATION MODELS

Figure 16 presents requirements of the cost estimation process which demonstrates two core elements, quantities and pricing, and their extended relationship for BIM processes.

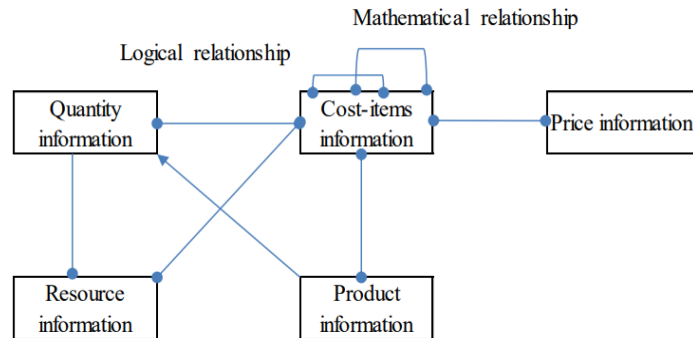


Figure 16 Required information as specified for BIM

Development of the framework initially considered the system’s input and output. Input in this context is any information or BIM model that a stakeholder produces that influences the cost of the construction work. Developing a framework is the main objective in this research which will serve as a guideline for engineers and estimators to use BIM in estimation of tender documents.

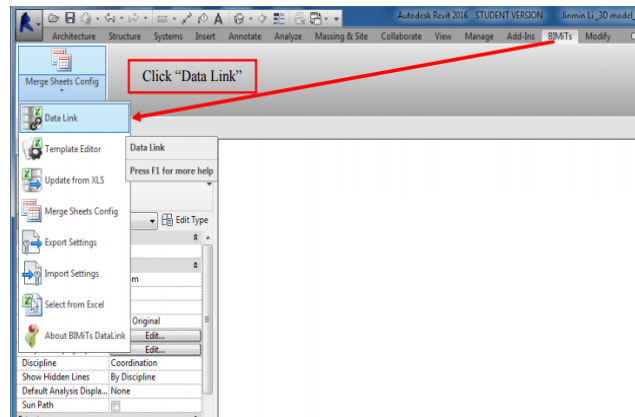


Figure 17 Required information as specified for BIM



Figure 18: Legend Representing the Framework Elements

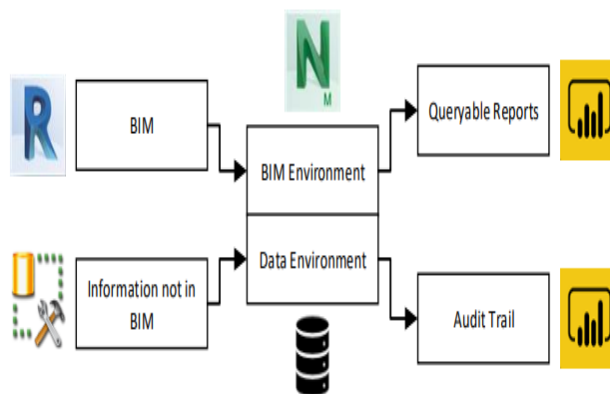
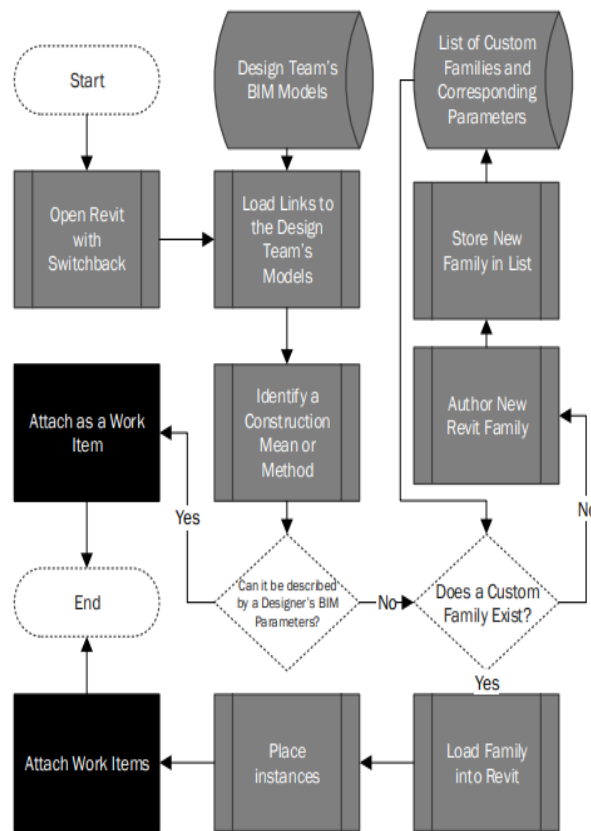


Figure 19: Input-Environment-Output Diagram with the Implemented Software

The estimate requirements must be established prior to any BIM authoring by stakeholders. The purpose of these requirements is to establish a BIM model that can produce a reliable cost estimate. Repeatability is achieved by flexible data mapping. The flexible map allows parameters stored in BIM elements produced by the design team to flow through to the proper cost estimate work items. This module sets the requirements for reliability and repeatability, which prepares the stakeholders’ models for conditioning.



## VI. CONCLUSION

This paper detailed the steps within the four modules of the model-based cost estimating framework. The first module prepared the project team to handle the BIM model conditioning process. These preparations enable accessibility of all the project's data required for a cost estimate from within the BIM model. The second module conditioned the BIM models that would be used in the quantification and costing process. This conditioning process established the estimate structure in the context of the BIM model. The third module established the project's cost within the BIM model environment. The estimators added work items that were hosted and driven by the BIM elements and their parameters. The fourth module leveraged the model conditioning and cost estimation to refine the construction phase data collection process. The production data captured in this framework is contextually linked to the work items and host BIM elements. This fourth module allows database refinement that should evolve the accuracy of future model-based cost estimates.

The Indian CI is facing challenges similar to those challenges faced by the global CI; it is known as adversarial, fragmented and side base industries and is facing difficulties in delivering construction project with in planned time, cost and quality. The CI has high impact on economy of India as it contributes to nearly 8% (Saurav Dixit et al., 2017) of the country GDP. Egan 1988 recommends using new technology like 3D object oriented to enhance CI to be on path with aerospace and automobile industry which has achieved a significant breakthrough due to advance technology implementation. According BIM can be used in the CI to efficiently to overcome the challenges as well as to lead the industry to a paradigm shift.

As discussed above, one of the main objective of this research is to “Critically review of current practices for estimation and pre estimation cost control” and to find out barriers in implementing BIM in India and to give recommendations to uptake of BIM in India for reducing the errors in pretender cost estimates. To achieve the main aim of this research five objective were developed. To achieve first three objectives, intense literature review was done with the help of e-books, journals, etc. on the other hand, to achieve the last two objective of this research online questionnaire was circulated among the CI professionals of India because these objectives are particularly related to Indian CI and aim of our research.

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