

Cost-Benefit Analysis of BIM Implementation Into off-Site Construction

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Abstract- *Construction industry has been continuously growing despite the complexities and risks involved with the projects. To continue this growth path and to meet with the increasing demands due to urbanization, the industry has been adopting various new trends and technologies such as Building information modelling and Off-site construction methodology. However, the cost associated with the deployment of new technologies proved to be an obstacle for stakeholders to make such paradigm shift. The objective of this paper was to analyze the benefits which can be achieved by investing in integration of two modern construction approaches and how it can help in achieving cost advantages, while achieving high quality construction work in less time. BIM with off-site construction can help in creating a streamline off-site production process with an integrated digital platform which includes virtual 3D and 2D models of the project, pre-fabrication models, detailed design database and stakeholder's involvement at different levels of a project which creates high level of collaboration which can reduce complexities and increases long term project benefits and returns on investment. Initially the research paper analyzed data gathered through questionnaire surveys conducted with construction industry stakeholders to investigate cost and other important factors which are critical in BIM implementation into offsite construction. Performing a benefit-cost analysis using survey outcomes and creating cost models showed that even though the initial cost for implementation of BIM with Off-site construction is high, still the capabilities of BIM to minimize Off-site construction risks, costs, duration and change orders are very significant.*

Keywords- BIM, Off-site construction, Integrated digital platform, Pre-fabrication, Cost-benefits, Stakeholders, Investment

I. INTRODUCTION

In recent times the world has seen an increasing demand for infrastructural and residential projects due to urbanization and growth in population. Conventional methods used in AEC industry does not provide sustainable and

efficient solutions to challenges such as complexity of project, working conditions, quality, improper resource utilization, wastages, etc. The industry needs to be revamped with emerging trends and technologies to cope with increasing demands and challenges faced.

To meet the requirements of advancement of the industry and to makeshift from manual construction towards automated construction process various new approaches have been developed, but the reluctance of stakeholder to adopt these new approaches is becoming a barrier for developing an advanced construction industry. Two of the major cutting-edge approaches or technologies developed are Off-site construction and Building Information Modelling.

Off-site construction approach was developed by taking lessons from the manufacturing industry where production is done in supervised and controlled conditions. The issue with construction industry is the complexity and uniqueness of every construction project. Because of this a streamlined work process cannot be developed at site where the project is being executed. Off-site construction process was developed to somewhat streamline the construction process to increase the productivity and reduce wastages. Off-site construction approach involves breakdown of project into smaller construction elements and manufacturing these smaller elements in specially designed production units under controlled environment. The manufactured elements are then transported to the site of the project where, they are assembled together to form complete structure as per the requirements of the client. Off-site construction reduces the total construction duration of projects, optimizes resource utilization as manufacturing is done in controlled environment thus making a positive impact on the efficiency of construction works to be carried out. Various nomenclatures have been given to Off-site construction in different literatures such as Pre-fabricated construction, Pre- Cast construction, Modern Method of construction [1].

Building information modelling (BIM) is another advanced approach developed to for construction industry to

achieve efficient project delivery. Building information modelling is a concept where information technology can be used with construction sector to achieve desired outcome efficiently. BIM involves integration of various software's to form a digital platform which can help connecting all the stakeholders involved in a project such as Architects, Engineers and Construction professionals so that they can efficiently design, build and operate construction projects. The digital platform helps in creating virtual models of projects can be created to which data related to physical and functional aspects of the project and its components can be linked. This can help in proper analysis of scope of work, provides good control over the project by increasing multi- disciplinary collaboration between project team.

Off-site construction comprises of a framework for manufacturing structural components. The framework consists of various interconnected processes which requires proper integration for successful delivery of product. Very high amount of information and inputs are required for successfully delivering an Off-site construction projects therefore, minor errors can lead to project risks. Inefficiently managed data can reduce the speed of production process thus affecting the productivity. BIM can be integrated with Off-site construction as a tool which can efficiently manage the data and information required for Off-site construction. Not just management benefits it can increase economic value for businesses by optimizing processes and reducing reworks and wastages and ensure optimal use of resources.

II. LITERATURE REVIEW

Plenty of research work directed to exhibit the advantages of BIM in the construction sector. Still, next to no factual information is accessible about the cost saving advantages which can be accomplished through investing in BIM. According to a journal published in 2006, construction industry can make a potential saving of 15-40% in the cost of construction [2]. Another survey conducted by McGraw Hill showed that stakeholders use factors such as collaboration, reduced reworks, enhanced productivity, training and setup cost, 3D modelling and value creation to assess the outcomes of investment made [2]. The matter of putting resources into BIM is subjected to various factors. Each firm chooses to go ahead with different factors related to time and cost [3]. Adopting BIM requires shifting from old ways to new approach, data must be integrated for productive use. The level of coordination between organizations needs to be aligned with goals and objectives, these changes can be troublesome for some time but will expand the benefits which can be achieved[3]. Investment made in BIM is dependent upon the scale of the organisation, how much production is

required by the organization [3]. Quantification of investment requires analysis based on organization's vision for business transformation, scale of organization, services delivered by the organization and whether BIM services are taken by a third-party[3]. It is difficult to calculate the returns which stakeholders can get by investing in integration of BIM and Off-site. Exact monetary quantification of BIM integration with Off-site construction cannot be achieved as benefits achieved can be tangible as well as intangible [3]. Implementation of BIM requires additional budget allocation. This is required for setting up work station, purchasing and licensing of software's and hiring professionals who have knowledge in this domain[4]. BIM's effect on expenses amid planning and development stages is to such an extent that specific expenses are redistributed which could thusly affect strategies for acquisition. The effect of BIM isn't as it was moving expenses inside the development life-cycle as far as time yet additionally between partners as certain costs move to start with one partner then onto the next[5]. Outcomes of research done by

W. Lu *et. al* in 2014 showed around 27.05% of increase in project budget after integration of BIM[4]. Benefits of BIM are recognized during the execution phase of a project, in a study related to BIM implementation it was found that it provided about 6.92% budget saving/m² when compared to a conventional project[4]. Pre-fabricated construction relies on optimized information sharing throughout the supply chain involved. Advanced data management framework can be easily developed using BIM to support pre-fabricated construction. Integration of BIM with off-site/ pre- fabricated construction should consider existing digital platform and software, types of information and codes and standards[6]. As per survey conducted by[6] examples of commonly used software's for BIM are: Revit Architecture, ArchiCAD, Bentley, ProjectWise, BIM energy analysis tolls etc. Solutions offered by these software's include 2D/3D modelling, AR/VR facilities, Energy management, detailing and clash detection. AR/VR facilities can minimize errors in off-site construction, reduce RFI's as details of each element can be understood using digital models[6]. Off-site construction is more or less same as building block toy game where children assemble small components of required dimensions to form a structure. BIM helps in creating a library of elements designed for project as per requirement. These elements in the library can be employed to assembled together to form a complete digital model of the structure. All the information related to physical, structural and design aspects of the element are stored with it. The library can be used to prepare virtual models for multiple off-site projects[6]. Another research developed by analyzing different case studies showed that initial changes due to BIM implementation are challenging but it is beneficial in long run

as intangible benefits such as increased productivity, superior quality of work, reduction in wait time and logistics management can be achieved[7]. Profitability can increase in organizations where BIM data used for construction is produced in-house[5]. The utilization of BIM innovation takes into consideration the making of insightful logical semantic computerized models as far as structure components and frameworks, for example, spaces, dividers, shafts, segments and MEP frameworks[8]. Storage, handling and transportation of structural elements from manufacturing units to site is an important aspect in off-site manufacturing. Planning of site logistics is important and BIM can help in managing complete supply chain for off-site manufacturing process by considering information regarding, resources, vendors, wait time, requirement date and time, allocation of responsibility. The production and assembly of structural components must consider the type of transport and material development courses important for the advancement of the structure. This must be composed with the thought of the area, shape and size of fixed and transitory offices amid each location of the site[9]. BIM programming can be connected to development of logistics in various ways. 3D stages enable complex calculated techniques to be conveyed rapidly and obviously. 4D BIM with detailed schedule of project and time of activities allows the workers to decide when the site is accessible for inventory storage and when the material is required for work, thus optimizing logistics between production unit and project site[10]. The literature review provides the insight of how stakeholders gets both tangible and intangible returns on the investment made on BIM implementation with Off-site construction. BIM helping stakeholders in making the business sustainable and more organized to cope with changes and meet the demands is 100% ROI[3].

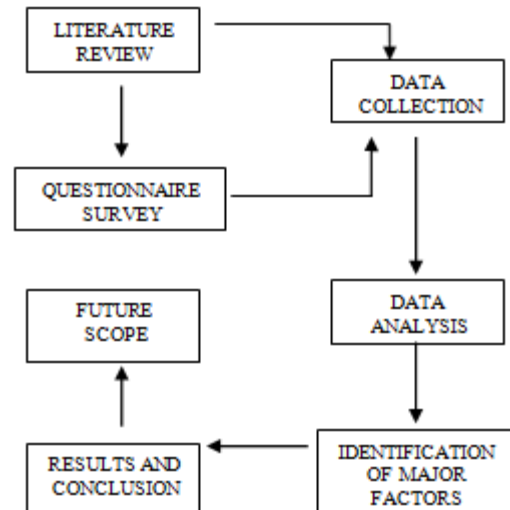
A. Objective

The cost associated with adoption of new technology in any process can become an obstacle for the stakeholders to take the initiative. The purpose of this study is to analyse both tangible and intangible benefits which can be achieved through investing in implementation of BIM into off-site construction. Recognition of long-term project benefits and analysis of how BIM can impact the return of invest for an off-site project can encourage stakeholders to invest in the integration of two modern construction approaches.

B. Methodology

A thorough literature review was done on the research topic and a questionnaire survey was designed. The questionnaire survey was floated to analyse critical factors

affecting BIM implementation into off-site construction. The questionnaire was floated to construction industry stakeholders to find important factors opinion of stakeholders about the requirement of BIM in off-site construction. The outcome of the survey would be used to support the objective of this research study.



III. DATA COLLECTION

A questionnaire survey was designed based on the insight gathered through intensive literature review. After floating the survey to around 80 different stakeholders in the construction sector, 55 responses were collected which is 68.75% response rate. The questionnaire was designed to analyse multi-fold benefits which can be achieved in different aspects of off-site construction through BIM implementation. The responses were taken based on Likert scale system with five responses: 5-Strongly Agree 4-Agree, 3-Neutral, 2-Disagree and 1-Strongly Disagree

IV. DATA ANALYSIS

Responses collected through questionnaire survey were ranked based on Relative importance Index (RII), using the following equation:

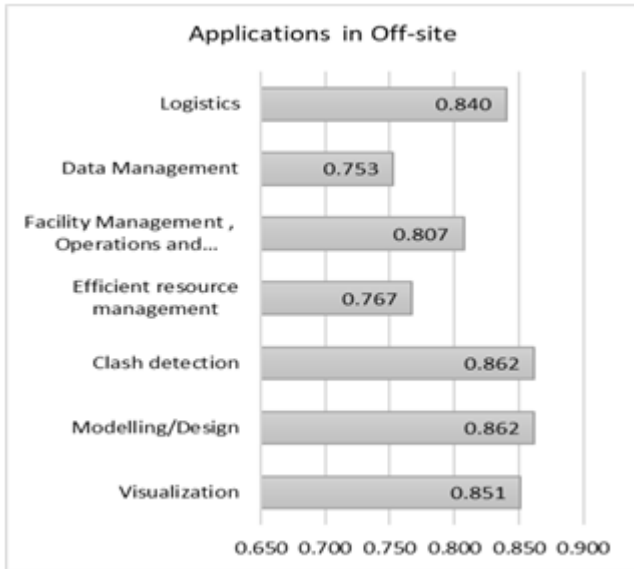
$$RII = \sum W / (A \times N)$$

Where,

W = Scale given in survey response
A = Maximum scale
N = Total responses

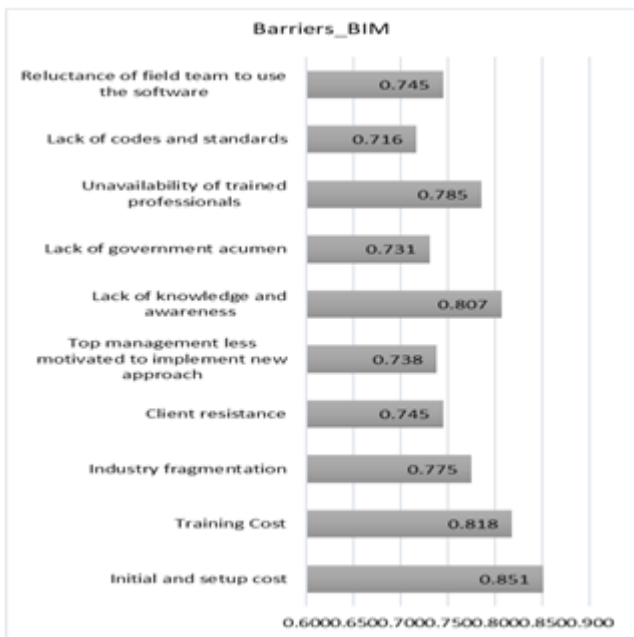
Following graphs shows the critical factors which were identified for different aspects of BIM into off-site construction:

- Application aspects of BIM in off-site construction



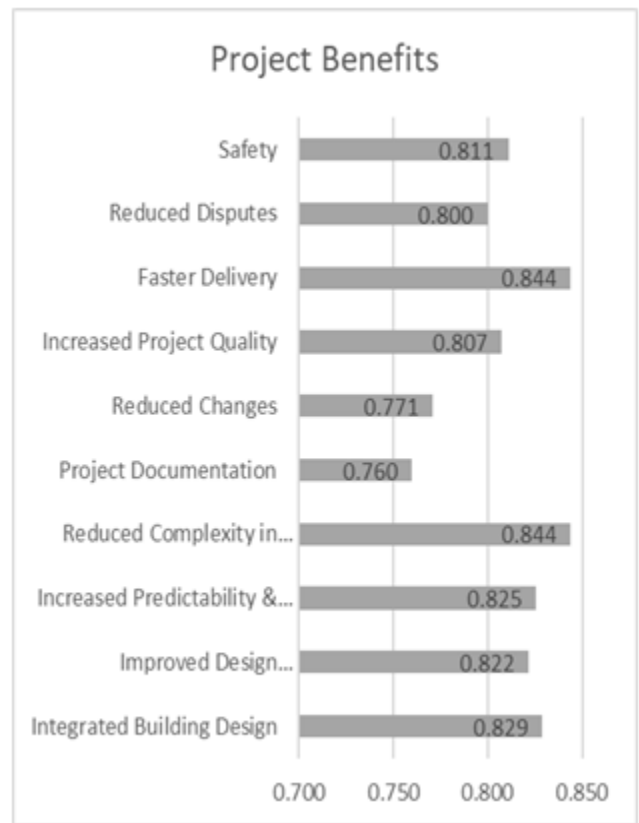
Graph 1: Applications of BIM in off-site construction.

- Barriers in implementation



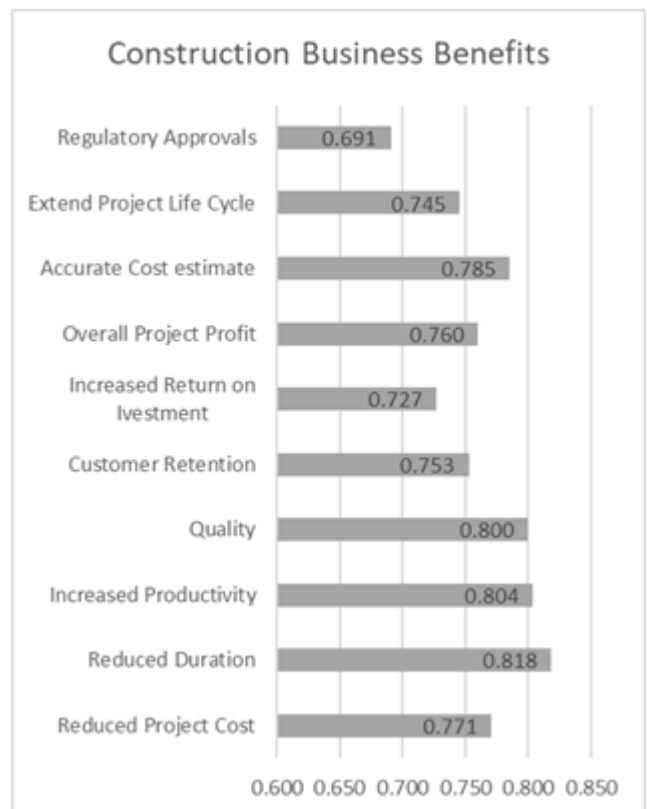
Graph 2: Barriers in integration of the two approaches. Project aspect of integration of two approaches

- Project aspect of integration of two approaches



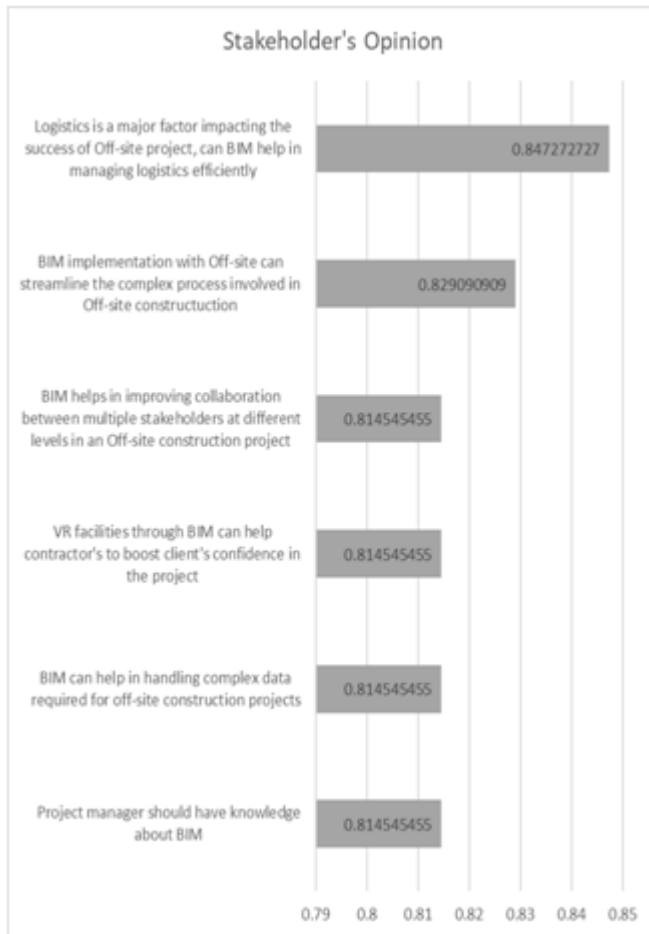
Graph 3: Potential project benefits.

- Business aspect of BIM in off-site construction



Graph 4: Potential benefits to construction business.

- Stakeholder's aspect on integration of BIM and off-site construction



Graph 4: Stakeholders opinion on benefits and potential use of BIM in off-site construction.

V. OUTCOMES AND CONCLUSION

Integration of two of the most advanced construction approaches i.e. BIM and Off-site construction can be fruitful for the construction industry. It can help in rectifying the irregularities and develop new and improved standards of work in the sector. Survey outcomes suggested various factors which affect the integration of the two approaches, it also showed what potential benefits can be achieved if investment is made in using the two approaches together. The RII index showed that stakeholders rated Modelling/designing and clash detection equally to be the major application of BIM in off-site construction. Initial- setup cost was rated as the highest barrier in implementation with off-site. This shows that stakeholders are reluctant to invest in BIM due to increase in project cost. The initial investment made into BIM for off-site construction can provide various benefits in the over-all project lifecycle and for sustaining the competitive business. Shorter delivery time and reduction in the complexity of the

project were rated equally as top benefits which off-site construction projects can achieve through BIM. Integrated Building design and better risk control were rated as second and third. Shorter time for project delivery, increased productivity and increased quality are the top three benefits which businesses can achieve through integration of BIM and off-site construction. Shorter project duration can lead to saving on project budget and increased profits for the businesses. Stakeholder's opinions suggested that logistics in off-site construction can be a major factor impacting the success of the project. As the industry is fragmented throughout the globe, sometimes accessibility to the site becomes difficult. BIM can help in managing and streamlining logistics operations for off-site construction through increased collaboration and information management framework. Investment required for integration of BIM off-site can be assessed or evaluated but the benefits which can achieved through it cannot be assessed directly in terms of money. Ethereal advantages of BIM can sometimes exceed the monetary benefits. Evaluation of actual returns on investment is complex as the benefits are both ethereal as well as monetary. However, the integration of BIM and off- site construction will be beneficial for the industry and profitable to the stakeholders and businesses for the entire project life cycle.

VI. FUTURE SCOPE

To understand the monetary aspect and economical benefits of BIM with off-site quantification of benefits is required. A research can be undertaken to determine the monetary impacts. Different construction projects can be analyzed to develop a case study to quantify the benefits obtained by BIM. A comparison of cash flow between off-site project executed using BIM and a conventional off-site project can provide factual results on monetary benefits which BIM can provide to off-site construction.

VII. ACKNOWLEDGMENT

I would like to thank Dr. Sanjay Patil, Associate Dean and Director, RICS-SBE, Mumbai and Mr. H.R. Pradeep program co-ordinator CPM, RICS-SBE, Mumbai for giving me this opportunity to conduct my research work on this topic. I am grateful to my guide Asst. Prof Kaushik Bhattacharya has provided me with the insight about work and guiding me throughout the research work.

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