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Is BIM Adoption Advantageous for Construction Industry of Pakistan?

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Abstract

Lack of Information technology applications on construction projects lead to complex flow of data during project life cycle. Building Information Modeling (BIM) has gained attention in the Architectural, Engineering and Construction (AEC) industry, envisage the use of virtual n-dimensional (n-D) models to identify potential conflicts in design, construction or operational of any facility. A questionnaire has been designed to investigate perceptions regarding BIM advantages. Around 102 valid responses received from diversified stakeholders. Results showed very low BIM adoption with low level of 'Buzz'. BIM is a faster and more effective method for designing and construction management, it improves quality of the design and construction and reduces rework during construction; which came out as the top thee advantages according to the perception of AEC professionals of Pakistan.BIM has least impact on reduction of cost, time and human resources. This research is a bench mark study to understand adoption and advantageous of BIM in Pakistan Construction Industry.

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Keywords: BIM, BIM Adoption, BIM Advantages, Construction Industry, Pakistan

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1. Introduction

Implementation of Information system in the construction industry has been an issue of great importance in order to enhance the effectiveness of construction projects throughout their life cycle and across different construction business functions[1]. Developing nations still lack in true utilization of information system and technology tools and techniques. Usage of different engineering and management software is a critical part of implementing IT tools. Drawings are prepared in CAD software (two dimensional approach) [2]. The traditional project delivery approach for construction projects, Design-Bid-Build, fragments the functions of stakeholders during design and construction phases. In other words, it hinders the joint involvement of the construction contractor or the project manager during the design phase of the project. The use of general and conventional two dimensional CAD drawings does not support a true collaborative approach. Architects and engineering consultants produce their own fragmented CAD design drawings / documents to relay theirs designs to owners and contractors. These drawings are not integrated and usually pose clash of information which results into inadequacy in labour productivity. The estimators need to calculate and produce their own quantity take offs based on the CAD documents produced by consultants. Moreover, the 2D CAD approach does not endorse the integration of the drawings with schedule and cost. Due to unpredictable demand and unique site requirements the construction companies are very small specialized and regional firms.

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

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

Building Information Modelling (BIM) is a set of interacting policies, processes and technologies generating a "methodology to manage the essential building design and project data in digital format throughout the building's life-cycle" [4]. BIM is a three dimensional digital demonstration of a building with its intrinsic components and characteristics. It is made of intelligent building components which comprises of data attributes and parametric rules for each object. BIM is the process and practice of virtual design and construction (VDC) through its entire lifecycle. It is a platform to share knowledge, data and communicate between project participants. Specifically, information contained in conventional drawings leads to redundancy which create confusion in interpretation. In contrast BIM expressed as non-redundant master model to streamline project life cycle processes [5].

According to [6] BIM represents a combination of fairly revolutionary ideals for design technology. Although some researchers aver that BIM related technologies were discovered in the early 80s, several others often refer to BIM as a nascent paradigm in the industry. Some studies have also argued that BIM adoption is still slow and some significant concerns about the reluctance of the industry to adopt or deploy potential change attributes in BIM have been evidenced. As a panacea to this, have suggested that this situation can be alleviated when industry stakeholders and disciplines understand their roles and opportunities in BIM. As BIM integrates multi-dimensional capabilities and facilitates major improvements in design and construction processes, there are strong indications that this could revolutionize project delivery in construction. Some authors have conceptualized systemic benefits that associate with BIM deployment, however it is not yet definitive from those studies who gets what and how, and how this could affect existing conventions in the industry. Moreover, while other studies focus on underpinning business drivers of BIM, other authors have continued to resist popular opinions that BIM"s potential "wind of change" could significantly revamp the industry's age-long challenges. The way forward therefore is to explore ways of comparing significant benefits (gains) with the demerits (pains) arising from BIM deployment.

Building Information Modeling has not taken roots as a designing approach in Pakistan. Building models are used only for presentations and, to some extent for architectural design review and do not contain any data / information beyond spatial relationships, colours, materiality and textures etc. Few architectural firms (examples are Ahmed Associates, Khatri Associates, Schematics, Icon) have adopted BIM for architectural design and many other firms are in process to adopt the BIM. The main obstacle is the lack of engagement of other consultants (MEP, Structural etc.) in the BIM process [7].

2. Literature Review

2.1. Understanding BIM

Building Information Modeling (BIM) stands for the process of development and implementation of a computer generated model to integrate the planning, design, construction and operation of a facility. The resulting Building Information Model is a data-rich, intelligent, object-oriented and parametric digital representation of the building, from which drawings and data appropriate to various users' needs can be extorted and analyzed to produce information that can be used in decisions making and to improve the project delivery process [8]. [9] has provided a comprehensive definition of BIM as Modeling (shaping, forming, presenting and scoping); Information (an organized set of data, meaningful and actionable) and Building (a structure, an enclosed space, a constructed environment) for functioning tool to virtually construct, analysis, scenario based, integration, costing, constructability, destruction and even maintain facilities.

A building information model portrays the geometry, geographic information spatial relationships, quantities and characteristics of building elements, material inventories, cost estimates and schedule of performance. This model can be used to express the entire building life cycle [10]. As a result, quantities and shared properties of materials can be easily extracted. Scopes of work can be easily isolated and defined. Systems, sequences and assemblies can be shown in a relative scale with the whole facility or group of facilities. The construction documents such as the drawings, submittal processes, procurement details and other specifications can be easily interrelated [11].

According to [12], the principal difference among BIM and 2D CAD is that the latter explains a building by isolated 2D views such as plans, sections and elevations. Variation in one of these views requires that all other views must also be checked and updated accordingly, an error-prone process that is one of the major causes of poor documentation. In addition, data in these 2D drawings comprise of graphical entities only, such as lines, arcs and circles, in contrast to the intelligent background semantic of BIM models, where objects are defined in terms of building elements and systems such as spaces, walls, beams and columns. A BIM model carries all required information related to the building, including its aesthetic and functional properties and project life cycle information, in a combination of "smart objects". For example, an air conditioning unit within a BIM would also contain data related to its supplier, operation and maintenance procedures, flow rates and clearance requirements.

BIM processes are for development and use of computer generated n-dimensional (n-D) models to simulate the planning, design, construction and operation of a facility. It is helpful for architects, engineers and constructors to visualize what is to be built in virtual environment and to identify potential design, construction or operational clashes and problems [13]. [14] found BIM is "an intelligent simulation of architecture," with characteristics as digital; spatial (3D); measurable; comprehensive; accessible; durable.

BIM also supports the concept of integrated project delivery, which is a novel project delivery approach to integrate people, systems, and business structures and practices into a collaborative process to reducewaste and optimize efficiency through all phases of the project life cycle [15].

2.2. Application of BIM (nDs)

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

Table 1.*n* Dimensions of BIM with application.

Dimension	Application	Author
3D Coordination	Visually interface checking with MEP integration reduce conflicts	[16-18]
Designand Constructability Reviews	Analyze design for practicality and identification of errors and omissions	[17]
4D Scheduling and Sequencing	Activities sequencing with visualization. Simulation for update time and resource schedule	[19, 20]
5D Cost Estimation	Material quantities are extracted automatically and changed when any changes are entered in model. Micro and Macro Costing Models.	[16, 21, 22]
6D Procurement	Integration of subcontractor supplier and vendor data into isolated models.	[17]
Prefabrication	Optimization of prefabricated construction components. Integration with MEP components.	[21, 23]
Structural Analysis	External analytical engine develop architecture design to structure and then analyzed for loading.	[24]
Lightening Analysis	Creation of effective, efficient, ambient and constructible lightening systems with enhancement in quality, cycle time and cost.	[25]
Mechanical (HVAC) Analysis	Clash, conflict and overlapping detection with computerized visualization.	[17]
Energy Analysis	Energy analysis, delighting, orientation analysis, solar analysis, building, massing analysis and site analysis with Virtual Environment (VE).	[26]
7D Operation and Maintenance	Facilities management for renovations, repairs, restorations, space planning, and operations maintenance. Security management and safety information such as emergency lighting, emergency power, egress, fire extinguishers, fire alarm, smoke detector and sprinkler systems. RFID application for gathering information from real world components in to BIM.	[16, 27, 28]
GIS based Visualization	The model satisfies an enhanced visualized system by incorporating of as-built site photographs	[29]
8D Modeling with PTD	Risk assessment of design component of facility for prevention through design.	[30]

2.3. Benefits of BIM Adoption

[6] narrates some evidence from technical reports from industry stakeholders, including software developers and vendors, CAD drafters, BIM modelers, construction administrators, researchers and contractors‟ testimonials have continued to echo how discipline-specific professionals, clients, institutions and the industry are likely to benefit when BIM is correctly deployed. An outstanding part of this however, is the feasibility of these benefits when combined across disciplines. As more capabilities of BIM could become more explicit in the nearest future, it is expedient to explore them in relation to the enablers of unusual paradigm shifts in construction conventions, especially as per possible changes in professionals‟ roles and responsibilities. However, while efforts are being made to document the directions of these changes, it is noteworthy that not many meaningful changes would come without a price. Some of the benefits of BIM are discussed as follow:

3. Research Objective

This research study is an attempt to investigate current state of BIM adoption in Pakistan. Advantages are also explored and ranked. Based on results, future of BIM in Pakistan is also predicted.

4. Questionnaire Survey

Questionnaire has been used as research instrument to collect data for the fulfillment of research objectives. This questionnaire is comprised of Seven (7) advantages after extensive literature review. A likert's scale consisting of five points, with 1 being is lowest and 5 is highest, is utilized to judge the respondent's perception about the question. The principal consideration for using likert scale is to determine the extent to which respondents agree or disagree with a particular statement or view. The responses to each statement/question are then used to calculate RII ranging from 0 to 1. RII method has the limitation that it may capitalize on skewed data thus inflating the relative weight for a certain factor.

Table 2.Benefits of BIM Adoption.

Benefit	Description
Simultaneous access	BIM users benefit from BIM as it permit timely integration, data sharing and creation of robust information on design components which are transferrable through the entire project life.3D Coordination.
Robust information	Embedded data in BIM are not limited to 3D models; they remain comprehensive even when designs are manipulated from 3D to 2D, and can be rendered fully functional in all parts of integrated systems
Auto-quantification	BIM has potential to conceptualize automated measurement of quantities in useable scales and formats that allow stakeholders to sort and analyze information they require at any time. Construction professionals resort to strenuous denial of faults when confronted with error dilemmas, auto-quantification is a potential saving grace as it entrenches accuracy, accountability and value integration in CPDPs.
Quality communication	BIM uses photo-realistic graphics, or convertible formats thereof, to transmit information. BIM provides enduring platforms for on screen training, simulation, and information sharing and value integration. Thus, this reduces risks associated with errors, inconsistencies and subjectivity. Project stakeholders are more likely to integrate and collaborate effectively when project information and communication are simplified.
Multidimensional integration	Manifestation of risks is multidimensional in construction processes which explain why construction is highly fragmented. BIM software has the ability to communicate with compatible applications facilitates collaboration and multi-dimensional applications. This is known as *n*D phenomenon, does not only optimise integration, it reduces process fragmentation and inconsistencies.
Project visualization	BIM"s facilitation of project visualization and simulation of project components under different environments will be a significant competitive advantage for packaging CPDP business both now and in the future. BIM to replicate real life challenges such as sustainability, build-ability, energy-efficiency, flexibility and so on.
Project documentation	BIM provides platforms for thorough integration of project documentation right from conceptualization through to detailed design, procurement, construction and facilities management. With BIM, contractors can now be received pre-quantified designs in electronic formats and still be able to modify fabrication and construction models, and store same for application in the project's life cycle model.
Digital facilities management	BIM for developers and facilities managers to test and validate design options in relation to post-construction modifications, the integration of certain information into project databases can also facilitate cost-in-use and automated responses from facilities components regarding use and application limits, maintenance and management.

5. Sampling

The sample for this investigation is chosen from population of AEC industry of Pakistan. All the stakeholders of AEC including Architects, Consultants / Engineers, General Contractors, Trade / Specialist Contractor, Design Builder / Project Management and Academics / Research are made part of this survey. Out of 150 questionnaires sent out, 104 are received. Two incomplete questionnaires are excluded so final analysis is carried out basing on 102 questionnaires (68% response with 95% confidence level). Respondents to this survey include 14 architects,24 Consultants / Engineers, 18 General Contractors, 8 Trade / Specialist Contractor,16 Design Builder / Project Management and 22 Academics / Research.

6. Data Analysis

6.1. Respondents' information

Respondents are having varied experience in the AEC. Approximately 41% (42) of the respondents have accumulated over 10 years of professional experience, 21.6% (22) have 6 to 10 years of construction experience, whereas 37.3% (38) have 1 to 5 years of construction experience (professional graduated after 2005 have more exposure to BIM). Therefore, the information provided by these professionals can be considered authentic and reliable.BIM Experience of stakeholders holders who responded to this survey is approximately 54.9% (56) respondents have no professional experience related to BIM but having some knowhow of BIM, 25.5% (26) have one year or less BIM experience, 11.8% (12) have 1 to 3 years BIM experience and only 7.8% (8) having 3 to 5 years of BIM experience. Respondents to this study are working in different construction companies on various projects. Distribution of the respondents basing on size of their organizations is 13.7% (14) respondents belong to very small organizations, 17.6% (18) to small organizations. Cumulatively 68.7% (70) respondents belong to either large or very large organizations. Respondents' organizations have working experience in all areas of Pakistan. 69 % organizations have their business in Punjab, 33 % having in Sindh, 25% in Kashmir, 22% KPK, 16% Baluchistan and 14% in GilgitBaltistan.

6.2. Scenario for BIM in Pakistan

Most of the professionals consider that there is low (39.2%) or medium (25.5%) level of buzz about BIM is present in the Pakistani AEC market. 21.6% considers, no buzz about BIM. 11.8% responses that there is a high buzz and only 2% considers very high buzz. Respondents were asked, to rank their level of knowledge related to BIM. Respondent have either little, fair or experts level knowledge of BIM. Only 20% responded considers that they have no knowledge related to BIM. It is established in this survey that only 27% organization are using BIM or involved in BIM adoption process in any capacity whereas 73% organization are neither using BIM nor involved in BIM adoption process in any capacity. The positive point is that most of AEC professional are very optimistic about the future of the BIM. 96% professionals are in favour of implementing BIM in the Pakistani market. For future of BIM in Pakistan 52.9% respondents say 'definitely Yes' for the future of BIM whereas only 2% respondents consider 'No'.

6.3. Reliability of Sample

Cronbach's Coefficient Alpha method is the most common measure of internal consistency (reliability). It is most commonly used to check the reliability of scale when questions are asked on likert scale. If Cronbach's Coefficient Alpha value is higher than 0.7, this means that the data is reliable for analysis.. In our case, its value is calculated as 0.828 for advantages of BIM.

To check the normality of the collected data, 'Shapiro Wilk normality test' is conducted because sample size is less than 2000. It is performed to know whether the data is normally distributed or not, i.e. is the data parametric or non-parametric in nature. Significance values found are 0.000 which are less than 0.05. (Significance value should be larger than 0.05 for the data to be sufficiently normal). Therefore, data is not normally distributed and non-parametric tests are required for further analysis. Table 3 shows the data regarding test of normality by Shapiro Wilk test.

6.4. Perceptions regarding BIM Advantages

Collected data is non para-metric so Kruskal Wallis test is performed to check whether all stakeholders including architects, Consultants / Engineers, General Contractors, Trade / Specialist Contractor, Design Builder / Project Management and Academics / Research, have similar perception regarding the advantages. Table 4 explains that all stakeholders have similar perception about advantages associated with the adoption of BIM except 'reduce construction cost',and 'reduce construction time'. Significance value of these three BIM advantages is less than

0.05, which means that stakeholders have given different ranking to these BIM advantages. So these three BIM advantages are further analyzed.

Table 3.Test for Normality – Shapiro Wilk TestTable 4. Kruskal Wallis Test[a,b] for Advantages of BIM

Advantages	Shapiro-Wilk		
	Statistics	df	Sig.
Reduced Construction Cost	0.885	102	0.000
Reduced Construction Time	0.816	102	0.000
Improve Quality	0.823	102	0.000
Reduced Human Resources	0.878	102	0.000
Reduce Contingencies	0.850	102	0.000
Faster and More Effective method	0.825	102	0.000
Reduce Rework During Construction	0.839	102	0.000

Advantages of BIM	Sig.
Reduced Construction Cost	0.015*
Reduced Construction Time	0.031*
Improve Quality	0.097
Reduced Human Resources	0.528
Reduce Contingencies	0.908
Faster and More Effective method	0.082
Reduce Rework During Construction	0.094

a. Kruskal Wallis Test
b. Grouping Variable
* Sig. Value < 0.05

Table 5 clarifies that significance value of “Reduce construction cost” is less than 0.05 because of difference in opinion of Design Builders and Specialist contractors. Design builder / Project management firm rates “reduces construction cost” at 87.5% because their profit is directly proportional to reduction in the construction cost of the project while trade / specialist contractors are least concerned with the reduction in the cost of the project, they are only concerned with their part of work, so they rated this Advantage as low as 60%. The resulted RII values for other stakeholders depict the concern of each of stakeholder for cost reduction.
Table 5 shows the difference of stakeholder’s perception regarding “reduce construction time” as an advantage of BIM adoption. All the stakeholders rate it high as an advantage, design builder / project management professional’s rates highest at 90%. Academic / Research professional’s rate lowest to reduce its significance in Kruskal Wallis test. Academic / research people are not involved in real time construction, so it is impossible for them to know the importance of “time reduction”. Lesser is the time of construction lesser will be overhead expanses.

Table 5.Stakeholder’s RII Difference

Advantages	RII (Reduce Construction Cost)	RII (Reduce Construction Time)
Architects	0.7142	0.8000
Consultants / Engineers	0.6666	0.7166
General Contractors	0.7555	0.8666
Trade / Specialist Contractor	0.6000*	0.7500
Design Builder / Project Management	0.8750*	0.9000*
Academic / Research	0.6363	0.6545*

6.5. Ranking of BIM Advantages

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

The questionnaire comprises of seven BIM advantages to assess and rank them according to the respondents’ replies. The data collected through 102 respondents is analyzed using MS excel and SPSS-18. Means, percentages, relative importance indexes (RIIs) and ranking of seven BIM advantages is calculated shown in Figure 2. Out of seven BIM advantages, 'Faster and more effective method' has the highest value of RII (0.8118) whereas 'Reduce Construction Cost' has the lowest value of RII (0.7098). It implies that AEC professionals don't consider BIM as a cost reduction tool, followed by 'Reduce Human Resources' and 'Reduce Construction Time'. On the other hand the factor of 'Faster and more Effective Method' is the better perceived BIM advantage in AEC industry of Pakistan, followed by 'Improve Quality' and 'Reduce Rework during Construction'.

To note the difference in perception of different stakeholders for advantages of BIM, which AEC industry may get by the adoption of BIM, Table 5 depicts the RIIs given by each type of professional respondents to each of the advantage. It is clear from the Table5, Design builders / Project management firm rates RIIs for each advantage higher relative to the professionals belonging from other type of organizations. Specialist contractors are the one, who rates 'Reduce Construction Cost' at 0.6000 (RII), which is the lowest rating given by any type of professionals to this advantage. Lowest rating for 'Reduce Construction Time' is given by professionals from Academics and Research. All professionals rates 'Improve quality' more than 0.8000 (RII) except Academics and Research professional, who rate it round about 0.7000 (RII). Lowest rating for 'Reduce Human Resources' comes from Architectural professionals. Again, Academics and Research professional's gives lowest rating to 'Reduce Contingencies'. 'Reduce Rework during Construction' is lowest rated by Specialist contractors. 'Faster and more Effective Method' is best rated by most of the professionals except Architectural professionals and therefore its overall rank is first.

7. Conclusions and Recommendations

Current state of BIM adoption is not satisfactory in Pakistan. Only 27% of AEC organizations are using BIM or involve if BIM adoption process in any capacity. 73% organizations are neither using BIM nor involved in BIM adoption process in any capacity. There is earnest need of technology transfer (BIM) to Construction stakeholders. Conventionally, coordination among employer and employee (designer, contractor, supplier, etc.) is not effective. Specifically, both consultant and contactor have no effective channel to provide progress monitoring for evaluation of performance for project life cycle. [31, 32] According to a research study for measuring effectiveness of websites as business tool (referring projects), both consultants and contractors have poorly designed websites, without appropriate progress monitoring facility. In this stance, adoption of integrated design is highly needed to avoid coordination issues.

It is good to note that average RIIs for advantages (0.7709) is relatively closer to 1.It indicates that barriers are being shattered due to increasing awareness about BIM advantages and application. BIM education is lacking in formal and informal education providers. Universities across Pakistan has less focus on Construction Engineering and Management discipline and in contrary around 60-70% of Civil Engineering graduate students from public and private universities join Contractors and rest to other domains. There is great provision to introduce BIM education from university level so that when these students become professionals then it will be easy for them to adopt BIM on projects. Further, institutions providing continuing education should hold workshops and trainings for students and professions to understand and learn BIM technology. Induction of experts will enhance the adoption of this technology. Prime responsibility is of employer (especially public sector), who can induct requirement (through contract clauses) from architects, consultants and contractor to adopt BIM for design and planning.

BIM and BIM adoption is more popular in architectural professionals relative to other AEC professionals. BIM adoption rate in Karachi is higher than rest of Pakistan. Firms like Ahmed Associates, Khatri Associates have shifted to BIM and utilizing its application like "3D coordination", "Lighting analysis", "design review" and "4D Scheduling".Advance technology adoption has been seen on projects which are funded by international bodies (Aid agencies, Banks, NGOs, and Governments etc.). These project are large in scale and peer monitoring system is deployed as various stakeholders involved. Pakistan is under threat of natural and manmade disasters, which directs sustainable construction in future. BIM has proven to be useful for sustainable design and construction.

78.5% of professionals consider that there is some level of "BUZZ" about BIM is present in Pakistani market, "BUZZ" level ranges from low to very high.Obviously, new technologies take time to be implemented in full swing. In Pakistan, working cultures has great influence on operations and procedures. So the transfer of technology is a problem but acceptance for change is hurdle to implement innovative technologies. Organization should hold awareness sessions and train their employees to adopt this change slowly to avoid resistance.

80.5 % of the respondents have knowledge of BIM, ranging from little knowledge, fair knowledge and expert type of knowledge. Internet is a source to provide equal opportunities to professionals from developing or developed countries for information. Further, a significant ratio of Pakistan work force (engineers, technicians, traders, labors etc.) is working abroad (Middle East, South East Asia and various western countries). They have proven to be best in their specialties. They are authentic source of information and knowledge about advance technologies being implement in international projects.

Faster and more effective method for designing and construction management, improvement in quality of the design and construction and reduction in rework during construction are the top thee advantages according to the perception of AEC professionals of Pakistan and BIM has least impact on reduction of cost, time and human resources.96% of AEC professionals are in favour of implementing BIM in Pakistan. Professionals are willing to implement BIM. Most needed aspects are its awareness and education.

It is recommended that for understanding and to gain maximum benefits, stakeholders should take drawings and construction data of an already executed buildings and study the problems faced during its execution. Suggest the solution of the problems by redrafting the project using BIM concepts and also highlight BIM advantages in comparison to traditional design approach. This will help to learn the complexities and motivates application of BIM on future projects.

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