Cost Benefit Evaluation using BIM Enabled Designs

FINAL YEAR PROJECT UG – 2019

By

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CERTIFICATION

This is to certify that the thesis entitled.

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has been accepted towards fulfillment of the requirements.
for the undergraduate degree
in
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DEDICATION

We hereby dedicate this project to our parents, teachers, our seniors, our juniors, the labour force of Pakistan and the unfound potential of the construction industry.

DECLARATION

We hereby declare that the thesis entitled "**Cost benefit Evaluation using BIM Enabled Designs**" submitted by us is based on the study and work done solely by us. Any references to work done by any other person, institutions or sources have been duly cited. We further clarify that this thesis has not been published or submitted for publication anywhere else.

ACKNOWLEDGMENTS

We are grateful to the **Almighty ALLAH**, who gave us the strength to complete this work. We would also like to pay utmost gratitude to our advisor, **Dr. Khurram Iqbal Ahmad Khan** for the profound encouragement, support, and valuable time he provided for this work. It is with his support that we have been fruitful in accomplishing our goals.

ABSTRACT

With the rise of the construction industry in Pakistan and the shift of major sectors towards automating their workflow for a greater yield overall,the adoption of Building Information Modelling (BIM) has gained significant momentum in the construction industry. BIM enables enhanced collaboration, improved project coordination, and streamlined data management throughout the project lifecycle. However, the cost implications of implementing BIM-enabled designs have not been extensively studied, especially from an industry perspective. This final year project aims to conduct a comprehensive cost benefit evaluation of BIM-enabled designs, focusing on their impact on project delivery, construction efficiency, and long-term operation and maintenance costs. The study employs a systematic research methodology, including a literature review, case studies, and data collection from industry professionals and project stakeholders and it will provide valuable insights into the economic advantages and challenges associated with implementing BIM-enabled designs in the Construction Industry. By highlighting the potential cost savings, increased project efficiency, and improved decision-making processes, this study aims to promote the wider adoption of BIM among industry practitioners, project owners, and regulatory bodies. The significance of this research lies in its ability to bridge the existing knowledge gap regarding the cost benefits of BIM-enabled designs. By establishing a comprehensive understanding of the financial implications, this project will enable stakeholders to make informed decisions when considering BIM implementation and help drive industry-wide digital transformation initiatives.

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CHAPTER 1
INTRODUCTION

1.1 BACKGROUND

The construction industry plays a crucial role in the economic development of Pakistan. The sector contributes around 2.56 to the country's GDP and employs over 7.6 million people, making it one of the largest employment providers in the country (Ahmed, 2022).
However, it fails to complete the projects within the specified cost, time,and quality due to the use of traditional management techniques.(Farooq, 2020). The cost efficiency of the construction industry in Pakistan has been a major concern for policymakers, as the sector has been facing various challenges that hinder its growth and development.

The lack of contemporary tools and technology is one of the primary causes of Pakistan's construction industry's low-cost efficiency. Most of the construction work in the nation is manual, which requires a lot of time and labor. As a result, the cost of building increases and the project's completion is delayed. The industry's inefficiency is also a result of the usage of antiquated construction techniques and materials.

The corruption and inefficiency in the regulatory framework are another issue that have an impact on cost effectiveness. Pakistan, on enforcing contracts, ranks 156th.(Bank, 2020)which highlights the difficulties faced by enterprises there. Regulations that are overly burdensome and the widespread corruption add to the cost of doing business, making it difficult for construction companies to operate efficiently.

Additionally, the lack of trained workers and training programs in the construction sector reduces the sector's ability to operate efficiently. There are a lot of untrained workers in the sector, and they frequently lack the training needed to use cutting-edge machinery and technology, which increases the risk of accidents and injuries on construction sites. This raises the price of building while also having an impact on the industry's productivity.

1.2 PROBLEM STATEMENT

Due to deviating degree of complexity in construction projects leading to design alterations primarily in structural aspects of a project, leads to cost overrun and may increase the cost of project between 5-40%. What are the main causes of these design alterations? How can we mitigate them even before the construction phase? This leads us to the use of Building Information Modelling (BIM) that would address this issue efficiently. Pre-dominantly in a country like Pakistan which is at mere 11% in BIM adoption.
(Aslam, 2019) (Farooq, 2020)

1.3 MOTIVE BEHIND THE RESEARCH

Our idea to encourage the adoption of BIM in the construction sector of Pakistan**.** Visually demonstratesits impact and success in its ability in decreasing the overall cost of a project. As a developing Nation it will significantly aid in reducing burdens on its economic structure which requires a paradigm shift to new and modern technologies in the construction sector. The cost/benefit of BIM application has become a critical factor for construction enterprises to determine whether BIM can be implemented in construction projects.(Wang, 2022)

Cost-benefit evaluation of BIM-enabled designs can provide insights into the economic feasibility and effectiveness of using BIM in the construction industry. This research can help project stakeholders to make informed decisions. Certain aspects which primarily involves BIM faces variable challenges and issues and detecting or overcoming these barriers is important.

The use of Building Information Modeling (BIM) has been gaining popularity in the construction industry worldwide due to its potential to improve project efficiency, reduce errors and rework, and enhance collaboration among stakeholders. Exploring the potential benefits of BIM implementation in the construction industry of Pakistan. The use of BIM in the construction industry has been rapidly increasing worldwide due to its potential to improve collaboration, increase efficiency, and reduce errors and rework. However, its adoption in Pakistan has been slower than in other countries. Conventional methods may not be effective, reliable, or more precise in evaluating the required construction materials. (Naimi, 2023). Therefore, the research aims to evaluate the cost-benefit of BIM implementation in the Pakistani construction industry to determine its potential benefits and encourage its adoption.
The implementation of BIM has the potential to address these challenges by improving project planning, design, and construction. The use of BIM can also enhance the accuracy and coordination of construction documentation, leading to cost savings and improved project delivery. However, the implementation of BIM in Pakistan requires investment in technology and training, and the cost-benefit analysis can provide insight into the potential return on investment.

Overall, BIM can lead to significant cost savings by reducing rework, improving efficiency, minimizing waste, reducing errors, enhancing collaboration, and optimizing building performance. By adopting BIM, project stakeholders can achieve their project goals in an effective and sustainable while minimizing overall project costs.This research can help to accelerate the adoption and use of BIM for cost-benefit evaluations, leading to improved project outcomes and a more sustainable construction industry.

1.4 RESEARCH OBJECTIVES

The research objectives for a thesis on cost-benefit evaluation using BIM in Pakistan includes the following:

- To assess the benefits of BIM adoption in terms of cost savings, time efficiency, and quality improvement in construction projects in Pakistan.
- To identify factors leading to cost overruns affecting the construction projects.
- To quantify the cost savings and efficiency gains that can be achieved through the adoption of BIM in the construction industry of Pakistan.
- To establish a comparison between traditional and modern construction practices stating benefits of modern technology i.e., use of Revit for model development and performing clash detection, also the analysis of early and improved BOQ.

The construction industry has been known for its complex and costly projects, making it essential to evaluate the cost and benefits of construction projects accurately. We will discuss the aims and objectives of cost-benefit evaluation using Building Information Modeling (BIM).

BIM provides accurate and reliable information to stakeholders regarding the cost and benefits of a construction project. By evaluating the costs and benefits of a construction project, stakeholders can make informed decisions about whether to proceed with the project, how to optimize the project, and how to manage project risks.

Another key objective of using BIM is to provide accurate cost estimates. BIM provides stakeholders with detailed and accurate information about the materials, equipment, and labor required to complete a project. By enabling stakeholders to access this information in real-time, BIM reduces the likelihood of errors and rework, improving the accuracy of cost estimates. Accurate cost estimates are critical for managing project budgets, reducing the likelihood of cost overruns, and ensuring project viability.

BIM optimizes project design. BIM enables stakeholders to simulate different design scenarios, evaluating the cost and benefits of each option. By enabling stakeholders to compare different design options, BIM reduces the likelihood of costly changes later in the project, improving project outcomes and increasing overall efficiency. By optimizing project design, stakeholders can improve project outcomes, reduce project duration, and minimize project costs.

Cost-benefit evaluation using BIM also aims to provide stakeholders with accurate and reliable information about the benefits of a construction project. BIM provides stakeholders with detailed information about the performance, maintenance, and sustainability of a building or infrastructure. By providing stakeholders with this information, BIM enables them to make informed decisions about the value of a construction project, reducing the likelihood of costly mistakes and improving project outcomes.

Another objective of cost-benefit evaluation using BIM is to enable stakeholders to manage project risks effectively. BIM provides stakeholders with detailed information about potential risks, including safety hazards, environmental risks, and project delays. By enabling stakeholders to access this information in real-time, BIM reduces the likelihood of costly delays, accidents, and other risks, improving project outcomes and increasing overall efficiency.

1.5 IMPORTANCE OF RESEARCH:

Research on cost benefit evaluation using BIM is important for several reasons for the construction sector in Pakistan:

Demonstrating the value of BIM: Provides evidence of the benefits and potential cost savings associated with implementing BIM technology in a construction project. This helps to demonstrate the value of BIM and encourages stakeholders to adopt the technology. Certainly, of substantial value to Pakistan to compete with neighboring countries. Building information modelling (BIM) applications are being increasingly introduced throughout the construction industry and within academia, a large amount of BIM applications has been recommended within literature. (Sara Shirowzhan, 2020)
Identifying areas for improvement: Helps to identify areas where BIM technology can be improved or optimized to achieve greater cost savings. This information can be used to guide the development of future BIM software and workflows. Overcoming the barriers in adoption of BIM, passing certain policies and regulations to help in its implementation.
Supporting decision-making: BIM provides decision-makers with the information they need to make informed decisions about whether to implement BIM technology in a construction project. This information can help to reduce the risk of making costly mistakes and improve project outcomes.
Informing policy and regulation: This can help to inform policy and regulation related to BIM implementation in the construction industry. This can lead to more effective policies and regulations that support the adoption of BIM technology and the realization of its potential cost savings.

Past Major Projects of Pakistan: Countless infrastructure projects have been exceeding allotted or planned project cost, compromising its feasibility and ability to serve the public. One of many examples can be The Peshawar Bus Rapid Transit (BRT) system in Peshawar, Khyber Pakhtunkhwa, Pakistan. The project was launched in 2017 and was expected to be completed within six months with a budget of PKR 49 billion ($330 million). However, the project faced multiple delays and cost overruns, and its final cost has exceeded the planned project cost. According to the (Report, 2020), the cost of the Peshawar BRT project had increased to PKR 69 billion ($452 million), which is 41% higher than the original budget. The report also highlighted several irregularities in the project, including delays in project completion, poor quality work, and inflated prices for goods and services.
This also included frequent design alterations even after completion which was subjected to change incurring huge cost overheads.Public sector projects in KP suffers time delays leading to years of delay and cost overrun of over Rs25 billion, surprisingly close to half of this amount i.e. 11.2 billion is reported in the health sector projects in KP.(Zaffar, 2019)The finding reveals that factors leading to time and cost overrun are administrative issues, delays in fund release, political Issues, monitoring &control, work site issues, inflationary effects, poor cost estimation, issues from contractor's side, stakeholders and IT issues. While certain factors causing overrun in specific to IT projects are resistance by the stakeholders for change, lack of understanding on the part of consumer about the benefit of the project and rapid changes in technology.

Encouraging innovation: Encouraging innovation in the development of BIM software and workflows. This can lead to the creation of new and improved tools that can help to achieve greater cost savings in the construction industry.

Despite its many advantages, BIM also presents some challenges. One of the most significant challenges is the cost of implementing BIM. While the long-term benefits of BIM are significant, the initial cost of implementing BIM can be high, making it difficult for some organizations to adopt BIM. Another challenge is the need for specialized skills and training to use BIM effectively. While many stakeholders in the construction industry have experience with traditional 2D drawings, using BIM requires specialized skills and training, which can be a barrier to adoption.

Savings are paramount for BIM adoption, however rarely estimated due to lack of data and proper ana- lysis techniques. As a result, cost-benefit analyses are frequently either underestimated or exaggerated. As stated by (Chan, 2019)lack of certainty in assessing BIM impact on cost and waste remains on multiple occasions as a significant barrier to BIM implementation. Moreover, according to this research, the main benefits of implementing BIM relate to cost-control and design, i.e., reduced errors, or in other words, resolved clashes.

Hence, overcoming these challenges and establishing a comparison between its benefits to the construction industry with challenges it faces to infiltrate the traditional methodologies in current practices that would certainly have a positive impact.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

Now based on the previously done related studies a literature review has been conducted extensively. Almost **20 research papers** published by various well-known universities and professors have been made part of this project's literature review. So as result more than **60 factors** have been identified which can play their part in the design failures and adoption of this technology.

Pareto Analysis was conducted accordingly, and each factor was allotted a specific ranking and literature score.

In this literature review, we will examine the existing research on cost-benefit evaluation using BIM.

Factors Affecting Cost Overheads

Questionnaire *(Ranking of Factors According to Literature Score)*				
Sr.	**Factors Affecting Overhead Cost of Project**	**Ranking**	**Literature Score**	**Normalized Score**
1	Design Complexity	1st	0.55	0.097001764
2	Design Alterations	2nd	0.39	0.068783069
3	Insufficient utilization of BIM	3rd	0.36	0.063492063
4	Collaboration and Coordination	4th	0.33	0.058201058
5	Poor Project Scheduling	4th	0.33	0.058201058
6	Competitive pressure	5th	0.3	0.052910053
7	Technical feasibility	6th	0.21	0.037037037
8	Cost of Technology	7th	0.2	0.035273369
9	Inaccurate docementation	8th	0.18	0.031746032
10	Regulatory support (Govt. support)	9th	0.15	0.026455026
11	Perceived benefits	9th	0.15	0.026455026
12	Firm size	9th	0.15	0.026455026
13	Security issues	9th	0.15	0.026455026
14	Complexity	10th	0.12	0.021164021
15	Policy framework	11th	0.1	0.017636684
16	Compatibility	12th	0.09	0.015873016
17	Trust and cooperation	12th	0.09	0.015873016
18	External Support (In implementation)	12th	0.09	0.015873016
19	Client requirement	13th	0.06	0.010582011
20	Organizational motivations	13th	0.06	0.010582011
21	Technical risk	13th	0.06	0.010582011
22	Awareness of technology	13th	0.06	0.010582011
23	Observability	13th	0.06	0.010582011
24	Legal issues	13th	0.06	0.010582011
25	Interim Payments	13th	0.06	0.010582011

2.2 Explanation of Factors

Insufficient Utilization of BIM: The adoption of BIM in Pakistan is only at 11%. (Farooq, 2020)BIM has the potential to revolutionize the construction industry by improving collaboration, reducing errors, and saving time and money. However, the adoption of BIM has been slow in the construction industry, and there are several reasons for this:

Resistance to change: Many companies in the construction industry are resistant to change and prefer to continue using traditional methods of construction. They may not see the value of BIM or be willing to invest in the necessary technology and training.
Lack of knowledge and skills: BIM requires a high level of technical expertise and specialized software. Many companies in the construction industry may not have the necessary knowledge and skills to implement BIM effectively.
High initial costs: Implementing BIM requires significant investment in software, hardware, and training. This can be a barrier for smaller companies or those with limited resources.
Lack of industry-wide standards: There is no universal set of standards for BIM, which can create confusion and make it difficult for companies to adopt and implement the technology.
Resistance from suppliers and subcontractors: Suppliers and subcontractors may be reluctant to adopt BIM if they do not see the value in it or if they feel it will add to their workload.
Despite these challenges, the adoption of BIM is increasing, and it is likely to become more widespread in the construction industry in the coming years. Governments and industry organizations are promoting the use of BIM, and companies that are early adopters of the technology are reaping the benefits of improved efficiency, reduced costs, and enhanced collaboration.

Design Alterations: The impact of plan changes on development project cost can differ contingent upon a few variables, like the extent of the modification, the phase of the undertaking, and the intricacy of the plan. Changes to the design could have an impact on construction project costs in the following ways:

Cost of materials: Material costs can rise because of design adjustments that necessitate different or additional materials. For instance, altering a building's shape may necessitate additional materials or specialized components, which may increase the project's overall cost.
Costs of labor: Modifying the plan may likewise require extra work to oblige the changes, which can increment work costs. This may be especially true if the changes call for tradespeople or skills that are more specialized.
Project Delays: Changes to the design can lead to project delays, which can cost more money in the form of higher rent or lost productivity. Postponements can likewise prompt extra expenses related with rescheduling subcontractors and other task partners.
Changes to regulations: New regulatory requirements or permit fees may arise because of design modifications, which can raise project costs overall. For instance, if the design changes necessitate additional safety measures, this may necessitate more inspections or higher permit fees.

Costs of rework: If work that has already been completed needs to be undone or altered, changes to the design may also incur rework costs. Because more work will need to be redone, this can be especially costly if the changes are made later in the project.

Limited research on the impact of clash detection on construction cost: Clashes can be described as waste in the production system(Tommelein, 2012)Clash detection is a critical component of the Building Information Modeling (BIM) process, which helps identify potential conflicts between various building components during the design stage, thereby reducing rework, delays, and cost overruns during the construction phase. However, there is limited research on the direct impact of clash detection on construction costs. More research is needed to quantify the cost savings associated with clash detection. Addressing these gaps will help to further improve the effectiveness and efficiency of clash detection. One study by (Yuliastuti, 2021)Lack of integration in the design of a construction project planning, often resulting in clashes between elements. The purpose of this study was to analyze the number and causes of clashes between structural design, precast design, and MEP design for warehousing projects. Then the quantity take-off analysis will be carried out after resolving the clashes. In this study, BIM-based software was used namely Revit® 2020 and Navisworks® Manage 2020. The results of this study found that the number of clashes for the Structural vs Precast components was 289 clashes, for Structural vs MEP components was 191 clashes, and for Precast vs MEP components was 42 clashes. The cause of clashes with the highest percentage was caused by design error (52.36%), followed by design inconsistency (39.13%), and the last was a design discrepancy (8.51%). Based on the calculation of cost changes, a potential saving can be made for HCS panel material and for ducting pipe material as much as 10% of the initial cost

Lack of Project collaboration and coordination: Cost-benefit evaluations using BIM can involve multiple stakeholders, including owners, architects, engineers, contractors, and facility managers. Research is needed to evaluate the effectiveness of BIM in facilitating communication and collaboration among these stakeholders, as well as its ability to improve decision-making and reduce conflicts. Traditional construction practices often lead to poor project collaboration amongst all stakeholders leading to cost overruns. One of the critical factors that cause these overruns is poor communication.(Ismail, 2019)BIM is not just a 3D design tool, collaboration and coordination are critical aspects of BIM-enabled models. BIM technology provides a platform for project stakeholders to collaborate and coordinate more effectively throughout the project life cycle. Improved communication, enhanced project visualization which provide a 3D visualization of the project, which helps project stakeholders to better understand the project design and construction processes. This improves decision-making and can help to identify potential issues before they become problems. Increased project quality: BIM-enabled models help project stakeholders to identify and address potential issues before they become problems. This can result in higher quality projects that meet or exceed stakeholder expectations.

Risk Management: The risks and uncertainties inherent to the construction industry are more than any other industry and this industry exhibits poor management of these risks.

Hence, many projects fail to meet time schedules and budget targets. Transport sector is an important part of the construction industry and is vital to its growth.FATA received maximum share of development projects especially road infrastructure however, these projects could not fulfill their desired purpose due to lack of evaluation of risks associated with the dynamics and culture of that area resulting in severe cost overrun of these projects.(Zafar, 2015)

26	False Positives	13th	0.06	0.010582011
27	Uncertainity	13th	0.06	0.010582011
28	External pressure (organizational)	13th	0.06	0.010582011
29	Vendor support	13th	0.06	0.010582011
30	CEO innovativeness	13th	0.06	0.010582011
31	CEO knowledge	13th	0.06	0.010582011
32	Customers pressure	13th	0.06	0.010582011
33	Innovativeness	13th	0.06	0.010582011
34	Lack of Standards	14th	0.05	0.008818342
35	Critical mass	14th	0.05	0.008818342
36	Precision in Quantity take-offs	14th	0.05	0.008818342
37	Software availability and affordability	14th	0.05	0.008818342
38	Enabling environment	14th	0.05	0.008818342
39	Information distribution	14th	0.05	0.008818342
40	Information interpretation	14th	0.05	0.008818342
41	Comparative advantage	15th	0.03	0.005291005
42	Adopters' Affect	15th	0.03	0.005291005
43	Business Situation	15th	0.03	0.005291005
44	Resistance to change	15th	0.03	0.005291005
45	Culture of organization	15th	0.03	0.005291005
46	Improved collaboration	15th	0.03	0.005291005
47	Increased traceability and auditability	15th	0.03	0.005291005
48	IT managers' fear of losing control of their IT environment	15th	0.03	0.005291005
49	Expectations of market trends	15th	0.03	0.005291005
50	Industry (The type of industry)	15th	0.03	0.005291005
51	Market scope	15th	0.03	0.005291005
52	Supplier computing support	15th	0.03	0.005291005
53	Globalization level	15th	0.03	0.005291005
54	Knowledge / education	16th	0.01	0.001763668
55	Attitude towards technology adoption	16th	0.01	0.001763668
56	Power distance	16th	0.01	0.001763668
57	Cultural change among industry stakeholders	16th	0.01	0.001763668
58	Collaborative Procurement methods	16th	0.01	0.001763668
59	Training hours	16th	0.01	0.001763668
60	Scarcity of Experts	16th	0.01	0.001763668
61	Social network	16th	0.01	0.001763668
62	Perceived ease of use	16th	0.01	0.001763668
			5.67	

Overall cost of project: Use of clash detection in BIM plays a vital role with its ability to identify clashes (errors or omissions) in the early design phases of the project, saving precious time and cost in terms of rectifying those errors. Hence, using clash detection, lower number of change orders issued has a direct link with cost of project. One important and well-known issue for most construction projects such as buildings, roads, bridges, airports and many more projects all over the world is time and cost overrun. Project pricing and period delay are also major issues. The current investigation is taking into consideration the mega construction projects in the provinces of Pakistan, looking into various components controlling and dominating time and cost overrun.(Shaikh, 2020)Time and cost overrun are of the leading financial mismanagement issues of the economy of Pakistan.(Shaikh, 2020)

False positives: False positives in BIM refer to the identification of issues or conflicts that are not actually present in the project. False positives can lead to unnecessary rework and delays, which can increase project costs. In this section, we will examine the existing research on the effect of false positives in BIM, along with relevant references and statistics. The clash detection algorithm used in design coordination tools can lead to a number of clashes not all of which may be relevant. (Liete, 2011)

Design Complexity: Design complexities can have a significant impact on the construction industry, leading to project delays, cost overruns, and decreased productivity. In this section, we will examine the existing research on the effects of design complexities in the construction industry, along with relevant references and statistics. Overall, the existing research suggests that design complexities can have a significant impact on the construction industry, leading to decreased productivity, increased cost, and schedule duration. Effective stakeholder involvement, communication, and collaboration, as well as project planning and risk management, are essential for addressing design complexities and minimizing their impact on construction projects.

Scarcity of experts: Existing research suggests that the scarcity of BIM experts is a major challenge facing the construction industry.(Arayici, 2011)examined the skills and knowledge required for BIM implementation in the construction industry. The study found that the shortage of skilled BIM experts was a major challenge for the industry, and that there was a need for increased education and training programs to address this shortage. The study also highlighted the importance of effective collaboration among industry stakeholders, including education providers, professional bodies, and industry practitioners, in addressing this challenge.

Low accuracy and precision in quantity take-offs:BIM models provide accurate cost estimates to stakeholders with detailed and accurate information about the materials, equipment, and labor required to complete a project. By enabling stakeholders to access this information in real-time, BIM reduces the likelihood of errors and rework, improving the accuracy of cost estimates. Accurate cost estimates are critical for managing project budgets, reducing the potential for overestimation or underestimation of the required materials, leading to cost savings.

Cost of Technology: Overall, the existing research suggests that while the cost of implementing BIM technology can range from 0.5% to 3.5% of the total project cost, the potential cost savings and efficiency gains can offset these costs. The studies mentioned above provide evidence of the potential benefits of BIM in reducing project cost, improving construction quality, and reducingproject duration. However, the precise cost and benefit of implementing BIM technology will depend on project-specific factors, and cost-benefit evaluations are necessary to ensure that the benefits of BIM technology outweigh the costs of its implementation.

Poor Project Scheduling: Poor project scheduling can have a significant impact on cost in the construction industry. When project schedules are inaccurate or not properly managed, it can lead to delays, rework, and increased labor and material costs. Overall, the existing research suggests that poor project scheduling can have a significant impact on cost in the construction industry, resulting in delays, rework, and increased labor and material costs.

Low accuracy and precision in quantity take-offs:BIM models provide accurate cost estimates to stakeholders with detailed and accurate information about the materials, equipment, and labor required to complete a project. By enabling stakeholders to access this information in real-time, BIM reduces the likelihood of errors and rework, improving the accuracy of cost estimates. Accurate cost estimates are critical for managing project budgets, reducing the potential for overestimation or underestimation of the required materials, leading to cost savings.Compatibility is one of the key contextual factors of Diffusion of Innovation theory that involves predicting BIM adopters' behaviors and identifying what components require extra effort for successful BIM implementation. (Sara Shirowzhan, 2020)Cost-benefit evaluation of BIM-enabled designs can provide insights into the economic feasibility and effectiveness of using BIM in the construction industry. This research can help project stakeholders to make informed decisions.

Compatibility issues: One of the challenges associated with the adoption of Building Information Modeling (BIM) in the construction industry is the issue of compatibility with existing systems and software. BIM-enabled models require significant investment in software and hardware infrastructure, and there is often a lack of compatibility with existing systems used by construction companies. Statistics from a survey conducted by the National Institute of Standards and Technology (NIST) in the United States found that 44% of construction companies cited compatibility issues as a barrier to BIM adoption (NIST, 2017). The survey also found that the cost of implementing BIM and the lack of industry standards were other significant barriers to adoption.

Prior to the before mentioned factors contributing to design failures and cost overruns, some strategies and objectives could be opted that link directly to cost saving.

Identifying strategies for optimizing the return on investment using BIM-enabled models: Define project goals and objectives: The first step in optimizing the rate of return using BIM is to define the project goals and objectives. This includes identifying the key performance indicators (KPIs) that will be used to measure the success of the project.Allocating resources effectively is critical to optimizing the rate of return using BIM. This includes investing in the right hardware and software, as well as providing personnel training and support.

Overall, the existing research suggests that optimizing ROI using BIM-enabled models requires a combination of strategies such as early stakeholder involvement, integration with other project management systems, continuous improvement, and decision support. The studies mentioned above provide evidence of the potential cost savings and efficiency gains that can be achieved with BIM-enabled models. However, the precise ROI will depend on project-specific factors. Effective cost-benefit evaluations are necessary to ensure that the benefits of BIM-enabled models outweigh the costs of their implementation.

Early identification and resolution of design and construction issues:BIM models enable the identification and resolution of design and construction issues at an early stage. This reduces the potential for rework, change orders, and delays, leading to cost savings.

2.3 Summary

The construction industry in Pakistan contributes significantly to the country's GDP, but the sector's cost efficiency is a major concern for policymakers due to various challenges that hinder its growth and development. Including the lack of modern tools and technology, inefficient regulatory frameworks, and a shortage of trained workers. To address this issue, the research proposes the adoption of Building Information Modelling (BIM) to decrease overall project costs and mitigate design alterations. The research aims to evaluate the cost-benefit of BIM implementation in the Pakistani construction industry to determine its potential benefits and encourage its adoption. The research objectives include assessing the benefits of BIM adoption, identifying factors leading to cost overruns, quantifying the cost savings and efficiency gains, and establishing a comparison between traditional and modern construction practices. Thus, by utilizing BIM, an economical, timely, properly managed project can be obtained in Pakistan and other developing construction markets all over the globe.(Rehman, 2020)The use of BIM can lead to significant cost savings, improved efficiency, reduced errors, enhanced collaboration, and optimized building performance.

Chapter 3
Research Methodology

3.1 Introduction

This chapter includes the methodology that was used to extrapolate the required data, and analysis that are linked to our research. It provides information about the design failures that effected the cost of a project. Clash detection would be discussed and how does it help in reducing the cost and finally a reformed model, which would contain all the amendments that were incorporated to cater those clashes and simultaneously refraining the client from the drastic repercussions of the design failures and decreasing the cost.

Our methodology includes of the following stages:

1. **Identifying problem statement and research gap.**
2. **Literature review and identifying objectives.**
3. **Execution stage and Conclusion**

3.2 ProblemIdentification

The construction industry is getting advanced day by day and due to complexity of the designs, the chances for a design to have failures increases with that. Construction projects require a good design to be successful and profitable. Any errors in the design can easily affect the revenue that would be generated from it. These failures should be identified at the designing phase of a project so that any increase in budget or delay in schedule can be prevented before the actual construction begins.

Savings are a paramount for major construction projects, but they are rarely estimated due to lack of information and appropriate analysis techniques.
Construction industries should place a higher significance on saving money for the following reasons:

1. Capital investment: Significant capital investments are needed for the purchase of tools, materials, and labor to complete construction projects. Construction companies can use their savings to make these investments and pay for their projects.

2. Business sustainability: Due to intense competition in the construction sector, businesses must continue to turn a profit to survive. Companies may manage cash flow, invest in future growth, and weather economic downturns with the aid of savings.

3. Cost-cutting measures: Careful planning, effective resource utilization, and waste reduction are just a few examples of ways to cut costs. Construction companies may benefit from this by lowering their overhead expenses and increasing their profit margins.

4. Resilience: Savings can help construction businesses deal with unforeseen circumstances like project delays, equipment failures, or natural disasters. Savings enable businesses to avoid financial strain and guarantee the timely and cost-effective completion of their projects.

5. Innovation investment: Savings can also help construction companies invest in new technologies and innovations, which can increase production and efficiency. Savings, for instance, may be utilized to buy new tools or software that would speed up and lower the cost of building.

Furthermore, BIM adoption is also not being considered as a practice. It allows a collaborative environment for all the teams working on the project and puts document management in a single platform that can be accessed by anyone.

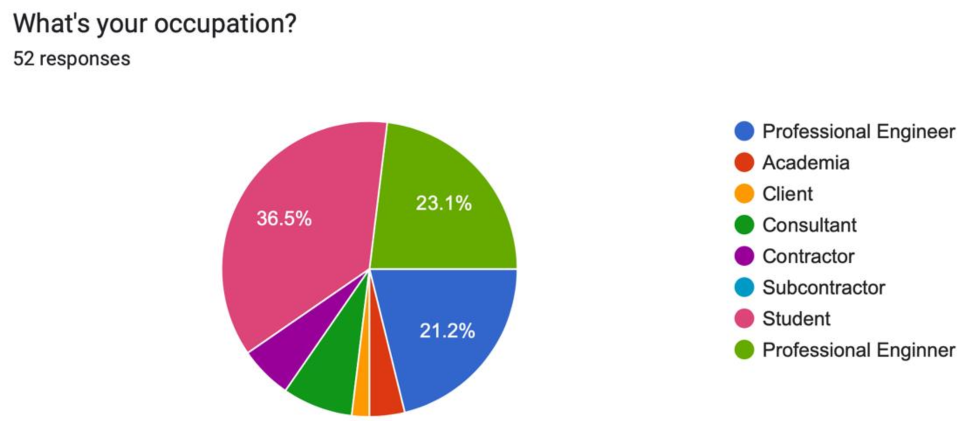
In summary, designing is considered as an important phase in projects that can affect the entire project in many ways. It needs to treat with utmost care so that the project runs smoothly without any errors or mistakes.

3.3 Questionnaire Analysis

We conducted a survey linked to our project and received a significant number of responses from participants. The survey covered various aspects such as respondent demographics, participants knowledge regarding building information modelling and effect of common practices on the construction industry.

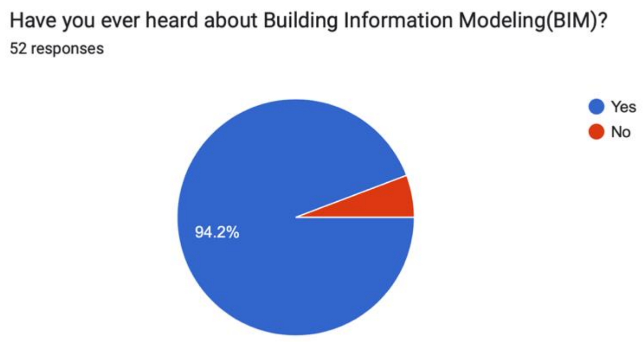
We used Google Forms to draw a conclusion on the data that was provided by the participants and divided this analysis in three phases.

Phase 1: Respondents Demographics

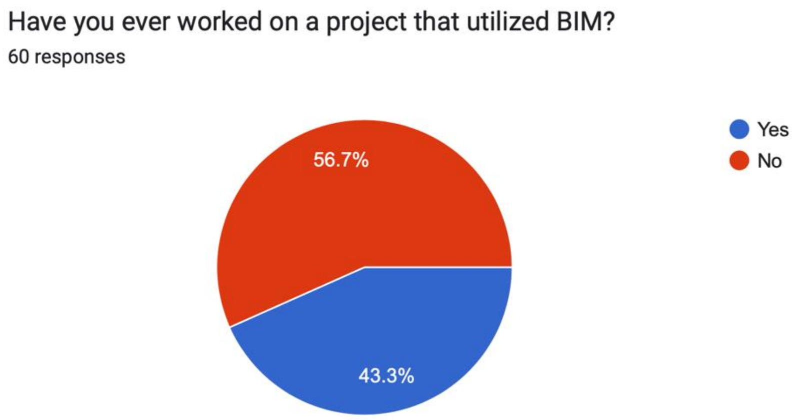


A total of 70 responses were received through this survey out of which 36.5% were related to academia, 23.1% of the participants were consultants and 21.2% were professional engineers.

Phase 2: Awareness of Building Information Modelling



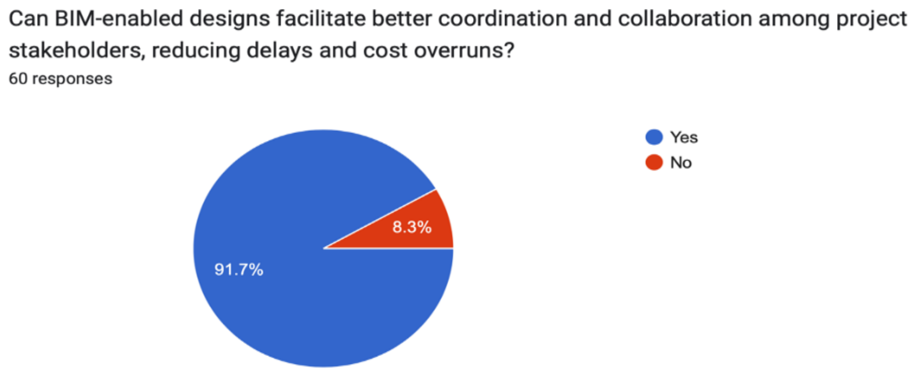
Majority of the participants were aware of building information modelling but after analyzing only 17.3% out of the 94.2% of the people who knew about BIM, were working on projects that were using this platform.



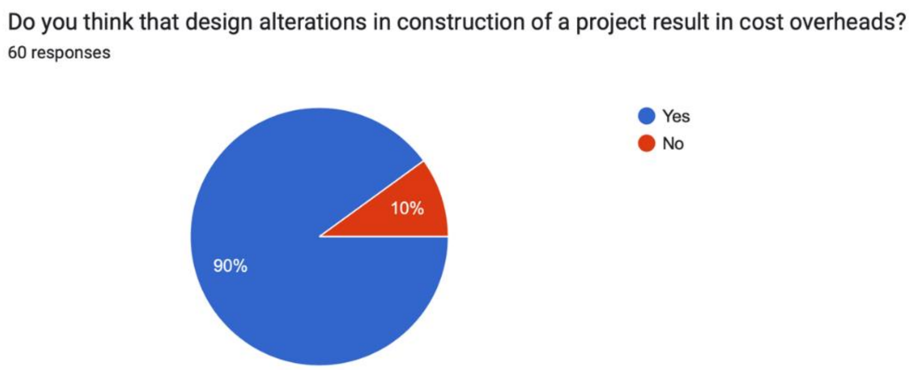
Most of the participants were aware of building information modelling but after analyzing only 43.3% out of the 95% of the people who knew about BIM were working on projects that were using this platform.

Phase 3: Implementation of BIM in construction industry

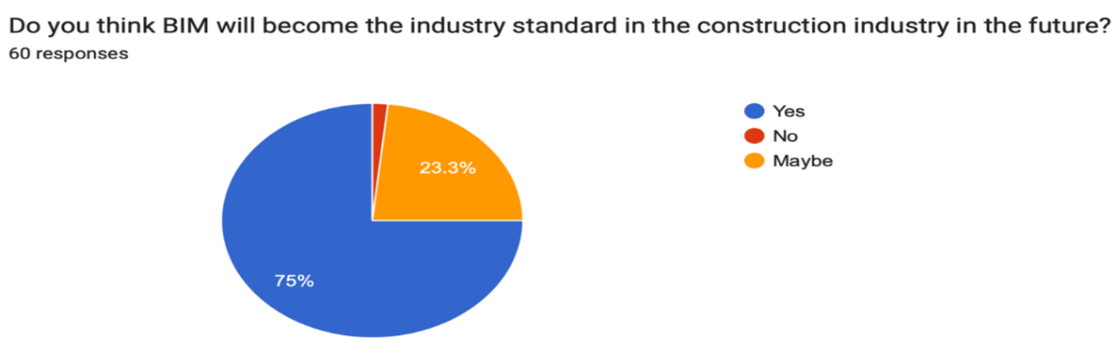
Although many of the participants heard about BIM, they had very minimal experience of the platform. 75% of the participants believe that BIM would become a standard in our industry and it's important to know the perks of this platform by spreading more awareness about BIM and stressing over BIM adoption.



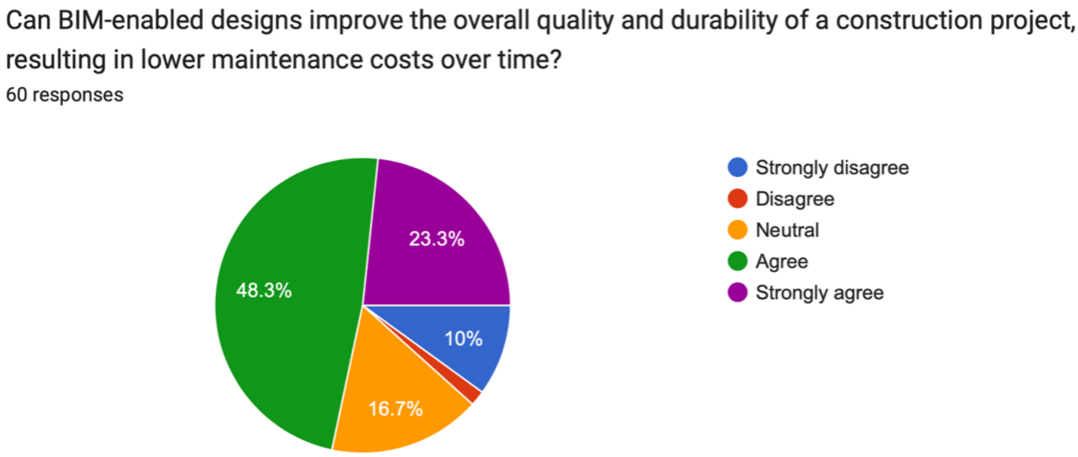
Overall, BIM provides a centralized, digital platform that improves coordination and collaboration among project teams, leading to improved project outcomes, reduced costs, and increased efficiency. 91.7% of the participants voted "yes" and agreed with the statement.



Design alternations can have drastic effects on a project, and it is important to amend them before they proceed to the next phase of the construction. 90.4% of the participants voted "yes" for design alterations having a direct effect on the cost overheads.



71.6% of the participants strongly agree with BIM-enabled designs lowering the maintenance cost over time by improving the durability and overall quality of construction project.



3.3 Summary

Many benefits come with modern construction methods, including increased efficiency, reduced cost, and increased sustainability. However, they also deal with several difficulties and potential issues such as complexity, integration issues, lack of flexibility, compatibility issues and cost overruns.

Construction projects success also depends on the design phase, which is a crucial part of those projects. During the designing phase, the projects plans and requirements are defined, and specifications are developed. Since this phase lays the groundwork for the entire building process, any mistakes or oversights here could have a significant impact on how the project turns out. It plays a key role in fulfilling the client's requirements and ensures that the project is completed on time and within budget.

After analyzing our survey, Majority of the participants believed BIM can be advantageous to construction projects in many ways and we conclude that more awareness should be circulated regarding BIM adoption and designing phase should be completed with utmost care and even if there are some errors in the design, clash detection should be used to amend those errors and omissions.

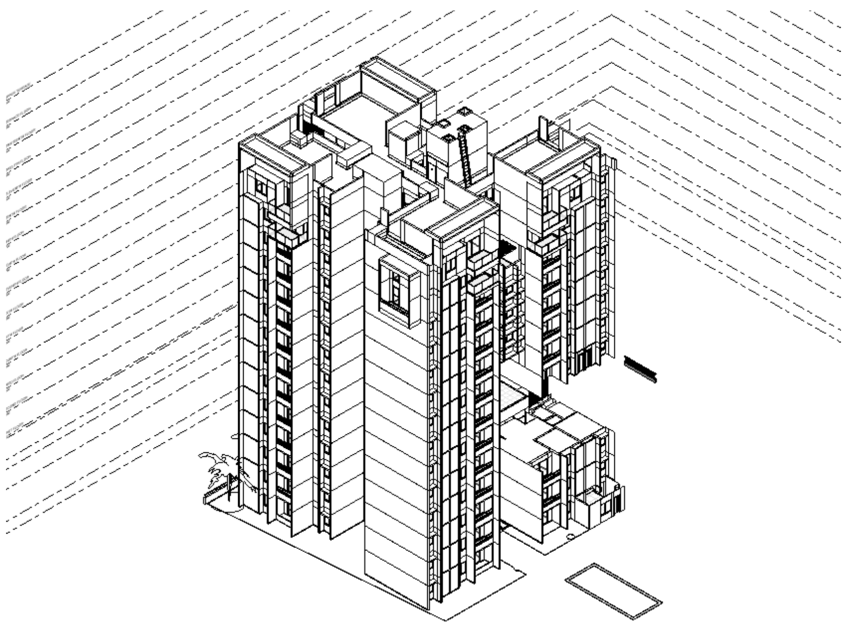
Chapter4
MODEL DESIGN and EXECUTION

4.1 Model Design and Execution Stage

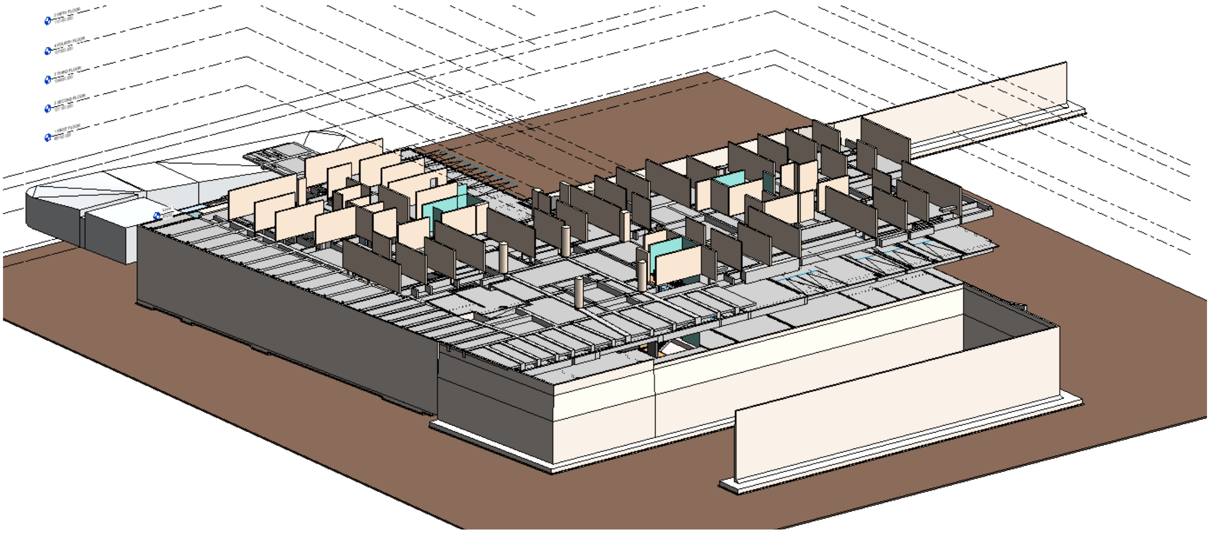
4.1.1 Created a BIM enabled 3d model in Autodesk Revit

Building Information Modeling (BIM) is a digital representation of a building project that encompasses its physical and functional characteristics. Autodesk Revit is a popular BIM software that allows for the creation of a detailed 3D enabled BIM model. Our goal was to make our construction industry adopt a cost-effective method in designing and building of the projects. By using BIM enabled 3d models in Revit we were able to achieve that. A 2d drawing drafted in AutoCAD was used and it was then created in Revit as a BIM enabled 3d model using the tools in Revit.

A 15-storey residential building model in Autodesk Revit was designed for the need of our project. As we are performing cost benefit analysis, 2 floors of the basement were used to perform the calculations and tests for clear and smooth understanding of the execution process.



There were 2 models created, one was the architectural model, and the second model was the structural model. These both models were linked and used together in context of our project.



4.1.2 Calculated Concrete schedule and quantities.

As part of the project, you need to calculate the schedule and quantities of the concrete elements in the building. After both the structural and architectural models were created and linked in Revit, the concrete schedule for non-structural walls was generated which included the area, volume, height, count of the non-structural walls and the material grade used. These are the quantities and values which are important in the scope of our project. The schedule was generated in Revit and then exported in excel format.

4.1.3 Exported the Revit model in Navisworks format.

00 - 01 WALL SCHEDULE						
FLOOR LEVEL	COUNT	ITEM	AREA	VOLUME	HEIGHT	Price (20000/cubic m)
-01 LOWER BASEMENT FLOOR	7	150THK NON STRUCTURAL WALL	33.05 m²	5.46 m³	23.35	109,200
-01 LOWER BASEMENT FLOOR	1	200 THK NON STRUCTURAL WALL	3.85 m²	0.70 m³	0	14,000
-01 LOWER BASEMENT FLOOR	36	200THK NON STRUCTURAL WALL	233.49 m²	48.66 m³	117.58	978,200
-01 LOWER BASEMENT FLOOR	1	200THK NON STRUCTURAL WALL TYPE2	0.60 m²	0.02 m³	3	400
-01 LOWER BASEMENT FLOOR	2	300THK NON STRUCTURAL WALL	5.78 m²	1.73 m³	7	34,600
-02 UPPER BASEMENT FLOOR	7	150THK NON STRUCTURAL WALL	28.01 m²	4.20 m³	19.69	84,000
-02 UPPER BASEMENT FLOOR	33	200THK NON STRUCTURAL WALL	134.99 m²	27.00 m³	93.96	540,000
-02 UPPER BASEMENT FLOOR	1	300THK NON STRUCTURAL WALL	3.48 m²	1.04 m³	2.9	20,800
00 GROUND FLOOR	1	200THK NON STRUCTURAL WALL	3.54 m²	0.71 m³	2.95	14,200
Grand total: 89	89		446.78 m²	89.52 m³	270.43	17,95,400

Once the concrete schedule was generated, now we had to observe if there were any clashes in the model, to do so, the RVT. File was converted into the Autodesk Navisworks format (i.e.,nwd. File) to run clash detection tests on the model. This was done because the detailed detection of clashes is done in a different software i.e., Autodesk Navisworks. Navisworks is a software tool specifically designed for visualizing, reviewing, and analyzing 3D models and project data. Exporting the Revit model to Navisworks allows for better collaboration and clash detection among various disciplines involved in the project.

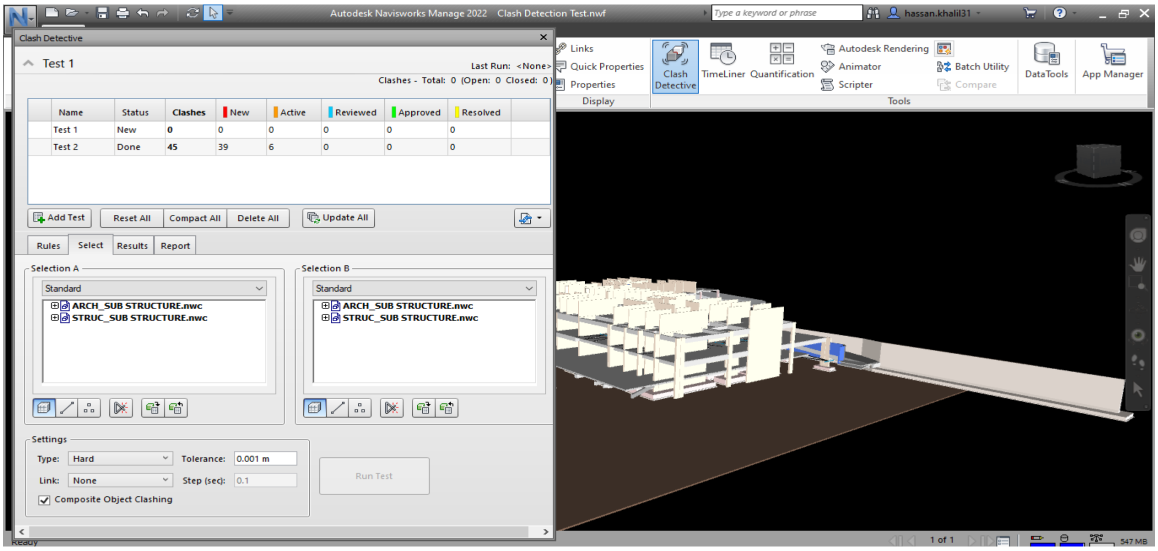
4.1.4 Imported the model in Navisworks to check for clash detection.

Once the model was converted into the Navisworks format, we imported the file in Autodesk Navisworks. This step enables us to bring together multiple models and disciplines into a single coordinated environment. By visualizing the models together, we can identify clashes or conflicts between different building elements, such as structural members and architectural components.

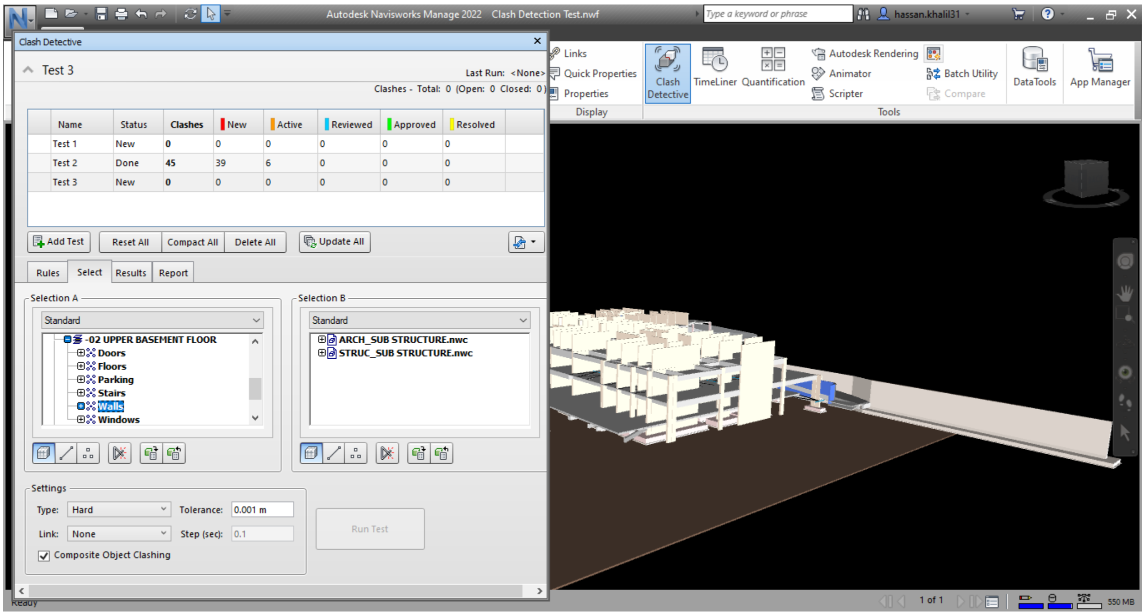
4.1.5 Clash detection tests ran in Navisworks.

Navisworks offers powerful clash detection capabilities. During this step, we ran clash detection tests to identify clashes or collisions between different objects within the 3D model. Clash detection helps detect conflicts that could arise during construction, such as pipes intersecting with structural elements or ductwork conflicting with architectural elements. For the scope of this project, we have clashes between structural and architectural elements.

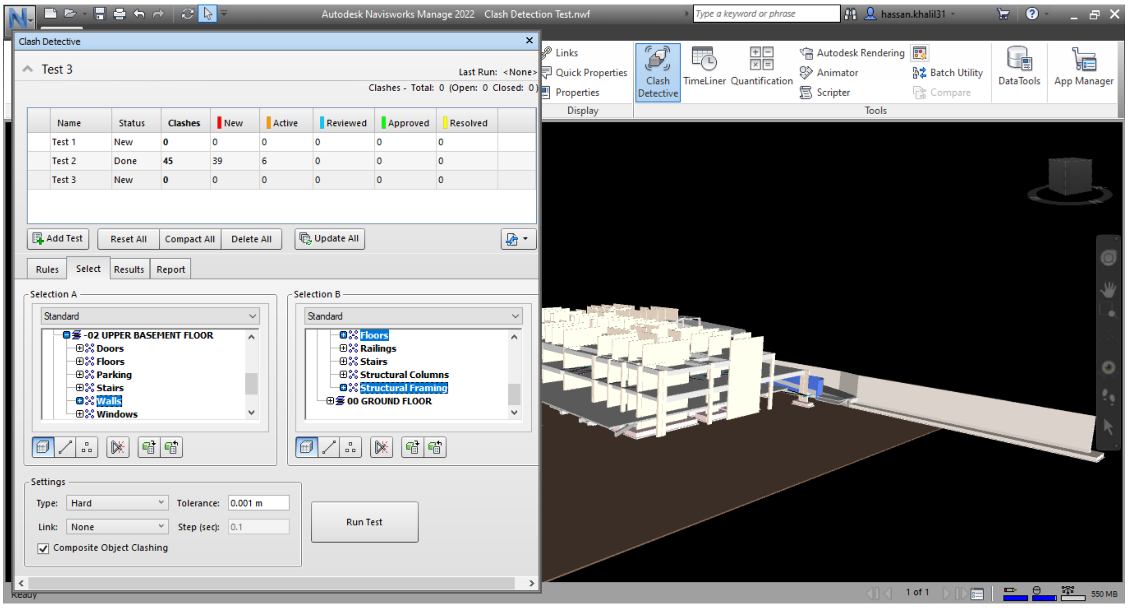
- Clash detective option is selected in Navisworks.



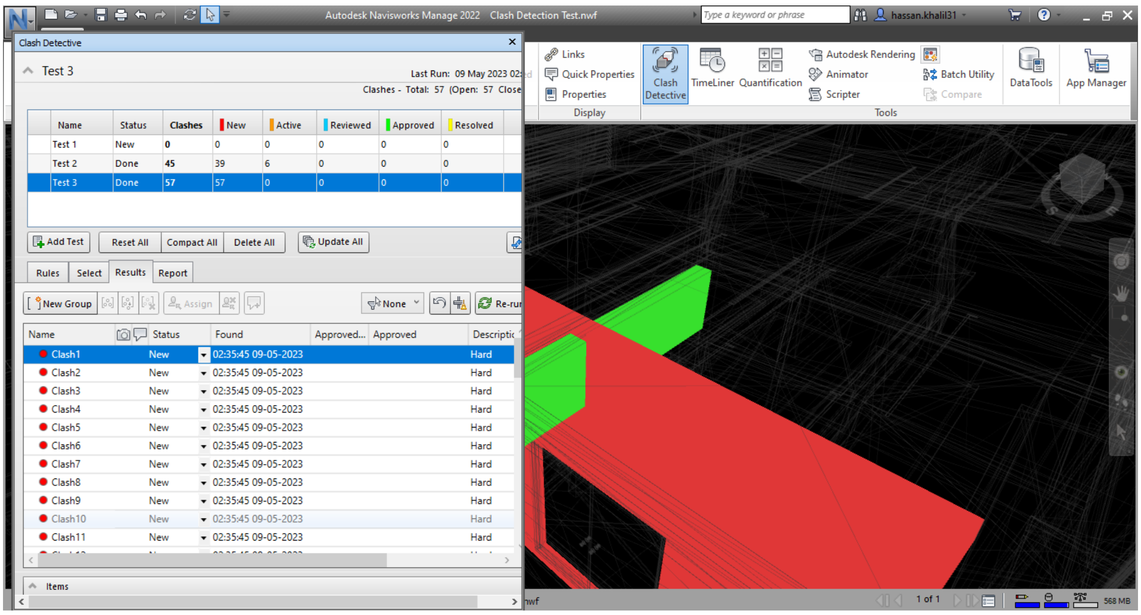
- Selection A and Selection B are made for architectural and structural models respectively.



- The elements we want to use in our clash detection test are then selected and are highlighted as seen in the figure.



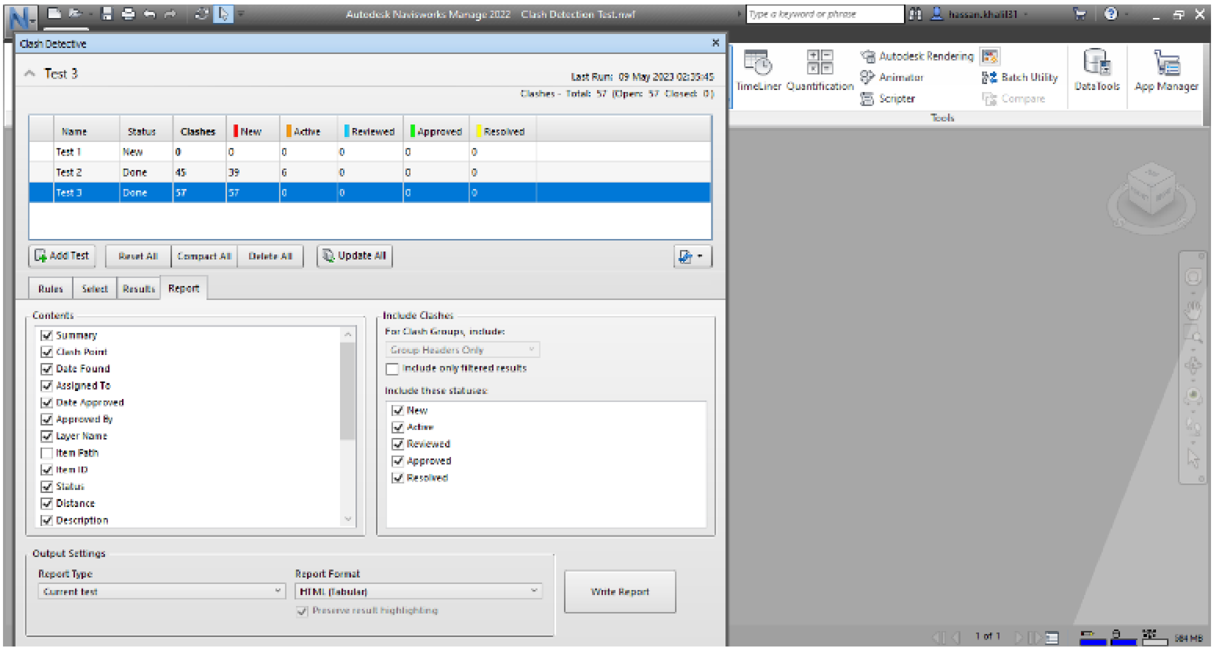
- Clash detection test is ran, and we are provided with all the existing clashes detected in the model.
- As we can see, our software has detected 57 clashes during this test.



4.1.6 Clash detection report generated in excel format

Once the clash detection tests were completed in Navisworks, we generated clash detection reports. These reports provide detailed information about the clashes identified, including their locations, severity, and the objects involved. Typically, clash detection reports are exported in Excel format, making it easier to analyze and share the clash information with project stakeholders.

- The contents we want to display in our report are ticked, the report type and format are selected. Then we click on write report which generates our clash detection report in our desired format. (i.e. Excel)



- The report when created in the excel format gives us all the details of the clashes and their properties as well. Description for each of the property is as per:

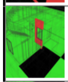
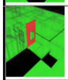
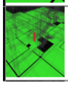
- Tolerance: This is the minimum distance of the clash. We have taken 0.001m here. If the architectural and structural element are causing disturbance beyond 0.001m, we will consider it as a clash.

- Clashes: This is the number of the clashes detected in our model.

- New: The clashes we have detected are new and have not been detected before.

- Type: This is the type of the clash we have detected. It is either hard or soft. Hard clashes are the clashes which cause major disturbance in the model.

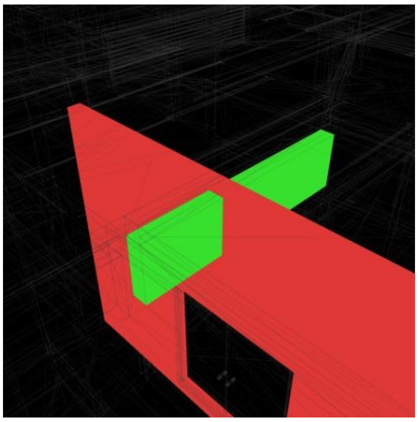
Test 1	Tolerance	Clashes	New	Active	Reviewed	Approved	Resolved	Type	Status
	0.001m	57	57	0	0	0	0	Hard	OK

							Item 1				Item 2			
Image	Clash Name	Status	Distance	Description	Date Found	Clash Point	Item ID	Layer	Item Name	Item Type	Item ID	Layer	Item Name	Item Type
	Clash1	New	-0.84	Hard	2023/2/8 21:05	x:-6.260, y:2.010, z:-4.011	*Element ID* : 204251	-01 LOWER BASEMENT FLOOR	200 THK NON STRUCTURAL WALL	Solid	*Element ID* : 356413	-02 UPPER BASEMENT FLOOR	BEAM MATERIAL	Solid
	Clash2	New	-0.4	Hard	2023/2/8 21:05	x:20.520, y:35.590, z:-7.500	*Element ID* : 267774	-01 LOWER BASEMENT FLOOR	200 THK NON STRUCTURAL WALL	Solid	*Element ID* : 345302	-01 LOWER BASEMENT FLOOR	FLOORING BASEMENT	Solid
	Clash3	New	-0.4	Hard	2023/2/8 21:05	x:21.838, y:37.640, z:-7.500	*Element ID* : 207746	-01 LOWER BASEMENT FLOOR	150 THK NON STRUCTURAL WALL	Solid	*Element ID* : 345302	-01 LOWER BASEMENT FLOOR	FLOORING BASEMENT	Solid
	Clash4	New	-0.4	Hard	2023/2/8 21:05	x:21.820, y:37.640, z:-7.500	*Element ID* : 207806	-01 LOWER BASEMENT FLOOR	150 THK NON STRUCTURAL WALL	Solid	*Element ID* : 345302	-01 LOWER BASEMENT FLOOR	FLOORING BASEMENT	Solid
	Clash5	New	-0.4	Hard	2023/2/8 21:05	x:23.170, y:36.090, z:-7.500	*Element ID* : 207953	-01 LOWER BASEMENT FLOOR	150 THK NON STRUCTURAL WALL	Solid	*Element ID* : 345302	-01 LOWER BASEMENT FLOOR	FLOORING BASEMENT	Solid
	Clash6	New	-0.4	Hard	2023/2/8 21:05	x:19.320, y:31.714, z:-7.500	*Element ID* : 207439	-01 LOWER BASEMENT FLOOR	200 THK NON STRUCTURAL WALL	Solid	*Element ID* : 345302	-01 LOWER BASEMENT FLOOR	FLOORING BASEMENT	Solid
	Clash7	New	-0.4	Hard	2023/2/8 21:05	x:24.941, y:15.980, z:-7.500	*Element ID* : 206900	-01 LOWER BASEMENT FLOOR	150 THK NON STRUCTURAL WALL	Solid	*Element ID* : 345302	-01 LOWER BASEMENT FLOOR	FLOORING BASEMENT	Solid

4.1.7 Insight of a Clash Detection Report (Example)

							Item 1				Item 2			
Image	Clash Name	Status	Distance	Description	Date Found	Clash Point	Item ID	Layer	Item Name	Item Type	Item ID	Layer	Item Name	Item Type
	Clash1	New	-0.84	Hard	2023/2/8 21:05	x:-6.260, y:2.010, z:-4.011	*Element ID* : 204251	-01 LOWER BASEMENT FLOOR	200 THK NON STRUCTURAL WALL	Solid	*Element ID* : 356413	-02 UPPER BASEMENT FLOOR	BEAM MATERIAL	Solid

Firstly, we have the visual representation of the clash which was detected.



Then, we have the name of the clash as seen in the table above. It is then followed by status of the clash. Which in our cases is new. All the clashes detected are new clashes. After that we have the description of the clash. The given example has a hard type of clash. Data found shows the time and date when the clash detection test was run and the clash was detected. Then we have one of the most important points which is the coordinates of the location of our clash. We have two types of items which have different elements. These items are for structural and architectural models which we designed. It shows the item ID, layer, Item name, and item type.

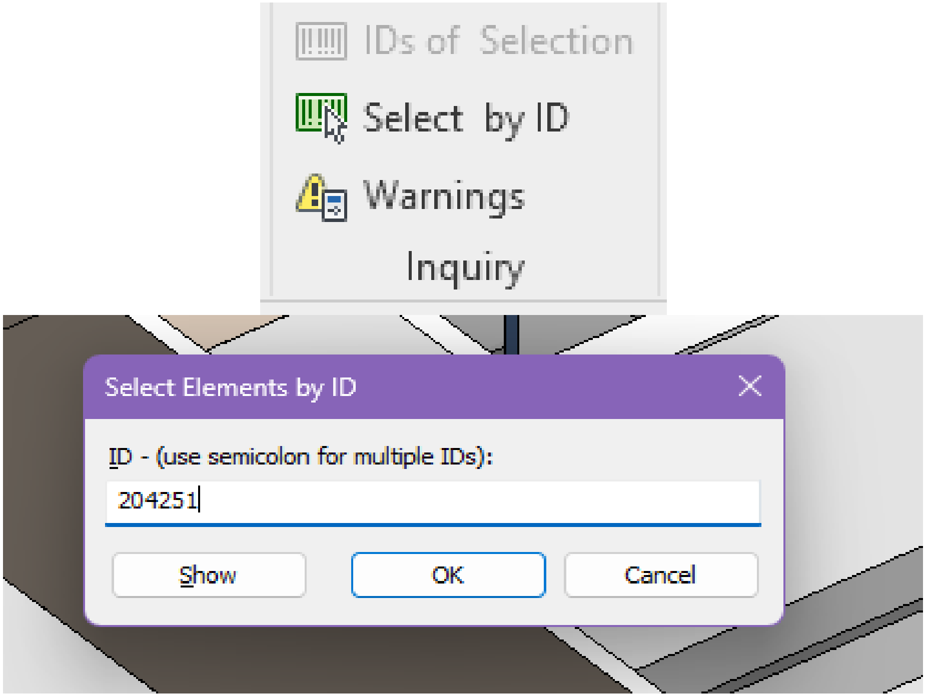
4.1.8 Clash detection report used to resolve clashes in Revit

The clash detection reports served as a valuable reference for resolving clashes. With the information provided in the reports, we went back to the Revit model and made the necessary adjustments to resolve the identified clashes. This involved modifying the design, repositioning elements, and coordinating with other disciplines to find suitable solutions.

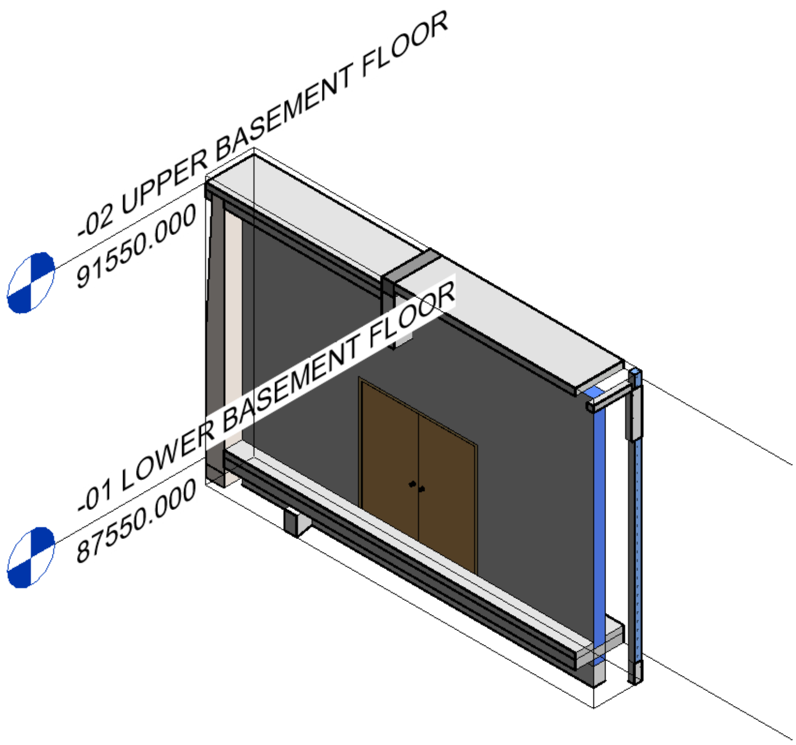
To resolve the clashes in Revit after generating the clash detection report in Navisworks is that first of all we have to copy the element ID of the clash we want to resolve.

Item ID
Element ID : 356413

This element id is then inserted into the *select by ID* option in Revit and then we click *show.* This shows us the exact location of the clash in the Revit model thus enabling us to single it out and then solving the clash.



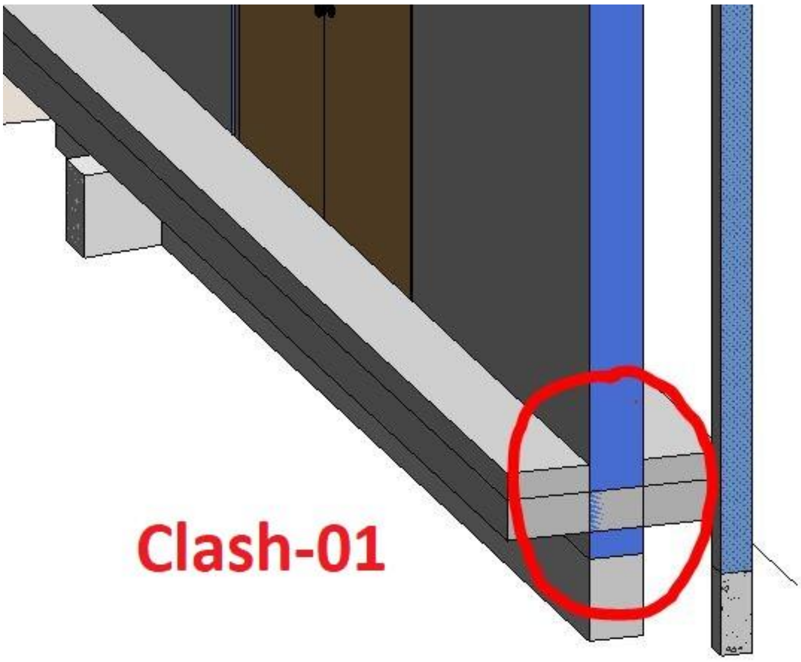
Clicking on *show* will give us the section box of the location of the clash we have used.



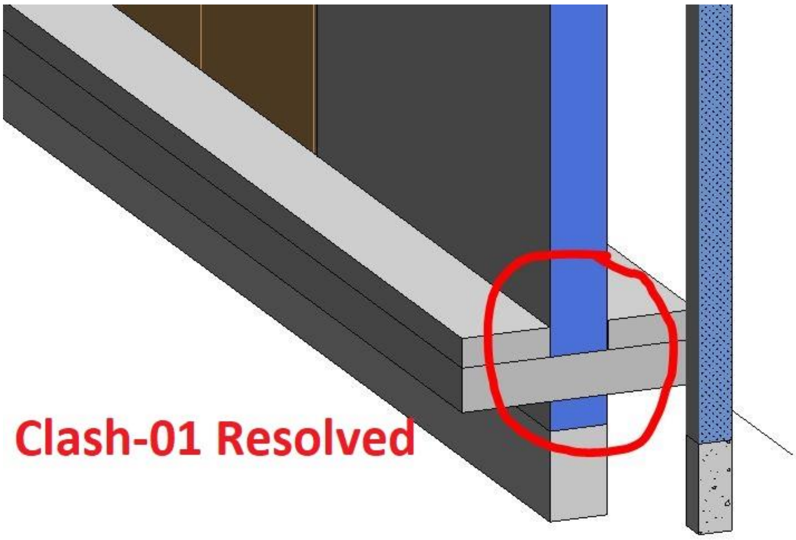
This is the part of the design which has a clash detected in it. Now we can resolve the clash by altering the design in Revit which will reduce the quantity of the material used in the model.

Below are some of the examples of elements with clashes and the resolution of those clashes.

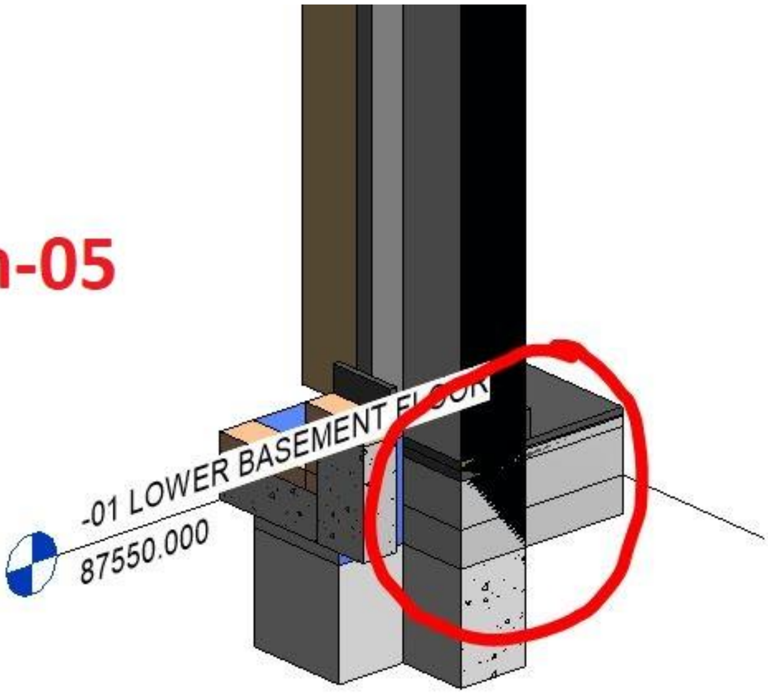
This is the element with clash detected.

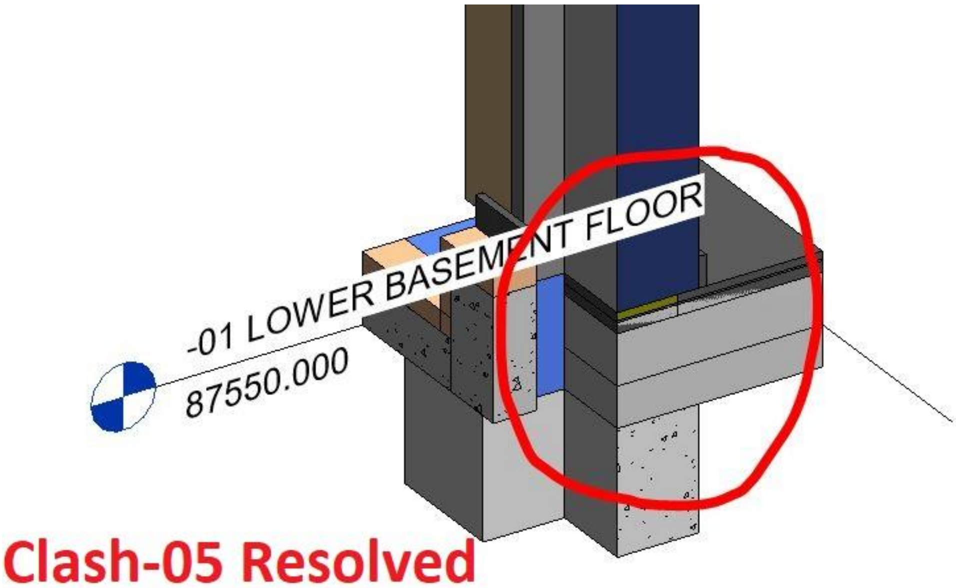


This is the resolved element in which the clash was detected.

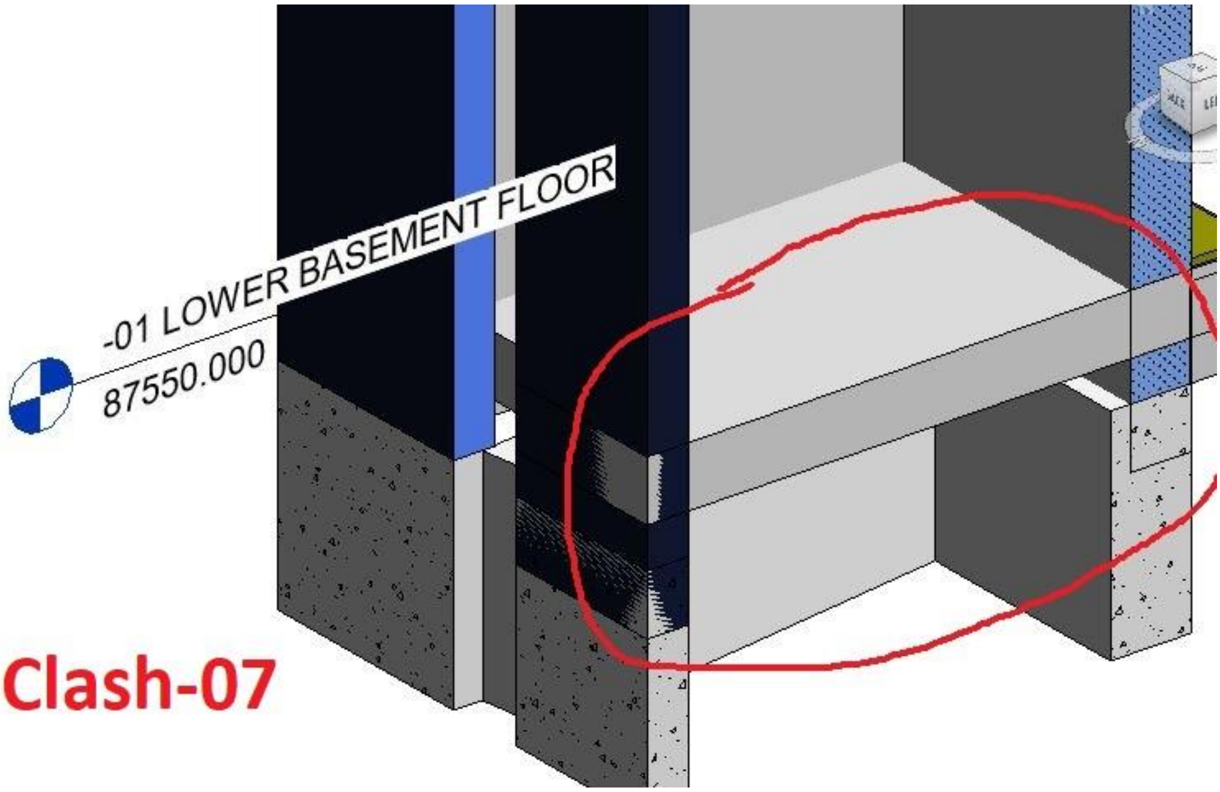


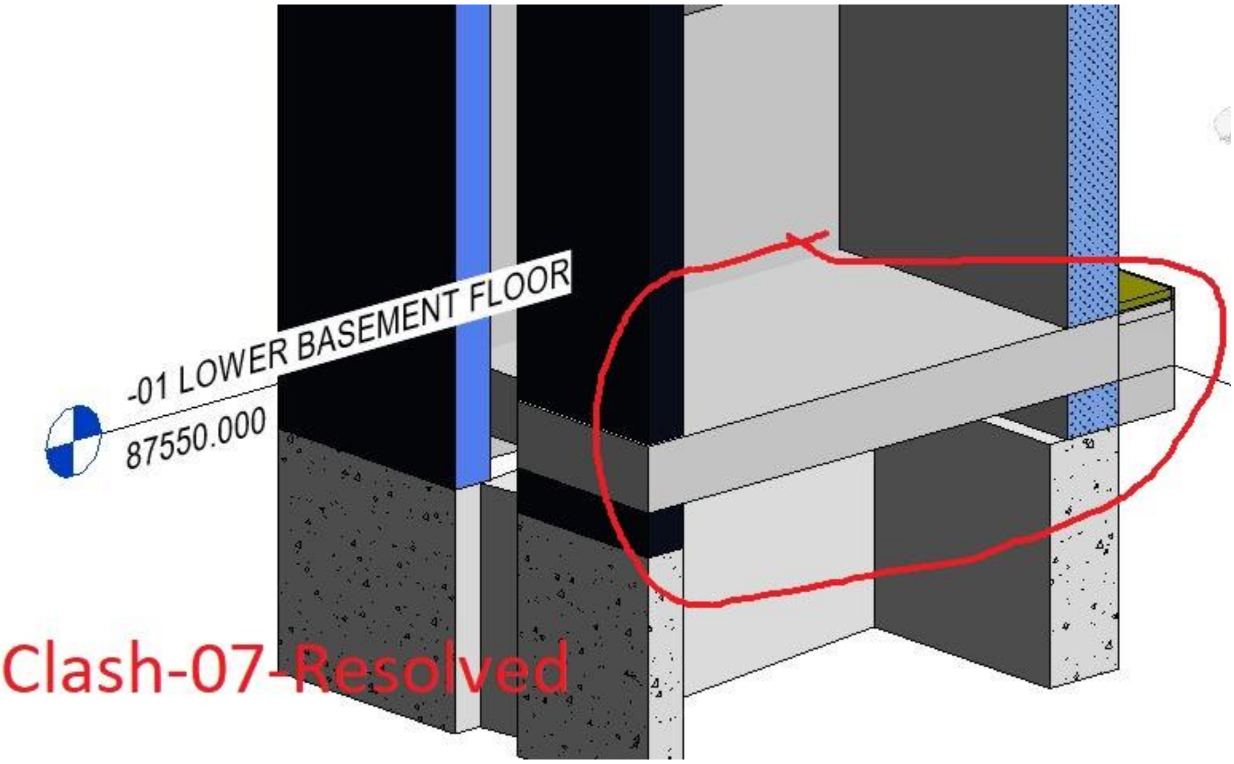
Here is another example of an element with clash and after resolution.





Another Illustration of clash resolution





4.1.9 Revised concrete schedule and quantities calculated.

After resolving the clashes and updating the Revit model accordingly, we revisited the concrete schedule and quantities calculation. The changes made due to clash resolution affected the quantities of concrete and reinforcements. By revising the concrete schedule and quantities, we ensured that the construction plans align with the clash-free design.

Here is the comparison of the quantities of concrete for non-structural walls in the lower and upper basement floors of the 11-storeys residential building.

Concrete quantities with Clashes

00 - 01 WALL SCHEDULE						
FLOOR LEVEL	COUNT	ITEM	AREA	VOLUME	HEIGHT	Price (20000/cubic m)
-01 LOWER BASEMENT FLOOR	7	150THK NON STRUCTURAL WALL	33.05 m^2	5.46 m^3	23.35	109,200
-01 LOWER BASEMENT FLOOR	1	200 THK NON STRUCTURAL WALL	3.85 m^2	0.70 m^3	0	14,000
-01 LOWER BASEMENT FLOOR	36	200THK NON STRUCTURAL WALL	233.49 m^2	48.66 m^3	117.58	978,200
-01 LOWER BASEMENT FLOOR	1	200THK NON STRUCTURAL WALL TYPE2	0.60 m^2	0.02 m^3	3	400
-01 LOWER BASEMENT FLOOR	2	300THK NON STRUCTURAL WALL	5.78 m^2	1.73 m^3	7	34,600
-02 UPPER BASEMENT FLOOR	7	150THK NON STRUCTURAL WALL	28.01 m^2	4.20 m^3	19.69	84,000
-02 UPPER BASEMENT FLOOR	33	200THK NON STRUCTURAL WALL	134.99 m^2	27.00 m^3	93.96	540,000
-02 UPPER BASEMENT FLOOR	1	300THK NON STRUCTURAL WALL	3.48 m^2	1.04 m^3	2.9	20,800
00 GROUND FLOOR	1	200THK NON STRUCTURAL WALL	3.54 m^2	0.71 m^3	2.95	14,200
Grand total: 89	89		446.78 m^2	89.52 m^3	270.43	17,95,400

Concrete quantities after resolution of clashes

00 - 01 WALL SCHEDULE						
FLOOR LEVEL	COUNT	ITEM	AREA	VOLUME	HEIGHT	Price (20000/cubic m)
-01 LOWER BASEMENT FLOOR	7	150THK NON STRUCTURAL WALL	30.91 m^2	4.64 m^3	21.9	92,800
-01 LOWER BASEMENT FLOOR	1	200 THK NON STRUCTURAL WALL	3.85 m^2	0.70 m^3	0	14,000
-01 LOWER BASEMENT FLOOR	36	200THK NON STRUCTURAL WALL	221.45 m^2	44.25 m^3	113.21	885,000
-01 LOWER BASEMENT FLOOR	1	200THK NON STRUCTURAL WALL TYPE2	0.60 m^2	0.02 m^3	3	400
-01 LOWER BASEMENT FLOOR	2	300THK NON STRUCTURAL WALL	5.36 m^2	1.61 m^3	6.65	32,200
-02 UPPER BASEMENT FLOOR	7	150THK NON STRUCTURAL WALL	28.01 m^2	4.20 m^3	19.69	84,000
-02 UPPER BASEMENT FLOOR	33	200THK NON STRUCTURAL WALL	135.80 m^2	27.16 m^3	94.61	543,200
-02 UPPER BASEMENT FLOOR	1	300THK NON STRUCTURAL WALL	3.48 m^2	1.04 m^3	2.9	20,800
00 GROUND FLOOR	1	200THK NON STRUCTURAL WALL	3.54 m^2	0.71 m^3	2.95	14,200
Grand total: 89	89		432.99 m^2	84.33 m^3	264.91	16,86,600

4.1.10 Comparison of concrete quantities

As we can see from the comparison of the figures, the concrete volume quantity with the clashes involved was 89.52$m^{3.}$ After the detection of clashes in Navisworks and then careful resolution of the clashes in Revit, we note that the concrete volume quantity has decreased to 84.33m^3. Which is approximately 6% less than the concrete volume with the clashes. Thus, reducing and minimizing our cost of concrete and in turn, the overall model.

4.2 Summary

Using BIM software Autodesk Revit, a 15-story residential building was created for this project. The structural and architectural models were developed and connected. The non-structural wall concrete schedule was computed and exported in Excel format. The Navisworks clash detection program was used to import the produced Revit model.

Clash detection experiments were run in Navisworks, and the results revealed 57 collisions between architectural and structural elements. The conflict detection reports, which provided thorough information about the confrontations, were generated in Excel format.

The clash detection reports were utilized to make the necessary design revisions and coordinate with other disciplines in order to fix the clashes in Revit. The concrete timeline and amounts were altered after the conflicts were resolved. The adjustments produced a more economically sound model with less concrete by ensuring that the construction plans were in line with the conflict-free design.

In order to improve the design and maximize construction efficiency, the project successfully used BIM-enabled 3D modelling in Revit, conflict detection testing in Navisworks, and clash resolution.

Significant material and expense savings were also obtained through the use of clash detection and resolution systems. A 6% reduction in concrete volume was found when the amounts of concrete before and after conflict resolution were compared. The updated concrete values showed a reduction from 89.52m^3 to 84.33m^3clashes were found in the model and resolved in Revit. In addition to minimizing material consumption, this decrease in concrete volume also helped the construction project's overall costs.

Chapter 5
Conclusion

5.1 Conclusion

In recent years, the construction industry in Pakistan has experienced a remarkable rise, driven by increased infrastructure development and the need for efficient and sustainable building practices. Concurrently, major sectors in the country have recognized the benefits of automating their workflow to achieve greater productivity and improved project outcomes. In this context, Building Information Modelling (BIM) has emerged as a game-changer, offering enhanced collaboration, streamlined data management, and improved project coordination throughout the construction lifecycle.

However, despite the growing interest in BIM, the specific cost implications of implementing BIM-enabled designs have not been extensively studied, particularly from an industry perspective. This final year project has aimed to fill this crucial knowledge gap by conducting a comprehensive cost benefit evaluation of BIM-enabled designs in the construction industry in Pakistan.

Through a systematic research methodology, including an in-depth literature review, detailed case studies, and data collection from industry professionals and project stakeholders, this study has provided valuable insights into the economic advantages and challenges associated with implementing BIM-enabled designs. The research findings have been instrumental in quantifying the potential cost savings, improved project efficiency, and enhanced decision-making processes that can be achieved through BIM adoption.

One of the key outcomes of this study is the identification of significant cost savings throughout the project lifecycle. BIM-enabled designs have been shown to reduce rework, minimize construction errors, and improve project coordination, resulting in reduced project costs. The efficient collaboration facilitated by BIM allows for better coordination among project teams, leading to optimized construction schedules, reduced material waste, and improved resource allocation. Additionally, the streamlined data management provided by BIM enhances communication and information sharing, reducing delays and costly errors during construction. Moreover, the research has highlighted the long-term cost benefits of BIM implementation in terms of operation and maintenance. BIM-enabled designs offer accurate and up-to-date information about building components, systems, and assets, enabling more efficient facility management and maintenance. This leads to reduced downtime, improved energy efficiency, and lower operational costs over the building's lifespan.

Furthermore, the study has underscored the potential for increased project efficiency through BIM adoption. The collaborative nature of BIM fosters effective communication and coordination among project stakeholders, leading to improved project outcomes and reduced construction time. BIM allows for early detection and resolution of clashes or conflicts between different building systems, reducing costly rework and ensuring smoother project progress. The ability to visualize and simulate the construction process in a virtual environment also enables better decision-making, mitigating risks and optimizing project performance.

By highlighting these cost savings, increased project efficiency, and improved decision-making processes, this research project aims to promote the wider adoption of BIM among industry practitioners, project owners, and regulatory bodies in Pakistan. The insights provided by this study serve as a compelling case for stakeholders to consider the economic advantages of implementing BIM-enabled designs.

The significance of this research extends beyond its immediate findings. By bridging the existing knowledge gap regarding the cost benefits of BIM, this project has contributed to the broader understanding of the economic implications of digital technologies in the construction industry. It has paved the way for future research and advancements in BIM implementation, encouraging the industry to embrace digital transformation initiatives.

Ultimately, the outcomes of this study have the potential to drive industry-wide change in the construction sector in Pakistan. The comprehensive evaluation of cost benefits has armed stakeholders with the necessary knowledge to make informed decisions about BIM adoption. Project owners can leverage these insights to evaluate the financial viability of BIM-enabled designs and make strategic choices to optimize project outcomes. Industry professionals can recognize the economic advantages and adjust their practices to incorporate BIM, enhancing their competitiveness and positioning themselves as leaders in the digital construction space. Additionally, regulatory bodies can consider the findings to inform policy decisions and support the wider implementation of BIM across the industry.

5.2 Limitations

Cost Benefit Evaluation of BIM (Building Information Modeling) enabled designs offers numerous advantages for construction projects. However, it also has certain limitations that need to be considered. Here are some limitations of Cost Benefit Evaluation of BIM Enabled Designs:

Complexity of implementation: BIM implementation requires significant resources, including hardware, software, and skilled personnel. The initial investment and learning curve can be quite high, especially for smaller firms or projects with limited budgets. This complexity can deter some organizations from adopting BIM and conducting comprehensive cost benefit evaluations.

Accuracy of data: BIM relies on accurate and up-to-date data to produce reliable cost benefit evaluations. However, the quality and accuracy of the input data can vary depending on the information sources and the level of detail captured during the modeling process. Inaccurate or incomplete data can lead to unreliable cost estimates and skewed cost benefit analyses.

Subjectivity in quantifying benefits: BIM offers various benefits throughout the project lifecycle, such as improved collaboration, clash detection, and reduced rework. Quantifying these benefits in monetary terms can be challenging and subjective. Different stakeholders may have varying opinions on the value and importance of these benefits, making it difficult to achieve consensus in cost benefit evaluations.

Limited data availability: To conduct a comprehensive cost benefit evaluation, historical project data is often required. However, the availability of relevant and reliable data can be limited, particularly for projects that are unique or innovative in nature. This limitation can impact the accuracy and completeness of the cost benefit analysis.

Future uncertainty and long-term effects: Cost benefit evaluations typically focus on the short to medium term. It can be challenging to predict the long-term effects and benefits of BIM-enabled designs accurately. Factors such as evolving technology, changing project requirements, and market conditions can influence the benefits realized over time, making long-term projections less reliable.

External factors: BIM implementation and its benefits can be influenced by external factors beyond the control of the project team. These factors may include changes in regulations, economic conditions, and client requirements. Evaluating the cost and benefit impacts of such external factors accurately can be difficult, potentially affecting the reliability of the cost benefit analysis.

Lack of standardized metrics: Standardized metrics for quantifying and evaluating the benefits of BIM-enabled designs are still evolving. The absence of universally accepted metrics can lead to inconsistency in cost benefit evaluations across different projects and organizations. This lack of standardization makes it challenging to compare and benchmark the cost benefit outcomes effectively.

It is important to consider these limitations and conduct a thorough and critical evaluation when using BIM for cost benefit analysis. The expertise of professionals experienced in BIM implementation and cost estimating can help address some of these limitations and enhance the accuracy and reliability of the evaluations.

REFERENCES

(Design Changes in Construction Projects – Causes and Impact on the Cost, July 2019 C.E.J 5(7):1647-1655)

Baelish, K., and Sullivan, K., 2012. How to measure the bene- fits of BIM — a case study approach. Automation in con-striction, 24, 149–159.

Chan, D.W.M., Oleum, T.O., and Ho, A.M.L., 2019. Perceived benefits of and barriers to Building Information Modelling (BIM) implementation in construction: The case of Hong Kong. Journal of Building Engineering, 25, 100764.

Farooq, Umar & Rehman, Sardar & Rehman, Ur & Faisal, Arab& Jameel, Mohammed & Aslam, Fahad&AL Yousef, Rayed. (2020). Investigating BIM Implementation Barriers and Issues in Pakistan Using ISM Approach. Applied Sciences. 10. 7250. 10.3390/app10207250.

https://naphda.gov.pk/naphda.gov.pk/docs/Economy%20Survey%20-%20Real%20Estate%20Highlights.pdf

Leyte, F., et al., 2011. Analysis of modelling effort and impact of different levels of detail in building information models. Automation in construction, 20 (5), 601–609.

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Shiro Zhan, Sara &Sapsagos, Samad & Edwards, David & Li, Heng & Wang, Chen. (2020). BIM compatibility and its differentiation with interoperability challenges as an innovation factor. Automation in Construction. 112. 103086. 10.1016/j.autcon.2020.103086.

Tomalin, I.D. and Ghulam, S., 2012. Root causes of clashes in building information models. In: Proceedings for the 20th Annual Conference of the International Group for Lean Construction. IGLC San Diego, LA, 10.