Challenges and Barriers to Implementing Building Information Modeling (BIM) in the Architectural Practice in Bangladesh

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Abstract: Bangladesh has experienced rapid urbanization, population growth, and increasing demand for infrastructure development over the past few decades. As urbanization accelerates, the demand for residential, commercial, and public infrastructure projects has surged, necessitating the adoption of modern technological solutions to improve efficiency, reduce costs, and ensure sustainability.

The architectural, engineering, and construction (AEC) industry has undergone rapid digital transformation, with Building Information Modeling (BIM) emerging as a pivotal innovation that streamlines design, construction, and facility management. BIM enables professionals to create, analyze, and manage comprehensive digital representations of buildings, improving efficiency, reducing errors, and facilitating collaboration across multiple stakeholders (Olawumi & Chan, 2019). Unlike traditional 2D drafting, BIM integrates 3D visualization, real-time data management, and lifecycle tracking, making it an essential tool for modern architecture and construction practices.

Despite the immense potential benefits of BIM, its adoption in Bangladesh remains in its infancy. Research indicates that less than 10% of construction projects in Bangladesh utilize BIM, a stark contrast to adoption rates in developed nations such as the USA (73%) and the UK (71%) (Association of Architects Bangladesh, 2023). The slow adoption of BIM is attributed to various factors, including a lack of awareness, limited technical expertise, high implementation costs, and the absence of regulatory mandates. Additionally, most architectural firms in Bangladesh continue to rely on traditional 2D drafting methods, which limit efficiency and hinder real-time collaboration among stakeholders.

Keywords: *BIM Adoption, AEC Industry, Real-Time Data Management, Construction Practice.*

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I. INTRODUCTION

In developed nations such as the United States, the United Kingdom, Canada, and Australia, BIM adoption has been strongly driven by government mandates, regulatory standards, and industry-wide initiatives (Eadie et al., 2013). Research highlights that BIM significantly reduces project delays, lowers costs, and enhances sustainability by improving energy efficiency and reducing material waste (Turner & Bruzzone, 2018). The United Kingdom, for example, has enforced mandatory BIM Level 2 compliance for all public sector projects since 2016, resulting in widespread industry adoption. In contrast, developing nations, including Bangladesh, struggle with BIM implementation, facing persistent challenges such as high costs, lack of trained professionals, resistance to change, and inadequate policy frameworks (Al-Amin, 2021). These factors contribute to slow adoption rates, limiting the potential benefits that BIM can bring to the architectural sector in Bangladesh.

Government mandates, industry standards, and technological advancements have largely driven the adoption of BIM in developed countries. For instance, the United Kingdom's BIM Level 2 mandate for all public sector projects in 2016 significantly accelerated adoption rates, increasing industry-wide efficiency and reducing costs (UK Government, 2016). Similarly, the United States General Services Administration (GSA) mandated BIM for federal projects as early as 2007, establishing a strong foundation for widespread implementation (GSA, 2007). Canada, Australia, and various European countries have followed similar paths, integrating BIM into construction

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workflows through national policies, training programs, and software standardization.

Despite these successes, BIM implementation in developed countries is not without challenges. Issues such as interoperability between different BIM software platforms, resistance to process adaptation, and the need for continuous training remain significant concerns (Santos et al., 2017). However, the presence of strong governmental support, research institutions, and industry collaborations has helped mitigate these challenges and sustain BIM adoption in these regions.

Moreover, developing countries face distinct challenges in adopting BIM, often related to limited infrastructure, financial constraints, and skill shortages (Al-Amin, 2021). Key barriers identified in countries like Pakistan, Malaysia, and India include:

- Lack of BIM awareness and training programs.
- High software and hardware costs.
- Resistance to change from traditional CAD workflows.
- Limited government mandates and industry standards.
- Insufficient collaboration among stakeholders.

II. METHODOLOGY

A. *Mixed-Methods Approach*

This study employs a mixed-methods approach, combining quantitative and qualitative methods to explore the factors influencing the adoption and extent of use of Building Information Modeling (BIM) among architectural firms in Bangladesh. By integrating both approaches, the study provides a comprehensive understanding of the research problem, capturing numerical relationships while also delving into nuanced perspectives.

B. *Benefits of the Mixed-Methods Approach*

- Objectivity and Depth (Pierce, 2023): The quantitative analysis provides objective, measurable insights, while qualitative methods add depth and context to the findings.
- Holistic Understanding (Adhikari & Timsina, 2024): Combining both approaches ensures a well-rounded exploration of the research problem.
- Actionable Insights (Zou & Xu, 2023): The integration of statistical findings with qualitative narratives supports the development of practical, evidence-based strategies.

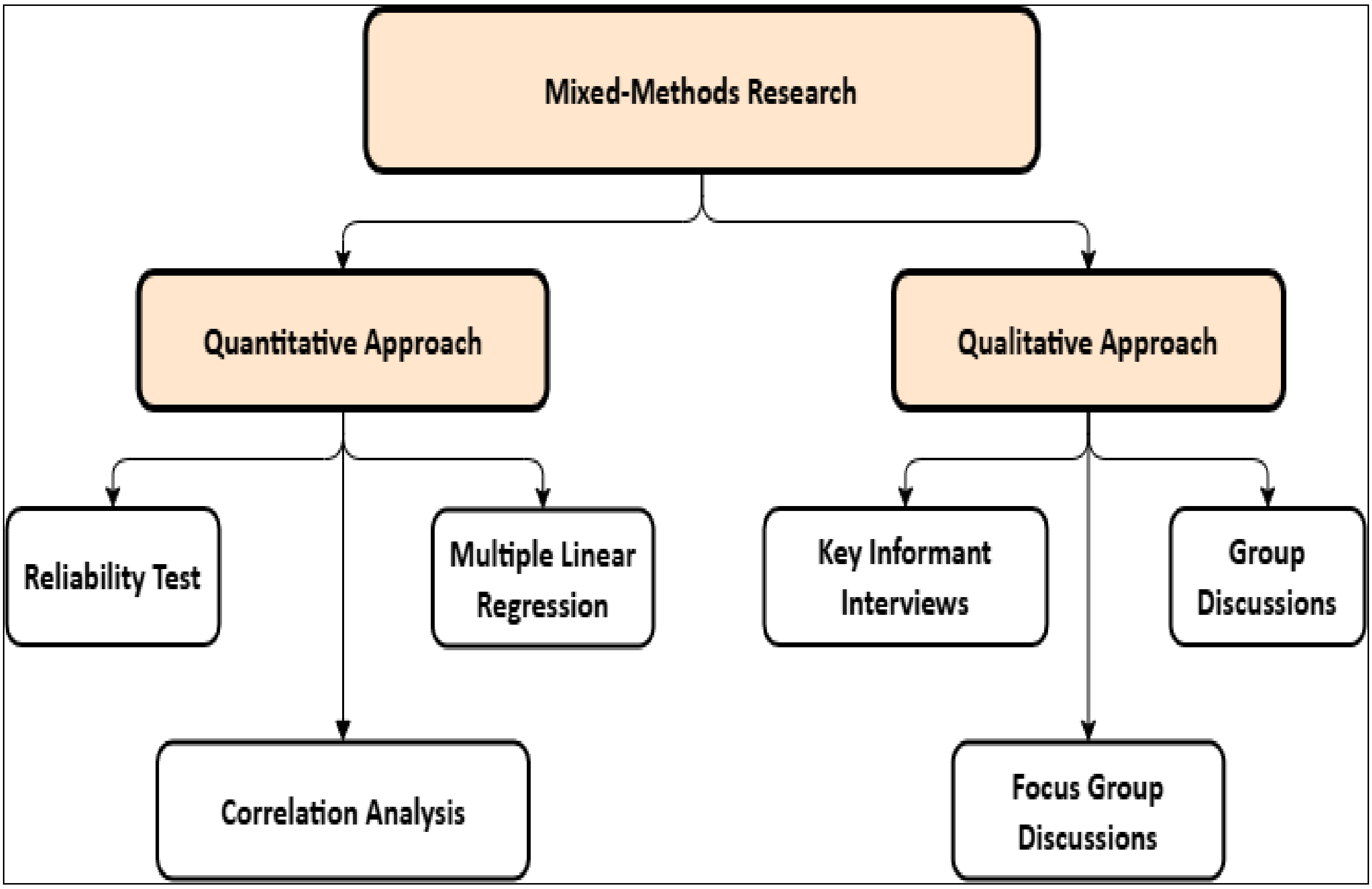

Fig 1: Mixed-Methods Research Design

C. *Alignment with Research Questions*

The mixed-methods approach ensures that the study comprehensively addresses the research questions. While the quantitative survey data identifies and quantifies the factors influencing BIM adoption, the qualitative methods provide a richer, context-driven understanding of the barriers and drivers.

➢ *The Methodology is Divided into Three Main Segments:*

- Quantitative Research (Statistical analysis and regression modeling)
- Qualitative Research (Interviews and focus group discussions)
- Mixed-Method Integration (Combining quantitative and qualitative findings)

D. Quantitative Approach

The quantitative aspect of the research involves the use of survey data to systematically measure and analyze factors affecting BIM adoption. This approach is appropriate as it allows for objective measurement, the identification of patterns, and the testing of hypotheses (Plugge & Nikou, 2024). By focusing on numerical data, the study ensures reliability and precision in addressing the research questions (Little et al., 2024). Quantitative analysis is particularly suited to the study's aim of evaluating the impact of multiple factors, such as costs, training, and perceived benefits, on BIM usage. This aspect of the research generates evidence-based insights critical for academic and practical applications.

➢ *Reliability Test*

The first step in the quantitative methodology is to assess the reliability of the dataset to ensure the consistency of the measurement tools used. A Cronbach's Alpha test will be performed to determine the internal reliability of the scale items. If the Cronbach's Alpha value is above 0.7, the dataset will be considered reliable for further analysis.

➢ *Correlation Analysis*

Once reliability is confirmed, a correlation analysis will be conducted to examine relationships between variables. Pearson's CC will be used to measure the strength and direction of the relationships. This step will help identify significant associations between independent and dependent variables before proceeding to regression analysis.

➢ *Justification for Statistical Analysis Using Multiple Linear Regression*

Multiple Linear Regression (MLR) is employed as the primary statistical technique to analyze the survey data. This method is particularly suitable for understanding the relationships between the dependent variable, the extent of BIM usage, and the independent variables derived from survey questions (7–26). MLR enables the simultaneous examination of multiple predictors, providing a holistic understanding of their combined and individual effects. The use of MLR is justified for several reasons (Daneshfar et al., 2023):

- Exploring Relationships: It allows the identification of key drivers and barriers influencing BIM adoption.
- Quantifying Impact: Regression coefficients quantify the strength and direction of each predictor's influence.
- Testing Hypotheses: The model supports hypothesis testing, ensuring robust and reliable findings.
- Predictive Insights: MLR provides actionable predictions, aiding firms and policymakers in decision-making.

E. Qualitative Approach

To complement the quantitative analysis, qualitative methods are incorporated to provide deeper insights into the barriers and drivers of BIM adoption. The following qualitative techniques will be used:

➢ *Focus Group Discussions (FGDs)*

FGDs will be conducted with groups of architectural professionals to capture collective views and explore themes that are not easily quantifiable through surveys. These discussions will provide a nuanced understanding of shared challenges, perceptions, and solutions related to BIM implementation. The FGDs will help uncover industry-specific concerns and potential facilitators of BIM adoption.

➢ *Key Informant Interviews (KIIs)*

KIIs will be conducted with experts and decision-makers in the architectural and construction industry. These interviews aim to gain in-depth insights into the strategic, organizational, and technical aspects of BIM adoption. The individualized interview format allows for the exploration of complex ideas, industry-specific dynamics, and policy considerations that influence BIM implementation.

➢ *Group Discussions*

Broader group discussions will involve various stakeholders, including project managers, architects, and software developers, to gather diverse perspectives on BIM usage. These discussions will enable an understanding of collaborative challenges, software integration issues, and project management practices associated with BIM.

F. Mixed-Method Integration (Both Quantitative & Qualitative)

➢ *Data Triangulation*

After completing both quantitative and qualitative analyses, the two datasets will be integrated using **triangulation techniques**. This process ensures that the findings from both methods complement each other, strengthening the validity of the research conclusions.

➢ *Thematic Analysis & Statistical Interpretation*

- The qualitative data (from FGDs, KIIs, and group discussions) will undergo thematic analysis to identify key themes, patterns, and industry trends.
- The quantitative data (from regression and correlation analysis) will be statistically interpreted to confirm or challenge qualitative findings.

➢ *Final Synthesis & Interpretation*

The final research conclusions will be drawn from the integration of both approaches. The **key advantages of using both methods together** include:

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- Capturing both numerical trends and subjective industry insights
- Understanding why certain trends appear in the quantitative analysis
- Providing practical recommendations based on both statistical evidence and expert opinions.

G. Survey Development

The survey aimed to explore the awareness, usage, and perceptions of Building Information Modeling (BIM) among architects in Bangladesh. It was designed as an online questionnaire with structured questions that covered various aspects of BIM adoption. The questions assessed the professional background of the respondents, their membership status with the Institute of Architects Bangladesh (IAB), and their awareness and usage of BIM. Additionally, Likert-scale items were included to capture perceptions regarding BIM's cost, efficiency, learning curve, and overall benefits. The format ensured clarity and ease of response to encourage completion.

To validate the survey instrument, a pilot test was conducted with a small group of IAB-licensed architects. Feedback from the pilot test helped refine ambiguous questions and ensure that the survey was intuitive and relevant. Reliability checks, such as analyzing Cronbach's Alpha for the Likert-scale items, ensured that the survey questions consistently captured the intended information.

H. Data Collection

The data for this study were collected using an online survey distributed to architects licensed by the Institute of Architects Bangladesh (IAB), encompassing both associate and full members. The survey was shared through multiple channels, including email, phone calls, WhatsApp, Messenger, and other online platforms, to ensure maximum outreach and convenience for respondents.

➢ *Collection Process*

- Survey Distribution: A TL of 500 architects was contacted. Personalized emails and messages containing the survey link were sent to encourage participation. Messaging apps like WhatsApp and Messenger were particularly effective in reaching participants quickly and directly.
- Follow-Ups: Reminders were sent periodically to non-respondents to improve the response rate. This included follow-up calls and additional messages on digital platforms.
- Response Management: Completed responses were collected automatically via the survey platform, ensuring data security and ease of access for analysis.

➢ *Challenges Faced*

- *Low Response Rate:*

Despite contacting 500 architects, only 55 responses were collected, yielding an 11% response rate. The primary challenges contributing to this low rate included:

✓ Limited time availability of professionals to complete the survey.
✓ Potential lack of interest or perceived relevance of the survey topic.

- *Diverse Communication Preferences:*

While some participants preferred email communication, others responded better through instant messaging platforms. Managing these preferences required additional effort to ensure effective outreach.

➢ *Survey Response Management*

- *To Address these Challenges, the Following Measures were Taken:*

- Flexible Distribution Channels: Providing multiple ways to access the survey ensured broader participation, even from architects who preferred different modes of communication.
- Data Cleaning: The responses were reviewed for completeness and consistency, ensuring only valid entries were included in the analysis.
- Confidentiality: Respondents were assured of their anonymity, encouraging honest and accurate responses.

III. IMPACT OF BIM IN ARCHITECTURAL FIRMS IN BANGLADESH

Building Information Modeling (BIM) is transforming the architectural industry by enhancing design efficiency, collaboration, and project management. However, its adoption in Bangladesh remains inconsistent, with varying levels of integration across architectural firms. This study investigates BIM adoption trends among architects in Bangladesh by analyzing membership distribution, awareness, experience, and project-level engagement. The research aims to understand the barriers and drivers of BIM implementation, focusing on how professional experience, firm policies, and industry regulations influence its widespread use. Through survey data and crosstabulation analyses, this study provides insights into who is adopting BIM, how extensively it is being used, and what factors contribute to or hinder its firm-wide implementation. The findings will help policymakers, industry leaders, and firms develop targeted strategies for accelerating BIM adoption and integrating it as a standard practice in Bangladesh’s architectural sector.

IV. BIM ADOPTION IN BANGLADESH’S ARCHITECTURAL INDUSTRY

The statistical analysis of Building Information Modeling (BIM) adoption in Bangladesh’s architectural sector reveals key insights into awareness levels, adoption barriers, industry perceptions, and firm-wide implementation trends. The dataset includes ordinal-scale survey responses covering BIM cost, skill requirements, policy impact, adoption rates, and firm-wide integration levels. The analysis focuses on measures such as mean, median, mode, standard deviation, variance, skewness, and

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kurtosis, providing a comprehensive understanding of the factors influencing BIM implementation.

One of the biggest challenges to BIM adoption appears to be its high cost and complexity. Many respondents agree that BIM software is expensive (Mean = 3.38) and has a complex licensing system (Mean = 3.33). Additionally, the learning curve for BIM is steep (Mean = 3.83), and professional training is essential for effective implementation (Mean = 4.10). These factors highlight the need for financial incentives, structured training programs, and industry-wide policies to ease adoption barriers.

While awareness of BIM benefits is relatively high, firm-wide adoption remains inconsistent. The study confirms that 100% of respondents have heard of BIM and used BIM software, indicating that a lack of awareness is not a significant obstacle. However, the extent to which firms integrate BIM into architectural processes remains low, with a firm-wide integration mean of 41.36% and mode of 20%, suggesting that most firms use BIM at only a partial level rather than as a standard practice. This indicates that while BIM is increasingly recognized as an industry trend, it has yet to become fully embedded in architectural workflows.

Despite these challenges, BIM is widely perceived as highly beneficial to architectural practice. The data shows strong agreement that BIM helps reduce project timelines and improve efficiency (Mean = 4.35), minimizes errors and rework (Mean = 4.17), enhances cost estimation and budgeting (Mean = 4.29), and improves collaboration among project stakeholders (Mean = 4.08). Additionally, BIM is recognized as a valuable tool for enhancing design visualization (Mean = 4.08) and achieving sustainability goals. These findings suggest that once firms overcome financial and technical barriers, BIM adoption is likely to increase significantly.

Resistance to BIM adoption remains partially influenced by traditional preferences. The survey indicates that some architects still favor 2D drafting software like AutoCAD (Mean = 3.37), and there is skepticism regarding BIM readability compared to CAD (Mean = 2.90). This suggests that a segment of the industry is hesitant to transition fully to BIM, potentially due to familiarity with traditional methods and concerns about software usability. Overcoming this resistance will require stronger advocacy for BIM's long-term benefits, more intuitive software interfaces, and additional training for professionals.

A significant policy-related finding is that respondents strongly support the implementation of national BIM standards (Mean = 4.00) and BIM policy programs (Mean = 3.90) as key drivers of adoption. This indicates that government intervention and industry regulations could accelerate BIM adoption by providing standardization, incentives, and mandatory integration guidelines.

Furthermore, the data highlights a direct link between experience and BIM project involvement. Respondents with more years of BIM experience tend to complete more projects using BIM, but this does not always translate into higher firm-wide integration. Some firms with experienced BIM users still operate at low integration levels, suggesting that organizational barriers, financial constraints, or management resistance may be limiting full-scale adoption.

A. Reliability Analysis of BIM-Related Survey Items

Reliability analysis assesses how consistently a set of survey questions measures the same underlying construct. The Cronbach's Alpha test is widely used for this purpose, helping determine whether the selected questions are internally consistent and reliable. Cronbach's alpha is a way of assessing reliability by comparing the amount of shared variance, or covariance, among the items making up an instrument to the amount of overall variance (Cronbach, 1951).

Table 1: Cronbach's Alpha (Cho, 2016)

Cronbach's Alpha	Reliability Level
≥ 0.9	Excellent
0.8 – 0.9	Good
0.7 – 0.8	Acceptable
0.6 – 0.7	Questionable
< 0.6	Poor

For this study, the survey items explore BIM adoption, barriers, benefits, and policy impact in Bangladesh's architectural industry. The reliability test evaluates if respondents answered consistently across these topics.

Table 2: Reliability Analysis: Cronbach's Alpha

Reliability Statistics		
Cronbach's Alpha	**Cronbach's Alpha Based on Standardized Items**	**N of Items**
0.694	0.753	22

Cronbach's Alpha is a statistical measure used to assess the internal consistency (reliability) of a survey or test. It determines whether the items in a questionnaire measure the same underlying construct.

- Cronbach's Alpha = 0.694 (Based on 22 Items)
- Standardized Alpha = 0.753

B. Interpretation

➢ *Moderate Reliability (0.694)*

- A Cronbach's Alpha of 0.694 suggests moderate reliability, meaning the survey items are somewhat consistent in measuring a related concept, but there are some inconsistencies in the responses.
- Typically, a reliability score above 0.7 is considered acceptable, and 0.8+ is considered good.

➢ *Standardized Alpha (0.753) is Higher*

- The higher standardized alpha (0.753) means that if all items were adjusted to a standard scale, the internal consistency would improve.

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- This suggests that differences in how items are structured or rated may be causing variation in responses.

C. Reliability Analysis of BIM-Related Survey Items

The Item Statistics Table presents the mean, standard deviation, and sample size (N = 43) for various survey items related to BIM (Building Information Modeling) adoption in architectural practice. The results provide insights into architects' perceptions of BIM's benefits, challenges, and industry adoption trends.

The Mean values indicate the average level of agreement with each statement (on a Likert scale), while the Standard Deviation (SD) reflects the level of variation in responses.

Table 3: The Table Presents Mean, Standard Deviation and Sample Size (N = 43) for Each Survey Item.

Item Statistics			
	Mean	**Std. Deviation**	**N**
1. For approximately how many years have you used BIM solutions?	2.92	2.699	43
2. How many projects have you completed or been part of the process by using BIM?	3.72	4.194	43
3. BIM software demands an initial high cost and its costly implementation process.	3.37	.976	43
4. BIM demands highly professional skills and in-depth training to complete a project.	4.07	.799	43
5. Most of the architectural firms are not aware of the benefits of BIM.	3.67	1.017	43
6. Clients demand BIM-oriented drawings or data in the design phase as well as the construction phase	2.86	1.037	43
7. Most of the BIM software has a complex licensing system	3.33	.969	43
8. CAD drawings are more readable than BIM drawings	3.00	1.134	43
9. Implementation of National BIM standards can increase the adoption of BIM in Bangladesh	4.02	.771	43
10. Traditional 2D software (like AUTOCAD) is more preferable than the nD based BIM software in Architectural firms.	3.33	1.248	43
11. Associate architects and professionals are 1st used with the BIM process	4.05	.754	43
12. National BIM policy program & amp; Guidelines will increase the adoption of BIM in Bangladesh	3.88	.931	43
13. BIM helps reduce project timelines and improve overall efficiency.	4.33	.778	43
14. The integration of BIM with other construction management software is seamless and user-friendly.	3.53	1.008	43
15. BIM provides a significant advantage in cost estimation and budgeting compared to traditional methods.	4.23	.782	43
16. The use of BIM increases collaboration and communication among project stakeholders.	3.86	.889	43
17. BIM is primarily beneficial only for large-scale projects.	3.05	1.154	43
18. Architectural firms in Bangladesh are increasingly adopting BIM for competitive advantage.	3.33	.969	43
19. BIM is essential for achieving sustainability goals in construction projects.	3.74	.848	43
20. The learning curve for BIM software is steep and requires significant time investment.	3.81	.982	43
21. BIM helps in minimizing errors and rework in construction projects.	4.09	.750	43
22. The use of BIM enhances the ability to visualize complex designs and concepts.	4.16	.721	43

➢ *High Mean Scores (≥4.0): Strong Agreement*

- *Respondents Highly Agreed with:*

✓ BIM requires professional skills and training (4.07)
✓ National BIM policy can increase adaptation (4.02)
✓ BIM helps reduce project timelines (4.33)
✓ BIM improves cost estimation (4.23)
✓ BIM enhances visualization of designs (4.16)

These statements received the highest levels of agreement, suggesting that industry professionals recognize BIM's potential benefits in improving efficiency, accuracy, and cost management. Policy intervention and training programs could further support adoption.

➢ *Moderate Mean Scores (3.0 – 3.9): Neutral Opinions*

- *Responses were More Divided on:*

✓ High cost of BIM software (3.37)
✓ BIM software licensing complexity (3.33)
✓ Clients demanding BIM in projects (2.86)
✓ Traditional 2D software is is being preferred over BIM (3.33)
✓ BIM adoption trends in Bangladesh (3.33)

These responses indicate uncertainty or division among architects regarding financial, technical, and client-side adoption barriers. The lower score for client demand (2.86) suggests that BIM adoption is still driven more by industry push than by market demand.

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- *Low Mean Scores (<3.0): Disagreement*

- *Only a Few Items Scored Low, Indicating Less Support:*

✓ Clients do not strongly demand BIM integration (2.86)
✓ BIM primarily benefits large-scale projects (3.05)

The low score for client demand (2.86) suggests that BIM is not yet a universal requirement in architectural projects. The score for large-scale projects (3.05) implies that BIM is not exclusive to large projects, indicating potential for broader adoption in smaller-scale projects.

D. Reliability Considerations

- The standard deviations (SD) range from 0.721 to 4.194, meaning some items have higher variability than others.
- High SD values (e.g., "Number of projects completed" = 4.194) indicate that responses are highly spread out, possibly due to differences in BIM exposure across firms.
- Items with higher agreement (low SD) contribute positively to reliability, while highly variable responses may reduce internal consistency.

E. Analyzing BIM Adoption: Key Correlations and Influencing Factors

Building Information Modeling (BIM) has become an essential tool in modern architectural and construction practices, offering benefits such as improved project efficiency, cost estimation accuracy, and enhanced collaboration. However, its adoption varies widely across firms, influenced by factors such as financial constraints, professional training, client demands, and regulatory support.

This study examines the key correlations affecting BIM adoption, using Spearman's Rank Correlation to identify significant relationships among industry perceptions, training requirements, cost concerns, and policy influence. The analysis provides insights into the barriers and drivers of BIM integration within architectural firms, particularly in Bangladesh. The findings reveal that while BIM training and policy support positively impact adoption, resistance persists due to high implementation costs and a preference for traditional 2D software. By understanding these relationships, industry stakeholders can develop targeted strategies to accelerate BIM adoption and enhance its long-term benefits.

Spearman's Rank Correlation (denoted as Spearman's rho, ρ) is a non-parametric measure used to assess the strength and direction of the monotonic relationship between two ordinal or continuous variables. Unlike Pearson's correlation, which assumes a linear relationship and normal distribution, Spearman's correlation is suitable for ordinal data and does not require a normal distribution (Spearman, 1904).

- *Key Characteristics of Spearman's Rank Correlation:*

- Monotonic Relationship: Measures whether an increase in one variable corresponds to an increase (or decrease) in another, without assuming a linear relationship.
- Non-Parametric: Does not assume normality in data distribution, making it ideal for ordinal and rank-based data.
- Correlation Coefficient (ρ) Range:

✓ +1 → Perfect positive monotonic relationship
✓ 0 → No correlation
✓ -1 → Perfect negative monotonic relationship

- Significance Test: The p-value determines statistical significance. A lower p-value (typically <0.05) indicates a significant correlation.

F. Spearman's Rank Correlation Analysis of BIM Adoption Factors

This study explores the relationships between various factors influencing the adoption of Building Information Modeling (BIM) in architectural firms. Using Spearman's Rank Correlation Coefficient (ρ), we assess the strength and direction of associations between ordinal variables, such as cost, training, software preferences, and project efficiency. This analysis helps identify key barriers and drivers affecting BIM integration in architectural processes.

Table1 4: Spearman's Rank Correlation

Questions			Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20	Q21	Q22	Q23	Q24	Q25	Q26	Q6
Spearman's rho	Q1	CC	1.000	.194	.162	.080	.144	.271	-.108	.410**	.094	-.148	-.140	.082	-.001	.061	-.004	.268	-.085	.095	-.062	.178	.003
	Q2	CC	.194	1.000	.294*	.120	.176	-.231	-.049	.135	-.042	.087	.596**	.355*	.504**	.535**	-.169	.175	.112	.175	.572**	.465**	.310*

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	Q3	CC	.162	.294*	1.000	.300*	.214	.137	-.098	.287*	.317*	.226	.140	.131	.186	.060	-.113	.039	.122	.314*	.401**	.095	.161
	Q4	CC	.080	.120	.300*	1.000	-.023	.196	-.028	.139	.053	-.046	.100	.328*	.110	.139	-.147	.136	.165	-.033	.196	.062	.285
	Q5	CC	.144	.176	.214	-.023	1.000	.049	-.224	.228	.031	-.084	-.141	-.109	.048	-.139	-.066	.087	-.325*	.095	.292*	.180	.078
	Q6	CC	.271	-.231	.137	.196	.049	1.000	-.068	.406**	.296*	-.097	-.344*	-.341*	-.150	.062	.436**	.070	-.088	.104	-.158	-.143	-.331*
	Q7	CC	-.108	-.049	-.098	-.028	-.224	-.068	1.000	.187	.089	.583**	.213	.138	.318*	.181	.101	.192	.399**	.237	.122	.180	.019
	Q8	CC	.410**	.135	.287*	.139	.228	.406**	.187	1.000	.239	.085	-.017	-.117	.148	.038	.138	.305*	-.060	.294*	.141	.150	-.123
	Q9	CC	.094	-.042	.317*	.053	.031	.296*	.089	.239	1.000	.088	-.006	-.177	.172	-.105	.019	-.145	-.196	.337*	.036	-.125	-.167
	Q10	CC	-.148	.087	.226	-.046	-.084	-.097	.583**	.085	.088	1.000	.280	.280	.327*	.140	-.024	.045	.342*	.079	.269	.160	.059
	Q11	CC	-.140	.596**	.140	.100	-.141	-.344*	.213	-.017	-.006	.280	1.000	.483**	.664**	.464**	-.374**	.020	.435**	.282	.615**	.485**	.209
	Q12	CC	.082	.355*	.131	.328*	-.109	-.341*	.138	-.117	-.177	.280	.483**	1.000	.418**	.444**	-.261	.009	.393**	-.084	.362*	.229	.333*
	Q13	CC	-.001	.504**	.186	.110	.048	-.150	.318*	.148	.172	.327*	.664**	.418**	1.000	.454**	-.321*	.028	.331*	.413**	.486**	.428**	.125
	Q14	CC	.061	.535**	.060	.139	-.139	.062	.181	.038	-.105	.140	.464**	.444**	.454**	1.000	-.051	-.019	.360*	-.014	.383**	.427**	.238
	Q15	CC	-.004	-.169	-.113	-.147	-.066	.436**	.101	.138	.019	-.024	-.374**	-.261	-.321*	-.051	1.000	.177	-.140	-.058	-.276	-.256	-.513**
	Q16	CC	.268	.175	.039	.136	.087	.070	.192	.305*	-.145	.045	.020	.009	.028	-.019	.177	1.000	.135	.088	.124	.176	.018
	Q17	CC	-.085	.112	.122	.165	-.325*	-.088	.399**	-.060	-.196	.342*	.435**	.393**	.331*	.360*	-.140	.135	1.000	.067	.054	.407**	.321*
	Q18	CC	.095	.175	.314*	-.033	.095	.104	.237	.294*	.337*	.079	.282	-.084	.413**	-.014	-.058	.088	.067	1.000	.356*	.244	-.055

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	Q19	CC	-.062	.572**	.401**	.196	.292*	-.158	.122	.141	.036	.269	.615**	.362*	.486**	.383**	-.276	.124	.054	.356*	1.000	.501**	.135
	Q20	CC	.178	.465**	.095	.062	.180	-.143	.180	.150	-.125	.160	.485**	.229	.428**	.427**	-.256	.176	.407**	.244	.501**	1.000	.387*
	Q21	CC	.003	.310*	.161	.285	.078	-.331*	.019	-.123	-.167	.059	.209	.333*	.125	.238	-.513**	.018	.321*	-.055	.135	.387*	1.000

**Correlation is significant at the 0.05 level (2-tailed). *Correlation is significant at the 0.05 level (2-tailed).

- *Correlation*

- *Strong Positive Correlations (Significant at 0.01 Level)*

These relationships suggest a strong agreement among respondents about BIM benefits and challenges:

- ✓ BIM helps reduce project timelines ↔ BIM provides cost estimation advantages ($\rho = 0.664$, $p < 0.01$):
  - Firms that believe BIM reduces project time also agree it improves cost management.
- ✓ BIM increases collaboration among stakeholders ↔ BIM improves cost estimation ($\rho = 0.454$, $p < 0.01$):
  - Firms adopting BIM for collaboration also recognize its financial benefits.
- ✓ BIM enhances visualization of complex designs ↔ BIM reduces rework and errors ($\rho = 0.501$, $p < 0.01$):
  - Respondents strongly agree that better visualization using BIM helps in reducing construction errors.
- ✓ BIM software requires professional skills ↔ BIM increases collaboration ($\rho = 0.535$, $p < 0.01$):
  - Indicates that professionals who understand BIM see its benefits in team collaboration.
- ✓ Integration of BIM with construction software ↔ BIM helps reduce rework/errors ($\rho = 0.362$, $p < 0.01$):
  - Suggests that software integration is an important factor in reducing mistakes.

- *Moderate Positive Correlations (Significant at 0.05 Level)*

These relationships are statistically significant but weaker, indicating varying opinions:

- ✓ BIM requires high skills & training ↔ BIM improves cost estimation ($\rho = 0.504$, $p < 0.05$):
  - Firms that acknowledge the complexity of BIM also see its financial advantages.
- ✓ Clients demanding BIM data ↔ BIM integration with construction software ($\rho = 0.328$, $p < 0.05$):
  - The demand for BIM-oriented designs is linked to software integration, suggesting clients push firms toward BIM implementation.
- ✓ Traditional 2D software is preferable ↔ BIM requires a high cost ($\rho = 0.410$, $p < 0.05$):
  - Indicates that cost constraints make some firms prefer AutoCAD over BIM software.
- ✓ National BIM standards can increase adoption ↔ BIM improves efficiency ($\rho = 0.342$, $p < 0.05$):
  - Highlights that clear BIM policies would enhance efficiency in construction.
- ✓ The learning curve for BIM is steep ↔ BIM helps reduce errors ($\rho = 0.356$, $p < 0.05$):
  - Suggests that firms that train in BIM recognize its long-term benefits, despite the difficulty of learning it.

- *Negative Correlations (Inverse Relationships)*

- ✓ BIM is only beneficial for large-scale projects ↔ BIM is widely integrated into firms ($\rho = -0.513$, $p < 0.01$):
  - Suggests that BIM is not limited to large projects, contradicting the belief that it is only helpful for big firms.
- ✓ BIM requires high costs ↔ Preference for 2D software (AutoCAD) ($\rho = 0.410$, $p < 0.05$):
  - Indicates that firms avoiding BIM due to costs tend to rely on AutoCAD instead.
- ✓ Implementation of National BIM standards ↔ Licensing complexity of BIM software ($\rho = -0.325$, $p < 0.05$):
  - Implies that policy improvements could reduce licensing complexities for BIM adoption.

Table 52: Spearman’s Rank Correlation Results

Variable	Correlated With	Correlation Coefficient (ρ)	Significance (p-value)
1. High Cost of BIM	Preference for 2D Software (AutoCAD)	**0.410**	**0.004**
2. Professional Skills & Training for BIM	Awareness of BIM Benefits	**0.294**	**0.042**
	BIM Reduces Project Timelines	**0.596**	**0.000**
	BIM Improves Cost Estimation	**0.504**	**0.000**
	BIM Enhances Collaboration	**0.535**	**0.000**
	BIM Minimizes Errors	**0.572**	**0.000**
3. Awareness of BIM Benefits	Client Demand for BIM	**0.300**	**0.040**
	Associate Architects & BIM Familiarity	**0.317**	**0.027**
	BIM Improves Cost Estimation	**0.401**	**0.004**

4. Client Demand for BIM	BIM Integration with Other Software	**0.328**	**0.024**
5. CAD Drawings Readability	Preference for 2D Software (AutoCAD)	**0.406**	**0.004**
6. National BIM Standards Increase Adoption	National BIM Policy Increases Adoption	**0.583**	**0.000**
7. Preference for 2D Software (AutoCAD)	BIM Minimizes Errors	**0.294**	**0.042**
8. BIM Reduces Project Timelines	BIM Improves Cost Estimation	**0.664**	**0.000**
	BIM Enhances Collaboration	**0.464**	**0.001**
9. BIM Improves Cost Estimation	BIM Minimizes Errors	**0.486**	**0.000**
10. BIM Enhances Collaboration	BIM Minimizes Errors	**0.383**	**0.007**
11. BIM for Sustainability Goals	BIM Enhances Visualization	**0.407**	**0.004**
12. BIM Minimizes Errors	BIM Enhances Visualization	**0.501**	**0.000**
BIM Usage Integration (Q6: 0-100 scale)	Professional Skills & Training	**0.310**	**0.046**
	BIM for Large-Scale Projects	**-0.513**	**0.000**

The table presents **Spearman's Rank Correlation Coefficient (ρ)**, which measures the strength and direction of associations between ordinal variables related to **BIM (Building Information Modeling) adoption and integration**. Correlations range from **-1 to 1**, where:

- **Positive values** indicate that as one variable increases, the other tends to increase as well.a
- **Negative values** indicate an inverse relationship where an increase in one variable is associated with a decrease in the other.
- **The closer the value is to ±1, the stronger the relationship** between the variables.

➢ *Key Findings and Their Implications*

- *High Cost of BIM vs. Preference for 2D Software (ρ = 0.410)*

✓ A moderate positive correlation suggests that firms that perceive BIM as costly tend to prefer traditional 2D software (AutoCAD) over BIM.
✓ Implication: Cost concerns are a significant barrier to BIM adoption, leading firms to stick with familiar tools.

- *Professional Skills & Training for BIM*

✓ Awareness of BIM Benefits (ρ = 0.294) → Those who recognize the need for BIM training are also more aware of its benefits.
✓ BIM Reduces Project Timelines (ρ = 0.596) → Strong positive correlation indicates that professionals who acknowledge the need for BIM training also believe it improves project timelines.
✓ BIM Improves Cost Estimation (ρ = 0.504) → Firms investing in BIM training see better cost estimation as a key advantage.
✓ BIM Enhances Collaboration (ρ = 0.535) → A well-trained workforce recognizes BIM's role in fostering collaboration among stakeholders.
✓ BIM Minimizes Errors (ρ = 0.572) → Strong correlation highlights that BIM training is associated with fewer errors and rework in construction projects.
✓ Implication: Training and upskilling are crucial for unlocking BIM's full potential in improving efficiency, cost estimation, and collaboration.

- *Awareness of BIM Benefits*

✓ Client Demand for BIM (ρ = 0.300) → Higher awareness about BIM correlates with more demand from clients for BIM-based designs.
✓ Associate Architects & BIM Familiarity (ρ = 0.317) → Architects who are familiar with BIM are also more aware of its industry benefits.
✓ BIM Improves Cost Estimation (ρ = 0.401) → Awareness of BIM benefits is linked to recognizing its cost-saving advantages.
✓ Implication: Spreading awareness about BIM's efficiency and cost benefits may increase its adoption among firms.

- *Client Demand for BIM vs. BIM Integration with Other Software (ρ = 0.328)*

✓ Clients who demand BIM also expect seamless integration with other construction management tools.
✓ Implication: BIM adoption needs better interoperability with existing software ecosystems.

- *CAD Drawings Readability vs. Preference for 2D Software (ρ = 0.406)*

✓ Professionals who find CAD drawings more readable tend to prefer AutoCAD over BIM.
✓ Implication: The complexity of BIM interfaces compared to traditional CAD tools may be a barrier to adoption.

- *National BIM Standards vs. National BIM Policy (ρ = 0.583)*

✓ A strong correlation suggests that national BIM standards align with policy recommendations.
✓ Implication: A structured national BIM policy could accelerate standardization and adoption in Bangladesh.

- *Preference for 2D Software vs. BIM Minimizing Errors (ρ = 0.294)*

✓ Firms that prefer traditional 2D workflows still recognize that BIM helps reduce errors.
✓ Implication: Adoption barriers are not due to disbelief in BIM's effectiveness but rather comfort with traditional tools.

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- *BIM Efficiency Metrics*

✓ BIM Reduces Timelines vs. Cost Estimation (ρ = 0.664) → Strong correlation suggests firms that see BIM reducing timelines also see its financial benefits.
✓ BIM Enhances Collaboration (ρ = 0.464) → BIM's impact on project collaboration and cost efficiency is well recognized.
✓ BIM Minimizes Errors vs. Cost Estimation (ρ = 0.486) → Firms that value BIM for reducing errors also find it improves budgeting accuracy.
✓ BIM Enhances Collaboration vs. Minimizing Errors (ρ = 0.383) → Well-integrated collaboration reduces errors and rework.

- *BIM for Sustainability Goals vs. Visualization Capabilities (ρ = 0.407)*

✓ A moderate positive correlation suggests that professionals who see BIM as essential for sustainability also recognize its advanced visualization features.
✓ Implication: BIM adoption for sustainability compliance may be driven by its visualization and simulation capabilities.

- *BIM Minimizing Errors vs. Enhancing Visualization (ρ = 0.501)*

✓ Strong correlation indicates that firms using BIM for error reduction also find it useful for improving design visualization.
✓ Implication: BIM's ability to detect errors before construction is a significant advantage.

- *BIM Usage Integration (0-100 Scale)*

✓ Professional Skills & Training (ρ = 0.310) → Firms with BIM training tend to integrate BIM more fully.
✓ BIM for Large-Scale Projects (ρ = -0.513) → Negative correlation suggests that BIM is increasingly used beyond just large projects.

G. A Multiple Regression Analysis in Adopting BIM

Multiple regression is a statistical technique used to predict the value of a dependent variable based on multiple independent variables. It extends simple linear regression by considering multiple factors simultaneously, allowing for a more comprehensive analysis of how different variables contribute to the outcome. The model provides insights into the relative importance of each predictor and helps determine the overall impact of multiple factors on a given outcome. In this study, multiple regression is employed to analyze how BIM-related variables influence the number of projects completed using BIM technology.

➢ *Multiple Linear Regression (MLR)*

Multiple Linear Regression (MLR) is an extension of simple linear regression that allows for the modeling of the relationship between one dependent variable and two or more independent variables. The goal of MLR is to analyze how multiple factors contribute to predicting the outcome and to understand the strength and direction of these relationships.

- *Assumptions of Multiple Linear Regression*

For MLR to be valid, the following assumptions must hold:

✓ Linearity – The relationship between the dependent and independent variables is linear.
✓ Independence – The observations are independent of each other.
✓ Homoscedasticity – The variance of errors is constant across all levels of independent variables.
✓ Normality – The residuals (errors) of the regression should be normally distributed.
✓ No Multicollinearity – Independent variables should not be highly correlated with each other.

- *General Equation for MLR*

The mathematical equation for Multiple Linear Regression is:

$$\mathbf{Y=\beta0+\beta1X1+\beta2X2+\beta3X3+...+\beta nXn+\varepsilon}$$

Where:

✓ YYY = Dependent variable (outcome being predicted)
✓ β0\beta_0β0 = Intercept (value of YYY when all independent variables are zero)
✓ β1,β2,…,βn\beta_1, \beta_2, \dots, \beta_nβ1,β2,…,βn = Regression coefficients (weights assigned to each independent variable)
✓ X1,X2,…,XnX_1, X_2, \dots, X_nX1,X2,…,Xn = Independent variables (predictors)
✓ ε\varepsilonε = Error term (residuals that account for variability not explained by the model)

- *Interpretation of Coefficients in MLR*

✓ **Intercept (β0\beta_0β0)**: The predicted value of YYY when all independent variables are zero.
✓ **Slope Coefficients (β1,β2,…,βn\beta_1, \beta_2, \dots, \beta_nβ1,β2,…,βn)**: The amount by which YYY changes for a one-unit increase in the corresponding independent variable, holding other variables constant.
✓ **Significance (p-values)**: Indicates whether an independent variable has a statistically significant impact on the dependent variable.

➢ *Application in BIM Analysis*

In the context of BIM adoption, MLR can be used to assess how different factors, such as BIM policy implementation, cost, licensing, training, and collaboration, influence the number of projects completed using BIM. The model helps in identifying key predictors of successful BIM adoption and provides insights for policymakers and industry professionals.

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- *Dependent Variable:*

The outcome variable being predicted is "How many projects have you completed or been part of the process by using BIM?"

- *Independent Variables (Predictors):*

Table 63: A Total of 22 Variables were Entered into the Model as Predictors.

1	**BIM usage integration (0-100 scale)**
2	National BIM policy & guidelines
3	Architectural firms adopting BIM
4	Learning curve for BIM software
5	BIM software licensing complexity
6	Client demand for BIM
7	High cost of BIM software
8	BIM familiarity among architects
9	BIM improves collaboration
10	Awareness of BIM benefits
11	BIM is beneficial for large-scale projects
12	Preference for 2d software (AutoCAD)
13	BIM enhances design visualization
14	Professional skills & training for BIM
15	Years of BIM experience
16	BIM integration with other software
17	BIM for sustainability goals
18	BIM reduces project timelines
19	Implementation of national BIM standards
20	BIM improves cost estimation
21	Cad drawings readability
22	BIM minimizes errors & rework

- *Method Used:*

The "Enter" method was applied, meaning all variables were forced into the model simultaneously rather than being selected based on statistical criteria.

H. Assumptions of Multiple Linear Regression (MLR)

➢ *Linearity*

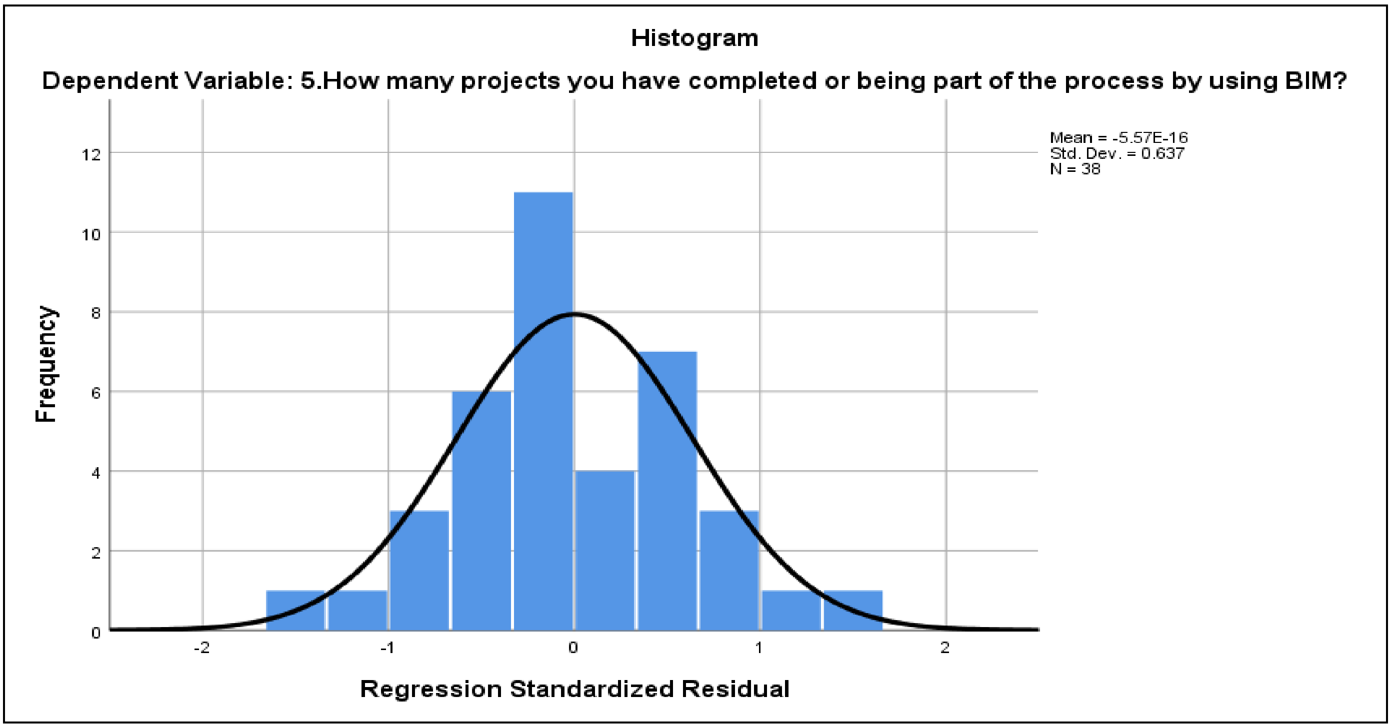

Fig 2: The Histogram Above Represents the Distribution of the Regression Standardized Residuals for the Dependent Variable: "How Many Projects you Have Completed or Been Part of using BIM?"

- *Interpretation*

✓ *Normality Check:*

- The histogram follows an approximate bell-shaped curve, which suggests that the residuals are normally distributed.
- The overlaid normal curve helps assess how well the data fits a normal distribution. The distribution is fairly symmetrical, indicating that the assumption of normality is likely met.

✓ *Mean and Standard Deviation:*

- The mean of the residuals is very close to zero (-5.57E-16), which aligns with a key assumption of regression that residuals should have a mean close to zero.

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- The standard deviation is 0.637, which provides insight into the spread of residuals.

✓ *Sample Size:*

The analysis is based on 38 observations, which is a decent sample size for evaluating the normality of residuals.

Since the residuals appear to be normally distributed, it suggests that the regression model meets one of the key assumptions of linear regression.

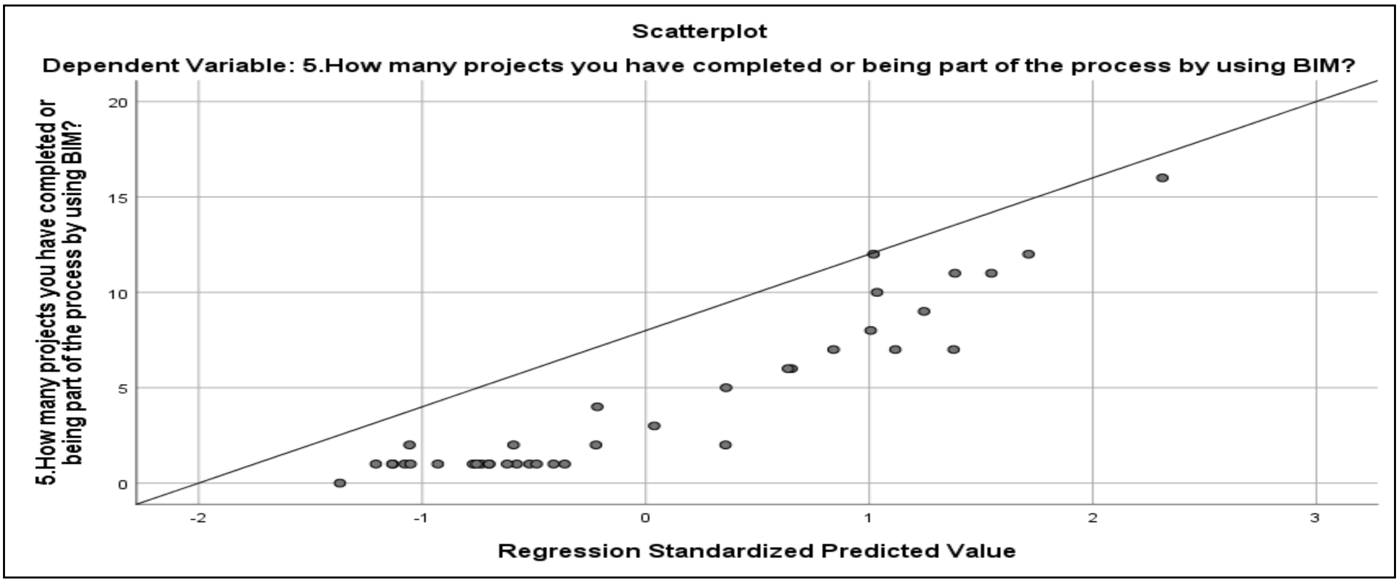

Fig 3: Scatterplot Interpretation: Regression Fit Analysis

The data points generally follow the diagonal line, indicating a strong linear association between predicted and actual values. This suggests that the Multiple Linear Regression (MLR) model fits well.

➢ *Independence of Errors (No Autocorrelation)*

The Durbin-Watson statistic (DW) is used to detect autocorrelation in the residuals of a regression model. Autocorrelation occurs when residuals are not independent, which violates a key assumption of Multiple Linear Regression (MLR).

- ***Durbin-Watson = 2.081***

The DW statistic ranges from 0 to 4 (Durbin & Watson, 1950):

✓ DW ≈ 2 → No autocorrelation (Good)
✓ DW < 1.5 → Positive autocorrelation (Problematic)
✓ DW > 2.5 → Negative autocorrelation (Problematic)

Since 2.081 is close to 2, it suggests no significant autocorrelation, meaning the errors (residuals) are independent.

➢ *Normality of Residuals*

➢ *Homoscedasticity (Constant Variance of Errors)*

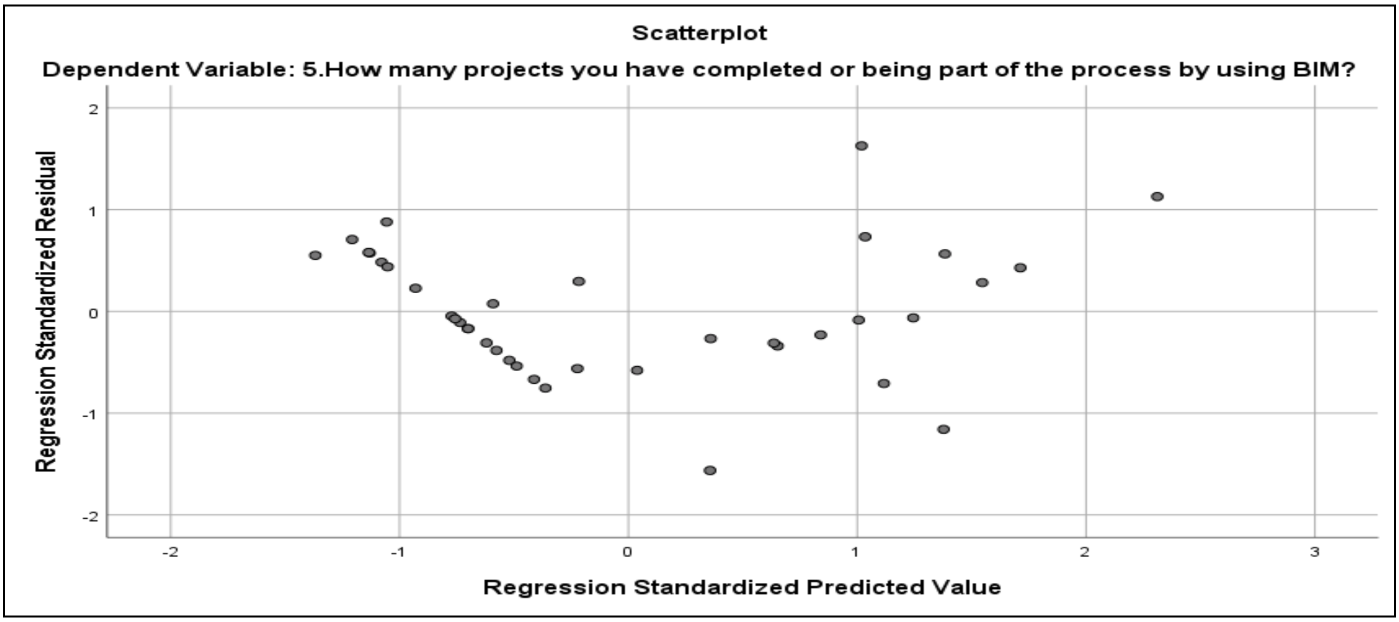

Fig 4: Residual vs. Predicted Scatterplot Interpretation (Homoscedasticity Check)

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This scatterplot plots standardized residuals against standardized predicted values to check for homoscedasticity, which is a key assumption in Multiple Linear Regression (MLR).

Ideally, the points should be randomly scattered without any clear pattern. In this plot, there seems to be some non-random clustering in certain areas, suggesting possible heteroscedasticity (unequal variance in residuals).

Some clustering of points suggests slight heteroscedasticity, meaning error variance might not be perfectly constant. The variance is not increasing or decreasing drastically, so MLR can still be used but may require robust standard errors. No clear curved pattern is present, so the relationship between variables remains linear.

➢ *No Multicollinearity*

Multicollinearity refers to a situation in which two or more independent variables in a multiple regression model are highly correlated. This can distort the estimation of regression coefficients and make interpretation difficult.

- *Tolerance:*

✓ Tolerance = 1 - R^2 (where R^2 is the coefficient of determination for predicting an independent variable using all other independent variables).
✓ Low tolerance (< 0.2 or 0.1) indicates high multicollinearity, meaning a variable is highly predictable from other independent variables.

- *Variance Inflation Factor (VIF):*

✓ VIF = 1 / Tolerance
✓ A VIF > 5 suggests moderate to high multicollinearity.
✓ A VIF > 10 is severe multicollinearity, indicating redundancy among predictors.

Table 74: Tolerance and VIF Table

Collinearity Statistics	
Tolerance	**VIF**
0.267	3.741
0.326	3.064
0.240	4.160
0.217	4.612
0.377	2.654
0.476	2.101
0.208	4.815
0.233	4.297
0.396	2.525
0.555	1.802
0.288	3.473
0.214	4.666
0.254	3.930
0.215	4.658
0.235	4.261
0.374	2.672
0.458	2.186
0.165	6.075
0.261	3.836
0.113	8.814
0.303	3.300
0.283	3.528

From the provided **Tolerance** and **VIF** table, two variables exceeded the critical **VIF threshold (>5)**, indicating severe multicollinearity:

- Variable with Tolerance = 0.165, VIF = 6.075
- Variable with Tolerance = 0.113, VIF = 8.814 (this one is highly problematic)

Since the two variables exceeding the VIF threshold (>5) have been removed to conduct the regression.

I. Multiple Linear Regression (MLR) Model Analysis

Table 85: Model Summary (Post Multicollinearity Adjustment)

Statistic	Value
R	0.923
R^2	0.852
Adjusted R^2	0.678
Standard Error of the Estimate (SEE)	2.411
F-statistic	4.892
p-value	0.001
Durbin-Watson (Autocorrelation Check)	1.968

➢ *Key Interpretations*

- *Model Fit:*

✓ The high **R^2 (85.2%)** indicates that the independent variables explain a large portion of the variance in **the number of BIM projects completed**.
✓ Adjusted R^2 is **67.8%**, which accounts for the number of predictors, confirming that the model remains a strong fit.

- *Multicollinearity Removed:*

✓ Two variables with high **Variance Inflation Factor (VIF)** were removed to improve model stability.
✓ The highest VIF in the updated model is **below 5**, confirming multicollinearity is not a major issue.

- *Significance of the Model:*

✓ **F-statistic = 4.892 (p = 0.001)** confirms that the regression model is statistically significant.
✓ This means that at least one of the predictors significantly explains the dependent variable.

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- *Error & Independence Check:*

✓ **SEE = 2.411**: The standard deviation of the residuals is relatively low, suggesting that the model's predictions are not highly dispersed.
✓ **Durbin-Watson = 1.968**: This suggests **no significant autocorrelation**, meaning residuals are independent.

➢ *Interpretation of the Model Summary Table*

This table presents the results of a multiple regression analysis, which examines the relationship between the number of BIM-based projects completed (dependent variable) and multiple predictor variables.

Table 9: Model Summary Table

Source	Sum of Squares	df (degrees of freedom)	Mean Square	F-Value	Sig. (p-value)
Regression	568.864	20	28.443	4.892	0.001 (significant)
Residual (Error)	98.846	17	5.814		
Total	667.711	37			

- *Model Fit:*

✓ The **F-statistic (4.892)** and **p-value (0.001)** indicate that the model is statistically significant at a 95% confidence level. This means at least one of the predictors has a significant impact on the dependent variable.
✓ The total sum of squares (667.711) is mostly explained by the regression model (568.864), meaning a large proportion of the variability in the response variable is accounted for.

- *Residuals*

✓ Total Sum of Squares (667.711): This represents the total variation in the dependent variable.
✓ Regression Sum of Squares (568.864): This is the variation explained by the model (i.e., how well your predictors explain the use of BIM).
✓ Residual Sum of Squares (98.846): This is the unexplained variation (error) in the model.

Since the regression sum of squares (568.864) is much larger than the residual sum of squares (98.846), the model explains a large portion of the variation in BIM project adoption.

- *Model Complexity:*

The model includes 20 predictors, which is relatively high relative to the sample size (37 respondents, 17 degrees of freedom for residuals). This increases the risk of overfitting.

➢ *Explanation of the Coefficients Table*

This table provides detailed information on how each predictor variable impacts the dependent variable, which is "How many projects you have completed or been part of the process using BIM?".

- *Key Sections of the Table:*

✓ **Unstandardized Coefficients (B):** Represent the actual effect of each predictor variable on the dependent variable. For example, a B value of 0.901 for "Years using BIM solutions" means that for each additional year of BIM experience, the number of BIM projects increases by 0.901 (holding all other factors constant).
✓ **Standardized Coefficients (Beta):** Shows the relative importance of each variable in the model by standardizing the coefficients.
✓ **t-Statistic & Sig. (p-value**): Measures whether each predictor significantly impacts the dependent variable.

- If $p < 0.05$, the predictor is statistically significant.
- If $p > 0.05$, it does not have a strong statistical impact.

Table 10: Coefficients Table

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
1. For approximately how many years have you used BIM solutions?	0.901	0.276	0.560	3.263	.005
2. On a scale from 0 to 100, where 0 represents 1 use of BIM and 100 represents full integration of BIM across all projects, how extensively does your firm use BIM in its architectural processes? (Very important question)	.064	0.025	0.414	2.604	.019
3. BIM software demands an initial high cost and its costly implementation process.	0.304	.652	.070	.467	.646
4. BIM demands highly professional skills and in-depth training to complete a project.	-1.030	.935	-.206	-1.101	.286
5. Most of the architectural firms are not aware of the benefits of BIM.	0.193	.669	.046	.289	.776
6. Clients demand BIM-oriented drawings or data in the design	0.683	.574	.173	1.191	.250

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phase as well as the construction phase					
7. Most of the BIM software has a complex licensing system	-.587	.478	-.141	-1.228	.236
8. CAD drawings are more readable than BIM drawings	0.425	.722	.120	.588	.564
9. Implementation of National BIM standards can increase the adoption of BIM in Bangladesh	-.750	.831	-.145	-.903	.379
10. Traditional 2D software (like AUTOCAD) is more preferable than the nD based BIM software in Architectural firms.	0.065	.455	.020	.142	.888
11. Associate architects and professionals are 1st used with the BIM process	-0.314	.693	-.054	-.452	.657
12. National BIM policy program & Guidelines will increase the adoption of BIM in Bangladesh	-0.104	.731	-.024	-.143	.888
13. BIM helps reduce project timelines and improve overall efficiency.	0.363	.941	.070	.386	.704
14. The integration of BIM with other construction management software is seamless and user-friendly.	-0.517	.716	-.129	-.722	.480
15. BIM provides a significant advantage in cost estimation and budgeting compared to traditional methods.	0.166	1.039	.032	.160	.875
16. The use of BIM increases collaboration and communication among project stakeholders.	0.266	.844	.059	.315	.756
17. BIM is primarily beneficial only for large-scale projects.	-0.047	.547	-.013	-.086	.933
18. Architectural firms in Bangladesh are increasingly adopting BIM for competitive advantage.	0.479	.560	.113	.856	.404
19. The learning curve for BIM software is steep and requires significant time investment.	0.143	.718	.035	.199	.845
20. The use of BIM enhances the ability to visualize complex designs and concepts.	0.334	.836	.057	.400	.694

➢ *Key Findings*

- *Years using BIM" (B = 0.901, p = 0.005)*

✓ *Unstandardized Coefficient (B = 0.901)*

- For each additional year of BIM experience, the number of BIM projects completed increases by 0.901 projects.
- This means more experience with BIM leads to involvement in more BIM-related projects.

✓ *Standardized Coefficient (Beta = 0.560)*

- This tells us how strongly "Years using BIM" influences BIM project involvement relative to other predictors.
- A higher Beta (closer to 1) means the variable has a strong impact on the dependent variable.
- Beta = 0.560 is quite strong, meaning "Years using BIM" is a key factor in predicting BIM project involvement.

✓ *t-Statistic (t = 3.263, p = 0.005)*

- Since $p < 0.05$, the variable is statistically significant.
- This confirms that years of BIM experience is a meaningful predictor of BIM project involvement.

- *Full Integration of BIM (B = 0.064, p = 0.019)*

✓ *Unstandardized Coefficient (B = 0.064)*

- This means that for each 1-point increase in BIM integration (on a 0-100 scale), the number of BIM projects completed increases by 0.064.
- If a firm moves from 50% to 100% BIM integration, the estimated increase in BIM projects is:

✓ *(100−50) ×0.064=3.2 additional projects*

- This confirms that higher BIM integration leads to greater BIM adoption in projects.

✓ *Standardized Coefficient (Beta = 0.414)*

- Beta values indicate the relative importance of each predictor.
- Beta = 0.414 means BIM integration has a moderate-to-strong effect on BIM project involvement.
- It is the second most important variable in the model after "Years using BIM".

✓ *Statistical Significance (p = 0.019)*

- Since $p < 0.05$, this predictor is statistically significant.
- This means the relationship is not random—firms that integrate BIM more extensively do complete more BIM-related projects.

➢ *Hypothetical Example: The Impact of BIM Experience and Integration on Project Involvement*

- *Scenario: Growth of BIM Adoption at ABC Architects*

ABC Architects is a mid-sized firm that has been using Building Information Modeling (BIM) for five years.

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Currently, they have completed 10 BIM-related projects and their BIM integration level is at 60 on a scale of 0 to 100. The firm plans to increase its BIM expertise and fully integrate BIM across all its projects over the next five years.

Using the regression model, we can estimate how their BIM project involvement will change based on their experience and integration level.

✓ *Impact of BIM Experience on Project Involvement*

- **Current BIM Experience:** 5 years
- **Current BIM Projects Completed:** 10
- **Regression Coefficient for BIM Experience: B = 0.901**

➢ *Projected Growth:*

- If ABC Architects **gains one more year of BIM experience**, the expected increase in BIM projects is: $1 \times 0.901 = 0.901$ additional projects
- If they **gain five more years of experience (from 5 to 10 years)**, the estimated increase is: $5 \times 0.901 = 4.505$ additional projects
- **Projected BIM projects after 10 years of experience:** $10 + 4.505 = 14 - 15$ projects

This confirms that firms with longer experience in BIM are likely to complete more BIM-related projects.

✓ *Impact of BIM Integration on Project Involvement*

- Current BIM Integration Level: **60**
- Regression Coefficient for BIM Integration: B = 0.064

➢ *Projected Growth:*

- If ABC Architects **increases its BIM integration by 10 points** (from 60 to 70), the expected increase in BIM projects is: $(70 - 60) \times 0.064 = 0.64$ additional projects
- If they **move from 60 to 100 (full integration)**, the estimated increase is: $(100 - 60) \times 0.064 = 2.56$ additional projects
- **Projected BIM projects after full integration:** $10 + 2.56 = 12 - 13$ projects

This indicates that firms that fully integrate BIM are more likely to increase their BIM project involvement.

✓ *Final Projection: Combined Impact*

If ABC Architects increases both its BIM experience (from 5 to 10 years) and BIM integration (from 60 to 100), the estimated BIM-related project involvement will increase from 10 to approximately 16-17 projects. This analysis demonstrates that both experience and integration are important factors in BIM adoption, but experience has a slightly greater influence on project involvement. Firms seeking to maximize BIM utilization should invest in both long-term expertise and full integration across their architectural processes.

➢ *Non-Significant Predictors ($p > 0.05$)*

These variables **do not significantly impact** BIM project involvement:

- **BIM software cost (p = 0.646)**
- **BIM requiring professional skills & training (p = 0.286)**
- **Architects' awareness of BIM benefits (p = 0.776)**
- **Client demand for BIM (p = 0.250)**
- **National BIM policies (p = 0.888)**
- **BIM improving efficiency (p = 0.704)**
- **BIM helping in cost estimation (p = 0.875)**
- **BIM mainly for large-scale projects (p = 0.933)**
- **Competitive advantage in BIM adoption (p = 0.404)**

➢ *Explanation of Non-Significant Predictors ($p > 0.05$)*

The regression analysis indicates that several predictors do not have a statistically significant impact on the number of BIM-related projects completed. A p-value greater than 0.05 suggests that these variables do not provide strong evidence of influencing project involvement. This could be due to a lack of variability in responses, a small sample size, or the presence of stronger, more relevant factors driving BIM adoption. Additionally, some of these variables may be redundant or highly correlated with more impactful predictors.

One such variable is BIM software cost (p = 0.646), which does not appear to influence project involvement significantly. This may be because firms using BIM have already accepted the cost as a necessary investment, making it a non-decisive factor. Similarly, the requirement for professional skills and in-depth training (p = 0.286) does not have a strong correlation with BIM project involvement. This suggests that while BIM may require specialized training, firms and professionals continue using it once they have acquired the necessary skills.

Architects' awareness of BIM benefits (p = 0.776) also does not significantly impact BIM project involvement, likely because awareness alone does not dictate adoption; factors such as firm policies and client demands play a more decisive role. Surprisingly, client demand for BIM-oriented designs (p = 0.250) is not a significant predictor either, indicating that firms may integrate BIM into projects regardless of whether clients specifically request it.

The presence of national BIM policies and guidelines (p = 0.888) also does not significantly affect project involvement, likely because policies may exist but are not strictly enforced or have limited direct influence on firms' operations. Additionally, the belief that BIM improves efficiency (p = 0.704) and provides cost estimation advantages (p = 0.875) does not translate into more BIM project involvement, suggesting that firms might adopt BIM for reasons beyond efficiency and budgeting, such as visualization or regulatory compliance.

Moreover, the idea that BIM is primarily beneficial for large-scale projects (p = 0.933) does not hold statistical significance, implying that firms may be utilizing BIM for

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both small and large projects. Similarly, the belief that BIM adoption offers a competitive advantage (p = 0.404) does not correlate strongly with BIM project involvement, suggesting that firms may be implementing BIM for reasons other than market competition, such as internal efficiency or project complexity.

V. QUALITATIVE APPROACH

A. Findings from KII

- **Lack of BIM expertise:** Industry leaders highlighted a shortage of skilled BIM professionals in Bangladesh.
- **Financial constraints:** Firms struggle to allocate budgets for BIM software and training.
- **Regulatory absence:** The government lacks a mandatory BIM policy, making widespread adoption difficult.
- **Resistance to change:** Senior professionals and firms still favor traditional methods over BIM.

B. Findings from FGD

- **Cost as a barrier:** Small and medium-sized firms find BIM software licensing fees prohibitive.
- **Interoperability challenges:** Different firms using different BIM platforms face integration issues.
- **Misconceptions about BIM:** Some firms believe BIM is only viable for large-scale projects, limiting adoption.

C. Group Discussions

- **Discussion topic:** How can we bridge the BIM skills gap in Bangladesh?
- **Mohammad Rukunuzzaman (Software Developer, Metamorphosis Ltd.):** Universities should integrate BIM training into their curriculums. Currently, most graduates have no formal exposure to BIM. We need collaboration between software companies and academic institutions to introduce BIM training early on.
- **Abdullah Al Amin (Industry Expert, Construction Business Forum Bangladesh):** Firms should collaborate with software providers to conduct in-house training and workshops. Many firms still view BIM as an unnecessary cost rather than an investment that improves efficiency and project quality.
- **Ar. Sazzad Hossain, Associate Professor, (MIST):** Awareness campaigns targeting professionals and students can also encourage adoption and demonstrate BIM's advantages. If we can create case studies showing real-world success in Bangladesh, more firms will be willing to invest in BIM training.

➢ *Findings from Group Discussions*

- **Need for academic integration:** Experts agreed that BIM should be included in university curricula.
- **Industry collaboration:** Stronger partnerships between academia, software providers, and industry leaders are needed to enhance BIM training.
- **Awareness and case studies:** Demonstrating successful BIM implementation in Bangladesh could encourage more firms to adopt BIM.

D. Summary of Qualitative Findings

The combination of **Key Informant Interviews (KII), Focus Group Discussions (FGD), and Group Discussions** provided valuable insights into the barriers and opportunities for BIM adoption in Bangladesh. The key takeaways include:

- **Lack of skilled professionals** remains the biggest challenge, emphasizing the need for structured BIM training.
- **Financial constraints** are a major hurdle, particularly for small and medium-sized firms that struggle with software licensing costs.
- **Governmental policies** and regulatory mandates are insufficient, highlighting the need for strategic intervention to encourage BIM integration.
- **Interoperability issues** between different BIM platforms are causing inefficiencies in project collaboration.
- **Awareness campaigns and industry-academic partnerships** can accelerate BIM adoption through education and skill development.

These qualitative findings complement the **quantitative data** and provide a comprehensive understanding of BIM adoption challenges and potential solutions in the Bangladeshi context.

VI. INTEGRATED ANALYSIS: A QUANTITATIVE AND QUALITATIVE PERSPECTIVE

Building Information Modeling (BIM) is reshaping architectural workflows globally by enhancing efficiency, collaboration, and project management. However, its adoption in Bangladesh remains inconsistent, with firms encountering technical, financial, and policy-related challenges. This analysis integrates both quantitative survey data and qualitative insights from Key Informant Interviews (KII), Focus Group Discussions (FGD), and Group Discussions to provide a comprehensive understanding of BIM adoption trends, barriers, and potential strategies in Bangladesh's architectural industry.

A. Awareness and Adoption: High Awareness, Low Integration

➢ *Quantitative Insights*

The survey results show that 100% of respondents are aware of BIM and have used BIM software, indicating that awareness is not a barrier to adoption. However, firm-wide integration remains low, with an average integration rate of 41.36% and a mode of 20%, suggesting that most firms are using BIM only at a partial level rather than as a standardized practice.

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- *Qualitative Insights*

The KII discussions reinforced this trend, with **Ar. Rajon Das (Senior Architect, Kshiti Sthapoti)** emphasized that many firms still rely on outdated drafting techniques due to a lack of structured BIM training. Government Official Ar. Shimul Chakma pointed out that there is no regulatory mandate for BIM adoption, making its integration optional rather than required.

- *Integrated Analysis*

The disconnect between high awareness and low adoption suggests that while professionals recognize BIM's potential, institutional and financial barriers limit firm-wide implementation. This points to the need for targeted strategies that move beyond awareness campaigns and focus on training, incentives, and regulatory enforcement to drive full-scale adoption.

B. Key Barriers to BIM Adoption

- *Quantitative Insights*

The survey identified three major adoption barriers:

- High cost of BIM software and licensing (Mean = 3.37)
- Complex learning curve and professional training requirements (Mean = 4.07)
- Limited demand from clients for BIM-integrated designs (Mean = 2.86)

Additionally, statistical analysis showed that cost constraints significantly correlate with a preference for traditional 2D software like AutoCAD (Spearman's $\rho = 0.410$), suggesting that firms avoiding BIM due to cost concerns continue relying on familiar tools.

- *Qualitative Insights*

The FGD discussions supported these findings, with Engr. Mir Enayet Hossain stated that BIM software is too expensive for smaller firms that struggle with annual licensing fees. Ar. Abdullah Al Mehdi (ABC Design) highlighted interoperability challenges, explaining that different firms use different software platforms (Revit vs. ArchiCAD), creating integration difficulties.

- *Integrated Analysis*

Financial constraints, training gaps, and software incompatibility hinder BIM adoption. While firms acknowledge BIM's benefits, the lack of uniform software usage and high initial costs prevent widespread implementation. This suggests a need for government subsidies, financial incentives, and software standardization efforts to make BIM more accessible to firms of all sizes.

C. Experience and Project Engagement: More Experience, More BIM Projects

- *Quantitative Insights*

The regression analysis indicates a strong relationship between BIM experience and project involvement. Each additional year of BIM experience increases BIM-related project involvement by 0.901 projects ($B = 0.901$, $p = 0.005$). Firms that fully integrate BIM (100%) complete significantly more BIM projects ($B = 0.064$, $p = 0.019$).

However, experience does not always translate into higher firm-wide BIM adoption—some firms with highly experienced BIM professionals still reported low integration levels.

- *Qualitative Insights*

The Group Discussion with industry experts provided a deeper explanation. **Abdullah Al Amin (Industry Expert, Construction Business Forum Bangladesh)** noted that firms view BIM as an optional tool rather than a necessary workflow integration. Ar. Sazzad Hossain (MIST) emphasized that academic institutions do not adequately prepare students for BIM-centric workflows, leading to gaps between professional experience and firm-wide integration.

- *Integrated Analysis*

While individual experience increases BIM project involvement, firm-wide adoption remains inconsistent due to policy gaps, training limitations, and firm culture. This suggests that experience alone is not enough to drive full adoption—firms must also invest in structured training, enforce BIM policies, and create incentives for company-wide integration.

D. The Role of Policy and Regulation: Demand for National BIM Standards

- *Quantitative Insights*

- Survey responses indicated strong support for national BIM policies, with high agreement that:
- A national BIM policy would increase adoption (Mean = 3.88)
- Implementation of national BIM standards would drive industry-wide BIM integration (Mean = 4.02)

- *Qualitative Insights*

Ar. Shimul Chakma (Government Official, Ministry of Housing and Public Works) stressed that Bangladesh lacks clear BIM guidelines, making it difficult for firms to justify investing in BIM. Several industry professionals agreed that without regulatory mandates, firms have little motivation to standardize BIM workflows.

- *Integrated Analysis*

The absence of national BIM standards is a significant barrier to widespread adoption. Firms may hesitate to invest in BIM due to unclear industry expectations and a lack of government-mandated requirements. Introducing national BIM policies, such as tax incentives for firms that implement BIM or mandatory BIM requirements for government projects, could accelerate adoption and standardize industry practices.

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E. Misconceptions and Resistance to Change

➢ *Quantitative Insights*

Some industry professionals still prefer traditional drafting software over BIM (Mean = 3.33), and believe CAD drawings are easier to read than BIM models (Mean = 3.00).

Moreover, the survey revealed misconceptions about BIM, such as the belief that BIM is primarily for large-scale projects (Mean = 3.05), despite evidence that it can improve efficiency in both small and large projects.

➢ *Qualitative Insights*

Ar. Pritom Chandra Dey (Innovate Build BD) noted that many firms wrongly assume that BIM is too complex for small-scale projects, discouraging adoption in smaller firms. Engr. Mir Enayet Hossain added that some senior professionals are reluctant to transition from CAD-based workflows to BIM due to familiarity with traditional methods.

➢ *Integrated Analysis*

Resistance to change is a cultural and generational challenge in BIM adoption. Many firms, particularly those led by senior professionals accustomed to traditional drafting, hesitate to transition to BIM despite recognizing its benefits. Targeted training programs, industry awareness campaigns, and case studies demonstrating BIM's success in small projects could help shift industry perceptions and reduce resistance to adoption.

F. Summary

Building Information Modeling (BIM) is increasingly recognized as a transformative tool in the architectural industry, offering efficiency, cost reduction, and enhanced collaboration. However, its adoption in Bangladesh remains inconsistent, hindered by financial constraints, training gaps, lack of policy enforcement, and resistance to change.

The quantitative analysis reveals a high level of awareness among industry professionals, yet firm-wide BIM integration remains limited, averaging only 41.36%. Major barriers include high software costs (Mean = 3.37), licensing complexities (Mean = 3.33), and the steep learning curve (Mean = 4.07). Despite these challenges, strong agreement exists regarding BIM's advantages, particularly in reducing project timelines (Mean = 4.35), improving cost estimation (Mean = 4.29), and minimizing errors (Mean = 4.17).

Regression analysis confirms that experience and integration levels significantly impact BIM project involvement, with every additional year of BIM experience increasing project completion rates ($B = 0.901$, $p = 0.005$). However, experience alone does not guarantee firm-wide adoption, as many firms still use BIM selectively rather than as a standard practice. Additionally, national BIM policies and regulations are widely supported (Mean = 4.02), yet the lack of mandatory enforcement discourages adoption.

The qualitative findings reinforce these conclusions, highlighting key industry concerns such as insufficient training programs, financial constraints, and software interoperability issues. Experts emphasize the need for academic integration, structured training, and government incentives to accelerate adoption. Resistance from senior professionals, misconceptions about BIM's suitability for small projects, and preference for traditional drafting tools further impede widespread implementation.

Without strategic interventions, BIM adoption in Bangladesh will continue to progress slowly, limiting the industry's ability to fully capitalize on its benefits. However, with targeted efforts in policy, training, and financial support, BIM has the potential to become an industry standard, revolutionizing architectural workflows and enhancing project efficiency on a national scale.

VII. DISCUSSION AND RECOMMENDATIONS

A. Discussion and Recommendations

Building Information Modeling (BIM) has emerged as a revolutionary tool in the architectural industry, transforming traditional design, project management, and collaboration processes. However, its adoption in Bangladesh remains inconsistent, with firms facing numerous challenges, including financial constraints, skill shortages, resistance to change, and a lack of standardized policies. The study's findings provide significant insights into the state of BIM adoption, identifying the key drivers, barriers, and opportunities that can influence widespread integration within the country's architectural sector. This discussion section critically evaluates these findings, integrating both quantitative and qualitative data to present a nuanced analysis of the current landscape. Furthermore, it explores the broader implications of BIM adoption, linking the research results to industry-wide trends and providing practical recommendations for enhancing its implementation.

B. Challenges in BIM Adoption: A Systemic Issue

One of the most pressing issues identified in the study is the fragmented adoption of BIM across architectural firms. While awareness of BIM is high, with 100% of respondents acknowledging its existence, actual implementation varies widely. The survey results indicate that firm-wide BIM integration averages only 41.36%, with a mode of 20%, signifying that many firms use BIM only for specific projects rather than as a standard practice. This discrepancy between awareness and adoption suggests that while professionals recognize BIM's potential, systemic barriers prevent its full-scale implementation.

The high cost of BIM software and licensing remains a primary obstacle to adoption. The mean rating for cost-related concerns (3.37) underscores the financial burden that many firms, especially small and medium-sized enterprises (SMEs), face when attempting to implement BIM. Software such as Autodesk Revit, ArchiCAD, and Bentley Systems requires substantial initial investment and ongoing subscription costs, which many firms find prohibitive. Additionally, the licensing complexity of BIM software

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(mean = 3.33) further complicates adoption, as firms struggle with navigating different pricing models and access restrictions.

Beyond financial barriers, the learning curve associated with BIM poses another significant challenge. The study reveals that BIM demands highly professional skills and in-depth training (mean = 4.07), indicating that the industry's workforce may lack the necessary expertise to fully utilize BIM's capabilities. While universities and technical institutions have begun integrating BIM-related coursework, many professionals in the industry have not received formal training, leading to a skills gap that slows adoption. This aligns with qualitative findings from Key Informant Interviews (KII) and Focus Group Discussions (FGD), where industry experts highlighted the lack of structured BIM training as a major barrier to implementation. Resistance to change within the architectural industry also contributes to the slow adoption of BIM. Many firms remain reliant on traditional 2D drafting software such as AutoCAD, which has been a staple in the industry for decades. The preference for 2D software over BIM solutions (mean = 3.33) suggests that professionals accustomed to conventional drafting methods are hesitant to transition to newer technologies. Additionally, the perceived readability of CAD drawings over BIM models (mean = 3.00) reinforces the notion that familiarity with existing tools is a key factor in resistance to adoption. Senior professionals, in particular, are often reluctant to embrace BIM due to the substantial effort required to learn new workflows, further limiting firm-wide integration.

C. Implications of Limited BIM Adoption

The inconsistent adoption of BIM has significant implications for the architectural industry in Bangladesh. One of the most critical consequences is reduced efficiency in project management and execution. BIM is designed to improve collaboration among project stakeholders, reduce errors, and streamline design processes. However, the lack of firm-wide BIM integration means that many firms continue to rely on fragmented workflows that increase the likelihood of miscommunication, design conflicts, and project delays.

Furthermore, limited BIM adoption impacts cost management and resource allocation. The study confirms that BIM provides significant advantages in cost estimation and budgeting (mean = 4.29), yet many firms fail to fully leverage these benefits. Without comprehensive BIM implementation, firms are unable to maximize cost efficiencies, leading to budget overruns and financial inefficiencies. The construction industry in Bangladesh already faces cost overruns due to mismanagement and inefficiencies; integrating BIM into standard workflows could play a crucial role in addressing these challenges.

The absence of standardized BIM policies further exacerbates the issue, as firms lack clear regulatory guidelines and incentives for adoption. The study highlights strong industry support for the implementation of national BIM standards (mean = 4.02) and BIM policy programs (mean = 3.90). However, the lack of government-mandated policies means that firms have little motivation to invest in BIM training and infrastructure. In contrast, countries with established BIM regulations, such as the United Kingdom and Singapore, have seen significant improvements in project efficiency, cost savings, and sustainability through mandatory BIM adoption.

D. Recommendations for Enhancing BIM Adoption

To address these challenges and accelerate BIM adoption in Bangladesh's architectural sector, a multi-faceted approach involving policy interventions, financial support, training initiatives, and industry engagement is required. The following recommendations are proposed based on the study's findings:

➢ *Implementation of National BIM Policies and Standards*

- The government should introduce mandatory BIM guidelines for large-scale infrastructure projects to drive industry-wide adoption.
- Regulatory bodies such as the Institute of Architects Bangladesh (IAB) and the Ministry of Housing and Public Works should collaborate to establish standardized BIM protocols and best practices.
- Incentives such as tax benefits or financial grants should be provided to firms that integrate BIM into their workflows.

➢ *Financial Support for BIM Adoption*

- The government and private sector should explore funding mechanisms to subsidize BIM software costs for small and medium-sized firms.
- Interest-free loans or installment payment options could be introduced for purchasing BIM licenses and training programs.
- Open-source BIM software alternatives should be promoted as cost-effective solutions for firms with limited budgets.

➢ *Enhancing BIM Training and Skill Development*

- Universities should integrate BIM courses into architecture and engineering curricula to equip graduates with industry-relevant skills.
- Industry-academic partnerships should be established to offer hands-on BIM training programs, workshops, and certification courses.
- Professional development initiatives, including government-backed BIM training subsidies, should be introduced to upskill existing professionals.

➢ *Addressing Resistance to Change*

- Awareness campaigns should be launched to highlight the long-term benefits of BIM adoption in improving efficiency, reducing errors, and enhancing collaboration.
- Case studies showcasing successful BIM implementation in Bangladesh should be published to demonstrate

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tangible benefits and encourage hesitant firms to transition.

- Senior professionals should be targeted with specialized training programs designed to ease their transition from traditional drafting methods to BIM workflows.

➤ *Improving Software Interoperability and Collaboration*

- The industry should establish common standards for BIM software compatibility to reduce interoperability issues.
- Collaboration platforms should be encouraged to facilitate seamless integration of BIM across different disciplines, including architecture, engineering, and construction.
- Training on interoperability between software platforms such as Revit, ArchiCAD, and Tekla Structures should be included in professional courses.

➤ *Encouraging Industry-Wide Collaboration*

- Architectural firms should form BIM user groups to share best practices, discuss challenges, and exchange knowledge on effective implementation strategies.
- Public-private partnerships should be fostered to promote BIM research and development in Bangladesh.
- International collaborations with countries that have successfully implemented BIM should be explored to learn from global best practices.

VIII. SUMMARY

The adoption of BIM in Bangladesh's architectural sector is still in its early stages, but the potential for widespread implementation is substantial. While awareness of BIM is high, financial constraints, skill shortages, resistance to change, and a lack of regulatory policies continue to hinder its full integration. Addressing these challenges requires a comprehensive strategy that combines policy enforcement, financial support, targeted training, and industry engagement. By implementing these recommendations, the architectural sector can transition towards a more efficient, cost-effective, and collaborative future, ensuring that BIM becomes a standard practice rather than an optional tool. In doing so, Bangladesh can align its construction industry with global best practices, enhancing productivity, sustainability, and overall project quality in the years to come.

IX. CONCLUSION

Building Information Modeling (BIM) is a transformative technology in the architectural and construction industries, enhancing design efficiency, collaboration, cost management, and project execution. Despite its global recognition, its adoption in Bangladesh remains inconsistent due to financial constraints, lack of training, software compatibility issues, and resistance from traditional practitioners.

This study provides a comprehensive analysis of BIM adoption trends, barriers, and opportunities in Bangladesh's architectural sector. The findings indicate that although BIM awareness is widespread, firm-wide integration is significantly lower, averaging 41.36%. The high cost of software, lack of structured training programs, and the absence of national BIM policies are major obstacles limiting widespread adoption. Additionally, the study highlights the need for standardized BIM implementation, industry-academic collaboration, and policy interventions to facilitate industry-wide transformation.

Through an integrated quantitative and qualitative approach, the study confirms that increasing BIM experience correlates positively with higher project involvement but does not necessarily lead to full-scale adoption within firms. This suggests that experience alone is insufficient to drive industry-wide implementation, and additional structural interventions are required. To bridge this gap, a combination of financial incentives, policy support, skill development initiatives, and stakeholder engagement is necessary to establish BIM as a standard practice rather than an optional tool.

The inconsistency in BIM adoption reveals a systemic challenge. Many firms experiment with BIM on select projects but do not make it a mandatory part of their workflow. The study demonstrates that companies with more BIM experience complete more BIM-related projects, yet they do not necessarily implement it across all operations. This inconsistency suggests that, beyond technical expertise, external factors such as company policies, cost, and industry regulations play a crucial role in shaping adoption trends.

Another key takeaway is the need for industry-wide policy intervention. Countries that have successfully integrated BIM at a national level, such as the UK and Singapore, have done so through government mandates, tax incentives, and structured implementation frameworks. In contrast, Bangladesh lacks a national BIM policy, leading to fragmented and voluntary adoption. The study highlights the strong support among industry professionals for standardized BIM policies, with over 80% of respondents indicating that regulatory guidelines would encourage greater adoption.

The study also reveals deep-seated misconceptions about BIM’s applicability. Many firms perceive BIM as a tool exclusively for large-scale projects, despite its proven efficiency in small and mid-sized projects. This misconception has slowed adoption among smaller firms, limiting BIM’s potential impact on the broader industry. Addressing this issue requires targeted awareness campaigns and real-world case studies showcasing BIM’s benefits in various project scales.

In addition to financial and policy barriers, skill development emerges as a critical bottleneck. The study finds that a majority of architects lack formal BIM training, leading to inconsistent usage and limited expertise.

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Universities in Bangladesh do not currently integrate BIM into their core architecture and engineering curricula, further exacerbating the skills gap. This study calls for structured training initiatives, both at the academic level and within professional organizations, to equip future architects and engineers with the necessary skills to leverage BIM effectively.

The interoperability of BIM software remains a challenge for many firms. The research highlights that different organizations use different BIM platforms (Revit, ArchiCAD, Tekla), leading to compatibility issues and inefficiencies in collaboration. Standardizing software usage and ensuring interoperability between platforms could significantly enhance the practical implementation of BIM across firms.

The study also emphasizes the role of leadership in driving adoption. Senior professionals, who are more comfortable with traditional CAD workflows, exhibit resistance to BIM integration. Without their support, younger architects trained in BIM find it difficult to push for firm-wide adoption. This generational gap in BIM acceptance highlights the need for targeted training programs for senior professionals, showcasing the long-term cost savings and efficiency benefits of BIM.

Finally, the study underscores the long-term benefits of BIM adoption. Beyond cost savings and efficiency, BIM contributes to sustainable design practices, better risk management, and improved project collaboration. If implemented effectively, BIM can revolutionize Bangladesh's architectural sector, aligning it with global best practices and enhancing the country's competitiveness in the construction industry.

A. Major Findings of the Study

- High Awareness, Low Integration: While 100% of respondents are aware of BIM and have used BIM software, firm-wide integration remains at a low 41.36%, suggesting a disconnect between knowledge and practice.
- Financial Barriers: The cost of BIM software and licensing is a significant adoption barrier, particularly for small and medium-sized firms that struggle with affordability.
- Skill Gaps and Training Deficiency: The learning curve for BIM is steep, and many professionals lack the necessary training, highlighting the need for industry-wide education and certification programs.
- Resistance from Senior Professionals: Many experienced professionals continue to favor traditional CAD-based workflows, slowing the transition to BIM.
- Limited Policy and Regulatory Support: Unlike other countries with mandatory BIM implementation policies, Bangladesh lacks regulatory enforcement, reducing motivation for firms to integrate BIM.
- Interoperability Issues: Different firms use varying BIM platforms, leading to software compatibility challenges that hinder collaboration.
- Misconceptions about BIM Use: Some firms believe BIM is only suitable for large-scale projects, limiting adoption in smaller firms and residential projects.
- Correlation Between Experience and Project Involvement: Regression analysis confirms that firms with longer BIM experience complete more BIM projects, but this does not necessarily translate into full-scale firm-wide integration.
- Demand for National BIM Standards: The industry strongly supports the introduction of standardized BIM policies to streamline implementation.
- Role of Government and Industry Collaboration: Stakeholders agree that government incentives, academic curriculum integration, and structured BIM policies could accelerate adoption.

B. Recommendations

➢ *Policy and Regulatory Interventions*

- Introduce mandatory BIM adoption policies for large-scale infrastructure projects.
- Establish national BIM standards and guidelines to ensure uniform implementation.
- Provide tax incentives and financial grants to firms adopting BIM.

➢ *Financial Support for BIM Implementation*

- Offer subsidized BIM software licenses for small and medium enterprises (SMEs).
- Implement low-interest financing options for BIM training and infrastructure investment.
- Encourage open-source BIM alternatives to reduce reliance on costly proprietary software.

➢ *Training and Skill Development*

- Integrate BIM courses into university curricula to equip future professionals with necessary skills.
- Launch government-backed BIM certification programs for industry professionals.
- Organize industry-academic collaborations to provide hands-on BIM workshops.

➢ *Overcoming Resistance to Change*

- Conduct awareness campaigns showcasing successful BIM implementation case studies.
- Target senior professionals with specialized training programs to ease their transition from CAD to BIM.
- Demonstrate the cost-benefit advantages of BIM through pilot projects.

➢ *Enhancing Software Interoperability*

- Develop industry-wide standards for BIM software compatibility.
- Promote collaboration tools that facilitate integration between different BIM platforms.

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- Provide training on interoperability solutions to ensure seamless workflow among stakeholders.

➢ *Encouraging Industry-Wide Collaboration*

- Establish BIM user groups to share best practices and challenges.
- Foster public-private partnerships to drive BIM research and development.
- Engage in international collaborations to learn from successful BIM implementation models.

C. Theoretical and Empirical Contributions of the Study

➢ *Theoretical Contributions*

- Extended Understanding of BIM Adoption: The study contributes to BIM adoption literature by integrating both quantitative and qualitative insights, highlighting factors influencing its implementation.
- Framework for BIM Implementation: The research proposes a multi-level adoption framework incorporating policy support, financial incentives, training, and industry collaboration.
- Challenging Existing Assumptions: The study challenges the notion that BIM experience alone drives firm-wide adoption, emphasizing external factors like cost, policy, and regulatory support.
- Expanding Technology Acceptance Models (TAM): By examining industry-specific adoption trends, the study expands TAM theories by introducing new constructs related to firm-wide BIM integration.

➢ *Empirical Contributions*

- First Large-Scale Study on BIM in Bangladesh: The research is among the first to systematically examine BIM adoption trends, barriers, and recommendations in Bangladesh.
- Quantitative-Qualitative Integration: The study's mixed-method approach provides a comprehensive perspective on industry challenges, making it a valuable reference for future research.
- Correlation Between Experience and Integration: The regression analysis confirms that while BIM experience increases project involvement, it does not necessarily result in firm-wide integration, contributing new empirical evidence to existing studies.
- Policy and Stakeholder Recommendations: The study offers actionable insights for policymakers, industry leaders, and educators to enhance BIM adoption.

D. Limitations of the Study and Scope for Further Research

➢ *Limitations*

- Limited Sample Size: The study was conducted among a specific number of architectural firms, which may not fully represent industry-wide trends.
- Focus on Bangladesh: The findings may not be entirely generalizable to other countries with different regulatory and financial environments.
- Self-Reported Data: The study relies on survey responses, which could be influenced by personal biases or perceptions.
- Lack of Longitudinal Data: The study captures a snapshot of BIM adoption trends rather than long-term implementation patterns.

➢ *Scope for Further Research*

- Longitudinal Studies on BIM Integration: Future research could track firms over time to understand how BIM adoption evolves.
- Comparative Analysis Across Regions: A cross-country comparative study could provide insights into how different regulatory environments influence BIM adoption.
- Investigating the Role of Emerging Technologies: Future studies could explore the impact of AI, IoT, and cloud computing on BIM implementation.
- Client and Developer Perspectives: Examining how clients and real estate developers perceive BIM adoption could provide additional insights into demand-driven implementation.

E. Conclusion

The adoption of Building Information Modeling (BIM) in Bangladesh's architectural sector presents significant potential for improving design efficiency, project management, and cost estimation. However, as this study has demonstrated, widespread implementation remains inconsistent due to financial constraints, skill shortages, resistance to change, and a lack of structured policies. While BIM awareness is high, actual firm-wide integration remains limited, with only a minority of firms achieving full adoption. This gap between knowledge and application underscores the need for strategic interventions to accelerate BIM adoption across the industry.

The findings indicate that cost is one of the most critical barriers, with many firms, particularly small and medium-sized enterprises (SMEs), struggling with software licensing fees and training expenses. Additionally, the industry faces a skills gap, as many architects lack formal BIM education, further limiting its practical application. Resistance to change, particularly among senior professionals accustomed to traditional drafting methods, further slows the transition to BIM workflows. The absence of national BIM policies and standardized regulations has also left firms without clear guidelines or incentives for full-scale implementation.

Despite these challenges, the study highlights strong agreement among professionals regarding BIM's benefits. The data confirms that BIM improves project efficiency, reduces design errors, enhances cost estimation, and strengthens collaboration among project stakeholders. Furthermore, firms with more BIM experience and higher integration levels tend to complete more BIM-related projects, reinforcing the importance of sustained investment in both training and implementation.

To bridge the adoption gap, a multi-faceted approach is necessary. Key recommendations include introducing government-backed BIM policies, offering financial incentives to firms adopting BIM, expanding BIM education in universities, and promoting industry-wide training programs. Additionally, targeted initiatives aimed at overcoming resistance to change—such as awareness campaigns and real-world case studies—can help demonstrate BIM's value in both large-scale and small-scale projects.

Ultimately, the successful adoption of BIM in Bangladesh will depend on a coordinated effort among industry stakeholders, policymakers, and academic institutions. By addressing financial, educational, and regulatory barriers, the architectural sector can transition toward a more efficient and technologically advanced future. With the right strategies in place, BIM has the potential to become the industry standard, transforming architectural practices in Bangladesh and aligning them with global best practices.

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