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Building Sustainable Construction through the Adoption of Building Information Modeling (BIM)

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Abstract: The Indian construction industry plays a critical role in its socio-economic development and it will be a leading sector for the vision "Viksit Bharat @2047". However, this industry face several challenges such as cost overruns, time delays, material wastage, and poor inter-disciplinary coordination. These shortfalls leads to revision of the estimate, fine on Government Contractors, requirement of new administrative approval from the Government and ultimately all the stakeholders associated with the project suffers in many ways. The vision of "Viksit Bharat cannot be obtained without digitization of construction sector which contributes to around 8.29 % of annual GDP. For India to attain its vision it needs that all the state of India grows with the same pace. These Construction issues are often intensified in small-scale projects, especially in regions with limited digital infrastructure and technical capacity like Bihar (specifically Patna). For these construction issues, Building Information Modeling (BIM) has helped construction sector by digitization of construction workflows. Despite the advantages, BIM adoption in India, particularly in small-scale and government projects, remains limited due to several barriers including financial constraints, lack of awareness, insufficient technical capacity, and absence of standardized data environments. This paper set out to explore the transformative potential of BIM in addressing long-standing inefficiencies within the construction industry, particularly in the context of small-scale projects in Bihar's Patna region. Through an extensive literature review, technical simulations, and case-based observations, the study aimed to identify the role of BIM across various project lifecycle stages and its effectiveness in optimizing material, time, cost, and human resources. Parallelly, the research investigated the key barriers impeding BIM adoption in the regional context, focusing on awareness, organizational, market and client availability, technical, financial, policy-related challenges and maturity of BIM utilization. To support collaborative digital workflows, the study also proposed a conceptual context-specific Common Data Environment (CDE) framework aligned with CPWD BIM Guidelines 2024. This study consolidates the insights gained, evaluates the broader implications, and provides recommendations for future practice and research.

Keywords: Building Information Modelling (BIM), Survey Respondents, Resource Optimization, Project Life cycle, Common Data Environment (CDE), Bihar (Patna) region.

I. INTRODUCTION

The construction sector plays a vitol role in the development of Bihar with employment share of 18.6% and substantially contributes to 9.4% of the total GDP of Bihar but still this sector is least digitalized. [1]. The study focused on investigating the current level of use of BIM in Bihar, and elaboration of a process that could enable the industry to adopt and implement the technology on its construction projects life-cycle and facilities management. Bihar is going through the phase of rapid urbanization with lots of construction activities like Double Decker Bridge in Patna, Marine Drive, numerous flyovers, Rajgir Stadium, Patna Metro, PMCH, Grand Mata Janaki Temple, Sitamarhi. etc. So with these developments its sustainable repair and maintenance throughout its lifecycle remains a great challenge. Though Bihar Government has implemented specific technologies like Bridge Health Monitoring System, AutoMap, Project Management and Information System (PMIS), e-tendering etc but through the survey it revealed that though Bihar Major Projects are utilizing BIM facilities through Consultants, but large Scale and Small Scale projects are still practicing the traditional method of construction, though the awareness level is significantly good. To address these challenges, the Central Public Works Department (CPWD) has recently introduced BIM Guidelines (Introducing BIM in CPWD, July- 2024) [2] whose recommendations are aligned with ISO 19650, is advocating for a structured digital approach across all project stages.

CPWD has stated that "BIM based construction should be made mandatory with immediate effect for all the original works being executed through EPC mode, original works costing over Rs. 30 Cr. Being executed through other mode and all original works from January 1, 2025"[2]. But Bihar Government has not introduced any such policy on BIM till the time of this research. So through this paper author has identified the barriers and Challenges of BIM adoption in Bihar by identifying the key barriers through literature review and validated the result through statistical approach. This study employs a mixed-method approach combining quantitative survey analysis, BIM-based model evaluation, and a conceptual framework design for a Common Data Environment (CDE) tailored to small-scale projects in Bihar."

II. OBJECTIVE OF THE STUDY

The objective of this study is summarised as below: -

1) To Identify the Role of BIM in Project Lifecycle Stages to assess its impact on Resource Optimization through literature review.
2) To identify Barriers to BIM Adoption and determine possibility of its application in Small-Scale Projects in Bihar (Patna).
3) To suggest Framework for Common Data Environment (CDE) on the basis of study of projects identified in Bihar (Patna region).

III. LITERATURE REVIEW

A lot of work and researches in the field of BIM and associating BIM with various new technologies like GIS, IOT, VR, Lifecycle assessment has been done. Along with these lots study on its awareness, barrier and adoption has also been done with reference to different size of projects. The work done by various researchers is presented here.

1) Patel and Patel (2015),[3]"Investigating the Adoption and Implementation of Building Information Modeling (BIM) within the Indian Construction Industry"
   Summary: The study identifies key barriers and challenges, such as lack of awareness, inadequate training, and resistance to change, that hinder BIM's widespread adoption in India. However, the authors also highlight the potential benefits BIM offers, including improved design accuracy, enhanced collaboration, and reduced project delays. The research emphasizes the importance of promoting BIM awareness, providing training, and fostering industry collaboration to fully leverage BIM's capabilities and drive innovation within the Indian construction sector.
2) Soni and Khurana (2019),[4] "Examine the Application and Challenges of Building Information Modeling (BIM) in the Indian Construction Industry"
   Summary:. The study identifies significant challenges in its adoption, including a lack of skilled professionals, limited awareness, and high initial implementation costs. The authors stress the need for industry-wide training, government support, and standardization to overcome these barriers and maximize the benefits of BIM for Indian construction projects. The study provides valuable insights into the current state of BIM adoption and offers recommendations for its effective integration into the industry.
3) Rao et al. (2018),[5] "Barriers to the Adoption of Building Information Modeling (BIM) in the Indian Construction Industry"
   Summary: The study identifies several challenges, including a lack of awareness and understanding of BIM technology, insufficient training and skilled workforce, high initial costs, and resistance to change from traditional construction practices. Additionally, the research highlights organizational and cultural barriers, such as reluctance from stakeholders and the absence of regulatory support. The authors suggest that overcoming these obstacles requires targeted strategies such as increased education, government incentives, and industry collaboration to promote BIM adoption and realize its full potential in improving efficiency and project outcomes in India's construction sector.
4) Bansal and Gupta (2017),[6] "Use of Building Information Modeling (BIM) for Time and Cost Management in Indian Construction Projects"
   Summary: The study demonstrates how BIM can enhance project planning, scheduling, and budgeting by providing accurate, real-time data for decision-making. The authors highlight BIM's ability to visualize project timelines, optimize resource allocation, and detect potential issues early, ultimately reducing delays and cost overruns. However, they also identify challenges, such as limited BIM expertise and the high initial investment required for implementation. The research emphasizes the need for improved training and awareness to fully leverage BIM for effective time and cost management in the Indian construction industry.

5) Wang et al. (2014),[7] "Role of Building Information Modeling (BIM) in Large-Scale Construction Projects" Summary: The study highlights that BIM enables better collaboration among diverse project stakeholders by providing a shared digital model that improves communication, reduces errors, and streamlines workflows. The authors emphasize that BIM's capabilities in 3D visualization, real-time data sharing, and clash detection significantly improve project planning and execution, leading to more efficient management of time, cost, and resources. The research also discusses how BIM helps mitigate the complexities of large-scale projects by enabling effective coordination across multiple teams, thus improving overall project outcomes.
6) Rezende et al. (2016),[8] "Integration of Building Information Modeling (BIM) with Cost Estimation and Resource Management Tools"
Summary:The study emphasizes how combining BIM with cost estimation software allows for more accurate and dynamic budgeting, providing real-time insights into costs and resources throughout the project lifecycle. By enabling better forecasting and optimization of resources, BIM helps reduce the likelihood of budget discrepancies and delays. The authors also discuss how this integration improves decision-making, enhances collaboration among stakeholders, and ensures smoother project execution, leading to more cost-effective and efficient outcomes.
7) Smith (2014),[9] “Role of Building Information Modeling (BIM) in Improving Design Coordination within the Construction Industry”
Summary: The study highlights how BIM improves collaboration among architects, engineers, contractors, and other stakeholders by providing a centralized, digital representation of the project. By enabling real-time updates, clash detection, and better communication, BIM helps identify and resolve design conflicts early in the process, leading to more efficient project delivery. Smith emphasizes that BIM enhances the accuracy and transparency of design changes, reducing errors, minimizing rework, and ultimately improving the overall coordination and success of construction projects.

IV. INFERENCES FROM THE LITERATURE REVIEW

Following inferences have been drawn from the literature survey:
1) BIM is being increasingly utilized to improve the planning, design, and management of urban infrastructure throughout its lifecycle, offering enhanced visualization, better resource management, and improved project coordination. However, the challenges such as the lack of skilled professionals, resistance to new technology and insufficient government policies has to be addressed to support BIM integration.
2) While many studies focus on large-scale construction projects, there is a significant gap in research addressing how small and medium-sized enterprises (SMEs) adopt and implement BIM. SMEs face unique challenges such as budget constraints, limited access to advanced technology, and resistance to adopting new digital tools. Understanding how BIM can be adapted and utilized by SMEs to enhance collaboration and reduce project delays remains largely unexplored. Investigating the barriers and enablers to BIM adoption in these firms could provide valuable insights into how SMEs can optimize project timelines using BIM.
3) Construction firms face barriers to its adoption, including high costs, complexity, and lack of expertise. These barriers often prevent the full implementation of BIM, which may delay project timelines. However, there is limited research on how these adoption barriers specifically contribute to project delays. More research is needed to identify and quantify the challenges organizations face when adopting BIM and how these barriers hinder project completion on time.
4) Development of CDE in a BIM enabled workflow is a real challenge for small to medium scale Construction Project.
5) Despite the growing body of literature that promotes the benefits of BIM, there remains a lack of empirical, quantitative data to substantiate claims about BIM’s effectiveness in reducing delays. While case studies and anecdotal evidence support the notion that BIM improves collaboration and reduces errors, few studies have rigorously measured the impact of BIM on project timelines through empirical data, making it difficult to quantify its true effectiveness.

V. RESEARCH METHODOLOGY

The approach allows for :
1) Literature review focused on Case study and Empirical Study.
2) Compare BIM-enabled projects with traditional methods to highlight advantages in material waste reduction, scheduling, and resource allocation through whitepapers and industry insights.

3) Collect data through surveys, questionnaires, and seminars targeting small-scale construction in Bihar. Use statistical techniques like nir = $(z^2 * p * q) / d^2$ to ensure accuracy in survey sampling and analysis.
4) Consolidate data into actionable insights
5) Develop a conceptual based suggestion for establishing a CDE tailored for small-scale projects in Bihar aligned with CPWD guidelines.

VI. PROPOSED WORK

BIM integrates multi-disciplinary data to create detailed digital representations that support decision-making from project conception through demolition.

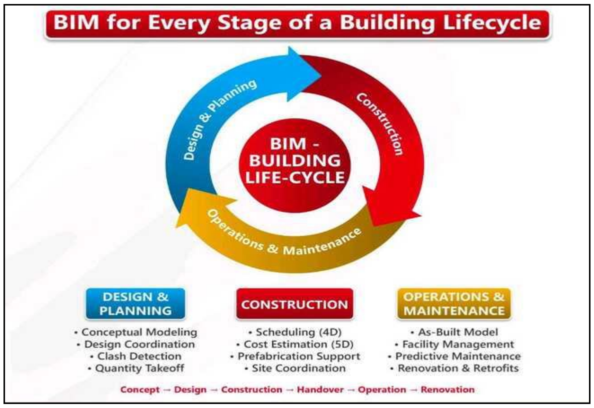

Figure 1 BIM- Building Life Cycle. (Source: Vitual Building Studio)

1) Design & Planning Phase In the early stages, BIM facilitates conceptual modeling and schematic design through 3D visualization tools (Azhar, 2011)[10]. Clash detection helps avoid design errors, and quantity takeoff tools enable material forecasting and budgeting.
2) Construction Phase During execution, 4D BIM supports project scheduling while 5D BIM enhances cost planning and tracking (Bryde et al., 2013)[11]. Site coordination is improved through federated models that integrate architectural, structural, and MEP disciplines.
3) Operations & Maintenance Phase BIM supports long-term facility management by providing an as-built digital twin that enables asset tracking, maintenance scheduling, and lifecycle cost analysis (Volk et al., 2014)[30].
4) Cross-Phase Integration According to Succar (2009) [12], BIM enhances cross-phase coordination by serving as a Common Data Environment (CDE), reducing information loss and improving collaboration

This VOSviewer network visualization titled “Role of BIM in Project Lifecycle Stages” displays the interconnections between Building Information Modeling (BIM) and various phases of a construction project's lifecycle. The map shows that BIM is not limited to the design phase but spans across the entire project lifecycle—from conceptual planning to facility management. The strong connections to “scheduling” and “coordination” suggest its key role in integrating timelines and multidisciplinary teams, while links to “operation phase” and “facility management” reinforce its long-term lifecycle value.

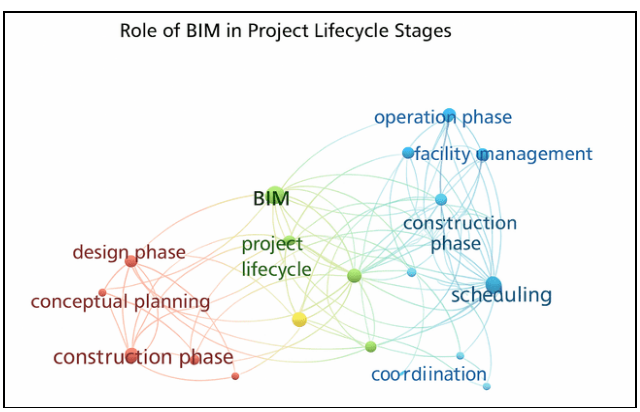

Figure 2: Role of BIM for an asset across its different lifecycle stages

The traditional construction process is prone to inefficiencies such as material waste, rework, and poor coordination. BIM offers a digital alternative that enables integrated planning and management of construction resources.

The key befits of BIM can be outlined through comparative case study as illustrated in Table 1 and Table 2.

- Case Study: The case studies over various parameters of construction issues are discussed below.

Key differences in Conventional Project Vs BIM-Based Project

Table 1 Comparison of Conventional Project Vs BIM-Based Project

Parameter	Conventional Project	BIM-Based Project	Source
Cost Overruns	10–20% over initial estimates	Reduced by 5–15% on average	McGraw Hill SmartMarket Report (2014), NBS BIM Report
Project Completion Time	Delays common, up to 20–30% of scheduled time	10–30% faster completion due to better coordination	CPWD BIM Guidelines (2024), Autodesk Whitepaper
Clash Detection	Manual, often found during construction	90% of clashes resolved during preconstruction	Autodesk BIM Case Studies (USA, UK)
Design Errors	5–10% design-related rework	Reduced by up to 40% through 3D coordination	Eastman et al. (2011), Autodesk Whitepaper
Request for Information (RFIs)	Higher frequency, delays in decision-making	Reduction by 25–35% due to centralized model access	Penn State BIM Execution Planning Guide
Material Wastage	10–15% on average	Reduced to 5–8% with better quantity take-offs	India Smart Cities Mission Reports, BSI BIM Case Studies
Productivity	Fragmented, siloed workflows	30–50% gain in team productivity	Dodge Data & Analytics Report (2021)
Lifecycle Facility Management	Poor integration of design data	Improved O&M due to rich asset information in BIM model	US GSA BIM Guide, Singapore BCA BIM e-submission system
Client Satisfaction	Moderate, limited visualizations	High, with immersive 3D walkthroughs and cost transparency	BIM Handbook (Eastman et al.), Bentley Whitepaper

Table 2: The Case studies of the projects which defines the capabilities of BIM adoption is tabulated below.

Metric	Conventional Approach	BIM-Based Approach	Source
Cost Overrun (%)	10–20%	5–10%	MDPI Study on Railway Projects
Time Overrun (%)	15–25%	5–10%	MDPI Study on Railway Projects
Material Wastage (%)	10–15%	5–8%	M Heavy Technology Report
RFIs per Month	20–30	10–15	Autodesk BIM Case Studies

1) Notable BIM Implementations in India

Several significant projects in India have successfully utilized BIM

- Delhi Metro Rail Corporation (DMRC): Adopted BIM for planning, design, and construction, resulting in improved coordination and reduced project timelines. Delhi Metro Rail Project used BIM for 33% reduced construction cost, 43% enhanced labor productivity and 50% decreased greenhouse gas emission. Delhi Metro Rail Corporation's Phase IV: One of the best examples of a large-scale project that used BIM technology. (archgyan.com)
- Nagpur Metro and Maha Metro: Implemented 5D BIM for project visualization, leading to enhanced quality control and cost savings. MAHA Metro: The MAHA Metro is the first organization in India to use 5D BIM project visualisation, which was implemented in 2015. The use of BIM in this project reduced time, effort and money, and was practically free of coordination problems, documentation errors, paperwork or miscommunication between the various stakeholders. (pmc.ncbi.nlm.nih.gov)

- Smart Cities Mission under Amrut: BIM plays a crucial role in planning and implementing infrastructure projects across various smart cities in India. The Indian government announced its BIM mandate for public infrastructure projects above Rs 500 crore in November 2020, with the goal of improving efficiency, reducing project delays, and enhancing project quality[Press Information Beureu].
- Chenab Bridge: in Kashmir, the tallest & longest spanning railway bridges in the world used BIM. The use of BIM in this project increased efficiency and allowed for clash detection.
- JIO World Centre used BIM integrated with BIM
- Currently, all the Namo Bharat stations are being designed and developed on BIM platform.
- Mumbai Airport: The use of BIM in the Chhatrapati Shivaji International Airport Terminal 2 helped with clash detection. Walkthroughs were generated from the BIM model which helped the team for inspection during installation.
- Bengaluru International Airport: BIM technology was successfully used in this project.
- Statue of Unity: BIM technology was successfully used in this project
- Indian Railway: It is using BIM for its station development. (CPWD BIM Guidelines)
- National Capital Region Transport Corporation (NCRTC): BIM guidelines for project implementation and O&M. (CPWD BIM Guidelines)
- Public Works Department, Madhya Pradesh: BIM mandate for contractors. (CPWD BIM Guidelines)
- Godrej Eternia project in Chandigarh, which resulted in a 22% decrease in energy use when compared to conventional techniques. (CPWD BIM Guidelines)
- Other Notable Projects: Rapid Transit in Amritsar, Maryada Purshottam Shriram international Airport, Surat diamond bourse.

2) Notable BIM Implementations in Bihar

While specific BIM implementations in Bihar are not extensively documented. Articles, reports, PIB, news, Author's Survey and personal interaction Confirms the use of BIM in Bihar. Also some of the complex structure though fully not implementing BIM throughout the Life Cycle stage but the nature of project's complexity confirms the use of 3D modelling by the use of softwares like Revit, Trimble, Navisworks, and Project Management Information System.

- Patna Metro Rail Corporation Ltd (PMRCL). It's still in its construction phase as on june 2025. DPR and JICA report validates BIM Implementation. (Tuaman and Mansycom Consultant are engaged in its BIM Implementation)
- Patna Medical College and Hospital (PMCH). L & T is involved in its construction. It's still in its construction phase as on june 2025. Complex Structure is utilizing BIM as confirmed from the survey respondent.
- Grand Mata Janaki Temple, Sitamarhi. It's a complex structure which is going to be constructed in Bihar. In June 2025, its design got approved. It complexity defines the use of digital technology.
- Patna Airport New Terminal Building. NCC is engaged in its Construction. The complexity of the structure engaged BIM platform as confirmed from survey respondent.
- Bihar Museum. The Bihar Museum in Patna was designed by Maki and Associates, in collaboration with Opolis Architects, Specifically, Japanese architect Fumihiko Maki led Maki and Associates. Opolis Architects, an Indian firm, partnered with them on the project.
- JP Setu: 6-Lane Bridge across River Ganga connecting Digha and Sonepur in Bihar with Total cost for the project is Rs.3,064.45 crore used latest technology like 5D-Building Information Modelling (BIM), by the Indian Railway.
- Double Decker flyover Patna: Complex Structure indicates the use of BIM.
- The Rajgir International Cricket Stadium: project is being overseen by Shapoorji Pallonji Group, with ARCOP Associates Pvt. Ltd. as the architects and consultants.

3) BIM applications in Resource Management.

This paper investigates the role of Building Information Modeling (BIM) in optimizing resources—labor, materials, time, and cost—in construction projects. The study is limited to a small-scale residential building project simulated using Revit (Version 2025 student's license) and Navisworks (Version 2025 student's license). Results are indicative but not exhaustive due to project constraints.

- A model case study of a G+1 residential building in Bihar (Patna) was selected to study the application of BIM up to 5D level.
- Tools and Software Used

a.) Autodesk Revit for 3D modeling

b.) Navisworks Manage for 4D/5D
c.) Excel for data analysis

- Project Selection and Data Collection

a.) Model building selected from local designer.
b.) Bill of quantities, manpower data, and scheduling baselines collected

- BIM Simulation Workflow

a.) Create coordinated 3D model
b.) Integrate construction schedule (4D)
c.) Assign material resources and cost data (5D)
d.) Compare baseline vs BIM-optimized outputs

- Evaluation Metrics

a.) Material wastage (% reduction)
b.) Labor productivity (man-hours saved)
c.) Cost variance (%)
d.) Project duration (days saved)

- Project Overview:

a.) Built-up area: 150 m²
b.) Project Value: ₹1 Crore
c.) Contract Duration: 6 months
d.) Tools Used: Autodesk Revit 2025, Navisworks Manage 2025 (Student's License v.2025)

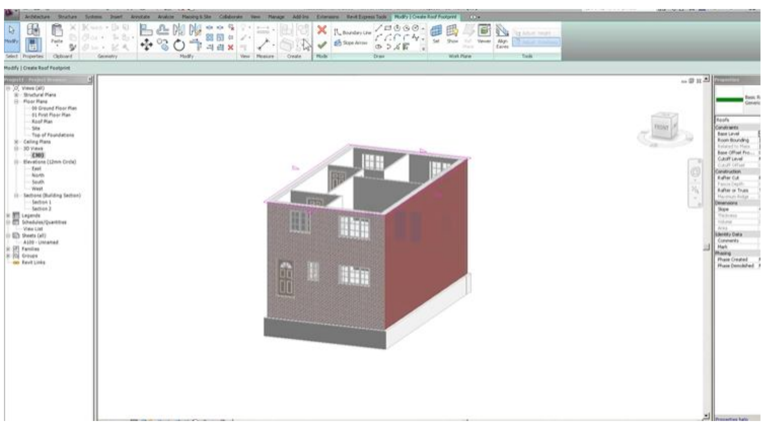

Figure 2.1 model of G+1 in Revit

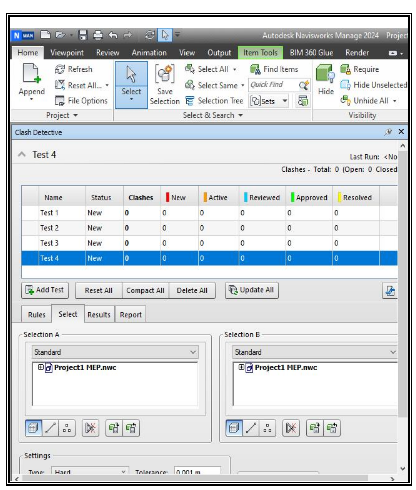

Figure 2.2 Clash detection in Naviswork

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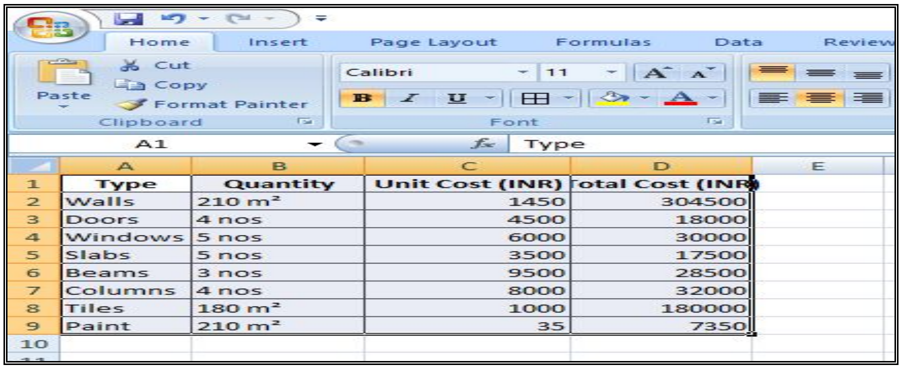

Type	Quantity	Unit Cost (INR)	Total Cost (INR)
Walls	210 m²	1450	304500
Doors	4 nos	4500	18000
Windows	5 nos	6000	30000
Slabs	5 nos	3500	17500
Beams	3 nos	9500	28500
Columns	4 nos	8000	32000
Tiles	180 m²	1000	180000
Paint	210 m²	35	7350

Figure 2.3 Quantity take off (MS Excel)

- Key Findings:
- Material Optimization: Clash detection resolved 36 MEP and foundation conflicts, preventing ₹1.1 lakh worth of rework.
- Labor Planning: Simulation led to smoother sequencing, reducing idle labor by 2,400 man-hours.
- Schedule Impact: 4D Time Liner simulation showed savings of 12 working days

- BOQ Comparison Table: The comparison table is created to find the variance over quantity.

Table 2.1: BOQ Comparison Table

Material	Quantity (Revit)	Quantity (Estimated by Contractor)	Variance
Cement	5,120 bags	5,300 bags	-3.4%
Rebar	29,800 kg	30,000 kg	-0.7%
AAC Blocks	41,200 nos	42,000 nos	-1.9%

- Cost Variance Summary:

Table 2.2 : Cost Variance Summary

Activity	Planned (₹)	Actual (₹)	Variance	% Difference
Excavation	2,50,000	2,45,000	-5,000	-2.00%
Concrete Framing	12,00,000	11,50,000	-50,000	-4.17%
MEP Installation	9,50,000	9,80,000	+30,000	+3.16%
Finishing Works	5,00,000	5,10,000	+10,000	+2.00%

- Conclusion: This case underscores how BIM adds value across design and Construction Phase stages by reducing errors, optimizing costs, and enhancing coordination. BIM's utility across the design, construction, and operational lifecycle of infrastructure projects is evident both in theory and in practice. Literature strongly supports BIM's effectiveness in improving cost, time, and quality outcomes. The case study of a residential building in Bihar demonstrates real, measurable benefits of BIM in material optimization, labor efficiency, and scheduling. With enhanced digital capacity and policy enforcement, BIM adoption in Bihar can deliver long-term infrastructure efficiency and sustainability.

A. Research Methodology adopted for assessing the barriers and Challenges of BIM adoption

To fulfil the objective of identifying the Barriers to BIM Adoption and determine possibility of its application in Small-Scale Projects in Bihar (Patna), Barriers and Challenges to Implementing BIM in Construction Projects in Bihar were identified through literature review which can be summarized as given in table 3.

Table 3: Barriers to Implementing BIM in Construction Projects of Bihar

Main Variable	Sub Variable	References
Financial Barrier	• High initial investment costs discourage small firm from adopting BIM. • BIM software and hardware are too expensive for small-scale projects. • Unclear return on investment (ROI).	[13]
Technical Barrier	• Lack of trained professionals in BIM is a major challenge. • BIM software complexity makes it difficult to implement in small firms	[13], [15]
Organizational & Cultural Barrier	• The local construction industry is not yet open to transitioning from traditional methods. • Resistance to change among construction professionals prevents BIM adoption	[13]
Awareness Training Barrier	• Educational institutions in Bihar do not adequately have BIM-related facilities. • Limited awareness about BIM benefits prevents widespread adoption.	[15], [16]
Legal & Regulatory Barrier	• There are no mandatory government policies enforcing BIM adoption in Bihar. • Legal risks associated with BIM discourage small firms from using it. • The lack of proper BIM contract frameworks creates uncertainty in its use.	[13],[14], [15]
Market &Client-Related Barrier	• Clients are unwilling to pay extra for BIM-based projects. • The local construction market does not demand BIM-based solutions. • BIM adoption does not currently provide a competitive advantage in small projects. • Project owners and stakeholders lack awareness of BIM benefits	[14]
Maturity of BIM Utilization	• Collaboration Team Building, Communication, and Clash Detection. • Utilization- Quality, repeatability and level of excellence in BIM service is a major concern.	[17]

For studying BIM adoption in small-scale projects in Bihar, there is limited prior research and the factors influencing adoption are unclear. As aim is to identify barriers, awareness levels, or stakeholder attitudes so research adopted was exploratory in nature.

B. Sampling Method

Target Population: Employees and owners of Construction Sector industry.

The target population consists of employee and owners of Construction sector along with academician across the Bihar region of diversified work experience. Also employees who were directly not working in Bihar but those who were engaged in Bihar Project from other locations were also part of this survey.

Sample Size Determination for Survey.

Standard Sample Size Formula (for Infinite Population):

$$n = [Z^2 \text{ x } p \text{ x } (1\text{-}p)]/e^2$$

Where:

- n = required sample size
- Z = Z-score for desired confidence level (e.g., 1.96 for 95%)
- p = estimated proportion (use 0.5 for max variability)
- e = margin of error (e.g., 0.13 or 13% assumed)

So, $n = [1.96^2 \times 0.5 \times (1-0.5)] / 0.13^2 = 56$

"For this exploratory study, a sample size of 56 respondents was determined to be sufficient, aligning with the recommended range of 30–100 for exploratory research (Saunders et al., 2012) [18]. An exploratory study is a type of research that is conducted to investigate a problem or situation that is not clearly defined. It is typically used when the researcher has limited information about the topic and wants to explore ideas, patterns, or insights to understand it better.

Table 4: Parameters and assumptions used for determining the required sample size (n = 56) for the BIM adoption survey in small-scale projects in Bihar

Parameter	Value	Description
Confidence Level	95%	Standard level for social science research
Z-score (Z)	1.96	Corresponding Z-value for 95% confidence
Estimated Proportion (p)	0.5	Maximum variability assumed (conservative estimate)
Margin of Error (e)	±13.1%	Acceptable margin of error for exploratory studies
Population Size (N)	Unknown / Not Applied	Finite population correction not applied (for generalizability)
Calculated Sample Size (n)	56	Required sample size based on assumptions above
Actual Responses Received	56	Number of valid survey responses collected
Total population assumed	100	Out of 100 survey invitations sent to target respondents, we received 56 completed responses, achieving a 56% response rate."
Sampling Technique	Purposive Sampling (Non-probability)	Targeted professionals in Construction projects in Bihar and academician from reputed institute.
Data Collection Mode	Online Survey (Google Form)	Survey distributed via email and messaging platforms

C. Data Collection

Questionnaires distributed through online platform was the main tool to undertake the data collection process for this research and was designed based on a status quo of BIM level of use and awareness in the construction industry in Bihar especially in the city of Patna and particularly intended to acquire the main objective of the study by answering the questions derived from it. The first part focuses on identifying the identities of the 56 selected respondents/institutions, which are owners, consultants, contractors/subcontractors, employees, of private companies and state-owned enterprises, central government, State government, PSUs, Institute of National Importance with the hope of representing the characteristics and population of the construction industry in Bihar. These experts or institutions have applied BIM or other digital technology in managing construction projects or are aware about BIM without being limited to certain types of construction. The second part of the survey concentrates on ascertaining experts' perceptions regarding the challenges of implementing BIM in construction projects with questions developed through a critical review of the literature. Thus, it is hoped that this process can provide valuable input for this research and have a positive impact on the construction industry in Bihar.

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D. Ethical Considerations

• Consent: Participants were informed about study objectives and responses anonymized.
• Confidentiality: No personal identifiers collected.
• Bias Mitigation: Neutral phrasing in survey questions to avoid leading responses.

In this research, the barriers faced in implementing BIM on construction projects as shown in Table 3 are challenges for organizations and construction projects. Therefore, the seven main variables in this research need to be considered as a challenges for implementing BIM in construction projects, especially in Bihar, as shown in Table 5.

Table 5: Variables Challenges of Implementing BIM in Construction Projects Variables

Code	**Variables of Challenges**
X1	Financial
X2	Technical
X3	Organizational & Cultural
X4	Awareness and Training
X5	Legal and Regulatory
X6	Market and Client Related
X7	Maturity of BIM utilization

E. Data Analysis

In this research, data analysis uses the Guttman scale[19] and Likert scale[20] to measure the research instruments, is questionnaires and the Correlation Coefficient a Measure of Linier Relation between variables and challenges in implementing BIM in construction projects.

Statistical Tools and Technique :

- Tools: MS Excel
- Techniques: The technique involves :
- Reliability Analysis : (Cronbach's Alpha) to check internal consistency.
- Correlation Analysis: Pearson's Correlation to see relationships between barriers and check validity of barriers.

In this research, positive and negative answers are used to measure the independent variable (X) which answers whether the variables in Table 3 are challenge variables for implementing BIM in construction projects. In this study, the level of suitability referred to in the Likert scale consists of five scale options whose interpretations are given in Table 6.

Table 6 Likert Scale Interpretation

Likert Scale	Gradation	Interpretation
5	Very strong relation	Strongly agree
4	Strong relation	Agree
3	Medium relation	Neutral
2	Weak relation	Disagree
1	Very weak relation	Strongly disagree

The value of r is calculated from n pairs of observation (x, y) according to the following formula [21], which gives the relationship between challenges variable with implementing BIM in the construction projects.

$$r = \frac{\sum (X_i - \bar{X})(Y_i - \bar{Y})}{\sqrt{\sum (X_i - \bar{X})^2 \sum (Y_i - \bar{Y})^2}}$$

Figure 3: Formuls for "r" Value

Interpretation of the magnitude of significant correlations by Guilford [21] shown in Tabel 7.

Table 7 : Interpretation of the magnitude of significant correlations

Correlation Coefficient (r)	Interpretation
0.00 to ±0.20	Very Weak or No Correlation
±0.21 to ±0.40	Weak Correlation
±0.41 to ±0.60	Moderate Correlation
±0.61 to ±0.80	Strong Correlation
±0.81 to ±1.00	Very Strong Correlation

F. Data Interpretation

A code was assigned, usually a number, to each possible response to each question. Recording and data transcription involved transferring the coded data from the questionnaires or coded sheets directly into Microsoft Office Excel. Data analysis can be done by variety of methods like SPSS, Python analysis etc the author used MS Excel for this purpose. For this exploratory study 15 questionnaires were distributed online in 2025.

1) Survey respondent Characteristics Summary

Respondents from varied background is shown in Table 8.

Table 8: Respondents Job Profile

Job Profile	**Nos. of Respondent**	**Percentage (%)**
(1)	**(2)**	**(3)**
Engineer	30	53.60
Architect	12	21.40
Academician	06	10.70
Construction Manger	04	7.10
Director	01	1.8
Design Manger	01	1.8
Researcher	01	1.8
Engineering Student	01	1.8
Total	**56**	**100**

The respondent composition of the BIM survey is heavily weighted toward engineers (53.6%), followed by architects (21.4%) and academicians (10.7%). This distribution ensures strong representation from the technical and academic communities, which are key drivers of BIM awareness and adoption. The inclusion of construction managers and senior-level roles such as directors and design managers, although limited, provides strategic and practical insights. Overall, the respondent profile is diverse and well-aligned with the objectives of understanding BIM adoption in small-scale construction projects."

2) Work experience of Respondents and their BIM awareness along with BIM adoption

The weighted BIM awareness score is 9.89 out of 15, across 56 respondents, segmented by work experience, reflecting the average awareness across all experience levels adjusted by group size.

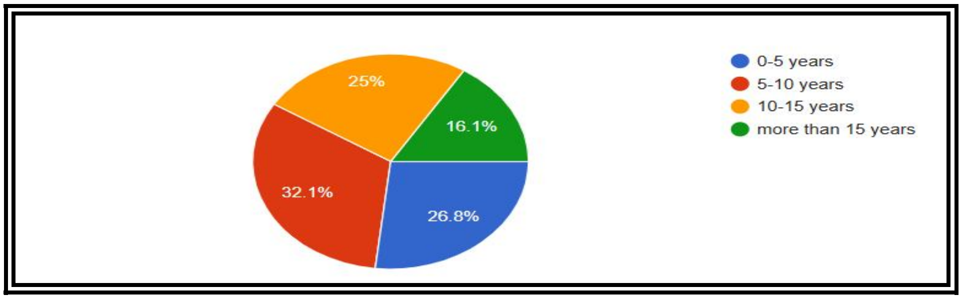

Figure 4: Respondents Work Experience

Source:- (Field Survey, 2025)

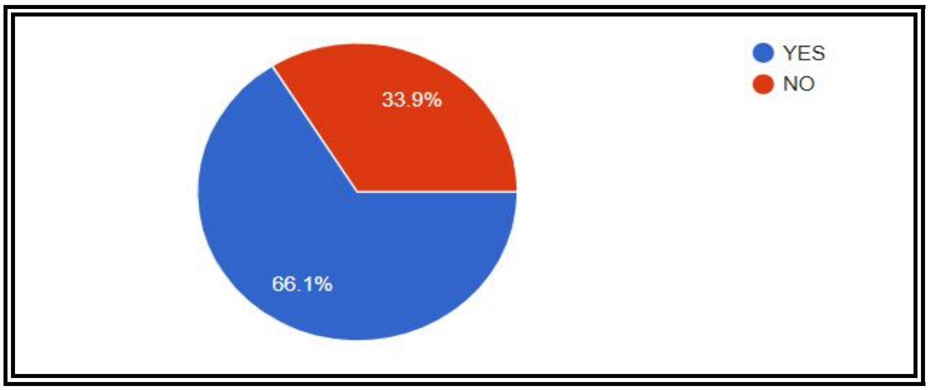

Figure 5: BIM awareness in Bihar

Source:- (Field Survey, 2025)

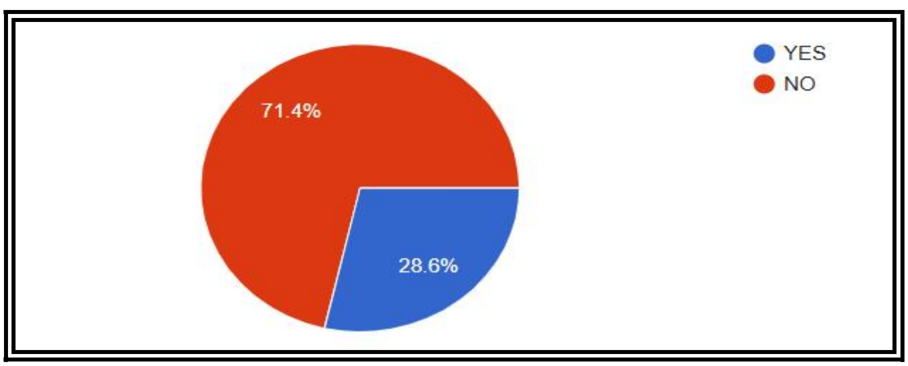

Figure 6 Percentage of BIM Adoption

Source:- (Field Survey, 2025)

Figure 7: BIM awareness score

A score of 9.89/15 (≈ 65.9%) suggests moderate awareness of BIM among professionals surveyed. This is neither low nor high, indicating that BIM is known by many, but not deeply integrated or fully understood by the majority. The 5–15 years experience groups (32.1% + 25%) contributed the highest awareness scores (12 and 13) and made up nearly 57% of total respondents. This implies that mid-career professionals are the most aware of BIM, likely due to their exposure to evolving industry trends and project-level responsibilities. Respondents with <5 years and >15 years experience had lower awareness scores (8 and 4).Junior professionals may have theoretical knowledge but lack practical exposure. Senior professionals may be less engaged with new technologies, relying more on traditional methods. Only 16 out of 56 respondents (28.6%) reported BIM adoption. This highlights a significant gap, suggesting that BIM adoption is still in early stages within small-scale projects in the region.

3) Awareness and Adoption based on Project Size

Respondent from varied profile and varied work experience engaged across different sizes of project and work are shown in Figure 8.

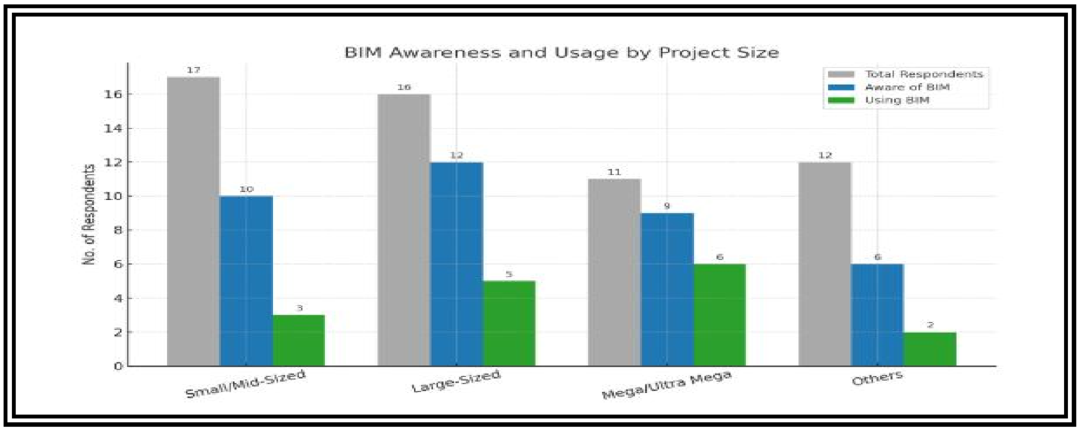

Figure 8: BIM awareness and usage by Project Size

BIM awareness is strongly linked to project scale**.** The larger and more complex the project, the more likely professionals are aware of BIM tools.

4) Construction Project Issues, BIM for sustainable repair & maintenance and Respondent's Perception on BIM as a Solution to Construction Project Issues

Common Construction issues such as Planning and Design Issues, Project Cost fluctuations, Delayed delivery of Project, Clash of Mechanical, Electrical and Plumbing work, Conflict between Client and Contractors over material quality, Post Construction issues like no maintenance plan, underutilization of assets was reported by the respondents. Nearly 43% of respondents believe BIM can play a significant role in sustainable repair and maintenance**.** Over 1 in 5 respondents do not believe BIM is useful for this purpose. A substantial proportion (35.7%) is unsure or hesitant, which reflects unclear ROI or unfamiliarity with sustainable lifecycle models.

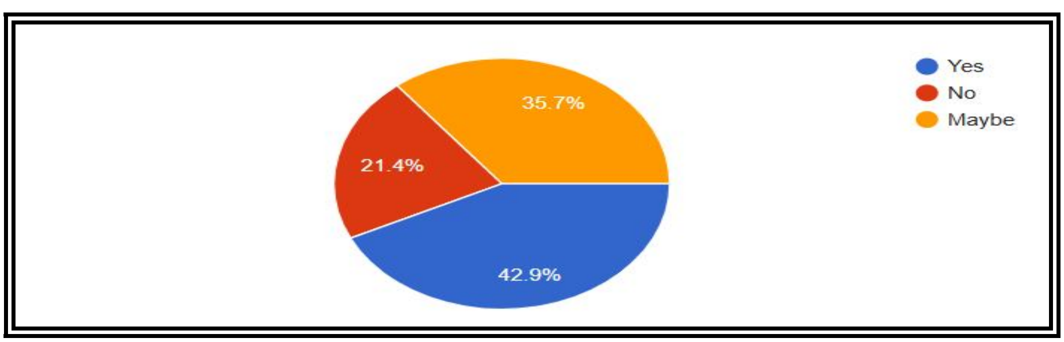

Figure 9: BIM for sustainable repair and maintenance.
Source:- (Field Survey, 2025)

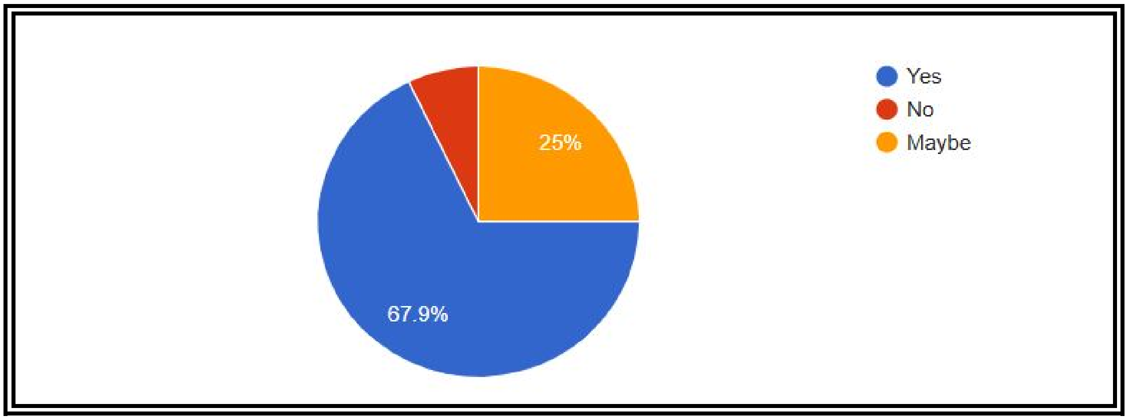

Figure 10: Perception of BIM as a Solution to Construction Project Issues
Source:- (Field Survey, 2025)

A large majority of respondents (38 out of 56) believe BIM effectively addresses construction issues. One in four respondents selected "Maybe", suggesting, Limited exposure or practical experience with BIM. Stakeholders from small-scale or low-tech projects where BIM is seen as overkill.

Using the Guttman scale, the results of the analysis of variables challenging the implementation of BIM in construction projects are shown in Table 9. This table presents the frequency and percentage of respondents identifying various barriers to **BIM adoption** in construction projects in Bihar. Each variable (X1–X7) represents a common category of barriers observed in previous literature and industry practice.

Table 9 Variables of Challenges of Implementing BIM in Construction Projects

Code	Variables of Barriers	Respondent Response				Total Respondent
		Yes	%	No	%	
X1	Financial	43	76.79	13	23.21	56
X2	Technical	35	62.50	21	37.50	56
X3	Organizational & Cultural	32	57.14	24	42.86	56
X4	Awareness and Training	49	87.50	07	12.50	56
X5	Legal and Regulatory	28	50	28	50	56
X6	Market and Client Related	36	64.29	20	35.71	56
X7	Maturity of BIM utilization	34	60.71	22	39.29	56

G. Validity and Reliability Test

1) Validity Test

A questionnaire is said to be valid if the questions in the questionnaire can reveal something that is measured by the questionnaire. The significance level used is 0.05. Testing the validity and reliability of questionnaire data uses the correlation formula with the application of MS Excel. To check the validity, Correlation coefficient of the variables X1, X2, X3, X4, X5, X6 and X7 was found. This is then verified using the "r" table, which is a table containing numbers which are usually used to test the results of the validity test of a research instrument.

- If r stat > r table, then the question or statement is declared valid.
- If r stat ≤ r table, then the question or statement is declared invalid.

With a significance level = 5%, df = (n-2) = 56-2= 54, obtained "r" table = 0.2640, then the results of the analysis are shown in Table 10 and Table 11.

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Table 10: Validity Test Results

Code	Variables of Challenges	"r" stat	"r" table	Description
X1	Financial	0.4373	0.2640	Valid
X2	Technical	0.3321	0.2640	Valid
X3	Organizational & Cultural	0.3848	0.2640	Valid
X4	Awareness and Training	0.3776	0.2640	Valid
X5	Legal and Regulatory	0.3878	0.2640	Valid
X6	Market and Client Related	0.3250	0.2640	Valid
X7	Maturity of BIM utilization	0.2687	0.2640	Valid

As all the variables from X1-X7 have "r" stat > "r" table, hence the question or statement is declared valid.

2) Reliability Test Results

"To assess the internal consistency of the survey constructs measuring barriers to BIM adoption, Cronbach's Alpha was calculated. The number of items in coded variable is 7 for which Cronbach's Alpha Interpretation (Guilford-style) is "Good" if "α " value ranges from 0.8 to 0.9.

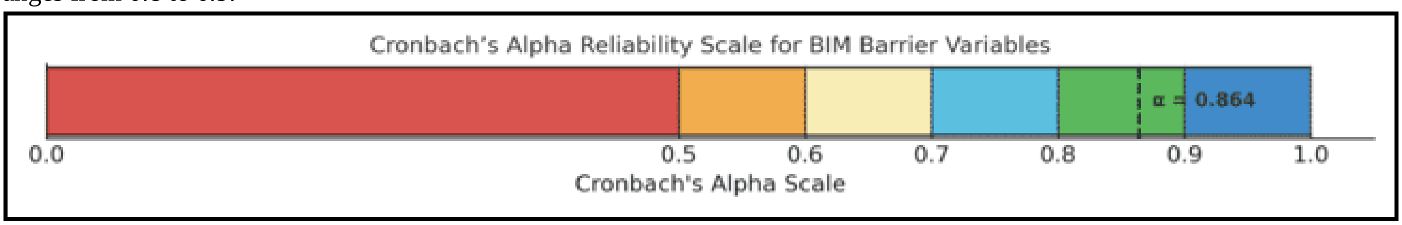

Figure 11: Cronbach's Alpha Summary interpretation chart

Table 11 Cronbach's Alpha Summary Table

Construct	No. of Items	Cronbach's Alpha	Interpretation
BIM Adoption Barriers (X1 to X7)	7	0.86431	Good Reliability

All constructs showed good reliability, with an overall alpha of 0.86 which is greater than 0.7 for the combined barrier items, indicating high internal consistency among the survey items. This suggests that the items are reliably measuring the underlying construct barriers to BIM adoption and are suitable for further statistical analysis such as factor analysis or correlation studies.

H. Relationship of Challenges with Implementing Building Information Modeling in Construction Projects.

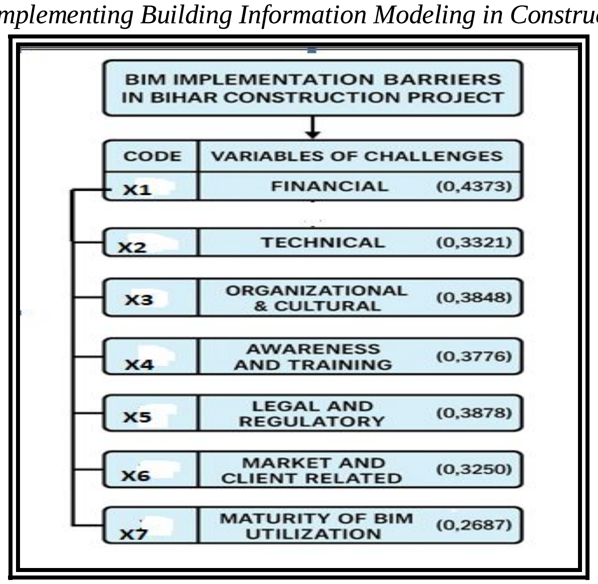

Figure 12 Relationship of Challenges with Implementing Building Information Modeling in Construction Projects

- Financial Barrier (X1 – r = 0.4373)
  - Strongest correlation with poor BIM implementation.
  - Indicates that cost-related factors are the most significant deterrent, especially in small-scale projects.
  - Suggests urgent need for cost-sharing models, open-source tools, or government financial incentives.

- Legal & Regulatory (X5 – r = 0.3878)
  - Moderate relationship.
  - Lack of mandates or standards creates inconsistency in BIM workflows.
  - Highlights the need for state policy or guidelines (like ISO 19650 or CPWD BIM Manual).

- Organizational & Cultural (X3 – r = 0.3848)
  - Indicates internal resistance to change, top-down inertia, or lack of BIM leadership.
  - Change management is critical to overcome this.

- Awareness and Training (X4 – r = 0.3776)
  - Correlated moderately—shows skill and knowledge gaps significantly hinder BIM use.
  - Need for capacity building, professional development, and BIM curriculum inclusion.

- Technical (X2 – r = 0.3321)
  - Lack of hardware/software or expertise weakens implementation.
  - Infrastructure development is needed.
- Market & Client Related (X6 – r = 0.3250)
  - Reflects lack of client demand, which slows innovation.
  - Promoting BIM as a value-driven solution can help.

- Maturity of BIM Utilization (X7 – r = 0.2687)
  - Lowest but still relevant.
  - Indicates that BIM is being used only in early stages, not fully across lifecycle.

The interpretations align with reference [13], [14], [15], [16], [17] mentioned in Table 3 of our study.

Findings from questionnaire and expert interviews

1) Recommendations for BIM Adoption Plan in Bihar based suggestions from Survey

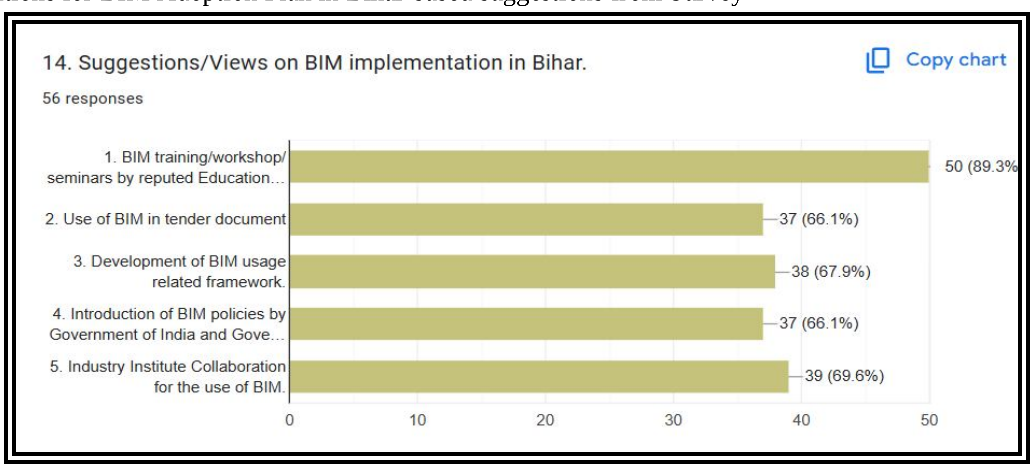

Figure 13 Recommendations for BIM Adoption Plan in Bihar (Check multiple responses)
(Source: Field Survey, 2025)

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➢ *Key Recommendations (Based on Response Percentage):*

- *BIM Training by Educational Institutes (89.3%)*

a) Highest priority recommendation.
b) Highlights the urgent need for capacity building through structured training programs, certifications, and awareness drives in Bihar.

- *Industry-Institute Collaboration (69.6%)*

a) Emphasizes the importance of joint initiatives between academia and the construction industry to promote practical BIM usage and research.

- *Development of BIM Framework (67.9%)*

a) Indicates that stakeholders require clear procedural guidelines or protocols for adopting and integrating BIM in projects.

- *Government Policy Interventions (66.1%)*

a) Reflects demand for formal policy-level support and incentives from state and central government.

- *Inclusion of BIM in Tender Documents (66.1%)*

a) Suggests stakeholders recognize the value of mandating BIM deliverables in public project tenders for standardization.

A process that could be followed to ensure BIM is fully used on every construction project in Bihar based on respondent's feedback and BIM CPWD Manual can be elaborated as shown in figure 14.

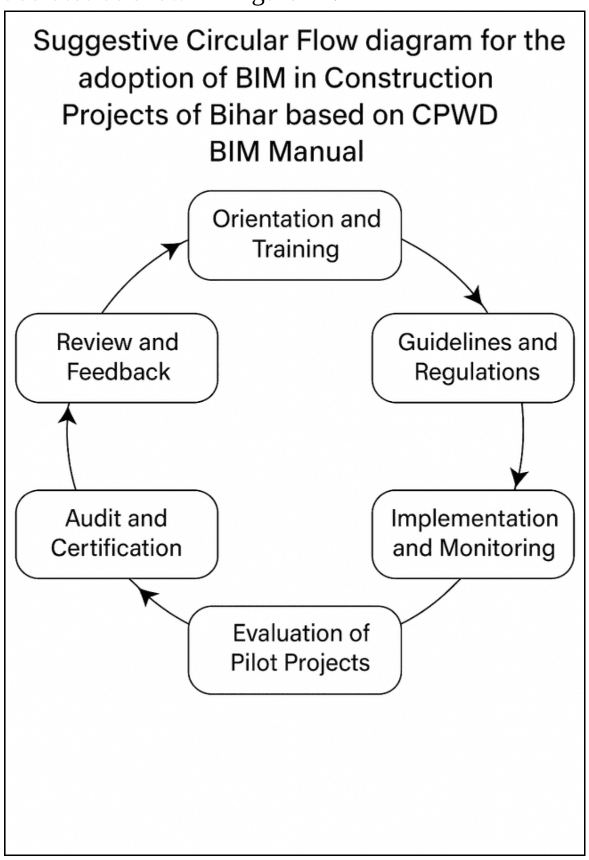

Figure 14: Based on Respondents Feedback and CPWD manual

The popularity of the BIM across the world and its increasing demand in the construction industry needs a platform for a developing country like India which is being supported by CPWD and as the Central Government is giving a push towards its implementation in India, Parallelly all State Government including the author's scope of study (Bihar) must integrate the workflow of BIM in its system by conducting orientation and training program to the stakeholders, issuing guidelines and regulations time to time for safe, secure and feasible implementation for small to medium sized projects of the state. Evaluation on some pilot projects need to be done to determine the range of project cost over which BIM related facility could be developed. A process of Audit and certification for selection of platform provider should be maintained.

Along with this educational institute must implement the softwares related course in BIM and an interdisciplinary project for all the branches of Engineering in association with architects to work on a live project sponsored by industry to gain practical knowledge. Finally, reviews and feedback system development to integrate the outcomes in orientation and training so that better adoption rate of BIM could be achieved.

➢ *Common Data Environment (CDE)*

A Common Data Environment (CDE) is a digital collaborative platform where all project stakeholders can manage, share, and exchange information efficiently across the lifecycle of a construction project—from planning to handover and facility management. The research investigates the framework developed by different BIM researcher, CPWD Guidelines, BIM Dubai Guidelines and proposes a Conceptual framework suitable for small scale construction projects in the state of Bihar (Patna region). This research limits its research up to suggestive CDE framework development communicated to the survey respondents.

Based on CPWD recommendations aligned with ISO 19650, a conceptual workflow model and CDE environment can describes in a series of steps as follows.

1) CDE Lifecycle Stages (Aligned with ISO 19650 & CPWD)

Table 12: CDE Lifecycle Stages

Stage	Description
Work in Progress (WIP)	Internal model development by each discipline (Architectural, Structural, MEP). Changes are made locally and not yet shared.
Shared	Verified and coordinated files/models shared for interdisciplinary review. Discipline models are federated here.
Published/Issued for Construction	Final verified models/drawings issued for site execution. Approved by Engineer-in-Charge.
Archived	Project deliverables archived for record, legal compliance, and future FM reference.

2) CDE Folder Structure (As per CPWD BIM Manual 2024)

```
/CDE_Project/
├── 00_Administration/
├── 01_Work_In_Progress/
│   ├── Architectural/
│   ├── Structural/
│   └── MEP/
├── 02_Shared/
│   ├── Models/
│   ├── Drawings/
│   └── Reports/
├── 03_Published/
│   ├── IFC_Docs/
│   ├── IFC_Models/
│   └── BOQ_Takeoff/
├── 04_Archived/
```

3) Information Exchange & Naming Protocol (CPWD 2024)

- Naming convention: ProjectCode_Discipline_Level_FileType_Revision.extension
  Example: Doubledeckerbridgepatna_STR_L2_IFC_R02.rvt
- All data exchanges must follow CPWD-approved Model Exchange Format (RVT, DWG, NWC, IFC). (In case it is approved by Bihar Government, it will follow its model exchange format)
- Weekly issue logs and change records maintained in Excel/XML logs within /Shared/.

4) Roles & Responsibilities in CDE Workflow

Table 13: Roles & Responsibilities in CDE Workflow

Role	Responsibility
BIM Lead (BCD/PMC)	CDE administrator, oversees file validation, version control
Discipline Modeler	Develops and updates WIP files
Engineer-in-Charge	Approves Published/IFC documents
Contractor/Vendor	Access to IFC data for execution

5) CDE Implementation Platform Suggestions

Table 14: Suggestive platforms for CDE

Platform	Suitability	Key Features
Autodesk BIM 360 Docs	High	Cloud-based, integrated with Revit/Navisworks
Trimble Connect	Moderate	OpenBIM support, IFC viewing
CDE via e-GEM or NIC Platform	Preferred (Govt)	Can be customized with BCD metadata & hierarchy

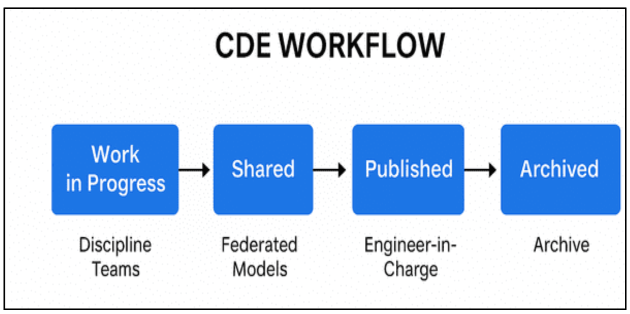

Figure 15 Suggestive CPWD-Aligned CDE Workflow

➢ *Recommendations*
- Institutionalize BIM-based CDE for all Engineering Departments projects above ₹5 Cr.
- Mandate CDE folder structures and naming conventions across tenders.
- Train Engineers and outsourced consultants in CDE workflows using NIC or BIM 360.

VII. CONCLUSIONS

The conclusions drawn from an extensive literature review, technical simulations, case-based observations, and exploratory Survey are listed below.

1) The present research reveals that the Bihar AEC sector has not entirely adopted digital technology such as BIM, and contributes to comprehend the current state of BIM advancement in Bihar.

2) While direct case studies from Bihar are limited, the documented successes of BIM in various Indian infrastructure projects suggest that adopting BIM methodologies can lead to substantial improvements in efficiency, cost-effectiveness, and overall project quality.

3) The survey results indicate a moderate overall BIM awareness rate of 66.1%. While high awareness is observed among academicians, architects, and senior professionals, the key operational roles—engineers and construction managers—show only 50% awareness. This discrepancy poses a significant challenge to the widespread adoption of BIM, particularly in small-scale projects where these roles dominate. Additionally, the complete lack of awareness among the student respondent suggests a need for stronger BIM integration in engineering education. These findings highlight the importance of targeted awareness and training programs to bridge the practical knowledge gap and support BIM adoption at the ground level."

4) "The survey reveals that while 66.1% of respondents are aware of BIM, only 28.6% actually use it. Engineers lead in both awareness (50%) and usage (33.3%), making them key stakeholders in BIM implementation. Despite high awareness among architects (91.7%) and academicians (100%), practical usage remains low, especially in academic and design environments. This highlights a critical gap between knowledge and practice. Specialist roles like design managers and researchers show full engagement with BIM, suggesting that when BIM is integrated into specific responsibilities, its adoption is high. To bridge the awareness–usage gap, targeted training and project-level adoption incentives are essential."
5) "The survey indicates a clear relationship between project size and BIM awareness and usage. While awareness increases steadily from small to mega-scale projects, actual usage of BIM tools is significantly higher in large and complex projects. Over 54% of respondents from mega-scale projects use BIM, compared to just 17% from small or mid-sized projects. These findings suggest that project complexity, scale, and resource availability are key drivers of BIM adoption, and small-scale projects may require targeted support and simplified tools to bridge the adoption gap."
6) "Survey results show that the most significant barriers to BIM adoption in Bihar are related to awareness and training (87.5%), followed by financial constraints (76.8%) and market/client-related factors (64.3%). These findings suggest that while the technological framework for BIM adoption is emerging, there is a critical need for capacity-building programs, financial incentives, and regulatory guidance to create an ecosystem supportive of digital construction practices."
7) "Correlation analysis reveals that financial barriers (r = 0.4373) show the strongest relationship with limited BIM adoption in Bihar's construction projects. Moderate correlations also exist for legal/regulatory, organizational, and awareness factors. Interestingly, BIM maturity and market demand have lower correlations, suggesting they are more likely consequences of the core barriers rather than root causes. This reinforces the need to address foundational issues such as cost, policy support, and training to enable widespread BIM integration."
8) "Cronbach's Alpha was computed to assess the reliability of the seven variables representing BIM adoption barriers (X1 to X7). The value obtained was 0.864, which falls within the range considered 'good' according to Guilford's interpretation scale. This confirms that the items are internally consistent and effectively capture the dimensions of BIM-related challenges in the construction industry in Bihar."
9) Based on International National BIM guidelines a workflow structure for Bihar Projects can be suggested. Institutionalize BIM-based CDE for all Engineering Departments projects above ₹5 Cr. Mandate CDE folder structures and naming conventions across tenders. Train Engineers and outsourced consultants in CDE workflows using NIC or BIM 360. These targeted steps can be taken in phased manner to implement BIM concept in state government of Bihar

VIII. RECOMMENDATIONS

1) Integrate BIM across All Project Lifecycle Stages
2) Strengthen Technical Capacity and Awareness
3) Establish a Scalable Common Data Environment (CDE)
4) Institutional and Policy Support for BIM Mandates
5) Pilot BIM in Select Public Projects in Bihar
6) Encourage Public–Private Collaboration

These recommendations, if adopted, can catalyze a broader transition toward digital construction practices in Bihar. By embedding BIM and CDE in small-scale project workflows, the region stands to gain significantly in terms of cost-efficiency, project delivery, and long-term infrastructure resilience.

IX. LIMITATION OF PRESENT WORK

While the study provides valuable insights into employees' perceptions and experiences regarding BIM benefits and their impact on Construction sector, it's essential to acknowledge certain limitations that may affect the generalizability and interpretation of the findings:

1) Sample Composition: The study's sample may not fully represent the diversity of the workforce within the Construction industries of Bihar. The overrepresentation of certain demographics, such as older employees with traditional work culture, could limit the generalizability of the findings to the broader workforce population.
2) Self-Report Bias: The data collected relies on self-reported responses from participants, which may be subject to biases such as social desirability bias or recall bias. Participants may provide responses they perceive as favorable or may inaccurately recall past experiences, affecting the reliability of the data.

3) Cross-Sectional Design: The study adopts a cross-sectional design, capturing data at a single point in time. As a result, it may not account for changes in employees' perceptions or experiences over time, limiting the ability to draw causal inferences or assess the long-term impact of BIM benefits.
4) Response Rate and Non-Response Bias: The study's response rate and potential non-response bias could affect the representativeness of the sample and introduce selection bias. Individuals who chose to participate may have different characteristics or perspectives compared to non-respondents, impacting the validity of the findings.
5) Single Method of Data Collection: The study relies solely on survey data for data collection, which may limit the depth of understanding and overlook nuanced factors that could influence employees' perceptions of BIM benefits and BIM barriers.
6) Lack of Qualitative Validation: The study is primarily quantitative in nature and lacks qualitative validation such as interviews, case studies, or field observations, which could provide deeper insights into contextual challenges.
7) Generalizability: The findings of the study may not be generalizable to all construction companies, as organizational cultures, management practices, and employee demographics vary across firms. Limiting the study to a specific subset of the construction sector could limit its applicability to other contexts.
8) Conceptual CDE: CDE developed in this thesis is limited to the conceptual model presented in the research is of a generic nature and can be refined through a comprehensive understanding of the diverse population types (based on IDT) that exist within the Indian construction industry.

Acknowledging these limitations is crucial for interpreting the study findings accurately and informing future research efforts aimed at addressing gaps in understanding and improving employee satisfaction, engagement, and retention within organizations.

X. SCOPE FOR FUTURE STUDY

Based on the findings and limitations of the current study, several avenues for future research can be explored to deepen our understanding of BIM benefits and their impact on small scale construction Industries of Bihar.

1) Longitudinal Studies: Conducting longitudinal studies to track changes in employees' perceptions and experiences of BIM benefits over time could provide valuable insights into the long-term impact of benefits on small scale construction Industries of Bihar.
2) Strategic Alignment: Examining the alignment between benefits offerings and organizational goals and values, it can help identify opportunities to leverage benefits as strategic tools for construction sector.
3) In-depth Qualitative Investigations: Future studies should integrate qualitative methods such as expert interviews, focus group discussions, and case studies of real-life BIM projects in Bihar to capture nuanced insights.
4) Evaluation of Government Policy Impact: Future work can analyze the impact of emerging policies, mandates, and guidelines (e.g., CPWD BIM Guidelines, PM Gati Shakti) on BIM uptake in public infrastructure and private real estate in Bihar.
5) Pilot Implementation and Testing of a Common Data Environment (CDE):Future research may involve developing and testing a CDE framework on a live construction project in Bihar to validate its effectiveness in coordination, data sharing, and lifecycle integration.
6) Cost-Benefit Analysis of BIM Implementation: A focused study on the economic feasibility and ROI of BIM in small-scale projects can help stakeholders assess practical viability and justify investments.
7) Educational Program: Impact of introducing BIM in curriculum and training Program on enhancement of employability of Engineer and Architects is area of study where state like Bihar can outperform.
8) CDE: Development of Common Data Environment for small- medium ranged Project and finding a practical solution for Data Security.
9) Study on the impact of competitive bidding on BIM adoption in Government Project.

By addressing these areas of future research, scholars and practitioners can further advance their understanding of BIM benefits' role in shaping employee experiences and organizational outcomes, ultimately contributing to the development of more effective and impactful benefits strategies within the Construction industry and beyond.

XI. ACKNOWLEDGMENT

I would like to extend my gratitude and thanks to my research Supervisor and my co-supervisor for their immense support, motivation, and shear guidance. Their guidance helped me a lot in the research.

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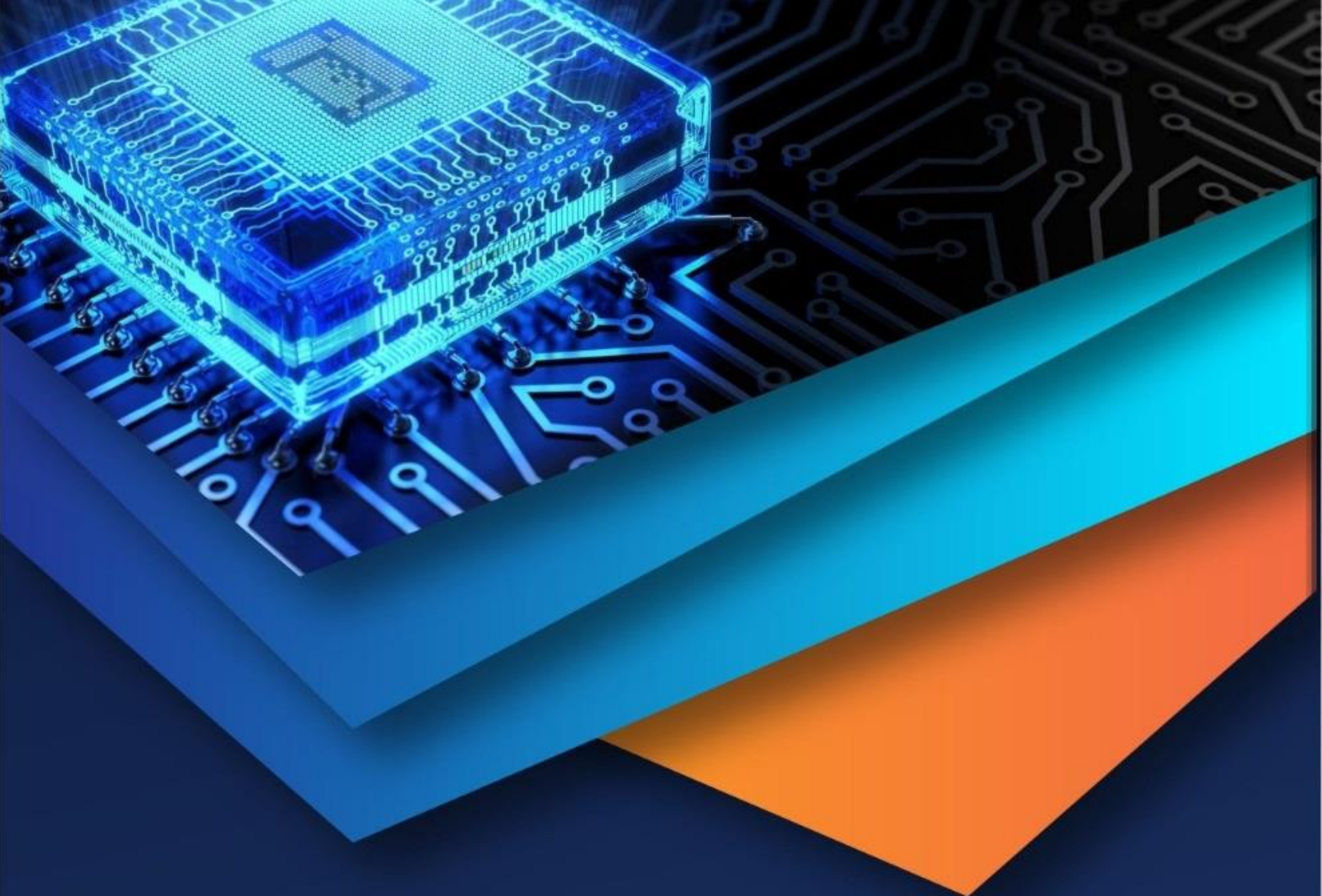

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