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A Study of the BIM Collaboration Concept to Reduce Building Construction Project Delays in Sri Lanka

U.I.G.D. Lakruwan[1]*, D.M. Mudalige[2]

[1] University of Liverpool John Moores, United Kingdom

[2] University of Moratuwa, Sri Lanka

*Corresponding Author: damithlakruwan@gmail.com

ABSTRACT

The time and cost overruns in construction projects are a usual challenge in the industry. The implementation of Building Information Modeling (BIM) has emerged as an evolutionary implement in the construction industry over the past decade, gaining continuous recognition and wider adoption worldwide. This research evaluated the effects BIM has on the construction project delays when compared to the standard practices OF managing construction projects. The literature review revealed significant delays impacting various stages of the project lifecycle, including the design stage, construction phase, and stakeholder communication. The study pointed out, however, that the use of BIM in the management of projects provides a viable mechanism to mitigate these challenges in the Sri Lankan construction industry. To determine the variance between projects utilising BIM and those undergoing conventional practices, a questionnaire survey was conducted with 150 industry experts. Respondents were encouraged to provide insight based on their experiences in the Sri Lankan context since this paper focuses on the impact of BIM on Sri Lanka's construction industry. 100 respondents were analysed. A single linear regression analysis and an independent t-test were conducted via the SPSS tool. The document also outlines the status of the practice of BIM implementation and its significance in the improvement of project performance. In addition, it explains the need for integration of BIM into the educational curricula of universities and policy of contractual agreements and its utilisation in the industry. However, this research paper has only been able to analyse the delays under three broad categories applicable in Sri Lanka because the causes of delays in construction projects are numerous. In the case of this research, a new avenue was opened for the construction business regarding the impact of BIM on performance and delays towards projects. It complements a paradigm shift in construction management practices by highlighting how BIM can alleviate delays throughout the lifecycle of a project.

Keywords:. Building Information Model, Project Delay, Construction Phase, Design Phase, Stakeholder Communication.

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INTRODUCTION

Time and cost are the two most difficult things to manage in construction. These factors are frequently neglected, which results in the postponement of projects in the context of Sri Lanka(Niroshana et al., 2023). The Project Management Body of Knowledge (PMBOK) emphasises the importance of diligently monitoring and controlling costs and time to achieve project goals according to initial project requirements (PIMBOKguid®).

In construction, there are several reasons for Project Delays, and this study examines three levels for project delay over the periods, the cause, and what Building Information Modelling (BIM) does to help overcome the delays.
First, the number one project delay factor is design changes. This is consistent with_data from(Sha'ar et al., 2017) that found that Modifications to the original design can disrupt the building process. However unstable client requirements and poor coordination between design team disciplines have a huge negative impact on the proper execution of the project.

Secondly, there is poor communication between the different stakeholders. Olander and Landin (2005), analysed different groups of stakeholders that have influenced project decisions in manners that go beyond the authority of the project management team. This poses another significant challenge. Poor information sharing and collaboration among project stakeholders may lead to misunderstandings, delays in decision-making, and subsequent project delays.

Thirdly, conflicts arising during the construction phase significantly influence project timelines. Challenges associated with material acquisition, coordination among suppliers, and procurement procedures have the potential to interrupt the construction schedule, resulting in delays.

Building Information Technology (BIM) has quite literally changed the face of the construction industry in recent years. BIM is critical in overcoming inefficiencies related to traditional construction management and improving the overall outcome significantly (Ali et al., 2021).

Construction activities in Sri Lanka have enjoyed enormous growth from the year 2009 onwards with respect to infrastructure and construction/reconstruction projects (Central Bank, 2009). Considering the complexity in this industry and its fast development, the creation of a common data platform accessible to stakeholders in a construction project can help reduce delays across its many stages. (Epasinghe et al., 2018).

The construction delays that occur during the aforementioned phases should be identified properly and addressed in a proper manner.

Aims and Objectives

This research study aims to determine the significant impact of BIM collaboration in reducing construction delays caused by selected root causes. These studies focus on the root causes of design delays, delays due to construction conflicts, and delays resulting from a lack of communication among stakeholders. To accomplish this aim, the following objectives have been outlined:

1. Assessing the efficiency improvements achieved through the collaboration of BIM at the selected stage of the construction process.

2. Comparing the impact of delays between projects utilizing BIM and those not utilizing BIM.

Research Methodology

The methodology of quantitative research is carried out using a questionnaire survey of 150 industrial experts.

Statistical Package for the Social Sciences (SPSS) software will be used for the purpose of statistical analysis to infer both descriptive and inferential statistics and to test if there are significant associations between variables under study. These statistics will offer a detailed examination of the variables and their respective distribution within the dataset.

LITERATURE REVIEW

The construction industry has a substantial impact on the Gross Domestic Product (GDP) of many nations. In 2012, global expenditure on construction-related activities reached approximately $4 trillion, and it is projected to reach $9 trillion by 2025. Currently, annual spending on the construction sector exceeds $11 trillion, accounting for nearly 13% of the global GDP. These figures highlight the significant economic significance of the construction industry and its potential for driving growth and development on a global scale (Luo et al., 2022).

The construction trade is a key sector of the Sri Lankan economy that has been displaying positive trends. Exchange Economics (2022) estimates that Sri Lanka's GDP from construction was 143035 million LKR in September 2021. The expansion of Sri Lanka's economy in recent years was significantly influenced by the construction industry.

Ogunlana et al. (1996) revealed that construction delay has a significant impact on the country’s economy in different ways, and this has to be addressed at various stakeholder levels.

Project Delays

Construction projects have been plagued with time overruns in 70% of the cases, where 76% of the contractors and 56% of the consultants reported a time overrun of between 10% and 30% over the initially planned duration. Such delays have led to a consequent 50% cost increase (Gebrehiwet & Luo, 2017). The issue of project delays in the building industry has been widely researched, where studies have looked at different aspects. Some studies have examined the most influential determinants that result in delay in different types of projects, while other studies have found frameworks to analyse such delays and recommended ways to mitigate them (Marzouk et al., 2018).

Numerous scholars have extensively studied the issue of project delays, as seen in Figure 1- Most studies divided delay into groups according to how much of an influence they had or how frequently they occurred. A team has identified the delay causes by focusing solely on how they will affect the project's overall schedule (Moungnos and Charoenngam, 2003).

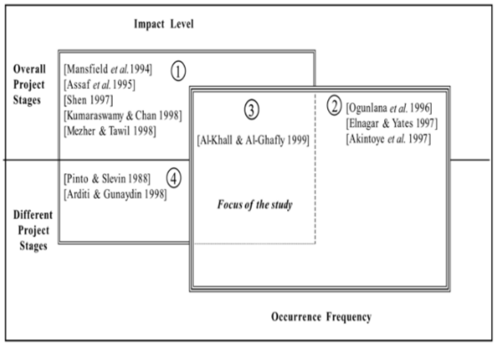


Figure 1- Most studies divided delay factors. Resource: Moungnos and Charoenngam, 2003

There are many investigations conducted by former researchers to determine the reasons for construction project delays and how to overcome those issues. Finally, delays were also attributed to causes related to contractual conditions, with notable factors including unrealistic contract durations, costs, and insufficient details in the contract document (Gebrehiwet & Luo, 2017). This write-up focuses on discussing conflicts between design and construction during the construction stage.

This study, through a comprehensive review of aforementioned literature, selected three primary root causes of project delays. These are challenges during the design stage, conflicts arising in the construction stage, and ineffective stakeholder communication. By focusing on these critical areas, the study aims to observe how the collaboration of BIM contributes to overcoming or reducing delays and propose strategies for mitigating their impact.

Construction Delay in Sri Lanka

The Reasons for construction time delays in Sri Lanka can be divided into three categories: those that are under the control of clients, those that are affected by contractors, and those that are out of either party's control as specified in the contract (Ramachandra et al., 2014). These delays could be brought on by both contracting parties' acts and outside forces.

In previous studies, it was observed that the main factors for delays in construction assignments in Sri Lanka are problems with the contractor's finances, poor planning and scheduling by the contractor, and lack of decision-making by the client (Ekanayake & Perera, 2016). Right from the beginning of the project, there were financial difficulties and poor planning. During the Design phase, mistakes occurred because people used conventional technology and stuck to the 2D plans instead of using more advanced methods. There were also many delays due to poor communication among the people involved in the project (eng. (prof.) shiromi karunaratne, 2021).

The participants in the studies suggested some solutions, such as using BIM at the start of the construction to help with planning, having fast communication for approvals and inspections by the consultants, and setting a realistic project duration that takes bad weather into account (Silva, 2011).

Previous studies reveal some limitations in understanding how Building Information Modeling (BIM) is applied to minimize project delays in the various stages of construction projects. The present study seeks to alleviate these shortcomings by conducting a comparison of projects that employ BIM with those carried out using traditional project management techniques.

BIM Adoption to Mitigate Delay

Building Information Modeling is applied in Architecture, Engineering, and Construction (AEC) industry broadly.

The client can use BIM in determining the needs of the project, the design team to study, strategize and develop the project as well as a contractor's team that handles the construction (Oraee et al., 2017). BIM, therefore can serve a dual purpose as a recipient as well as a driving factor towards integration of BIM practices(Lindner and Wald, 2011).

A recent study into BIM adoption in Sri Lanka found that 55.55% of construction company owners were not interested in adopting BIM in their projects (Perera et al., 2021).

The current study attempts to explain the significant differences in project delays encountered in BIM-integrated projects as compared to those managed with traditional project management practices. This study tries to show how BIM lessens delays and improves overall productivity while comparing both methods.

Delay Impact Due to Design Changes

Design changes are frequently caused by consultants, errors and omissions, inadequate work scopes, a shortage of coordination, insufficient working details, and a lack of experience that can occur during the design stage of a construction project (Mishra & Aithal, 2022).

The frequent changes in design often result in difficulties visualising the final product according to the client's requirements. The conventional practice of using two-dimensional (2D) blueprints has limitations in accurately conveying the intended deliverable. To address this challenge, numerous researchers have conducted extensive investigations into automated design modification detection in BIM-based processes.

Early detection of possible design challenges or conflicts can reduce or even completely eliminate design delays brought on by mistakes or conflicts.

BIM software facilitates Real-time feedback and decision-making, which enables various stakeholders to access and work on the design model concurrently (Datta et al., 2022). These tools assist in locating and resolving clashes between various building systems or components (Deng et al., 2019).

Furthermore, the former study provides a suggested classification of design changes that can serve as a foundation for the development and testing of new detection methods (Elghaish and Abrishami, 2020). By using Building Information Modeling (BIM) technology and following reliable detection approaches, construction projects can minimize the delays and uncertainties associated with frequent design modifications, improving project outcomes and customer satisfaction (Lin & Zhou, 2020)

Delay Impact Due to poor communication among the Stakeholders

The diversity of stakeholders poses a significant complexity about the multi-version nature of stakeholder engagement in the construction industry (Heravi et al., 2015). Since the stakeholders for the involved process have heterogeneous characteristics, managing their participation raises unique challenges in addition to a professional mechanism (Bal et al., 2013).

Identifying stakeholders involved in the project, such as clients, contractors, subcontractors, design professionals, regulatory agencies, local communities, and end-users, who have a direct or indirect stake in the project(Heravi et al., 2015). It is fundamentally important that the involved stakeholder gets timely and exact information regarding project objectives, progress, and potential impacts. This transparency helps build trust and fosters a sense of ownership among stakeholders. Figure 2- Stakeholder involvement in project represents the level of stakeholder involvement as per the research conducted (Al-Ashmori et al., 2020).

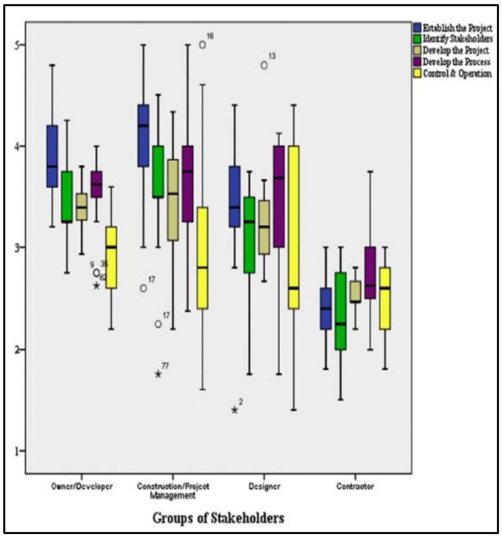


Figure 2- Stakeholder involvement in project phases. Source: (Yang et al., 2016)

Comprehending the apprehensions and ambitions of stakeholders facilitates the identification of possible conflicts and allows for the formulation of suitable strategies to proactively tackle these issues(Yang et al., 2016).

The application of Building Information Modeling (BIM) presents considerable benefits, as evidenced by the results of multiple research endeavors. For instance, (Al-Ashmori et al., 2020) emphasize that a primary benefit of BIM lies in its capacity to improve communication among multiple parties. Further research conducted (Sholeh et al., 2020) in Indonesia highlights the advantage of BIM in facilitating effective risk sharing amongst stakeholders.

BIM can bring benefits to construction project managers in terms of improved collaboration between stakeholders and increased efficiency in project documentation, which might lead to good project outcomes (Bryde et al., 2013). It has been defined that BIM goes beyond being a mere software tool (Al-Ashmori et al., 2020).

Delay Impact Due to Construction Conflict

Construction projects often encounter delays during the construction phase, stemming from various causes. These delays can result in increased project costs, compromised quality, and client dissatisfaction (Niazi & Painting, 2017). BIM, with its three-dimensional modelling capabilities and integrated information, provides a collaborative platform for project stakeholders to visualize and coordinate various aspects of the construction process (Al Amin, 2020). Through the use of clash detection tools, potential clashes between different building systems or components can be identified early on, allowing for adjustments to be made to prevent conflicts during construction (Oraee et al., 2019). This proactive approach minimizes the need for rework caused by design clashes, saving both time and resources (Oraee et al., 2019). It is a crucial aspect that affects how much money and time a building project ends up costing (Niazi & Painting, 2017). According to (Hwang et al., 2019), building projects have a larger rework cost than infrastructure projects.

Several research studies have leveraged BIM to identify and mitigate the factors contributing to construction conflicts, including defects and design errors. These studies have focused on developing BIM-integrated technical solutions within the construction industry, aiming to minimize the root causes of rework and enhance quality and schedule management.

In a study, they created a defect management system using augmented reality, image-matching technologies, and BIM. As a result, it is yet unclear if the deployment of BIM would reduce rework. The framework developed (Hwang et al., 2019) has the ability to lessen the need for rework by decreasing the likelihood of faults.

The literature studies surveyed Chinese BIM experts on their perceptions of the impact of BIM implementation, they discovered that fewer design flaws and the ensuing construction conflicts are seen as the top advantages of utilizing BIM (Jin et al., 2017). Furthermore, (Matarneh & Hamed, 2017) highlighted the most frequently cited advantages of employing BIM in construction projects.

In conclusion, the construction industry plays a pivotal role in contributing to GDP globally, with project performance in terms of time and cost having a direct impact on economic outcomes. Building Information Modeling (BIM) has emerged as a high-standard technology designed to address challenges throughout the construction project lifecycle. However, in Sri Lanka, the adoption of BIM technology remains limited, particularly at advanced levels such as 4D and 5D, underscoring the need for greater awareness and implementation to enhance project efficiency and outcomes.

Project delays narrowed to three primary stages: the design stage, construction conflicts, and poor stakeholder communication. This study seeks to address these challenges by conducting a comparative analysis of BIM-integrated projects and conventional project management approaches. The target is to demonstrate how adopting BIM can effectively reduce construction delays and enhance project performance across these critical stages.

RESEARCH METHODOLOGY

Quantitative methodologies are particularly appropriate for assessing the behavioral or descriptive dimensions of the Built Environment, in which statistical analyses are utilized to ascertain the significance of various relationships (Creswell, 2014). The main objective of this research is to collect data from a large sample of occupants, thereby enabling an extensive statistical examination intended to identify possible causal relationships and highlight significant trends.

Sampling

Probability sampling ensures that every individual within the aimed population has an identical chance of being nominated (David, 2011). Within the context of this research, the target population comprises professionals entrusted with delivering industrial expertise within the construction industry. A questionnaire list was distributed to the industrial experts. Targeting key stakeholders within the construction industry, including project managers, engineers, architects, and construction company owners. The sample size was expected to collect 100 numbers, and the questionnaire list was distributed above 150 experts.

Questionnaires Survey

The questionnaire was thoughtfully designed and structured into five sections (*Annexure 1)*. The primary section gathered minor demographic information from the respondents, including their respective sectors of work. After this section, respondents who had used BIM in their projects were distinguished from those who had not, resulting in their segregation.

Sections Two to Four of the questionnaire focused on gathering data on the impact of integrating BIM on the Design Stage, the Construction Stage, and Stakeholder communication, respectively. Only respondents with BIM collaboration experience in the industry, as identified in Section One, were directed to respond to Sections Two to Four. Conversely, respondents who did not use the BIM on their projects were directed to Section Five.

Among the respondents who had experience with BIM collaboration, further segregation was performed based on the extent to which they had employed BIM in the industry. This data was subsequently utilised to evaluate the extent to which the level of BIM usage significantly impacted project delays.

Section Five of the questionnaire, which was common to all respondents, aimed to collect data regarding the impact of project delays on different stages (i.e., the design stage, the Construction Stage, and Stakeholder communication). This section facilitated the evaluation of the relationship between BIM usage and project delays, both among BIM users and non-users.

Data Collection

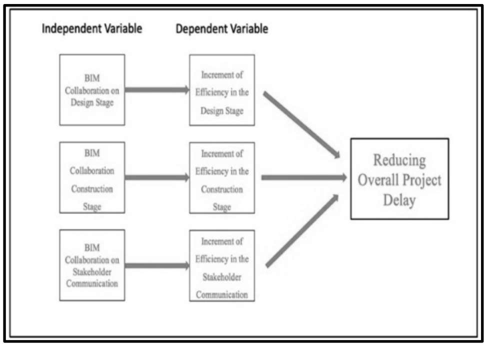
The list of questionnaires was prepared to collect the data required for analysing the research objectives. It was structured to address major areas related to project delays, BIM integration, and its impact on construction project performance. *Table 1 – Data Collection* emphasises a summary of the approach and methodology assigned to align the data collection process with the research objectives, ensuring a systematic and comprehensive analysis.

Table 1 – Data Collection

Research Objective	Approach	Method
Dose BIM usage Impact Efficiency Inclined on Design Work	Study relevant Literature and collect the data. Gathered On-Site data from the industry.	Read research Studies and distribute questionnaires among industrial experts.
Dose BIM usage Impact Efficiency Inclined on Construction Stage	Study relevant Literature and collect the data. Gathered On-Site data from the industry.	Read research Studies and distribute questionnaires among industrial experts.
Dose BIM usage Impact Efficiency Inclined on Stakeholder Communicatio n	Study relevant Literature and collect the data. Gathered On-Site data from the industry.	Read research Studies and distribute questionnaires among industrial experts.
Dose BIM usage Impact reducing delays in Selected 3 Categories	Gathered On-Site data from the industry	Distribute questionnaires among industrial experts.

Conceptual frameworks

Single linear regression analysis was used with SPSS software, where BIM collaboration among the three selected stages (design stage, construction conflicts, and stakeholder communication) was recognised as the independent variable. This variable was categorised to observe its impact on the efficiency improvements at each stage as a Dependent variable and its cumulative effect on overall project performance. Responses were collected as Likert scale questions, allowing the categorisation of participant feedback to quantify the relationship between BIM collaboration and project performance.



An independent t-test was conducted to evaluate significant differences between two groups of respondents: those who utilised BIM in their projects and those who did not. The Likert scale questions, and multiple-choice questionnaires were used to gather the required data, which were systematically input into SPSS for statistical evaluation.

Further details regarding the methodology and findings are presented in the Chapter: Analysis & Discussion.

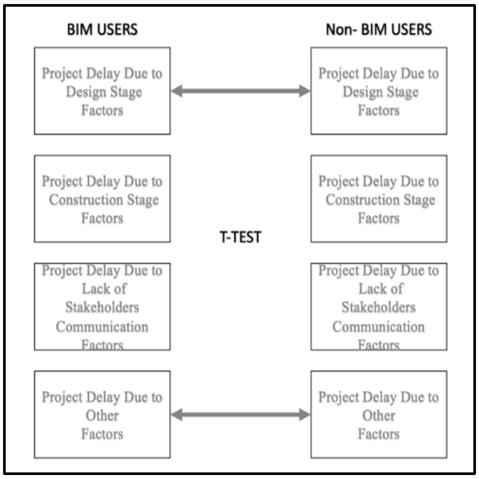


Figure 3 - Conceptual framework.

Data Collection Results

The questionnaire was administered to a sample of 150 industrial experts, encompassing both local and overseas participants. A total of 100 individuals completed the survey and provided their responses, yielding a response rate of 67%, which exceeds the minimum threshold of 50%, often considered satisfactory for survey research. Based on Figure 4 - Respondent's experience, it can be observed that out of the 100 respondents, 11% of individuals possess industrial experience ranging from Up to Five Years, while 24% of respondents have experience ranging from 06 to 10 years. Moreover, 37% of respondents possess 11 to 15 years of industrial experience and the other 28% of respondents have over 15 Years of experience. Additionally, 81% of respondents are currently employed in the building construction sector, while 7% of respondents have experience in road construction. The remaining 12% of members of the sample represent various other categories, as depicted in Figure 5 - Respondent's sector.

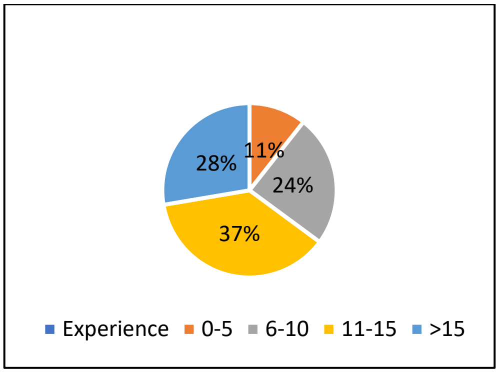


Figure 4 - Respondent's experience

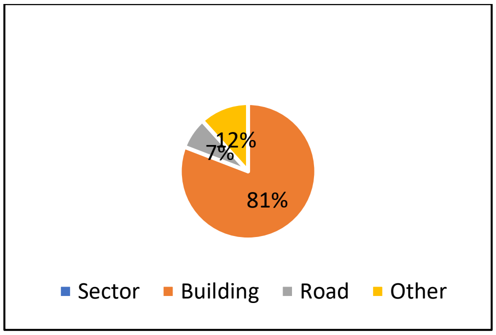


Figure 5 - Respondent's sector.

Furthermore, as depicted in Figure 6 - BIM collaboration, the data reveals that 44% of the respondents have reported having prior experience with the implementation of Building Information Modeling (BIM) in their projects, while 56% have not yet integrated BIM into their projects.

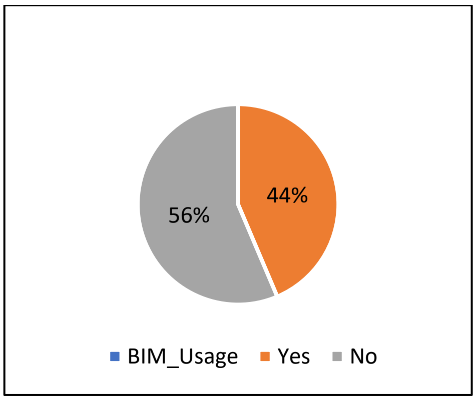


Figure 6 - BIM collaboration

Moreover, the survey also gathered data concerning the extent to which respondents utilized Building Information Modeling (BIM), providing valuable insights into the specific levels of BIM implementation as depicted in Figure 7 - Level of BIM . Among the respondents who reported using BIM, it was observed that 31% utilized BIM up to the 3D level, primarily for design-stage purposes. A significant majority of 58% reported employing BIM up to the 4D level, which involves planning and programming the work schedule on the construction site. Furthermore, out of the total BIM users (44%), 9% indicated the use of BIM up to the 5D level, primarily for cost estimating and financial scheduling. Interestingly, a mere 2% of respondents reported utilizing BIM up to the 6D level or beyond. This observation suggests that although BIM users display a preference for higher-level BIM utilization, the majority remain limited to the 3D and 4D levels of implementation.

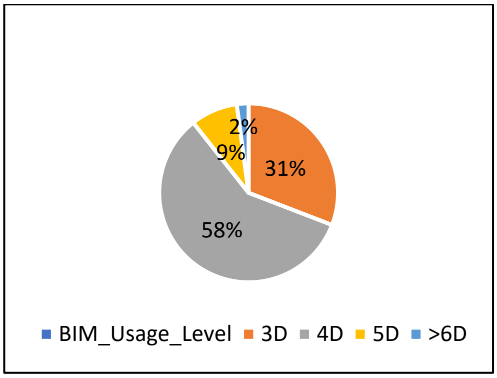


Figure 7 - Level of BIM usage.

ANALYSIS AND DISCUSSION

The Statistical Package for Social Sciences (SPSS) was employed in this study to conduct the analysis.

Single linear regression is an arithmetical method used to model the relationship between two variables: a dependent variable (also known as the response variable) and an independent variable (also known as the predictor variable).

The collected data were imported into SPSS for analysis. A summary sheet containing the collected data is provided in "Appendix B" for reference. The data includes responses to six questions under each of the three major categories. Specifically, three questions assess the utilisation of BIM at a particular stage, referred to as BIM collaboration in that stage, while the other three questions evaluate the efficiency impact of using BIM at each stage.

To facilitate the analysis, the compute variable function in SPSS was employed to create two new variables based on the implemented data. These newly derived variables were then utilised for the subsequent single linear regression analysis. This statistical analysis method aims to establish the relationship between the independent variable (BIM utilisation or collaboration) and the dependent variable (efficiency impact) for each stage.

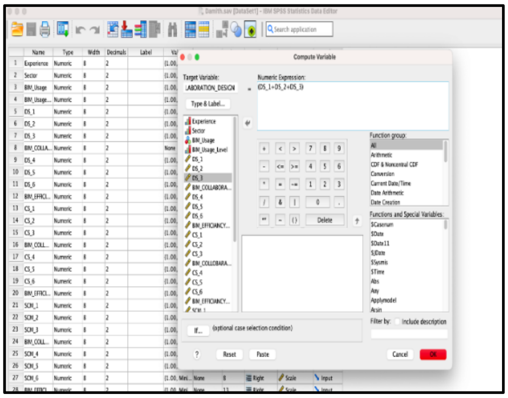


Figure 8 - Compute new variable

Collaboration of BIM in the Design Stage

The analysis was conducted for the Design Stage using the two newly generated variables: BIM Efficiency (dependent variable) and BIM Collaboration on the design (independent variable). The results, as presented in Table 2 - Design stage model summary, indicate that the R2 value is (0.325), corresponding to (32.5%) of the total variabilities explained by the model. The adjusted R2 value is (0.308).

The adequacy of the regression model was assessed using Table 3 - Design stage ANOVA. The significance (SIG) value, found to be (<0.001), is less than the predetermined threshold of (0.05). Consequently, the null hypothesis can be rejected, providing statistical evidence that the selected variables are suitable and adequate as independent variables associated with the dependent variable.

Furthermore, the results in Table 4 - Design stage coefficients reveal that the independent variable, BIM Collaboration on the design, exhibits a SIG value of (<0.001). This implies that BIM Collaboration on the design significantly impacts efficiency. The model can be summarised as follows:

Efficiency = $\beta0$ + $\beta1$(BIM Collaboration on the design)

The efficiency of the Design Stage = (3.299)+ 0.269 (BIM Collaboration on Design stage)

The statistical analysis supports the conclusion that BIM Collaboration on the design is a significant factor influencing efficiency in the given model.

Mishra and Aithal (2022) revealed that obligations and ambiguities during the design stage have a significant impact on project delays. Traditional project management practices use 2D paper-printed drawings and details. These traditional methods cannot fully understand the complex interaction between the various disciplines participating in the design phase.

The collaboration of powerful software tools, such as Revit and Navisworks, has been stated to be one of the best approaches to such hindrances. These BIM applications allow the design phase to effectively detect conflicts and interferences between Architectural, Structural, and MEP components.

Table 2 - Design stage model summary

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.570[a]	.325	.308	.28905
a. Predictors: (Constant), BIM_COLLABORATION_DESIGN				

Table 3 - Design stage ANOVA

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1.610	1	1.610	19.276	<.001[b]
	Residual	3.342	40	.084		
	Total	4.952	41			
a. Dependent Variable: BIM_EFFICIANCY_DESIGN_STAGE						
b. Predictors: (Constant), BIM_COLLABORATION_DESIGN						

Table 4 - Design stage coefficients

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	3.299	.261		12.629	<.001
	BIM_COLLABORATION_DESIGN	.269	.061	.570	4.390	<.001
a. Dependent Variable: BIM_EFFICIANCY_DESIGN_STAGE						

Collaboration of BIM in the Construction Stage

The same analysis method was employed for the Construction Stage using two newly generated variables: BIM Efficiency (dependent variable) and BIM Collaboration on Construction (independent variable). The results, as depicted in Table 5 - Construction stage model summary demonstrate that the R2 value is (0.386), indicating that (38.6%) of the total variabilities in the model are explained. The adjusted R2 value is (0.370), suggesting the generalizability of the model to another sample. The closer the adjusted R2 value is to the R2 value, the greater the generalizability of the model.

To assess the adequacy of the regression model, Table 6 - Construction Stage ANOVA was consulted. The significance (SIG) value, which is less than (0.001), falls below the predetermined threshold of (0.05). Consequently, the null hypothesis can be rejected, providing statistical evidence that the selected variables are appropriate and adequate as independent variables associated with the dependent variable.

Moreover, examining Table 7 - Construction stage coefficients reveals that the independent variable, BIM Collaboration on the Construction stage, exhibits a SIG value of less than (0.001). This suggests that BIM Collaboration during the construction stage significantly impacts efficiency. The model can be summarized as follows:

Efficiency = β0 + β1(BIM Collaboration on the Construction Stage)

The efficiency of the Construction Stage = (3.336) + 0.259 (BIM Collaboration on Construction stage)

These findings underscore the statistical significance of BIM Collaboration during the Construction stage in influencing efficiency within the given model.

Previous studies show that conflicts could arise when drawings move from the design to the production phase, mainly due to the presence of many revisions. These kinds of conflict may also arise at the construction stage. It, therefore, results in time and cost overrun of the project. Giving 3D electronic drawings at the production level as a paperless approach might reduce the conflicts arising due to construction. This way, the design intent is transferred smoothly, and discrepancies due to multiple changes and interpretations are minimized.

Table 5 - Construction stage model summary

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.621[a]	.386	.370	.27580
a. Predictors: (Constant), BIM_COLLOBARATOIN_CONSTRUCTION_STAGE				

Table 6 - Construction Stage ANOVA

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1.910	1	1.910	25.105	<.001[b]
	Residual	3.043	40	.076		
	Total	4.952	41			
a. Dependent Variable: BIM_EFFICIANCY_CONSTRUCTION_STAGE						
b. Predictors: (Constant), BIM_COLLOBARATOIN_CONSTRUCTION_STAGE						

Table 7 - Construction stage coefficients

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	3.336	.222		15.013	<.001
	Bim_Collobaratoin_Construction_Stage	.259	.052	.621	5.011	<.001
a. Dependent Variable: BIM_EFFICIANCY_CONSTRUCTION_STAGE						

Collaboration of BIM in Stakeholder Communication

The Stakeholder Communication Stage underwent the same analysis procedure using two newly generated variables: BIM Efficiency (dependent variable) and BIM Collaboration on Stakeholder Communication Stage (independent variable). The results, presented in

Table 8 - Stakeholder communication stage model **summary**, indicate that the R2 value is 0.278, meaning that approximately (27.8%) of the total variabilities in the model are accounted for. The adjusted R2 value of 0.259

suggests that the model is reasonably generalizable to other samples. A higher adjusted R2 value signifies a greater degree of generalizability. To evaluate the adequacy of the regression model, Table 6 - Construction Stage ANOVA was examined. The significance (SIG) value, which is less than 0.001, falls below the predetermined threshold of 0.05. Thus, the null hypothesis can be rejected, providing statistical evidence that the selected variables are suitable and effective as independent variables associated with the dependent variable.

Additionally, a closer examination of Table 10 - Stakeholder communication stage coefficients reveals that the independent variable, BIM Collaboration on the Stakeholder Communication stage, exhibits an SIG value of less than 0.001. This finding indicates that BIM Collaboration during the Stakeholder Communication stage significantly influences efficiency. In summary, the model can be expressed as follows:

Efficiency = $\beta 0 + \beta 1$(BIM Collaboration on the Construction Stage)

The efficiency of the Stakeholder Communication Stage = (3.083) + 0.234 (BIM Collaboration on Stakeholder Communication stage)

These findings underscore the statistical significance of BIM Collaboration during the Stakeholder Communication stage in influencing efficiency within the given model.

Planning of face-to-face meetings has also become increasingly difficult with stakeholders having hectic schedules (Bal et al., 2013) because of the diverse nature of the stakeholders in construction projects, such projects face unique challenges related to the management of stakeholders' participation and thus follow a systematic approach. Many stakeholders have a poor understanding of construction methods, making it difficult for project teams to successfully convey project deliverables.

Conversely, stakeholders can also find it hard to clearly express their needs to the project team. These communication gaps may lead to design changes and rework in construction, causing project delays and cost overruns.

Utilising (BIM) technology to provide not only 3D visualisations but also detailed internal arrangements, including up to service-level information, can significantly reduce these communication challenges." Ultimately integration of BIM technology beyond the conventional project management system leading inclined of project performance.

Table 8 - Stakeholder communication stage model summary

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.527[a]	.278	.259	.28975
a. Predictors: (Constant), BIM_COLLOBARATION_STAKEHOLDERCOMMUNI_STAGE				

Table 9 - Stakeholder communication stage ANOVA

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1.290	1	1.290	15.365	<.001[b]
	Residual	3.358	40	.084		
	Total	4.648	41			
a. Dependent Variable: BIM_EFFICIANCY_STAKEHOLDERCOMMUNI_STAGE						
b. Predictors: (Constant), BIM_COLLOBARATION_STAKEHOLDERCOMMUNI_STAGE						

Table 10 - Stakeholder communication stage coefficients

Coefficients[a]					
	Unstandardized Coefficients		Standardized Coefficients		
Model	B	Std. Error	Beta	t	Sig.
1(Constant)	3.083	.252		12.236	<.001
BIM_COLLOBARATION_STAKEHOLDERCOMMUNI_STAGE	.234	.060	.527	3.920	<.001
a. Dependent Variable: BIM_EFFICIANCY_STAKEHOLDERCOMMUNI_STAGE					

T-Test

An independent t-test was conducted to examine significant differences between two groups of respondents: those with experience of BIM and those without. The data collection process focused on three key criteria. In the initial step, a normality test was performed to determine if the sample data was drawn from a population that follows a normal distribution. It is crucial to establish normality as certain statistical tests, including the t-test and one-way/two-way ANOVA, require the sample population to adhere to a normal distribution.

Using the Statistical Package for Social Sciences (SPSS), it has been determined that the data utilised for analysis belong to the same population and exhibit a uniform distribution. The normality test conducted revealed that the significance (SIG) value is greater than 0.005. As a result, the null hypothesis (H0) cannot be rejected. In this context, H0 signifies "The variable does not deviate from a normal distribution," while the alternative hypothesis (H1) indicates "The variable deviates from a normal distribution."

Table 11- Test of normality

Tests of Normality						
	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Design_Delay_Weightage	.259	94	0.077	.815	94	0.067
Construction_Delay_Weightage	.255	94	0.046	.836	94	0.056
Stk_Com_Delay_Weightage	.256	94	0.072	.793	94	0.082
Other_Delay_Weightage	.250	94	0.011	.817	94	.0921
a. Lilliefors Significance Correction						

Subsequently, separate t-tests were conducted to analyze the Delay Impact during the Design Stage, the Delay Impact resulting from Construction Conflict, and the Delay Impact arising from a lack of communication between stakeholders. This approach allowed for a focused examination of each specific aspect.

Delay Impact due to Design Stage Issues

The determination was conducted using SPSS, and the analysis revealed that the significance (SIG) value is 0.011, which is below the threshold of 0.05. Consequently, the null hypothesis can be rejected. The conclusive findings demonstrate a significant impact between BIM users and non-BIM users on delays during the Design Stage. This indicates that the utilisation of BIM has a noticeable influence on reducing or mitigating delays at the Design Stage compared to those who do not utilise BIM.

Table 12 - Design stage group statistics

Group Statistics					
	BIM_Usage	N	Mean	Std. Deviation	Std. Error Mean
Construction_Delay_Weightage	Yes	42	1.8095	.86216	.13303
	No	52	2.0769	.70977	.09843

Table 13 - Independent sample test

Independent Samples Test											
		Levene's Test for Equality of Variances		t-test for Equality of Means							
		F	Sig.	t	df	Significance		Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						One-Sided p	Two-Sided p			Lower	Upper
Construction_Delay_Weightage	Equal variances assumed	6.737	.011	-1.650	92	.051	.102	-.26740	.16210	-.58935	.05455
	Equal variances not assumed			-1.616	79.114	.055	.110	-.26740	.16549	-.59679	.06199

Delay Impact due to Conflicts on the Construction Stage

Following the same procedure, the collected data regarding the impact of delays during the construction stage underwent analysis. The results of the analysis indicated a significance (SIG) value of 0.011, which falls below the predetermined threshold of 0.05. As a result, the null hypothesis can be rejected. The conclusive findings provide evidence of a significant impact between BIM users and non-BIM users on delays occurring during the Construction Stage. This suggests that the adoption of BIM has a discernible effect on reducing or mitigating delays at this stage, in comparison to those who do not utilise BIM.

Table 14 - Construction stage group statistic

Group Statistics					
	BIM_Usage	N	Mean	Std. Deviation	Std. Error Mean
Construction_Delay_Weightage	Yes	42	1.8095	.86216	.13303
	No	52	2.0769	.70977	.09843

Table 15 - Construction Stage Independent

Independent Samples Test											
		Levene's Test for Equality of Variances		t-test for Equality of Means							
		F	Sig.	t	df	Significance		Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						One-Sided p	Two-Sided p			Lower	Upper
Construction_Delay_Weightage	Equal variances assumed	6.737	.011	-1.650	92	.051	.102	-.26740	.16210	-.58935	.05455
	Equal variances not assumed			-1.616	79.114	.055	.110	-.26740	.16549	-.59679	.06199

Sample Test

Delay Impact due to Lack of Stakeholder Communication

The T-test was performed using the same procedure as before on the data related to the impact of delays caused by a lack of communication among stakeholders. The analysis yielded a significance (SIG) value of 0.051, exceeding the predetermined threshold of 0.05. Consequently, the null hypothesis cannot be rejected. The conclusive findings indicate no significant impact between BIM users and non-BIM users on delays arising from a lack of communication among stakeholders. This suggests that the adoption of BIM does not have a discernible effect on reducing or mitigating delays at this stage, in comparison to those who do not utilize BIM.

Table 16 - Stakeholder Communication Group Statistic

Group Statistics					
	BIM_ Usage	N	Mean	Std. Deviation	Std. Error Mean
Stk_Com_Delay_Weightage	Yes	42	1.6667	.92833	.14324
	No	52	1.9231	.83657	.11601

Table 17 - Stakeholder communication Independent Sample Test

Independent Samples Test											
		Levene's Test for Equality of Variances		t-test for Equality of Means							
		F	Sig.	t	df	Significance		Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						One-Sided p	Two-Sided p			Lower	Upper
Stk_Com_Delay_Weightage	Equal variances assumed	3.915	.051	-1.407	92	.081	.163	-.25641	.18229	-.61844	.10562
	Equal variances not assumed			-1.391	83.533	.084	.168	-.25641	.18433	-.62300	.11018

Delay Impact Due to Other Reasons

Finally, a Simple T-test was conducted using the same procedure as previously described on the data concerning the impact of delays caused by reasons not covered under the aforementioned stages. The analysis yielded a significance (SIG) value of (0.322), surpassing the predetermined threshold of (0.05). Therefore, the null hypothesis cannot be rejected. The conclusive findings indicate no significant impact between BIM users and non-BIM users on delays resulting from other reasons. This suggests that the adoption of BIM does not demonstrate a noticeable effect on reducing or mitigating delays at this stage, in comparison to those who do not utilize BIM.

Table 18 - Other Reason Group Statistic

Group Statistics					
	BIM_ Usage	N	Mean	Std. Deviation	Std. Error Mean
Other_Delay_Weightage	Yes	42	2.3571	.82111	.12670
	No	52	1.5769	.75006	.10402

Table 19 - Other Reasons for the Independent Sample Test

Independent Samples Test											
		Levene's Test for Equality of Variances		t-test for Equality of Means							
		F	Sig.	t	df	Significance		Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						One-Sided p	Two-Sided p			Lower	Upper
Other_ Delay_ Weightage	Equal variances assumed	.993	.322	4.806	92	<.001	<.001	.78022	.16234	.45779	1.10265
	Equal variances not assumed			4.760	84.158	<.001	<.001	.78022	.16393	.45424	1.10620

CONCLUSION

The main purpose of this dissertation was to find out the effect of using BIM as a project management technique in comparison with the traditional project management techniques in relation to project delays. This research had three main focuses which the literature review identified as stages in a project where project delays are commonly found, which are the design stage, disputes occurring during the construction stage, and communication gaps among project stakeholders. Other causes of project delays were summarized in "Other Reasons." The following targets were for achieving the main goals of this study.

1. Assessing whether BIM collaboration significantly influences the improvement of efficiency in the selected stages.

2. Investigating whether projects utilising BIM exhibit significant variations in delays compared to non-BIM projects.

The analysis conducted in this study revealed a significant impact of BIM usage on the Design stage of the project. Notably, the efficiency in this stage experienced a considerable increase as a result of BIM adoption. The investigation involved three key inquiries, which highlighted that BIM utilization effectively reduced time wastage and subsequently lowered costs. Additionally, the findings emphasized that communication among team members significantly improved through the implementation of BIM.

One noteworthy aspect of BIM usage is its ability to facilitate seamless communication, even when team members are physically distant from each other. This observation was derived from the responses provided by the participants in the study. Furthermore, the respondents expressed their willingness to engage in further research and unanimously believed that the utilization of Building Information Modeling had enhanced the overall efficiency of their respective organisations.

A simple T-test was conducted to analye the variance in delay impact between BIM users and non-BIM users. The results of the test revealed significant differences between the two groups. Specifically, the analysis determined that substantial variations existed in terms of delays encountered during the design phase and construction conflicts between BIM users and non-BIM users.

However, when examining delays arising from the lack of stakeholder communication and delays categorized under "Other" factors, no significant variations were observed between the two user groups. These findings suggest that the utilization of BIM may have a more pronounced impact on reducing delays during the design phase and addressing conflicts that arise during construction.

Based on the findings of this research, the integration of BIM into construction projects should be made mandatory for large-scale projects. In particular, government-related projects could incorporate policies requiring BIM as part of the project contract. Implementing such policies may add additional costs at the initial stages, but the overall construction costs can be significantly reduced by reducing the project time overrun, as per the findings in this paper. Furthermore, BIM models can be utilised not only during the construction phase but also during the operational phase for maintenance purposes, enhancing long-term efficiency.

Furthermore, introducing BIM-related studies into university curricula would help made foundational knowledge of BIM among future professionals, promoting its adoption and effective usage in the industry."

By identifying these specific areas of disparity, this study provides valuable insights into the differential effects of BIM adoption on project delays. The results highlight the potential of BIM to mitigate delays in certain critical stages, such as design and construction conflicts. These findings contribute to the existing knowledge of the benefits and limitations of BIM implementation regarding project delay management.

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