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THE INFLUENCES OF 4D BIM IMPLEMENTATION IN PUBLIC WORKS DEPARTMENT OF MALAYSIA: AN EMPIRICAL INVESTIGATION

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Abstract:

Building Information Modelling (BIM) technology has been increasingly adopted in the construction industry to improve project management and delivery. Among the various dimensions of BIM, 4D BIM has been recognized for its potential to enhance communication, coordination, and collaboration among project stakeholders. However, the adoption and implementation of 4D BIM in the public sector, particularly in the Malaysian context, have received limited attention. Therefore, this study aims to investigate the influences of 4D BIM technology on project implementation in the Public Works Department (PWD) of Malaysia. A mixed-methods research approach was utilized, comprising of a literature review and a questionnaire survey. The study found that the implementation of 4D BIM in PWD Malaysia has significant positive influences on project management, cost and time control, quality assurance, and risk management. The study provides practical implications for project managers, policymakers, and academics to enhance the adoption and implementation of 4D BIM technology in the Malaysian construction industry.

Keywords: 4D BIM, project management, construction industry, PWD Malaysia, implementation, adoption.

1 Introduction:

The construction industry has been facing various challenges, including cost overruns, schedule delays, quality issues, and safety hazards. These challenges have prompted the adoption of innovative technologies, such as Building Information Modelling (BIM), to improve project management and delivery. Among the various dimensions of BIM, 4D BIM has been recognized for its potential to enhance communication, coordination, and collaboration among project stakeholders. 4D BIM integrates the time dimension into the 3D BIM model, allowing project stakeholders to visualize and simulate the construction process in a virtual environment. The benefits of 4D BIM technology have been widely acknowledged, such as improved project planning, scheduling, and sequencing, enhanced communication and coordination among project stakeholders, reduced project risks and errors, and increased productivity and efficiency. However, despite these benefits, the adoption and implementation of 4D BIM in the construction industry, particularly in the public sector, have been limited.

The Public Works Department (PWD) of Malaysia is responsible for the planning, design, construction, and maintenance of public infrastructure and facilities. PWD Malaysia has recognized the potential of 4D BIM technology in improving project delivery and has implemented the technology in some of its projects. However, the extent of 4D BIM adoption and its influences on project implementation in PWD Malaysia have not been investigated comprehensively. Therefore, this study aims to investigate the influences of 4D BIM technology on project implementation in PWD Malaysia. The study aims to answer the following research question and to test a hypothesis:

Research Question: What are the influence constituents of 4D BIM Tool in PWD Malaysia's project implementation?

Hypothesis: Incorporating cost of software and training in construction contract will improve project planning and scheduling for effective implementation of 4D BIM in Public Works Department

2 Methodology:

The study employed a mixed-methods research approach, comprising of a literature review and a questionnaire survey. The research was conducted in quantitative method collection approach through questionnaire survey of 200 PWD Malaysia's staffs as primary data. The data collected from literature review was used as secondary data. The participants of the research were selected among technical staff of PWD Malaysia who involved in BIM project implementation. A questionnaire was distributed using Google Form to various discipline in PWD Malaysia such as design department of architectural, structural, mechanical, electrical and construction personnel.

3 Influences of 4D BIM

4D BIM Tool is commonly defined as the intelligent combination of a 3D BIM model with the dimension of time. This four-dimensional model allows project managers and stakeholders to visualize their project schedule in a three-dimensional space. Influence here merely means the impacts and benefit of 4D BIM Tool towards the performance of construction industry.

Crowther, J and Ajayi, SO (2019) from their research have indicated that as it thrives on high detail and user knowledge to represent them, 4D BIM brings forth the best in people's efforts to generate great positive contributions to project performance. This contribution has been experienced in project reliability, monitoring and diagnosis. But this paper does not reveal consequences of implementing 4D BIM in government projects.

Kane W. et al, 2021 from their study have mentioned through the simplicity with which possible conflicts and concerns were recognised using the 4D Modeling software, the implementation of 3D site coordination tools avoided major potential complications and sped up the completion of logistical planning. The Navisworks software is used to identify the clashes and problems. But this paper failed to identify concrete influence of 4D BIM Tool due to smaller sample size.

Abdel-Hamid, M. and Abdelhaleem, H.M. (2021) from their study found out that the variance between planned costs and actual costs decreased from 12% to 5% when 4D BIM is used instead of traditional methods. According to Swallow M. and Zulu S. (2019), 4D is to be particularly useful in assessing the constructability of work methodology, increasing visualization and communication, the ability to detect clashes and providing simulations which assist in planning and further analysis of project methodology. Wong, Zhou and Chan (2018) also mentioned that 4D BIM can play a pivotal role in the transferring and sharing of knowledge and information which has the potential for preventing errors and reworks. According to Gu and London (2010), the use of 4D BIM technology can improve communication, coordination, and collaboration among project stakeholders, which leads to better project outcomes. Additionally, they stated that 4D BIM technology can help reduce rework, save time, and improve cost management.

Another study by Hou et al. (2019) found that the use of 4D BIM technology can improve the accuracy of project scheduling, reduce construction time, and improve cost performance.

Table 1: Benefits of 4D BIM in Construction Projects

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Benefit	**Study Result**
Enhance communication and visualization	Gu and London (2010), Swallow and Zulu (2019)
Increase collaboration and coordination	Gu and London (2010)
Improve project planning and scheduling	Hou et al. (2019)
Strengthen the construction process	Gu and London (2010), Hou et al. (2019), Crowther and Ajayi (2019)
Reduce errors and rework	Gu and London (2010), Kane W. et al (2021), Wong, Zhou and Chan (2018)
Saving Project Cost	Gu and London (2010), Hou et al. (2019), Abdel-Hamid and Abdelhaleem (2021)

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The table 1 summarizes the benefits of 4D BIM technology in construction projects as found in literature. These benefits are significant and can have a positive impact on project outcomes. Therefore, this study aims to investigate the influence of 4D BIM technology on project implementation in PWD Malaysia, with a focus on the benefits of its adoption.

4 Data Analysis

In order to analyze the survey's data, the Statistical Package for Social Sciences (SPSS) software was used. The research data analysis will be based on this statistical data, and the analysis results will be explained in the form of interactive tables, SPSS analysis tables, bar charts and other charts. Demographic Profile Analysis, Descriptive Statistics Analysis, Reliability Analysis, and hypothesis tests were conducted to support this study.

4.1 Demographic Profile Analysis

A demographic profile refers to a summary of characteristics that describe the population being studied in this research. A broad information regarding the study distribution and the target population may be gleaned from the demographic overview. The respondents of this questionnaire are mainly personnel involved in construction projects of PWD Malaysia. The questionnaire investigated their gender, age, nature of job, years of working experience and years of experience in BIM. As much as possible, the respondents of the survey met the objectives of this study. It was also hoped that different feedback would be obtained from people with different years of experience to make this survey more objective and comprehensive.

4.1.1 Gender Profile

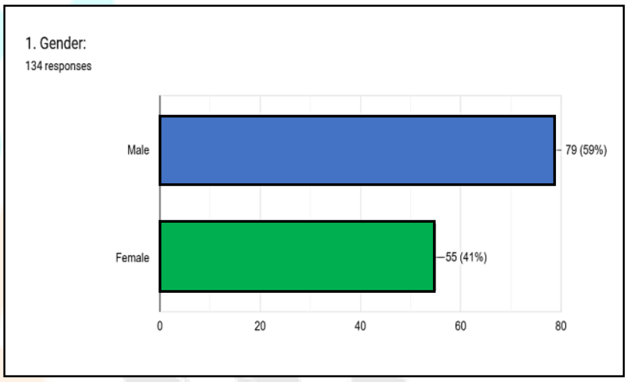

Figure 1: Respondents' Gender Diversity

Figure 1 shows that Male respondents are more than Females with Male dominates with 59% while Female with 41%. This might be because the construction industry in Malaysia is predominantly male dominated, with only a small percentage of females involved in PWD Malaysia's construction projects. Therefore, when implementing 4D BIM technology in PWD Malaysia's construction projects, it is important to consider gender diversity and inclusion. For example, companies can implement policies and initiatives to promote diversity and inclusion, such as recruiting and retaining women in construction roles, promoting women to leadership positions, and providing training and development opportunities for women.

4.1.2 Age Profile

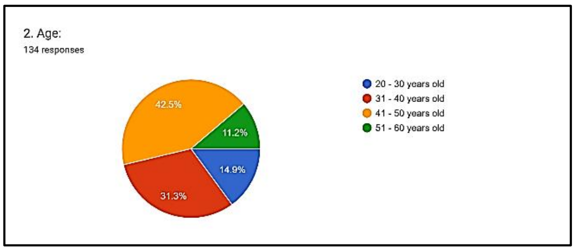

Figure 2: Respondents' Age Diversity

The age range of workers and professionals involved in PWD Malaysia's construction projects ranges from 20 to 60 years old. The majority of workers are between 41 and 50 years old (42.5%), while the majority of young professionals are between 31 and 40 years old (31.3%). The age of workers and professionals involved in PWD Malaysia's construction projects is an important demographic factor to consider when implementing 4D BIM technology. The construction industry is known for its aging workforce, and many countries, including Malaysia, are facing a shortage of skilled workers due to retirement and a lack of new entrants to the industry. Therefore, it is essential to understand the age distribution of workers and professionals involved in PWD Malaysia's construction projects to identify any potential challenges or opportunities for implementing 4D BIM technology.

Younger workers may be more comfortable with new technologies and more open to change, while older workers may be more resistant to change and require more support and training to adopt new technologies. In addition, older workers may have more experience and knowledge of traditional construction methods, which may need to be integrated with 4D BIM technology for successful implementation.

On the other hand, older professionals may have more experience and expertise in their respective fields, which can be invaluable in ensuring the successful implementation of 4D BIM technology. Older professionals may also have a better understanding of the overall construction process, which can help to identify potential challenges and opportunities for integrating 4D BIM technology.

Therefore, it is essential to develop training programs that cater to the needs of workers and professionals of different age groups. For example, younger workers may benefit from interactive and hands-on training that emphasizes the benefits of 4D BIM technology, while older workers may require more individualized training and support.

4.1.3 Job Background Profile

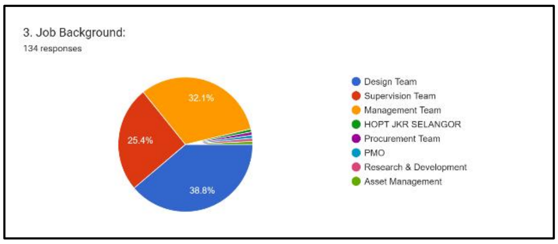

Figure 3: Respondents' Job Background Diversity

To gain insights into the job backgrounds of survey respondents, I had analyzed the job titles or positions held by each respondent. The survey results indicate that the majority of respondents (38.8%) were from the Designer Team, followed by the Management Team (32.1%) and the Supervision Team (25.4%). The remaining respondents (3.7%) were from other teams, such as the Asset Management Team or the Procurement Team.

The high proportion of respondents from the Designer Team may suggest that individuals who are responsible for creating the design and modeling of construction projects are more likely to have experience with and opinions on the implementation of 4D BIM technology. On the other hand, the high proportion of respondents from the Management Team may suggest that individuals who are responsible for overseeing and managing construction projects may also play a significant role in the implementation of 4D BIM technology.

The smaller proportion of respondents from the Supervision Team may suggest that individuals who are responsible for supervising and executing the construction of projects may have less experience with and opinions on the implementation of 4D BIM technology. However, this could also indicate that individuals from this team may have a unique perspective on the challenges and benefits of implementing the technology on the ground.

Overall, the job background analysis suggests that individuals from a variety of job roles within the construction industry in Malaysia may have experience with and opinions on the implementation of 4D BIM technology. Understanding the perspectives of individuals from different teams and job roles can provide valuable insights into the potential benefits and challenges of adopting the technology in construction projects.

4.1.4 Working Experience Profile

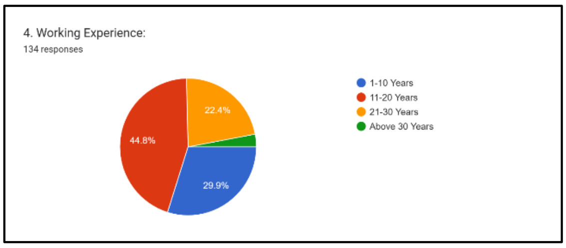

Figure 4: Respondents' Working Experience Diversity

Figure 4 shows the analysis of the working experience of survey respondents. The results indicate that the majority of respondents (44.8%) had between 11-20 years of working experience in the construction industry, followed by 1-10 years (29.9%), 21-30 years (22.4%), and above 30 years (2.9%).

The high proportion of respondents with 11-20 years of experience may suggest that individuals who have been working in the industry for a longer period of time may have more experience and knowledge about the challenges and benefits of adopting new technologies such as 4D BIM. They may also have more experience working on complex construction projects that would benefit from the use of 4D BIM technology.

The proportion of respondents with 1-10 years of experience may suggest that newer and younger employees in the construction industry are also interested in and have experience with 4D BIM technology. This could be an indication that younger individuals entering the industry are more technologically savvy and open to adopting new technologies.

The smaller proportion of respondents with over 30 years of experience may suggest that individuals who have been in the industry for a longer period of time may be less likely to adopt new technologies, such as 4D BIM. However, this could also indicate that individuals with this level of experience may have unique insights into the benefits and challenges of adopting the technology over the long-term.

Overall, the working experience analysis suggests that individuals from a variety of experience levels within the construction industry in Malaysia may have experience with and opinions on the implementation of 4D BIM technology. Understanding the perspectives of individuals with different levels of experience can provide valuable insights into the potential benefits and challenges of adopting the technology in construction projects.

4.1.5 BIM Experience Profile

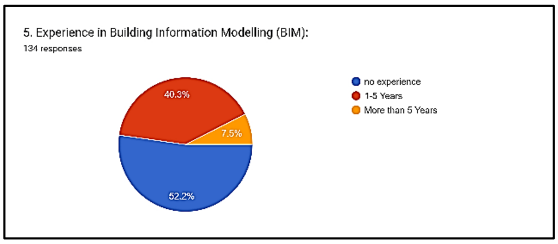

Figure 5: Respondents' BIM Experience Diversity

I also analyzed the BIM experience of survey respondents. The results from Figure 5 indicates that the majority of respondents (52.2%) had no prior experience with BIM technology, followed by those with 1-5 years of experience (40.3%), and those with more than 5 years of experience (7.5%).

The high proportion of respondents with no prior experience may suggest that many individuals in the construction industry in Malaysia have not yet had the opportunity to use BIM technology in their work. This could indicate that there is a need for more education and training on BIM technology to increase its adoption and use in the industry.

The proportion of respondents with 1-5 years of experience may suggest that BIM technology is becoming more prevalent in the industry, as individuals with this level of experience may have been exposed to the technology through their work in recent years. They may also be more open to adopting new technologies, such as 4D BIM, in their work.

The smaller proportion of respondents with more than 5 years of experience may suggest that individuals who have been using BIM technology for a longer period of time may have more experience and knowledge about the benefits and challenges of using the technology in construction projects. They may also have more advanced skills in using BIM technology, which could be valuable in implementing 4D BIM technology.

Overall, the BIM experience analysis suggests that while many individuals in the construction industry in Malaysia have not yet had the opportunity to use BIM technology, there is also a growing number of individuals with experience using the technology. Understanding the perspectives of individuals with different levels of BIM experience can provide valuable insights into the potential benefits and challenges of adopting 4D BIM technology in construction projects.

4.2 Descriptive Statistics Analysis

Descriptive analysis is an important aspect of any research study as it provides a summary of the data collected. Descriptive statistics analysis is used to summarize and describe the main features of a data set, and can include measures of central tendency, measures of variability, and measures of distribution.

4.2.1 Descriptive Analysis of Variable: Influence of 4D BIM

In this case, the data is presented in a table format with the variables B1 to B6 and their corresponding statistics. All Descriptive Statistics of 6 independent variables of dependent variable B- Influence of 4D BIM are listed as per table below:

Table 2: Descriptive Statistics Data of Independent Variables B1-B6

Statistics		B1	B2	B3	B4	B5	B6
N	Valid	134	134	134	134	134	134
	Missing	0	0	0	0	0	0
Mean		4.36	4.34	4.28	4.16	4.20	4.46
Median		4.00	4.00	4.00	4.00	4.00	5.00
Mode		5	4	4	4	4	5
Std. Deviation		.687	.684	.740	.696	.754	.898
Skewness		-.744	-.847	-.832	-.505	-.887	-1.667
Std. Error of Skewness		.209	.209	.209	.209	.209	.209
Kurtosis		-.007	.702	.441	.158	.891	2.107
Std. Error of Kurtosis		.416	.416	.416	.416	.416	.416
Minimum		2	2	2	2	2	1
Maximum		5	5	5	5	5	5
Percentiles	25	4.00	4.00	4.00	4.00	4.00	4.00
	50	4.00	4.00	4.00	4.00	4.00	5.00
	75	5.00	5.00	5.00	5.00	5.00	5.00

The data was collected from 134 respondents who completed the questionnaire. There were no missing values in the data. The mean scores for the variables B1 to B6 range from 4.16 to 4.46, with an overall mean score of 4.30. This indicates that the respondents had a positive perception of the topic being studied.

The median scores for the variables B1 to B6 range from 4.00 to 5.00. The mode scores for B1, B2, B3, B4, and B5 are 4, indicating that this was the most common response. The mode score for B6 is 5, indicating that this was the most common response. The standard deviation for the variables B1 to B6 range from 0.684 to 0.898, indicating that the data is relatively spread out from the mean. The skewness values for the variables range from -1.667 to -0.505, indicating that the data is not normally distributed. The kurtosis values range from -0.007 to 2.107, indicating that the data is not normally distributed (refer Appendix B for Histogram Charts).

The minimum scores for the variables B1 to B6 are 2, indicating that there were some respondents who had a negative perception of the topic being studied. The maximum scores for the variables B1 to B6 are 5, indicating that there were some respondents who had a very positive perception of the topic being studied. The percentiles for the variables B1 to B6 indicate that 25% of the respondents had a score of 4.00 or below, 50% of the respondents had a score of 4.00 or below, and 75% of the respondents had a score of 5.00 or below.

Overall, the descriptive analysis of Variable B suggests that the respondents had a positive perception of the topic being studied, although there were some respondents who had a negative perception. The data is not normally distributed, which should be taken into consideration when interpreting the results.

4.3 Reliability Analysis

Reliability Analysis is essential in research and data analysis because it helps to determine the consistency, stability, and accuracy of the measurements or instruments used to collect data. In other words, it measures the extent to which a measurement tool produces consistent and dependable results. A reliable measurement tool or instrument is necessary for research because it ensures that the results obtained are accurate and trustworthy.

One of the most common methods for measuring the reliability of a scale or questionnaire is Cronbach's alpha, which is a measure of the internal consistency of a scale. Cronbach's alpha is a coefficient that ranges from 0 to 1, with higher values indicating greater internal consistency of the scale. If the Cronbach's alpha value is high, such as 0.8 or above, it indicates that the items in the scale are highly correlated and that the scale is internally consistent. In contrast, if the Cronbach's alpha value is low, such as 0.5 or below, it indicates that the items in the scale are not highly correlated and that the scale may not be reliable.

Reliability analysis with Cronbach's alpha is important in research because it helps to ensure that the measurement instrument or questionnaire is consistent and dependable. This, in turn, improves the accuracy and validity of the research findings, allowing researchers to draw more robust conclusions from their data.

4.3.1 Results of Variable

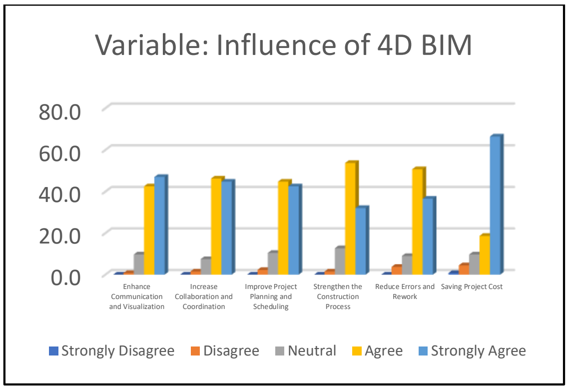

Figure 6: Feedback of Variable: Influence of 4D BIM

Table 3: Reliability Statistics of Variable

Reliability Statistics		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.913	.919	16

In this analysis, Cronbach's Alpha of 0.913 indicates a high level of internal consistency reliability among the 16 variables being analyzed. This means that the 16 variables are highly related to one another and highly reliable, as a group, provide a reliable measure of the construct or phenomenon being assessed. This indicates that the scale has very good reliability and the questionnaire measurement tool is reliable is strong.

4.4 Hypothesis Testing

The hypothesis posits that incorporating the cost of software and training in construction contracts will improve project planning and scheduling for effective implementation of 4D BIM in PWD. This hypothesis is crucial for the construction industry as it provides insights into the potential mechanisms that can enhance the implementation of 4D BIM in PWD projects. The study aims to contribute to the existing literature by providing empirical evidence on the effectiveness of these mechanisms. The key variables used in the analysis include the cost of 4D BIM software and training and project planning and scheduling. Regression analysis is used to test the hypothesis, and the report will provide a detailed description of the methods and results.

The results of regression analysis of Hypothesis in spss are as per tables below:

Table 4: Regression Analysis Result of H1-Model Summary

Model Summary[b]

					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	.269[a]	.073	.066	.715	.073	10.329	1	132	.002

a. Predictors: (Constant), Cost of 4D BIM Software and Training to be Incorporated in Construction Contract

b. Dependent Variable: Improve Project Planning and Scheduling

Table 5: Regression Analysis Result of H1-ANOVA

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	5.282	1	5.282	10.329	.002[b]
	Residual	67.502	132	.511		
	Total	72.784	133			

a. Dependent Variable: Improve Project Planning and Scheduling

b. Predictors: (Constant), Cost of 4D BIM Software and Training to be Incorporated in Construction Contract

Table 6: Regression Analysis Result of H1-Coefficients

Coefficients[a]

Model		Unstandardized Coefficients B	Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	3.249	.326		9.978	<.001
	Cost of 4D BIM Software and Training to be Incorporated in Construction Contract	.243	.076	.269	3.214	.002

a. Dependent Variable: Improve Project Planning and Scheduling

Based on the results of the regression analysis, it can be concluded that there is a significant positive relationship between the cost of 4D BIM software and training to be incorporated in construction contract and the improvement of project planning and scheduling. The model summary indicates that the predictor variable explains 7.3% of the variance in the dependent variable, and the F-test indicates that the model is significant ($F = 10.329$, $p < .05$).

The coefficients table shows that the constant is 3.249, indicating that when the cost of 4D BIM software and training to be incorporated in construction contract is zero, the expected value of the dependent variable (improvement of project planning and scheduling) is 3.249. The coefficient for the predictor variable is 0.243, indicating that for each unit increase in the cost of 4D BIM software and training to be incorporated in construction contract, the expected value of the dependent variable increases by 0.243, holding all other variables constant.

Therefore, based on the results of the regression analysis, Hypothesis 1 can be accepted, indicating that the cost of 4D BIM software and training to be incorporated in construction contract does improve project planning in PWD projects.

5 Conclusion

The theoretical implications of the study are discussed in terms of how the findings contribute to existing knowledge and theory in the field. The practical implications of the study are discussed in terms of how the findings can be applied to improve practices and policies in the Public Works Department and the construction industry in general.

The research question aimed to identify the influence constituents of 4D BIM Tool in PWD Malaysia's project implementation. The analysis of the data revealed several key findings as per below:

a. Enhance communication and visualization:

The use of 4D BIM Tool has **enhanced communication and visualization** among the project stakeholders. This is particularly important as it allows different parties involved in the construction project to visualize the design and the construction process more effectively, thus reducing misunderstandings and improving collaboration.

b. Increase collaboration and coordination:

The implementation of 4D BIM Tool has **increased collaboration and coordination** among project stakeholders. This is because the tool provides a platform for all parties to work together, share information, and coordinate the construction process more efficiently.

c. Improve project planning and scheduling:

The use of 4D BIM Tool has **improved project planning and scheduling**. This is because the tool provides a comprehensive view of the project timeline, allowing project managers to plan and schedule the construction process more effectively, thereby reducing delays and costs.

d. Strengthen the construction process:

The implementation of 4D BIM Tool has **strengthened the construction process**. This is because the tool allows construction professionals to identify potential problems and challenges before the actual construction process, reducing errors and rework, and improving the overall quality of the project.

e. Reduce errors and rework:

The use of 4D BIM Tool has helped to **reduce errors and rework** in the construction process. The tool allows professionals to identify potential errors and mistakes and make the necessary changes before the actual construction process begins, thus reducing the need for rework and saving time and cost.

f. Save project cost:

The implementation of 4D BIM Tool has **saved project costs**. This is because the tool allows project managers to identify potential issues and challenges before, they occur, and make the necessary changes to prevent delays and additional costs.

In conclusion, the use of 4D BIM Tool has several positive influence constituents on PWD Malaysia's project implementation, including enhanced communication and visualization, increased collaboration and coordination, improved project planning and scheduling, strengthened construction process, reduced errors and rework, and saved project costs. These findings highlight the importance of adopting 4D BIM Tool in construction projects, as it can significantly improve the construction process and reduce project costs.

6 Limitation of Research

Although this research has provided valuable insights into the use of 4D BIM Tool in PWD Malaysia's projects, there are certain limitations that must be taken into account. One of the main limitations of this study is the scope of the research, which is focused solely on projects implemented with BIM technology under the 12th Malaysia Plan (Rolling Plan 2). Therefore, the findings of this study may not be generalizable to other projects outside of this scope.

7 Recommendations

Based on the limitations identified in this study, there are several areas for future research that could expand on this study's findings. One area for further research could be to conduct a comparative analysis between the implementation of 4D BIM Tool in Conventional In-house method and Design and Build method. This research could explore the differences and similarities between the two methods in terms of 4D BIM Tool implementation, project outcomes, and overall project efficiency.

Another area for future research could be to investigate the impact of 4D BIM Tool on project outcomes beyond the scope of this study. Future studies could focus on exploring the impact of 4D BIM Tool on factors such as project quality, safety, and sustainability.

In addition, future research could focus on exploring the effectiveness of the recommended solutions to overcome the challenges identified in this study. For example, research could explore the impact of incorporating the cost of 4D BIM software and training in construction contracts or establishing training modules on 4D BIM Tool among JKR Employees and Contractors.

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