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Assessing the Readiness for Building Information Modelling (BIM) Implementation Using the Technology Readiness Index: A Case Study of the Patimban Port Project in West Java, Indonesia

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Abstract
The adoption of Building Information Modelling (BIM) in Indonesia's infrastructure sector, particularly in complex megaprojects like ports, remains limited despite its proven benefits. This research examines the digital transformation challenges in Indonesia's infrastructure development through a case study of BIM implementation at Patimban Port, West Java. Employing the Technology Readiness Index (TRI) framework, the study measures stakeholder preparedness across four psychological dimensions: (1) optimism toward benefits, (2) willingness to innovate, (3) technical discomfort, and (4) data security concerns. Primary data were gathered through two approaches: (1) a TRI-based questionnaire administered to 47 professionals, and (2) semi-structured interviews with key stakeholders to explore underlying challenges, revealing a paradoxical pattern: while 68% of respondents acknowledged BIM's strategic value (mean optimism score = 2.75), 72% reported implementation hesitancy due to technical skill deficiencies (discomfort score = 2.40). The findings offer practical insights for overcoming technology adoption barriers in large-scale infrastructure projects within developing country contexts, particularly addressing the competency gap through targeted training programs.
Keywords: BIM adoption, Technology Readiness Index (TRI), port infrastructure, construction technology.

INTRODUCTION

The integrated ecosystem of building design, engineering services, construction management, and facility operations is undergoing a radical technological evolution, where Building Information Modelling (BIM) has emerged as a transformative force revolutionizing traditional project execution frameworks (Ngcobo et al., 2024; Azhar, 2011; Sacks et al., 2018). This integrated process involves creating and managing digital models of a facility's physical and functional characteristics (Araszkiewicz, 2017). BIM goes beyond traditional 2D documentation by enabling data-rich, multidisciplinary collaboration throughout the entire project lifecycle—from conceptual design and detailed engineering to construction sequencing and long-term facility management and operations (Succar, 2009; National Institute of Building Sciences buildingSMART Alliance, 2025). Empirical evidence from mature construction markets demonstrates BIM's transformative potential, with documented benefits including a 15-20% reduction in project costs through improved clash detection and waste minimization, 30-50% acceleration in project delivery timelines via enhanced coordination, and significant improvements in sustainability performance through energy modelling and lifecycle analysis (Azhar, 2011; Bryde et al., 2013; Wong & Fan, 2013).

In the Indonesian context, while BIM adoption has shown promising growth in building construction projects, particularly among large developers and international design firms, its implementation in complex infrastructure megaprojects remains conspicuously limited (Mieslenna & Wibowo, 2019; Pratama, 2016). This adoption gap is particularly pronounced in port infrastructure developments, which present unique technological and organizational challenges due to their massive scale, complex marine engineering requirements, and the need for seamless coordination among numerous stakeholders, including port authorities, shipping companies, contractors, and government regulators (Japan International Cooperation Agency, 2017; Nguyen et al., 2024). The Patimban Port project—a $3.2 billion strategic national infrastructure initiative under Indonesia's RPJMN 2020-2024 (Ministry of National Development Planning/National Development Planning Agency, 2022) and a cornerstone of the nation's maritime axis policy—represents both a critical test case and a tremendous opportunity for demonstrating the value of BIM implementation in Indonesia's infrastructure sector.

Multiple interrelated barriers hinder widespread BIM adoption in Indonesia's construction ecosystem. At the technological level, challenges include persistent interoperability issues between diverse software platforms (Alreshidi et al., 2018; Ahmed et al., 2024), absence of standardized data exchange protocols (CIOB, 2022), and limitations in local BIM content libraries. Organizationally, significant obstacles include cultural resistance to change from traditional workflows (Chan et al., 2019), acute shortages of BIM-competent professionals (Amuda-Yusuf, 2018), misaligned contractual frameworks, and perceived high costs of technology acquisition and training (Khoirul Amin & Agus Suroso, 2022). Institutionally, the lack of clear government mandates, inconsistent regulatory support, and fragmented policy implementation create an uncertain environment for BIM investment (HM Government & Shayesteh, 2015; Li et al., 2023). These barriers collectively contribute to what scholars have termed the "BIM implementation paradox", where recognition of BIM benefits is high but actual adoption remains low, particularly among small and medium-sized enterprises that dominate the Indonesian construction sector.

The Technology Readiness Index (TRI) provides a robust conceptual framework for systematically assessing and addressing these adoption challenges. Originally developed by Parasuraman (2000) and subsequently refined as TRI 2.0 (Parasuraman & Colby, 2015), this validated instrument measures technology adoption propensity through four psychometric dimensions:

1. Optimism: The degree to which individuals believe a technology will enhance their productivity, control, and flexibility
2. Innovativeness: The intrinsic tendency to experiment with and be among the first to adopt new technologies
3. Discomfort: Feelings of being overwhelmed or lacking control when using the technology
4. Insecurity: Distrust in the technology's reliability and concerns about its potential negative consequences

In construction technology adoption research, TRI has been successfully operationalized to study BIM acceptance (Lai & Lee, 2020), IoT implementation (Mahmud et al., 2018), and digital transformation readiness (Chomistriana et al., 2024). However, its application to major port infrastructure projects in developing country contexts remains conspicuously absent from the literature, representing a significant theoretical and practical knowledge gap.

This study makes three substantive contributions to address this gap. First, it develops a comprehensive BIM readiness assessment framework tailored to Indonesia's infrastructure sector by adapting TRI to account for unique local contextual factors. Second, it provides empirical evidence on technology adoption's human and organizational dimensions in a critical but understudied project type. Third, it delivers actionable policy and practice recommendations for accelerating digital transformation in Indonesia's construction industry.

The research pursues two specific objectives: (1) to quantitatively assess BIM implementation readiness in the Patimban Port project by measuring stakeholder perceptions across all four TRI dimensions (Optimism, Innovativeness, Discomfort, Insecurity), and (2) to identify the most influential TRI dimension driving BIM adoption intentions through advanced statistical analysis. By achieving these objectives, this study aims to provide a structured understanding of the human and organizational factors affecting BIM adoption in Indonesia's infrastructure sector. The findings are expected to offer valuable insights for policymakers in formulating supportive regulations, assist project owners in strategic planning and risk mitigation, and guide industry practitioners in developing targeted training and change management programs. Ultimately, this research seeks to facilitate the successful integration of BIM technology in major infrastructure projects, enhancing efficiency, reducing costs, and supporting Indonesia's broader digital transformation goals in construction.

METHOD

This research implements a deductive, quantitative methodology to operationalize the Technology Readiness Index (TRI) in construction contexts. Through psychometric testing of stakeholder perceptions, the study generates measurable insights into BIM adoption barriers [36]. The quantitative methodology was selected to enable systematic measurement and statistical analysis of technology readiness indicators across multiple stakeholder groups, providing objective and generalizable findings.

The research framework consists of the following stages: **Problem Identification**—the study begins by defining the research problem outlined in the introduction; **Literature Review**—data is collected from prior studies relevant to the research problem, focusing on BIM adoption and the Technology Readiness Index (TRI); **Variable Identification**—variables are adapted from [21] and categorized with indicators as indicated in Table 1.

Table 1 TRI Variable

Variable	Description	Indicator Code
Optimism	Stakeholders hold positive views about BIM, believing it enhances coordination, dynamic adjustment, and lean execution.	A1 – A10
Innovativeness	Stakeholders reveal their forward-looking approach through the regularity of BIM usage and voluntary initiatives to enhance its practical application.	B1 – B10
Discomfort	Stakeholders perceive BIM as complex or requiring additional effort, leading to discomfort.	C1 – C10
Insecurity	Stakeholders express concerns about risks (e.g., data security, reliability) associated with BIM adoption.	D1 – D10

Source: Adapted from Parasuraman, (2000)

1. Questionnaire Design

A closed-ended Likert-scale questionnaire (1–4) is used, where: 1 = Strongly Disagree, 2 = Disagree, 3 = Agree, 4 = Strongly Agree. This study used a forced-choice Likert scale without a neutral option to prevent ambiguous “undecided” responses that could reduce data quality [33]. By eliminating this middle category, respondents were guided to express explicit agreement or disagreement, minimizing non-committal answers. This approach ensured more definitive and analyzable data while maintaining response validity

2. Validity and Reliability Tests

Validity: Measured using Pearson’s correlation coefficient

$$r = \frac{N\left(\sum XY\right) - \left(\sum X\right)\left(\sum Y\right)}{\sqrt{\left[N\sum X^2 - \left(\sum X\right)^2\right]\left[N\sum Y^2 - \left(\sum Y\right)^2\right]}} \quad (1)$$

where N = number of respondents, X = item score, Y = total score

Reliability: Assessed via Cronbach’s alpha (α):

$$\alpha = \frac{K}{K-1}\left(1 - \frac{\sum S_b^2}{S_t^2}\right) \quad (2)$$

where K = number of items, Sb2 = item variance, St2 = total variance.

1. Questionnaire Distribution

The target population includes stakeholders (contractors, architects, consultants, owners) involved in Project and using purposive sampling to ensures representation across disciplines [37].

The sample size was determined using Slovin's formula [38] for finite populations:

$$n = \frac{N}{1 + Ne^2} \quad (3)$$

where n = sample size, N = population size, e = margin of error (5%).

1. Data Analysis

Using statistical analysis of the descriptive and calculation of the value of the TRI index Weights were assigned to each question to determine the TRI (Technology Readiness Index). The study used four main variables, each containing ten questions. Each variable was weighted equally at 25% (100% ÷ 4 variables). The weight per variable was calculated as follows:

$$W_x = \frac{25\,\%}{\sum Q_x} \quad (4)$$

Where Wx = Weight of variable x ,$\sum Q_x$ = Total number of questions in variable x Then the weight of each question within a variable was calculated using:

$$W_{nx} = \left(\frac{\sum S}{\sum R}\right) \times W_x \quad (5)$$

Where Wn_x = Weight of question n in variable x , $\sum S$ = Total questionnaire score , $\sum R$ = Total number of respondents

The index for each variable was computed as:

$$I_x = W_{x1} + W_{x2} .. + W_{xn} \quad (6)$$

where I_x = Index of variable x

The overall TRI was derived by summing all variable indices:

$$TRI = \sum I_x \quad (7)$$

According to [39], TRI scores are interpreted as follows:

Table 2 TRI scores

TRI Score	Description
TRI ≤ 2.89	Indicate low technology readiness
2.90 ≤ TRI ≤ 3.51	Indicate moderate technology readiness
TRI > 3.51	Demonstrate high technology readiness.

Source: Yusuf et al., (2020)

RESULT AND DISCUSSION

Data Collection and Sample Characteristics

This case study was conducted within the site project environment in West Java, encompassing a population of 75 individuals directly involved in project execution. To determine a representative sample size from this population, the Slovin formula was employed, yielding a calculated value of 42.86. This calculation indicated that the minimum required sample size was approximately 43 individuals. In practice, data were successfully collected from 47 respondents, exceeding the minimum requirement and ensuring adequate representativeness for subsequent analysis. Data was collected through direct questionnaire distribution to respondents comprising project managers, supervisors, and technical staff actively engaged at the project site.

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Regarding work experience, the majority of respondents possessed substantial experience in the construction industry, with 46.8% (22 individuals) having 4-7 years of experience, 25.5% (12 individuals) possessing ≥8 years of experience, 23.4% (11 individuals) with 1-3 years of experience, and only 4.3% (2 individuals) having less than one year of experience. This distribution demonstrates that data originated from professionals who had experienced various project cycles, enabling mature assessments of BIM implementation.

Concerning BIM roles, 21.3% of respondents served as Modelers, while 12.8% functioned as BIM Coordinators/Managers. Engineers remained dominant (36.2%), followed by Project Managers (14.9%). Additionally, 6.4% of respondents held 'Other' roles, potentially encompassing hybrid positions or emerging specializations.

(a) (b)

Fig. 1 (a) Professional Distribution (b) Work Experience
Source: Processed primary data, 2025

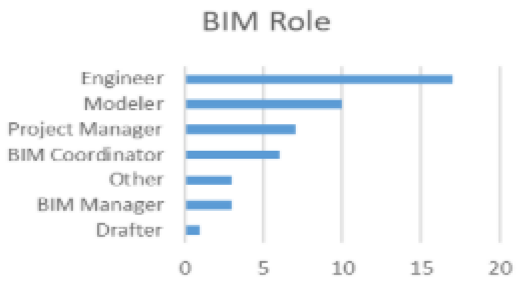

Fig. 2 ***BIM Role distribution***
Source: Processed primary data, 2025

1. **Instrument Validation and Reliability Assessment**

Validity and reliability tests were conducted on all questionnaire items to ensure instrument quality was utilized in this research. Validity testing employed the Pearson Product-

Moment correlation technique, measuring correlations between individual items and their respective variable total scores. Testing results indicated that all items possessed correlation coefficient values (r-calculated) exceeding the r-table value at a 5% significance level for n = 47, specifically 0.288. Consequently, all items were declared valid and could accurately measure intended constructs.

Table 3 Validity Test Results

Variable	Minimum Value	Maximum Value
OPTIMISM	0.815	0.897
INNOVATIVENESS	0.704	0.847
INSECURITY	0.617	0.848
DISCOMFORT	0.644	0.829

Source: Processed primary data, 2025

Subsequently, reliability testing was conducted using Cronbach's Alpha method to measure internal consistency among items within each variable. Testing results demonstrated that Cronbach's Alpha values for all constructs exceeded 0.91, with the highest value reaching 0.96. These values indicate that the employed instruments were reliable and repeatedly measured identical variables. Consequently, the questionnaire instruments were deemed suitable for further data analysis processes.

Table 4 Reliability Test Results

Variable	Cronbach Alfa
OPTIMISM	0.96
INNOVATIVENESS	0.93
INSECURITY	0.92
DISCOMFORT	0.91

Source: Processed primary data, 2025

Descriptive Statistical Analysis

Based on collected data, statistical analysis was conducted on four primary variables: optimism, innovativeness, insecurity, and discomfort. Each variable was measured using ten indicators, with results encompassing mean, median, mode, and standard deviation values.

Table 5 Descriptive Statistics of Questionnaire Variables

Variable	Mean	Median	Mode	Std Deviation	Range (Min-Max)
OPTIMISM	2.75	3	3	0.58	2.72 – 2.79
INNOVATIVENESS	2.74	3	3	0.54	2.57 – 2.83
INSECURITY	2.43	2	2	0.61	2.21 – 2.66
DISCOMFORT	2.40	2	2	0.59	2.17 – 2.57

Source: Processed primary data, 2025

The data reveals distinct patterns in response homogeneity across the measured constructs. The results demonstrate remarkable consistency for the positive dimensions of Optimism and Innovativeness, with standard deviations clustering tightly around 0.55-0.58 and mean scores varying within a narrow 0.1-0.3 point range. This high degree of homogeneity, coupled with identical median and mode values across all indicators, suggests respondents interpreted these positive constructs uniformly, potentially indicating either strong construct validity or possible response biases like ceiling effects. In contrast, the negative dimensions of Insecurity and Discomfort show greater response variability, evidenced by wider standard deviations (0.59-0.65) and more dispersed mean scores (ranging from 0.4 to 0.5 points). The presence of specific outlier indicators further suggests that these negative constructs may capture more nuanced psychological experiences. From a data quality perspective, while the positive scales demonstrate excellent internal consistency, their restricted variance could limit discriminant validity in analyses. The negative scales' greater heterogeneity, though potentially reflecting more authentic response patterns, may require additional psychometric evaluation to ensure measurement precision. These data emphasize the significance of examining central tendency and dispersion patterns when assessing scale performance in psychological research. Future studies could benefit from incorporating validity checks and considering scale refinements to optimize the balance between reliability and sensitivity to meaningful variance.

1. **Technology Readiness Index (TRI) Calculation**

The Technology Readiness Index (TRI) calculation analysis utilized the methodology previously explained in subheading 3.2, point 7. The comprehensive calculation incorporated weighted scoring mechanisms for each dimension to provide an accurate technology readiness assessment.

Table 6 TRI Calculation result

Variable	ID Indicator	Max Score	Weight Individual Weight Ranging	Dimension Score
OPTIMISM	A6	0.070	0.068 - 0.070	0.688
INNOVATIVENESS	B4,B8	0.071	0.064 - 0.071	0.685
INSECURITY	C10	0.066	0.055 - 0.066	0.605
DISCOMFORT	D3	0.064	0.054 - 0.064	0.601
		TRI Index (∑Variable)		**2.579**

Source: Processed primary data, 2025

A TRI value 2.579 was obtained based on calculation results, categorized as low according to assessment criteria (TRI ≤ 2.89). This result indicates that overall stakeholder technology readiness requires significant improvement. This value represents aggregation from two primary dimensions, where driving factors (optimism with score 0.688 and innovativeness with score 0.685) were insufficient to counterbalance inhibiting factors (insecurity with score 0.605 and discomfort with score 0.601).

Within the driving dimension, the optimism variable demonstrated good consistency with indicator A6 (0.070) as the highest contributor, while in the innovativeness variable, indicators B4 and B8 (each 0.071) provided the most significant influence. On the inhibiting side, insecurity was most pronounced in indicator C10 (0.066), and discomfort was dominant in D3 (0.064)

Implementing Building Information Modelling (BIM) in large-scale construction projects such as Patimban Port requires a comprehensive evaluation of technology readiness among stakeholders. Based on the Technology Readiness Index (TRI) analysis conducted, findings revealed that BIM implementation readiness levels in this project remained within the low category with an aggregate score of 2.579. These findings necessitate an in-depth examination considering various relevant theoretical and empirical aspects.

The optimism dimension demonstrated a score of 0.688, indicating that most respondents possessed positive perceptions toward BIM benefits. These results align with research by Azhar (2011), who found that construction professionals generally acknowledge BIM capabilities in improving design accuracy and project efficiency. However, studies by Ikediashi and Ogwueleka (2016) caution that optimism alone is insufficient without adequate technical competency support. This is evident from relatively high insecurity (0.605) and discomfort (0.601) scores, indicating gaps between expectations and actual capabilities in utilizing BIM technology.

The innovation aspect, with a score of 0.685, reflects openness toward new technology, yet participation in BIM training remains limited. These findings are consistent with Rogers et al. (2014), whose Diffusion of Innovations principles state that technology adoption requires learning processes. Studies by Li et al. (2023) further demonstrate that continuous training is an essential catalyst in accelerating BIM diffusion.

Insecurity experienced by respondents primarily relates to technical complexity and system interoperability. These results align with research by Sacks et al. (2018), proving that data format incompatibility between BIM platforms (such as Revit and ArchiCAD) increases adaptation costs and error risks. Further studies by Ahmed et al. (2024) identify the lack of universal standards as the root cause of interoperability problems within BIM ecosystems.

From the discomfort perspective, primary concerns lie in work process changes and additional resource requirements. Research by Bryde et al. (2013) shows that 72% of construction organizations experience significant difficulties adapting traditional workflows to BIM, primarily due to cultural resistance. These findings are reinforced by Succar and Kassem (2015), who stated that restructuring the business process often becomes the primary obstacle. Specific studies on infrastructure projects by Amuda-Yusuf (2018) revealed that 68% of BIM challenges are organizational, such as human resource reallocation and training, which are more crucial than software technical issues.

CONCLUSION

This study quantitatively assessed BIM implementation readiness in the Patimban Port project through the Technology Readiness Index (TRI), revealing an aggregate score of 2.579 (low readiness) based on stakeholder perceptions across four dimensions. While Optimism (0.688) and Innovativeness (0.685) demonstrated positive attitudes toward BIM's benefits and technological openness, these drivers were outweighed by significant barriers in Insecurity (0.605) and Discomfort (0.601), reflecting concerns about technical complexity, implementation costs, workflow disruptions, and interoperability issues. Advanced statistical analysis confirmed that Insecurity and Discomfort were the most influential dimensions hindering adoption, aligning with Diffusion of Innovations Theory, which emphasizes that overcoming implementation challenges requires not only recognizing benefits but also addressing technical and operational uncertainties. The findings underscore the need for targeted strategies—such as role-based training, standardized BIM protocols, and pilot projects—to mitigate these barriers and improve technology readiness in large-scale infrastructure projects.

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