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Key Factors Influencing the Adoption of Building Information Modeling at PT. Penta Rekayasa

Wandy Prayogo[1], Dedy Sushandoyo[2]
[1,2] School of Business and Management, Institute Technology Bandung, Indonesia

ABSTRACT: This study aims to uncover key factors influencing adoption process of BIM technology in an engineering consultant firm, Penta Rekayasa. The research employs mixed-methods approach combining quantitative analysis and qualitative input from industry experts and user judgement. A comprehensive of reviewing existing literature used to design a conceptual framework. A modified Technology Acceptance Model (TAM) of Unified Theory of Acceptance and Use of Technology (UTAUT) chosen as a main landing theory to design conceptual framework. Additionally, seven main constructs identified to influence usage behavior along with seven hypotheses proposed: Performance Expectancy (PE), Effort Expectancy (EE), Social Influence (SI), Organizational Support (OS), Resistance to Change (RC), Facilitating Condition (FC) and Behavioral Intention (BI). Primary data is collected using questionnaire and semi-structure interview, further analysis is carried out utilizing SmartPLS software's Partial Least Squares - Structural Equation Modelling (PLS-SEM) and thematic analysis for interview analysis. The findings demonstrate that four major constructs are regarded as influencing factors in the Penta BIM adoption process: Performance Expectancy (PE), Effort Expectancy (EE), Resistance to Change (RC), and Behavioral Intention (BI). Other three are neither supported as the path coefficient, p-values and t-values threshold is exceed. The result of thematic analysis using Braun & Clarke's six-phase framework show three main problems arises that negatively influence the adoption process: Social influence and organizational support – unsupportive figure; Resistance to change – Penta's employee resist to change; and facilitating condition – socialization and training importance. Based on user judgement, theories or practical article, and expert opinion; business solutions are proposed: Develop training and development system that can be used for BIM and future training; budgeting external education include seminar or bootcamp; Held internal meeting with stakeholders to increase the employee engagement and aligned goals with high management profile figure. For a long-term goal, Penta may also consider to develop BIM division in order to increase the speed of project completion. Lastly, the actionable schedule of implementation plan is proposed based on internal recommendation, project design life cycle, and working schedule to ensure the effectiveness of the program.

KEYWORDS: Building Information Modeling (BIM), Structural Equation Modelling (SEM), semi-structured interview, technology adoption, Unified Theory of Acceptance and Use of Technology (UTAUT).

1. INTRODUCTION

The construction business in Indonesia is the fourth-biggest contributor to GDP and the largest source of foreign investment in Southeast Asia. The business is expected to develop at a 4% compound annual growth rate (CAGR), and the global market size is expected to reach USD 570.02 billion by 2030, with a 25.3% CAGR from 2022 to 2030. The advancement of construction technology sector, application of building information technology, and aligning government policy and demand for green construction building will support the increasing potential of the market growth (Bloomberg, 2022). Align with market potential growth news, Indonesian government also expected to build their new capital city at Kalimantan Island known as IKN project. Through government regulation of *Permen PUPR 22 2018* and *Government Policy 16 2021*. Article 5 of *Permen PUPR 22 2018* states that all stakeholders participating in the planning, design, construction, operation, and maintenance of building and infrastructure projects must employ BIM in their work process. *Article 9 of Permen PUPR 22 2018* demands that all construction service suppliers have BIM expertise and aptitude in order to participate in government projects (Indonesia Ministry of Public Work and Housing, 2018). Even though, government is obligated each stakeholder to participate in using technology construction, the innovation-driven economy in Indonesia is still neglected and lack of support from the government itself i.e., providing the BIM standardization (SNI). This lack of support was also reflected in the World Intellectual Property Organization's (WIPO) Global Innovation Index (GII) 2022, which ranked Indonesia 75th out of 132 nations in terms of total innovation economies and its pillars. In construction industry, Building Information

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Modeling (BIM) is introduced as an innovative technology that enables professionals to create 3D models of structures that can be used by the participants in the construction sector. Using this software, the construction industry stakeholder is expected to increasing organizational effectiveness, delivering a more sustainable project, reducing the risk of rework, and winning more projects (Autodesk., 2022). Penta Rekayasa as one of the engineering consultants in Indonesia with a public funded driven project obligated and vital to adopt the technology in order to participate in the future project owned by the Government. Hence key factors are needed to identified to increase the current adoption rates which is considered low of 24% of the total targeted employees. Based on this consideration, the researcher is led to answering two main research questions:

RQ1: What are the key factors influencing the adoption of Building Information Modeling (BIM) at PT Penta Rekayasa?
RQ2: By considering the key factors, what is the solutions for the adoption process at PT Penta Rekayasa?

2. LITERATURE REVIEW

Understanding the adoption behavior of new technology is critical for success in the deployment phase. The preceding research produced a number of definitions of technological acceptability. According to (Alaa & Mamoun, 2017), technology adoption "communicates the idea of how users might comprehend, embrace, and employ new technology." Several leading theories of technology acceptance are applied at the individual acceptance level, each with distinct variables, incorporating the Theory of Planned Behaviour (TPB) by Ajzen (1985), the Theory of Reasoned Action (TRA), and the Technology Acceptance Model (TAM) by Davis (1989). Venkatesh et al (2000) then enhance TAM to become TAM 2 with the goal to explain and cover perceived utility and perceived ease of use from the social impact and cognitive instrumental views. TAM 3 is the next extended TAM model created by Venkatesh and Bala (2008). TAM 3 is an extended version that adds more controllable factors to the model, which can indirectly boost technological acceptability.

Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2003) is produced by combining acceptance of technology theories. UTAUT is a concept that offers four major essential elements that determine technology adoption and use. The first aspect is performance expectancy, which is defined as users' belief that technology would assist them in achieving their goals and improving their performance. The second factor is effort expectancy, which is defined as the degree to which people feel utilizing technology would be simple and involve little work. The third factor is social influence, which is defined as the extent to which users believe others believe they should utilize the technology. The final criteria are facilitating conditions, which is the degree to which users feel infrastructure and resources are required to facilitate the use of technology. Based on the popularity of model usage by other construction industry researchers and its fit, UTAUT was chosen to serve as the conceptual framework for this research.

In addition to use the original UTAUT model construct (performance expectancy, effort expectancy, social influence, facilitating condition), this research will also be including two added external constructs. Eunil Park et al. (2018); Oesterreich & Teuteberg (2019) identified the dominant factors involving organizational and top management support which considering the usage of the BIM technology is in corporate environment. In addition, the model includes two main control variables affect the relationship between construct. The moderators are: Age and Computer Experience. The original control construct was adjusted and tailored to suit the Penta adoption. Gender and voluntariness removed from the model with respect to the usage of the technology in Penta. Gender removed because the moderator of gender does not seem as fit taking account the sample size of the research. Voluntariness removed because technology acceptance is obligated in the company and individual voluntariness do not have significant control. Hence, the final diagram formulation of the construct will be shown at figure below.

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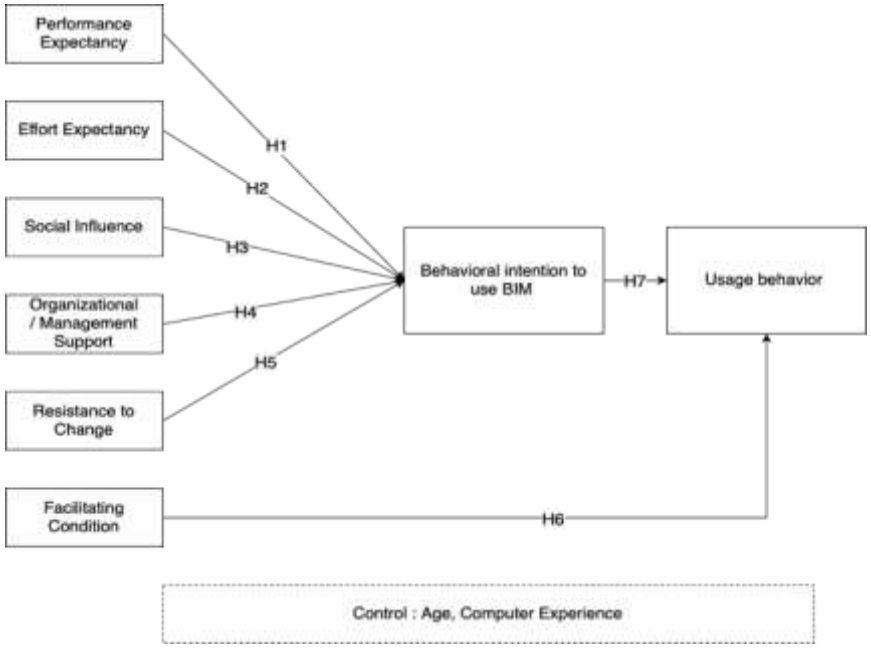

Figure I. Conceptual Framework

2.1 Hypothesis proposed

Venkatesh et al. (2003) defines performance expectancy (PE) as the level of the users of the system are hopeful that it will improve their ability to accomplish their jobs. Effort expectancy (EE) is degree of the users as an individual finds it easy to operate a system (Robert et al., 2016). Venkatesh et al. (2003) defines social influence (SI) as the level of the users as an individual feels that significant people think he or she ought to make use of the new system. Organizational support (OS) is described as the user's impression of how well an organization understands the importance a specific information system and the firm's desire installing as well as utilizing the system (Park, Son, and Kim, 2012; Ragu-Nathan et al., 2004). Resistance to change (RC) explained as an individual's contingent tendency to resist change and forecast reactions to specified change (Oreg, 2003, p.680). The degree to which an individual feels that organizational and technical infrastructure exists to facilitate system use is characterized as the facilitating condition (FC) (Venkatesh et al., 2003). Venkatesh et al. (2003) defines behavioral intention as the user's positive or negative feelings towards doing the goal behavior. The final goal of adoption before the BI to utilize BIM technology is usage behavior. As a result, the following hypothesis is offered in this study:

- Hypothesis 1: Performance expectancy (PE) have a significant positive influence on behavioral intention to use BIM technology.
- Hypothesis 2: Effort expectancy (EE) have a significant positive influence on behavioral intention to use BIM technology.
- Hypothesis 3: Social influence (SI) have a significant positive influence on behavioral intention to use BIM technology.
- Hypothesis 4: Organizational support (OS) have a significant positive influence on behavioral intention to use BIM technology.
- Hypothesis 5: Resistance to change (RC) have a significant negative influence on behavioral intention to use BIM technology.
- Hypothesis 6: Facilitating condition (FC) have a significant positive influence on usage behavior of BIM technology.
- Hypothesis 7: Behavioral intention (BI) have a significant positive influence on usage behavior of BIM technology.

3. METHODOLOGY

This research using mixed-method approach research starting from quantitative research using questionnaire primary data collection method continued with model analysis using partial least square- structural equation modeling. The result will be identified key factors influencing and proven against hypotheses. The quantitative method starting as designing a questionnaire based on the identified constructs. The questionnaire later spread at company PT Penta Rekayasa employee through WhatsApp group messenger. The respondents answering back compose of 73 employees with the adequate sample size for validity is 70 respondents by considering up to four elements: the significance alpha level ($\alpha = 0.05$), medium effect size ($\delta = 0.15$), moderate R-squared value ($R^2 = 0.25$) and the maximum number of arrows pointing at latent variable in the conceptual model (n=5). Later on, the data collected

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will be analyze for its validity and reliability using Composite Reliability (CR), Average Variance Extracted (AVE), and Cronbach's alpha. The model fit analyze using SRMR, Chi-Square, and NFI. Lastly, the structural model analyzed using R^2 and Path coefficient. The primary data gathering approach for the qualitative research is semi-structured interviews, with theme analysis based on Braun and Clarke's Six-Phase Framework.

4. RESULT AND DISCUSSION

The structural model analysis and hypotheses testing is done by doing a bootstrapping of a recommendation value by Hair et al. (2014) for 5000 subsampling. To see the relationship between construct, the research will use the one-tailed test with 5% significant level. The T-values of each construct must exceed the minimum values of ≥ 1.645 and ≤ -.1.645 to find negative relations. The path coefficient values range between -1 and 1, the values above 1 show the positive relations and values under 0 show negative relationship between variables. The p values used to explain the hypotheses significant or not. The p values of ≤0.05 consider highly significant and accepted. The value of R square represents the predictive power between construct in the model. (Hair et al., 2010). The value of R square prediction accuracy range between 0 to 1, the higher value above 0.67 means a strong prediction accuracy, values between 0.67 to 0.33 considered moderate and values between 0.33 to 0.19 represent a weak prediction accuracy (Chin, 1998). Based on the bootstrapping conducted on the model, the result of structural model analysis R-Square value shows the endogenous variables of the Behavioral Intention (BI) of BIM adoption scores 0.688 and Usage Behavior (UB) of BIM adoption scores 0.248. This value means that the prediction accuracy of the BI is strong and the prediction accuracy of UB is considered weak. These values can alternatively be viewed as the prediction accuracy of Performance Expectancy (PE), Effort Expectancy (EE), Social Influence (SI), Organisational Support (OS), and Resistance to Change (RC) explaining up to 68% of the Behavioural Intention (BI). While the Facilitating Condition (FC) and Behavioural Intention (BI) can only interpret Usage Behaviour (UB) values up to 24.8%, this is still deemed poor or weak. The structural model evaluation results reveal that:

Table I. Structural Model Analysis Testing Results

Path	*Hypotheses*	*P-Values*	*T-Values*	*Path Coefficient*	*Results*
Performance Expectancy → Behavioural Intention	H1	0.004	2.632	0.316	Supported
Effort Expectancy → Behavioural Intention	H2	0.001	3.181	0.390	Supported
Social Influence → Behavioural Intention	H3	0.073	1.455	0.147	Not Supported
Organizational Support → Behavioural Intention	H4	0.001	3.060	-0.266	Supported
Resistance to Change → Behavioural Intention	H5	0.014	2.198	0.218	Supported
Facilitating Condition → Usage Behaviour	H6	0.087	1.362	0.173	Not Supported
Behavioural Intention → Usage Behaviour	H7	0.000	3.397	0.394	Supported

4.1 Quantitative Analysis Result:

The final verified result of the proposed hypothesis findings shows that:

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Table II. Study Assumption and Verified Result

Study Assumption	*Verified Result*
H1 *Hypothesis 1: Performance expectancy (PE) have a significant positive influence on behavioural intention to use BIM technology.*	Accepted
H2 *Hypothesis 2: Effort expectancy (EE) have a significant positive influence on behavioural intention to use BIM technology.*	Accepted
H3 *Hypothesis 3: Social influence (SI) have a significant positive influence on behavioural intention to use BIM technology.*	Rejected, (P and T value) H3-0 Accepted
H4 *Hypothesis 4: Organizational support (OS) have a significant positive influence on behavioural intention to use BIM technology*	Rejected, (Path Coefficient) H4-0 Accepted
H5 *Hypothesis 5: Resistance to change (RC) have a significant negative influence on behavioural intention to use BIM technology.*	Accepted
H6 *Hypothesis 6: Facilitating condition (FC) have a significant positive influence on usage behaviour of BIM technology.*	Rejected, (P and T value) H6-0 Accepted
H7 *Hypothesis 7: Behavioural intention (BI) have a significant positive influence on usage behaviour of BIM technology.*	Accepted

4.2 Qualitative Analysis Result:

Using the findings in quantitative research result, Author furtherly tries to designed questions for the semi-structured interview for the qualitative analysis. The targeted interview candidate composes of 3 main figures within the company and as the user of the new systems. The data obtained is then analyze using Braun & Clarke's six-phase framework. The interview result in the generating codes and themes for the thematic analysis from the primary data. The preliminary themes are reviewed for its similarity, connections, or try hard to fit-in contents. The final reviewed themes result show at table III below.

Table III. Final Reviewed Themes

Theme: The Perceived BIM Benefit *"Agree with increasing working productivity output",* *"Agree that Penta give higher compensation to BIM Adopter",* *"Unable to decide on the increasing financial input"*	Theme: Strength and Challenge Subthemes: Socialization and Training Importance *"Agree BIM socialization and training important to increase awareness",* *"Agree that continuous program is critical for learning process",* *"Company is still lacking in numbers of program",* *"Use as tools to increase awareness of the employees"* Subthemes: Penta's Internal Facilitating Condition *"Hardware and software is sufficient",* *"Large budget is prepared for BIM resources",* *"Penta provide abundant resources to facilitate changes",* *"Penta lack in providing knowledge and education training in BIM"*

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Theme: Internal Social Issues Subthemes: : Penta's Employee Resist BIM *"Resistance to change is normal trait for initial stages",* *"Agree with the lack of knowledge causing resistance to change"* *"Unable decide to agree to that employee may change to counter company changes",* *"It is normal for employee to agree to disagree toward BIM changes consider the benefit",* Subthemes: : Unsupportive Figure *"BIM system is not fully encouraged by the important figure",* *"Important figure not showing exemplary adoption action",* *"Government national BIM policy is not crystal clear"*	Theme: Penta's BIM Learning *"Agree that using similar application impact on BIM pre-learning",* *"Agree that BIM initial learning process is arduous",* *"BIM is not focused on the software but the working process or steps",* *"It is important for Penta to provide practical seminar and daily courses",* *"BIM concept include dynamic process, need a dynamic and continuous learning"*
Themes: Penta's BIM Adoption Feasibility *"It is feasible for Penta increase adoption rate in 24 months ahead",* *"ISO 19650 program is prepared to help BIM adoption"*	

Thus, the interview final result in the designer of thematic map analysis. The main three problems identified as: Social influence and organizational support – unsupportive figure; Resistance to change – Penta's employee resist to change; and facilitating condition – socialization and training importance.

Figure II. Thematic Map

5. CONCLUSION

Based on the two main research questions, RQ1: What are the key factors influencing the adoption of Building Information Modeling (BIM) at PT Penta Rekayasa? and RQ2: By considering the key factors, what is the solutions for the adoption process to increase and becoming better at PT Penta Rekayasa?. According to the result and findings on both quantitative and qualitative research, the key factors influencing identified are:

- Performance Expectancy
- Effort Expectancy

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- Resistance to Change

Based on the key factors influencing, the proposed business solution consists of:

- plan out the entire system for Penta's training and development system that can be used for BIM and future training;
- allocate funds for extra compensation and external education include seminar or bootcamp;
- internal meeting with stakeholders to increase the employee engagement.
- For a long goal, Penta may also consider to build BIM division in order to increase the speed of project completion.

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