THE EFFECTS OF BUILDING INFORMATION MODELING (BIM) IMPLEMENTATION IN THE SUCCESS OF CONSTRUCTION PROJECTS

Bambang Herumanta [1], Rizky Citra Islami [2], Amalia Ula Hazhiyah [3]

[1,2,3] Civil Engineering Department, Vocational College, Universitas Gadjah Mada Yogyakarta, Indonesia

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Corresponding Author

Bambang Herumanta,
bherumanta@yahoo.com

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ABSTRACT

The Indonesian government through the Minister of Public Works and Public Housing Regulation number 22/2018 has required the use of BIM in the construction of state buildings with criteria above 2000 square meters and over two floors. These regulations are binding on stakeholders such as owners, consultants, and contractors. This study aims to analyze how the influence of the application of Digital Building Information Modeling technology on the implementation of construction projects, which consists of the advantages of BIM adoption variables, factors related to BIM adoption, challenges, and obstacles, on the success factors of BIM-based projects. The research was conducted using quantitative methods, using data from questionnaires of 40 respondents from 14 construction companies in Indonesia. The data of the dependent variable and the independent variable were analyzed using multiple regression using statistical analysis SPSS 25.0 software. The conclusion from the results of data analysis, states that there are significant effects between the variables of the application of digital technology BIM (X) in the construction service industry on the critical success factors for BIM-based projects (Y) together. Partially, the variable excess of BIM adoption (X1) and the variables related to the adoption of BIM (X2) has positive and significant effects on the determinants of the success of BIM-based projects.

Keywords: Construction Service, BIM, Project, Significant, Success

1. INTRODUCTION

Building Information Modeling (BIM) has fundamentally changed the approach of system design, construction, and operation in the construction industry. This comes as no surprise considering that over the years the construction industry has been heavily criticized in various countries for its inefficient systems and lack of productivity. BIM platforms carry a concept of collaboration between project stakeholders and project outcome improvement Abubakar et al. (2010) BIM has advantages in database modeling, visualization, analysis, and simulation in construction development. The growing adoption and implementation of BIM globally represent a paradigm shift towards an integrated digital information system that revolutionizes almost all aspects of the construction industry.

Advances in technology and information systems affect the construction climate in Indonesia without exception. The implementation of the concept of sustainable development consented by world leaders, including Indonesia, propels building designs to become more complicated and complex. The current paradigm shift focuses on increasing productivity, infrastructure value, quality, and sustainability, reducing life cycle costs, lead times, ineffective collaboration, and good communication between project stakeholders Hwang et al. (2019)

2. LITERATURE REVIEW

These days, Building Information Modeling (BIM) is a promising system for facilitating integration, interoperability, and collaboration in the future of the construction industry Vanlande et al. (2008) BIM is a centralized system that allows one to manage various types of information, such as enterprise resource planning, resource analysis packages, technical reports, meeting reports, and others. The study Hwang et al. (2019) on an assessment of the impact of BIM on reworks in construction projects mentioned that a project where BIM is implemented tend to have lower rework incidents compared to a project with no BIM Franz and Messner (2019) The study Franz and Messner (2019) exploring the effect of adoption of BIM and participation of BEP (BIM Execution Planning) found that BIM adoption is highest when contractors are involved during conceptual design and pre-design Isikdag and Underwood (2010). According to Isikdag and Underwood (2010) in A Synopsis of the Handbook of Research on Building Information Modeling, the reason for moving from CAD-based thinking to a BIM vision is much more complicated because it involves a fundamental change in data management philosophy Azhar (2011)

3. RESEARCH METHODS

This study used a quantitative method with a questionnaire. A quantitative research method was chosen because the data used and presented in this study were in the form of numbers and the analysis used statistics. This study aimed to identify the effect of the implementation of BIM (X) Mieslenna and Wibowo (2019), Badrinath and Hsieh(2019) on critical success factors of projects based on Building Information Modeling (BIM) (Y), identify the most influential variable(s) in the implementation of BIM, and the most influential item(s) in the implementation of BIM and success factors for projects based on Building Information Modeling. Data analysis was carried out using SPSS version 25 for Windows. The research flow chart can be seen in Figure 1, Figure 2

Figure 1

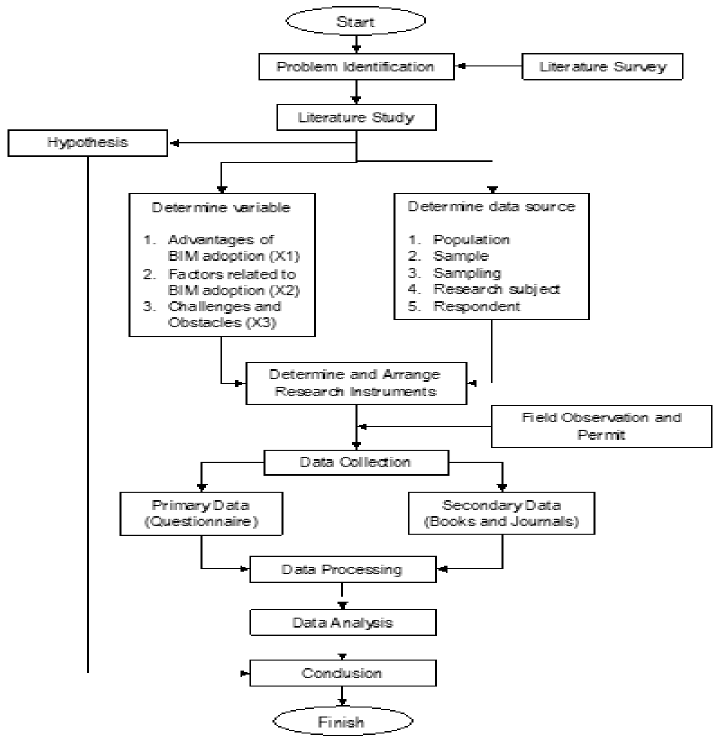

Figure 1 Research Activity Scheme

Figure 2

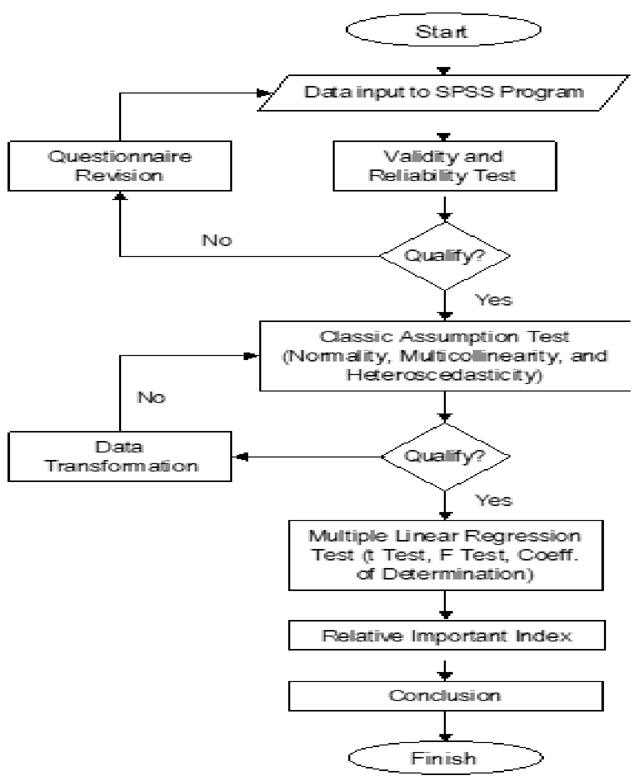

Figure 2 Data Analysis Stages

There were two variables used by the researchers, namely independent variables (cause or influence other variables) and dependent variables (influenced by other variables). Based on the literature review, we obtained a conceptual framework for this study presented in Figure 3

Figure 3

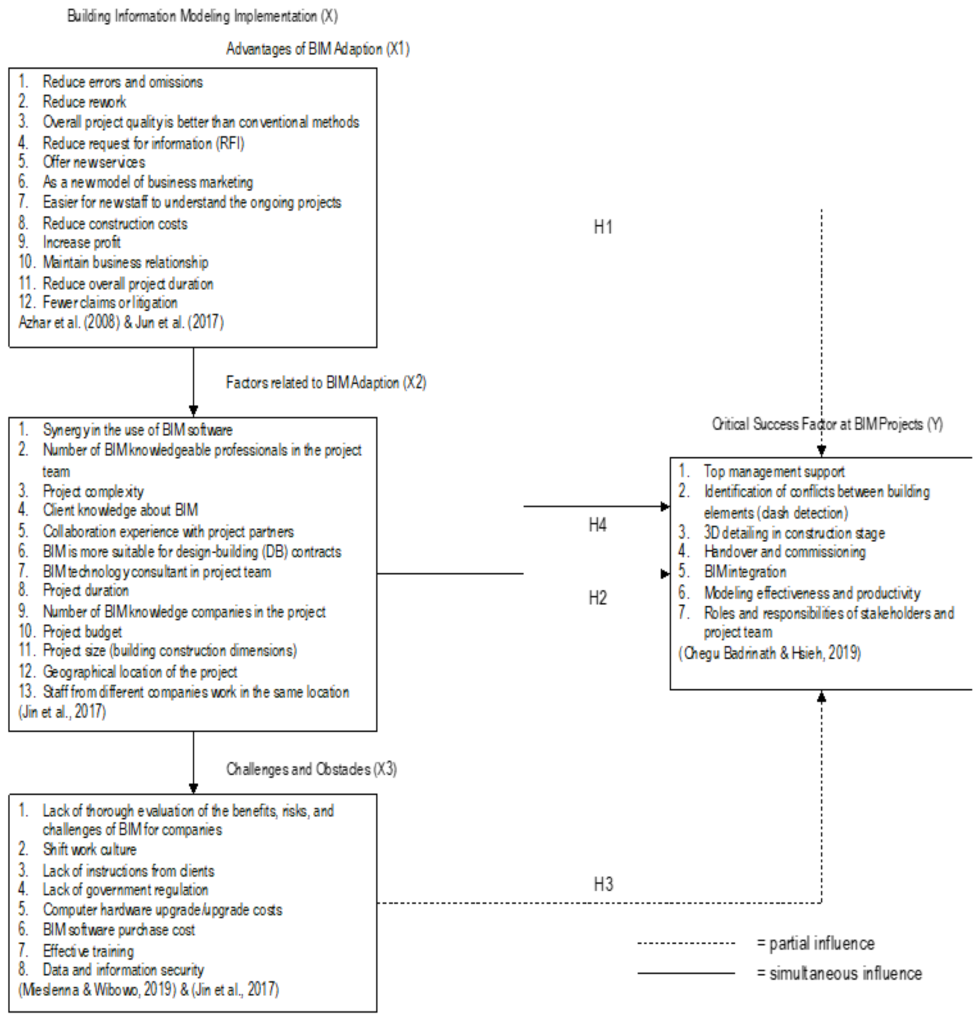

Figure 3 Theoretical Framework

4. RESULTS AND DISCUSSION

For data analysis, a two-way ANOVA was used. The questionnaire analysis consisted of 40 employees representing several companies in Indonesia that utilized BIM in their construction projects. In the results of validity test, one item in variable X1, namely Building Information Modeling can be used as a new model in business marketing (item A6) and one item in variable X2, namely Building Information Modeling is more suitable for design-build (DB) contracts (item B6), did not meet the requirements. Thus, the two items were excluded in the subsequent analysis stage. In the reliability test, all variables met the requirements, and they could be included in the next analysis. All variable items were evaluated using the classical assumption test and met the requirements for further testing in multiple linear regression analysis (two-way ANOVA). The distribution of questions used in this study is presented in Table 1

Table 1

Table 1 Question Distribution Based on the Variables

No	Variables	Total
1	The advantages of adopting BIM in the process of implementing BIM for construction project activities (X1);	12
2	Factors influencing the achievement of maximum potential of BIM in its implementation process for construction projects (X2);	13
3	Obstacles or barriers in the process of implementing BIM for construction projects (X3);	8
4	Critical success factors in BIM-based projects (Y)	7

4.1. MULTIPLE LINEAR REGRESSION ANALYSIS

The regression equation in this study was to determine how much influence the independent variables have, namely: the advantages of adopting BIM in the process of implementing BIM for construction project activities (X1); factors influencing the achievement of maximum potential of BIM in its implementation process for construction projects (X2); obstacles or barriers in the process of implementing BIM for construction projects (X3); on the critical success factors in BIM-based projects (Y) dependent variable. The mathematical formulation of multiple linear regression used in this study was:

$$Y = a + b_1X_1 + b_2X_2 + b_3X_3 + e \quad (1)$$

Description:

Y = Project success

A = Constant

b_1 = Regression coefficient between the advantages of adopting BIM in the process of implementing BIM for construction project activities and critical success factors in BIM-based projects

b_2 = Regression coefficient between factors influencing the achievement of maximum potential of BIM in its implementation process for construction projects and critical success factors in BIM-based projects

b_3 = Regression coefficient obstacles or barriers in the process of implementing BIM for construction projects and critical success factors in BIM-based projects

X_1 = The advantages of adopting BIM variable

X_2 = The factors related to BIM adoption variable

X_3 = The obstacles and barriers variable

e = Error rate

The results of the multiple linear regression analysis are presented in Table 2

Table 2

Table 2 Results of Multiple Linear Regression

Variables	Unstandardized Coefficient (B)	Standardized Coefficients (Beta)	t count	Sig. t
(Constant)	-0.692		-0.722	0.481

Variable X1	0.049	0.434	2.389	0.03
Variable X2	0.059	0.499	2.605	0.019
Variable X3	-0.003	-0.015	-0.015	0.933

Sources: Primary data processing, 2021

As seen in Table 2 the calculation of multiple linear regression using SPSS 25.0 program produced the following regression model:

$Y = -0.692 + 0.049 X_1 + 0.059 X_2 - 0.003 X3$

The equation above shows that a constant value of 0.692 has a negative direction. It means that the implementation of BIM for all contractors and consultants variable decreased by 0.692 units without the influence of independent variables.

4.2. F TEST

The basis of F test in a multiple linear regression analysis requires F test results having a sig. value below 0.05 (<0.05) or F count value greater than F table (F count > F table). An F table value was obtained based on the F0.05 value distribution table using the following formulation:

F table = F (k; n-k) (2)

F table = F (3; 40-3)

Based on Table 3 the sig. value was smaller than 0.05 (0.000 < 0.05) and the F count value was greater than F table (12.091 > 3.200). it means that H0 is rejected, indicating that the implementation of BIM for contractors and consultant's variable has an effect on the critical success factors in BIM-based projects variable simultaneously.

Table 3

Table 3 F Test Results

Model	Sum of Square	df	Mean Square	F count	Sig.
Regression	7.389	3	2.463	12.091	0
Residual	3.26	16	0.204	0.03	
Total	10.649	19			
F table			3,200		

Source: Primary data processing, 2021

4.3. T TEST

The basis of t test in a multiple linear regression analysis requires t test having sig. value below 0.05 (<0.05) or t count greater than t table (t count > t table). A t table value was obtained based the t value distribution table using the following formulation.

t table = t (α/2; n-k-1) (3)

t table = t (0.05/2; 40-3-1)

As seen in Table 4, we conclude that based on the results of data processing on the variable X3, H0 is accepted where t count < t table (-0.015 < 2.119) and sig. > 0.05 (0.933 > 0.05), indicating that obstacles and barriers in the implementation of

BIM in construction projects (X2) have no negative effect on critical success factors of BIM-based projects (Y), while other variables have a significant effect on critical success factors of BIM-based projects (Y) with positive relationship.

Table 4

Table 4 T Test Results

Variables	t count	Sig. t	Description
(Constant)	-0.722	0.481	
Variable X1	2.389	0.03	H0 is rejected
Variable X2	2.605	0.019	H0 is rejected
Variable X3	-0.015	0.933	H0 is accepted
t table	2,119		

Sources: Primary data processing, 2020

4.4. BETA TEST

A beta test shows the most dominant independent variable in a regression model. The higher the beta value in a variable, the more dominant the independent variable is. The beta values can be seen in the output coefficients in the standardized coefficients (beta) column. Table 5 shows the beta value of each independent variable.

Table 5

Table 5 Beta Values

Variable	**Standardized Coefficients** (Beta)
Variable X1	0.434
Variable X2	0.499
Variable X3	-0.015

Source: Primary data processing, 2021

Based on Table 5 the variable X2 (factors influencing the achievement of maximum potential of BIM in its implementation process for construction projects) is the most dominant variable in this regression model with an effect of 49.9% (0.499).

4.5. COEFFICIENTS OF DETERMINATION (R2)

The results of the SPSS Model Summary output analysis show that the Adjusted R Square value was 0.637 Table 6. It means that the independent variables, namely, the advantages of adopting BIM in the process of implementing BIM for construction project activities (X1), factors influencing the achievement of maximum potential of BIM in its implementation process for construction projects (X2), obstacles or barriers in the process of implementing BIM for construction projects (X3) have a significant effect on critical success factors in BIM-based projects (Y) with 63.7%, while the other 36.3% is influenced by other variables outside this model.

Table 6

Table 6 Coefficients of Determination (R2)

R	R Square	Adjusted R Square	Std.Error of the Estimate
0.833	0.694	0.637	0.451

Source: Primary data processing, 2021

4.6. RELATIVE IMPORTANT INDEX

Calculation of the Relative Important Index (RII) is used to determine the ranking of the effect of variable items on the independent and dependent variables. The following is the RII formula:

$$RII = \frac{5.n5+4.n4+3.n3+2.n2+1.n1}{5N} \quad (4)$$

Description:

n5 = Number of respondents who answered “strongly agree”

n4 = Number of respondents who answered “agree”

n3 = Number of respondents who answered “neutral”

n2 = Number of respondents who answered “disagree”

n1 = Number of respondents who answered “strongly disagree”

N = Total respondents

Table 7, Table 10 show the ranking of the effect of variable items based on the RII method.

Table 7

Table 7 RII Ranking for Variable X1

No	Statements	RII	Ranking
A5	Building Information Modeling offers better, newer service	0.92	1
A3	Overall project quality is better than conventional methods	0.86	2
A1	Building Information Modeling can reduce omissions and construction errors	0.84	3
A2	Building Information Modeling reduces reworks	0.83	4
A7	Building information Modeling facilitates newly recruited staffs to better understand ongoing projects	0.83	4
A4	Building Information Modeling can reduce request for information (RFI)	0.81	6
A11	Building Information Modeling can reduce overall project duration	0.79	7
A12	Building Information Modeling can reduce claims/litigation	0.79	7
A9	Building Information Modeling can boost profits	0.78	9
A10	Building Information Modeling helps maintain business relationship	0.77	10
A8	Building Information Modeling can reduce construction cost	0.74	11

Source: Primary data processing, 2021

Table 8

Table 8 RII Ranking for Variable X2

No	Statements	RII	Ranking
B1	Synergy in the use of Building Information Modeling software	0.89	1
B3	Project complexity	0.86	2
B2	Number of BIM knowledgeable professionals in the project team	0.85	3
B5	Collaborative experience with project partners	0.83	4
B4	Client’s knowledge about Building Information Modeling	0.82	5
B9	Number of companies with knowledge of Building Information Modeling in the project	0.82	5
B10	Project budget	0.82	5
B7	Building Information Modeling technology consultant on the project team	0.8	8

B11	Project size (building construction dimensions)	0.79	9
B12	Project geographic location	0.79	9
B8	Project duration	0.77	11
B13	Staffs from different companies working in the same location	0.7	12

Source: Primary data processing, 2021

Table 9

Table 9 RII Ranking for Variable X3

No	Statements	RII	Ranking
C5	Computer hardware upgrade costs	0.9	1
C2	Shift in work culture	0.89	2
C6	Cost of purchasing Building Information Modeling software	0.89	2
C7	Effective training	0.89	2
C8	Data and information security	0.87	5
C4	Lack of government regulation	0.81	6
C1	Lack of thorough evaluation of the benefits, risks, and challenges of Building Information Modeling for companies	0.79	7

Source: Primary data processing, 2021

Table 10

Table 10 RII Ranking for Variable Y

No	Statements	RII	Ranking
D5	BIM integration	0.9	1
D3	3D detailing in construction stage	0.88	2
D6	Modeling effectiveness and productivity	0.87	2
D1	Top manajemen support	0.86	4
D2	Clash detection	0.85	5
D4	Handover and commissioning	0.83	6
D7	Stakehordelrs and project team's role and responsibilities	0.83	7

Source: Primary data processing, 2021

As seen in the RII table above, the most influential item on the advantages of adopting BIM in the process of implementing BIM for construction project activities (X1) variable was Building Information Modeling offers better, newer service. Then, for the factors influencing the achievement of maximum potential of BIM in its implementation process for construction projects (X2) variable, the most influential item is Synergy in the use of Building Information Modeling software. The most influential item on the obstacles or barriers in the process of implementing BIM for construction projects (X3) variable was computer hardware upgrade costs. For the critical success factors of BIM-based projects variable, the most influential item is BIM integration.

5. CONCLUSIONS AND SUGGESTIONS

5.1. CONCLUSIONS

Based on the results of data analysis through the questionnaire distributed to contractor workers or Building Information Modeling (BIM) consultants in Indonesia, several relationships between variables were found as follows.

There is a relationship between the implementation of BIM for contractors and consultant's variable and the critical success factor in BIM-based projects variable simultaneously. The advantages of adopting BIM in the process of implementing BIM for construction project activities (X1) variable has a partial, significant effect on critical success factors of BIM-based projects with positive relationship. The factors influencing the achievement of maximum potential of BIM in its implementation process for construction projects (X2) variable has a partial, significant effect on critical success factors of BIM-based projects (Y) with positive relationship. The obstacles or barriers in the process of implementing BIM for construction projects (X3) variable has no partial effect on critical success factors of BIM-based projects (Y).

From the results of beta test of the variable X2, it is the most dominant variable in this regression model with a value of 49.9% (0.499).

From the results of Relative Important Index (RII) test, the most influential item on the advantages of adopting BIM in the process of implementing BIM for construction project activities (X1) is Building Information Modeling offers better, newer service. Then, for the factors influencing the achievement of maximum potential of BIM in its implementation process for construction projects (X2) variable, the most influential item is Synergy in the use of Building Information Modeling software. The most influential item on the obstacles or barriers in the process of implementing BIM for construction projects (X3) variable was computer hardware upgrade costs. Lastly, the most influential item on the critical success factor of BIM-based projects (Y) is BIM integration.

5.2. SUGGESTIONS

There are some limitations in the study above. Therefore, the authors would like to provide some suggestions to consider for interested parties.

For construction companies that are starting or planning to switch from conventional construction methods to Building Information Modeling (BIM)-based models, the cost of upgrading computer hardware needs to be considered because it often represents the main obstacle in the process of implementing BIM in construction projects.

One of the critical success factors in BIM-based construction projects is the integration of Building Information Modeling. Thus, it is important for companies to keep using BIM software by leveraging a centralized BIM system that allows them to manage all sorts of information, such as enterprise resource planning, resource analysis packages, technical reports, meeting reports, 3D modeling with data management, data sharing, and data exchange throughout the building life cycle to the fullest.

Future studies are expected to be able to develop a research model to identify other variables affecting critical success factors in BIM-based projects as well as larger number of respondents and companies in order to obtain more representative results as an evaluation of the implementation of BIM in Indonesia.

CONFLICT OF INTERESTS

None.

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None.

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