Assessment Of Bim In High-Rise Building Construction In Indonesia

Riqi Radian Khasani, Arif Hidayat

Abstract: The construction industry in Indonesia is progressing rapidly. Contractors are required to complete construction projects in a short amount of time, with minimal costs and efficient utilisation of human resources. The BIM method is 3D modelling technique containing all the construction information that works during the planning, design, implementation, and maintenance phases. BIM has the concept of 3D approach (modelling) to 7D (facility management applications). Several contractors in Indonesia have initiated the implementation of the BIM method for project construction in the construction phase, including the high-rise building construction category. This study discovers the achievement level of BIM implementation in the construction phase by contractors in Indonesia who have already implemented BIM. Data research was obtained from a questionnaire, using two methods of data analysis, Building Information Modeling Implementation Index (BIMII), and Importance Performance Analysis of Building Information Modeling (IPABIM). There are 25 criteria divided into four categories: people, cost, time, and integration. Calculations of BIMII produce a quite achieved score of 67.46%, with categories as follows: people, quite achieved, 62.47%; cost, achieved, 71.64%; time, achieved, 69.41%; integration, quite achieved, 66.32%. The IPABIM classifies the categories of achievement level of BIM implementation into four categories: quadrant A, areas of improvement, eight criteria; quadrant B, excellent work, 15 criteria; quadrant C, low priority, one criteria; quadrant D, disproportionate, one criteria. These findings give meaningful contributions for understanding the achievement level of BIM implementation in Indonesia.

Index Terms: Building Information Modelling, BIM, Implementation, Construction, High-Rise Building.

1 Introduction

Indonesia's construction industry is one of the fastest growing sectors supporting national economic growth. The government needs IDR 4,796 billion to fund the acceleration of infrastructure development. Based on data released by BPS through 'Statistik Indonesia' (2012-2016), the sum of completed project values in building construction in all Indonesia's provinces during the last five years increases every year and is expected to reach IDR 206 billion in 2016 [1]. More infrastructure development encourages contractors, consultants, and project owners to innovate, creating efficiency and effectiveness of project completion time, construction costs, human resources, and project quality. Achieving this requires a visionary concept and Building Information Modeling (BIM) can integrate all phases in the project life cycle, including planning and design, procurement, construction, operational, and maintenance [2][3]. BIM has become a hot issue in the development of digital construction technology in the last ten years [2]. In some developed countries, the use of BIM in the construction industry has been widely used [4], while in Indonesia the use of BIM by contractors is still limited [5]. A major factor influencing this lack of use is the expensive cost of software licenses and the lack of human resources competency[6]. Further measurement, apart from the measurement of the contractor's readiness to implement BIM, is needed to see the implementation level of BIM in the construction phase of high-rise buildings [5]. This study uses the Building Information Modeling Implementation Assessment. Research on the level of BIM implementation has not been done before because the use of the BIM method for construction is still relatively new for Indonesia.

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2 BIM Implementation in Asia

Jung indicates several countries in ASIA that have already implemented BIM, including South Korea, India, China, Philippines, Taiwan, Singapore, and Thailand. Singapore is the first BIM adoption country in Asia; the government mandated BIM's implementation in 2008 through two Building and Construction Authority (BCA) and Construction and Network Real Estate (CORENET) organisations [7]. The BIM guide for the construction industry in Singapore was released in 2011 and the government plans to have widely implemented BIM throughout Singapore's construction industry by 2015 [8]. In 2010, the Public Procurement Service (PPS) of South Korea published basic BIM application standards regarding using BIM data in the construction and maintenance phases. The PPS planned to mandate BIM on all public projects by 2016 [9]. The Chinese contruction industry has known about BIM since 2002. In 2012, BIM application soared when the Ministry of Housing and Urban Rural Development (MHURD) established a series of national-level BIM standards [10]. In Indonesia, several contractors have already begun using BIM, including both the Architecture, Engineering, Construction (AEC) and the Engineering, Procurement, Construction, Installation (EPCI). Hatmoko [11] measures the readiness level of BIM implementation using the Company Readiness Index (CRI) calculation, based on organisational process, management, people, and technology [12]

Assessing level of achievement toward BIM

BIM is an application that can process, generate, and manage data of a building during its life cycle in digital form. BIM utilises a 3D approach in visualising building construction, has real-time facilities, and dynamic building modelling to improve productivity in building design and construction. BIM production processes include building geometry, space relationships, geographic information, and the quantity and quality of building components [13]. BIM can improve the communication and cooperation between stakeholders [14]. During the design and construction phases, an inability to share the latest information and make real-time modifications results in reduced communication and collaboration between the involved work teams [15]. BIM is a faster, more effective method for improving design quality and, during the construction phase, can reduce reworking, construction costs, time, and human resources [2]. BIM is an effective way to reduce construction waste [16]. According to Bryde [17] cost reduction, time reduction, communication improvement, coordination improvement, quality increase, negative risk reduction, scope clarification, and organisation improvement are the positive effects of using BIM. The theoretical framework of the achievement level through BIM implementation is explained briefly below and summarised in Table 1. Measuring the achievement level of BIM implementation at the construction phase is the next step of the readiness assessment process for BIM implementation [11]. Measurement of this level of achievement uses the BIM function from stage 3d (Modeling), 4d (Scheduling), 5d (Estimating), 6d (Sustainability), and 7d (Facility Management). This study measures the achievement level of BIM implementation in the construction phase, as illustrated in Fig 1. Measurement of this level of achievement is based on 25 criteria and four categories, including people, time, cost, and integration.

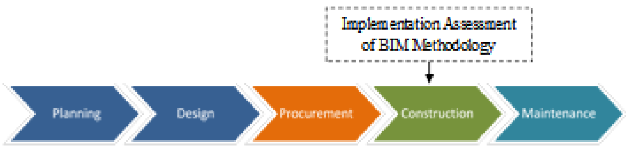

Fig. 1. *Implementation Assesment of BIM in Project life cycle*

3 Research Method

Data was collected through questionnaires distributed to 34 respondents. Respondents were dominated by BIM engineers (76%), BIM managers (6%), staff engineers (15%), and site engineer managers (3%) from eight high-rise building construction projects where BIM was implemented in construction phase, located in different cities i.e Jakarta, Surabaya, Banten, Pontianak, and Tangerang. In term of respondents years of experience, Most respondents' works experience are less then 5 years (53%), followed by 5-10 years (32%), 11-15 years (12%), and more than 15 years (3%)

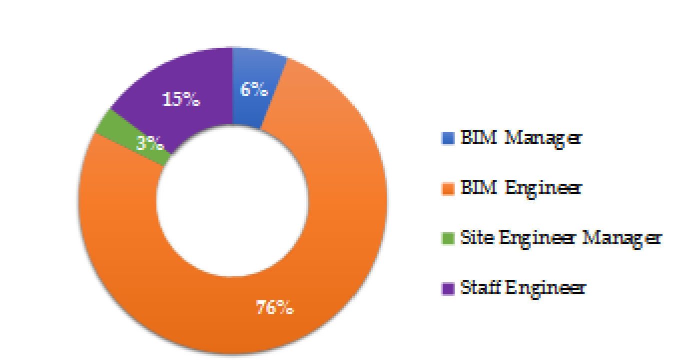

Fig. 2. *Respondents job positions percentages*

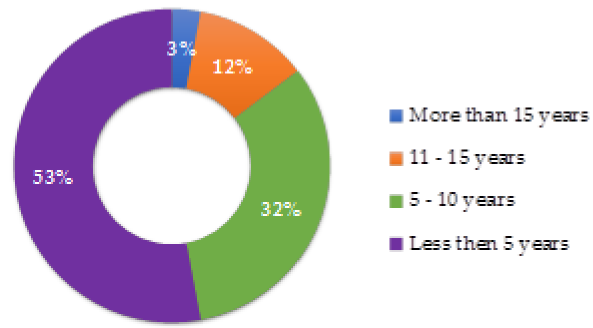

Fig. 3. *Respondents years of experience percentages*

Four categories, with a criteria of 25 questions, were assessed with a Likert scale of 1 to 5, representing the level of achievement and importance in BIM implementation. The data quality test in this research contains reliability and validity tests. Obtained calculations showed that the Cronbach Alpha Value for the achievement level, 0.939 and the importance level, 0.906, is greater than the value of 0.7, so the data on the level of implementation and importance is reliable. In this validation test, there is a significance test with (α = 5%), based on the calculation that each variable shows r value > r table 0.2869; thus, the data at the implementation and importance level is valid The following two methods assessed the achievement level of BIM implementation towards contractor performance, Building Information Modeling Implementation Index (BIMII), and Importance Performance Analysis of Building Information Modeling (IPABIM). BIMII is adopted from a Customer Satisfaction Index, used to measure the level of customer satisfaction. The BIMII measures the level of achievement of BIM implementation in the construction phase. Determining the range of numeric scale can be calculated by the highest value minus the lowest value of BIMII, divided by the number of classes. The numeric scale range for BIMII can be categorised as presented in Table 2.

***TABLE 1.** BIM IMPLEMENTATION FRAMEWORK IN CONSTRUCTION PHASE*

Category		Criteria	Definition	Reference
People	1	Employees	The BIM method reduces the number of employees in the construction phase	[2][5][18]
	2	Organisation	There is a section within the project organisation that is responsible for BIM implementation	[12][15][17][19] [20]
	3	Competency	individuals with appropriate skills and competencies to take a role in BIM implementation	[15][17][19][20][21]
	4	Certification	individuals who responsible for BIM implementation already have BIM's expertise certification	[18][22][23]
	5	Gadgets	individuals who take a role in BIM implementation can use supporting gadgets (such as virtual reality, augmented reality, etc.)	[24][25]
	6	Incentives	Individuals who responsible for BIM implementation get more incentives from the company	[15][21][26]
Cost	7	Cost Estimation	Use of BIM 5D facilities for project cost estimation	[22][23][27][28]
	8	Cost control	Use of BIM for project cost control during the construction phase	[2][23][27] [29]
	9	Construction cost	BIM can save project costs in the construction phase	[2][15][17][23] [27]
	10	Working papers	BIM can reduce the use of working papers in the construction phase	[18][22][30]
	11	Waste	BIM can minimise construction waste	[15][16][20][31]
	12	Repair/ rework	BIM can minimise repair / rework	[2][15] [26][28][32]
	13	Risk management	BIM implementation for risk management	[4][17][20][28]
	14	CCO	BIM can reduce the potential of change contract order	[14][17][20][28]
Time	15	Project Scheduling	Use of BIM 4D facilities for project scheduling	[10][15][17][27]
	16	Accelerate	BIM can accelerate the work completion time	[15][17][26][33]
	17	Time control	Use of BIM for project time control during the construction phase	[2][27][34]
	18	Sequence	BIM can be used to simulate the work sequence	[20][26][32]
	19	Material scheduling	Use of BIM to control material ordering schedules	[2][12][22]
	20	Time Constraint	BIM can minimise project time constraints during construction	[2][17][22][27][29]
Integration	21	Collaboration	BIM can facilitate interdisciplinary collaboration in the construction phase	[14][15][17][21][29]
	22	Visualisation	Use of BIM facility to show the visualisation of the building	[15][20][22]
	23	Sustainability	Use of BIM facility to simulate energy use	[2][10][20]
	24	Operational & Maintenance	Use of BIM facility to operational and maintenance phase	[10][17][22]
	25	Problem solving	BIM helps to solve project problems during the construction phase	[10][17][22]

***TABLE 2.** CLASSIFICATION OF ACHIEVEMENT*

BMII value	Mean Gap Interval	Implementation Level (IL)
20% - 35.9%	1.82 – 2.26	Not achieve (NA)
36% - 51.9%	1.37 – 1.81	Less achieve (LA)
52% - 67.9%	0.92 – 1.36	Quite achieve (QA)
68% - 83.9%	0.46 – 0.91	Achieve (A)
84% - 100%	0.00 – 0.45	Very achieve (VA)

4 RESULT AND DISCUSSION

Table 3 shows the calculation of BIMII. Column B shows the mean importance scores (MIS) for each criterion (Cr). The MIS calculate the weighting factors (WF, Column C). To calculate the WF, total all the MIS, then determine each one as a percentage of the total. To calculate the weighted scores (Column D), multiply each mean implementation score (MMS, Column D) by its similar WF. The overall weighted average (WT) is determined by adding all the weighted scores (WS, Column E). To calculate the BIMII, the weighted total is then divided by five (highest Likert scale score) and multiplied by 100. Based on the calculation of BIMII, the people category obtained a percentage of 62.47% (quite achieved), followed by the cost category with a percentage of 71.64% (achieved), the time category with a percentage of 69.41% (achieved), and the integration category of integration with a percentage of 66.32 % (quite achieved). The assessment of implementation, using the BIM method in the construction phase for all categories, gives an average value of 67.46% (quite achieved), as shown in Fig 4. Based on the gap between the mean values of importance and implementation level, 12 criteria (48%) rate 'very achieve', five criteria (20%) rate 'achieve', six criteria (24%) rate 'quite achieve', one criteria (4%) rates 'less achieve', and one criteria (4%) rates 'not achieve'. The top five rank criteria, with a very achieve status, show visualisation, reduced working papers, collaboration facility, risk management facility, and reduce the change contract order. The less rank, with a not achieved status, is the number of people used.

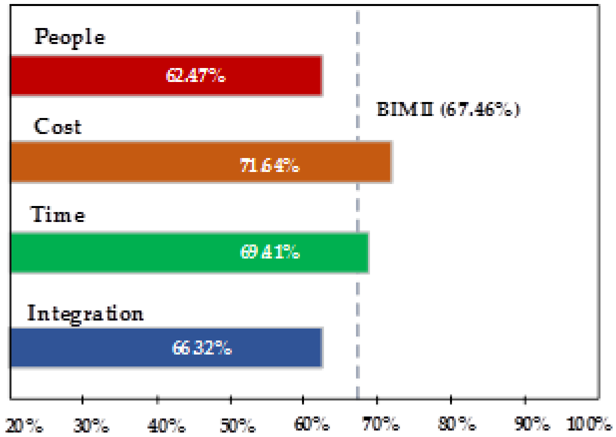

***Fig. 4**. Percentage of BIMII to each Category*

***TABLE 3.** CALCULATION OF BIMII*

Cr	MIS	WF	MMS	WS	Gap Score	IL	Rank
a	b	c	d	e	f=b-d	g	h
1	4.09	4.01	1.82	0.07	2.26	NA	25
2	4.12	4.04	3.74	0.15	0.38	VA	9
3	4.09	4.01	3.71	0.15	0.38	VA	10
4	4.12	4.04	2.97	0.12	1.15	QA	22
5	4.12	4.04	3.53	0.14	0.59	A	14
6	4.09	4.01	2.97	0.12	1.12	QA	21
7	4.12	4.04	3.24	0.13	0.88	A	17
8	4.12	4.04	3.06	0.12	1.06	QA	20
9	4.09	4.01	3.74	0.15	0.35	VA	7
10	3.56	3.49	3.50	0.12	0.06	VA	2
11	4.15	4.07	3.71	0.15	0.44	VA	12
12	4.12	4.04	3.74	0.15	0.38	VA	11
13	4.09	4.01	3.85	0.15	0.24	VA	4
14	4.09	4.01	3.82	0.15	0.26	VA	5
15	4.15	4.07	3.24	0.13	0.91	QA	18
16	4.09	4.01	3.53	0.14	0.56	A	13
17	4.09	4.01	3.35	0.13	0.74	A	16
18	4.09	4.01	3.74	0.15	0.35	VA	8
19	4.09	4.01	3.12	0.13	0.97	QA	19
20	4.12	4.04	3.85	0.16	0.26	VA	6
21	4.15	4.07	3.97	0.16	0.18	VA	3
22	4.15	4.07	4.15	0.17	0.00	VA	1
23	4.09	4.01	2.94	0.12	1.15	QA	23
24	3.82	3.75	1.97	0.07	1.85	LA	24
25	4.09	4.01	3.44	0.14	0.65	A	15
	(MIS)=4.07		(MMS)=3.39		BIMII=∑WS/5=67.46%		

Important-Performance Analysis of BIM Implementation (IPABIM)

IPABIM is adopted from Index Performance Analysis, used to measure the relationship between consumer perceptions and priority improvement of product or service quality, also known as quadrant analysis. IPABIM is used to map the achievement level of BIM implementation. The IPABIM analysis, using the Cartesian diagram as shown in Fig. 3, is divided into four quadrants consisting of quadrant A (areas of improvement), quadrant B (excellent work), quadrant C (low priority), and quadrant D (disproportionate), describing the level of achievement and importance to the BIM implementation in the construction phase. Quadrant 'A' (areas of improvement) indicates prioritised criteria, noted as high importance, but has low achievement within BIM implementation. Quadrant 'B' (excellent work) shows maintained criteria, indicating an area of high importance and achievement levels within BIM implementation. Quadrant 'C' (low priority) shows the criteria of less importance and achievement levels, indicating an area considered low importance and achievement level within BIM implementation. Quadrant 'D' (disproportionate) shows criteria considered low importance, but high performance. The calculations of the IPABIM method indicate the mean of achievement on the X axis is 3.39 and the mean importance on the Y axis is 4.07. The intersection of quadrants of the IPABIM uses both the X and the Y axis. The mean value of achievement is greater than 3.39, indicating a trend of good achievement level of BIM implementation, while the higher mean value of importance of 4.07 indicates the high expectation of the achievement level of BIM implementation

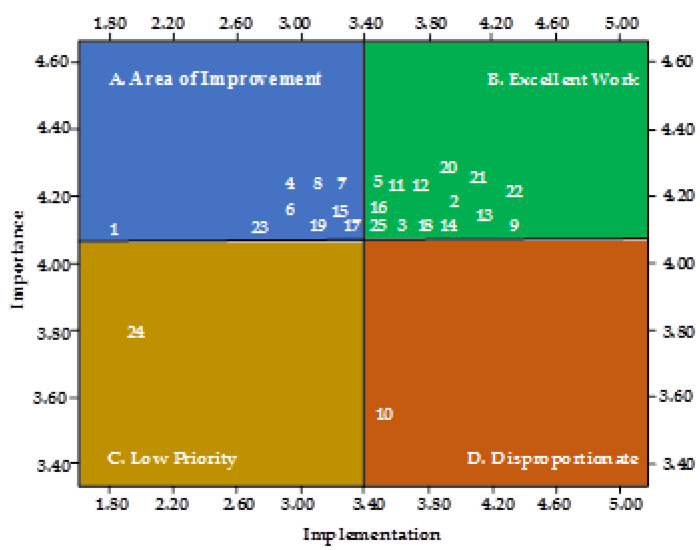

***Fig. 5.** IPABIM Cartesian Diagram*

Quadrant 'A' in the IPABIM Cartesian diagram shows the criteria of achievement level of BIM implementation needing improvement, including the number of employees, expertise certification, incentive gaining, cost estimation, cost control, project scheduling, material scheduling, and sustainability facility. Quadrant 'B' shows the criteria needing to be maintained that already have a good achievement level of BIM implementation, including project organisation, competency, use of gadgets, saving construction costs, minimising waste, minimising repairs/rework, risk management, reducing changes to contract order, accelerated project time, project time control, work sequence simulation, minimising time constraints, collaboration, model visualisation, and problem solving. Quadrant 'C' shows the criteria that are low priority, concentrated using BIM implementation to operate and maintain the facility. Quadrant 'D' shows the criteria with the possibility to reduce the use of working papers. This research completes the findings of Fundra [5], who states that BIM is well known and used by several construction companies in Indonesia. Hatmoko et al. uses the Company Readiness Index (CRI) to measure the level of readiness for BIM implementation, stating that all four contractors in Indonesia used as study objects and consisting of three EPCI (engineering, procurement, construction, installation) and one AEC (architecture, engineering, construction) contractors are ready to implement the BIM method. Chandra et al. [42] examined obstacles and advantages for the application of BIM in Indonesia. The findings of this research are also consistent with the findings of Jung and Lee [43], who state that in terms of skill, Asia is the only continent that does not have more than 70% advanced and expert users who also used the 3D BIM visualisation facility for coordination. This study reinforced the findings of BIM implementation in other developing countries [8][44][45].

5 Conclusion

This research measured contractor implementation of the BIM method in the construction phase in Indonesia, studying contractors who have already implemented BIM. The study used 25 criteria divided into four categories: people, cost, time, and integration. BIMII method measured the achievement level of BIM implementation, and the calculation produced a BIMII of 67.46% (quite achieved). Each category was calculated as follows: people, 62.47% (quite achieved); cost, 71.64% (achieved); time, 69.41% (achieved); and integration, 66.32% (quite achieved) The achievement level of BIM implementation for all 25 criteria are computed based on the gap score results, where 12 criteria (48%) are 'very achieve', five criteria (20%) are 'achieve', six criteria (24%) are 'quite achieve', one criteria (4%) is 'less achieve', and one criteria (4%) is 'not achieve'. The top five ranked criteria, with a 'very achieve' status, are visualisation, reduced working papers, collaboration facility, risk management facility, and reduced changes to the contract order. The lowest rank, having 'not achieve' status, is use of the number of people The IPABIM classifies the categories of achievement level of BIM implementation into four categories: Quadrant A (areas of improvement), Quadrant B (excellent work), Quadrant C (low priority), and Quadrant D (disproportionate). The first quadrant shows the criteria needing prioritisation for concentrate, including number of employees, expertise certification, incentive gaining, cost estimation, cost control, project scheduling, material scheduling, and sustainability facility. The second quadrant shows the criteria needing to be maintained, including project organisation, competency, use of gadgets, saving construction cost, minimise waste, minimise repair/rework, risk management, reduce change contract order, accelerate project time, project time control, work sequence simulate, minimise time constraint, collaboration, model visualisation, and problem solving. The third quadrant shows the criteria at a low priority, to be concentrated using BIM for operational and maintenance facilities. The fourth quadrant shows the criteria with the possibility to reduce the use of working papers. These findings are very necessary to give a meaningful contribution in understanding the achievement level of BIM implementation in Indonesia. Further research can be done by observing BIM implementation in a variety of construction projects.

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