

Building Information Modeling (BIM) Implementation Strategy in Construction Service Companies

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Abstract

This paper determines and analyzes related to the strategy for implementing Building Information Modeling (BIM) on the Hamawas Toll Road, the General Civil Division (DSU) of PT Hutama Karya (Persero). The background to this strategy was determined by the inhibiting factors for BIM implementation, such as the quality of human resources (HR), implementation methods, and implementation costs. The analysis was carried out using the Analytic Hierarchy Process (AHP) way, which describes complex problems in a multi-level structure to the last level of the alternatives. Level 1 consists of inhibiting factors for BIM implementation. In contrast, level 2 is a sub-criteria of level 1 which consists of work culture, HR capabilities, BIM system implementation, CDE platform utilization, BIM system operating procedures, BIM software, and hardware costs.. The results of the study show that the best strategy based on level 1 is HR quality with a Consistency Ratio (CR) value of 0.02, level 2 is HR capability with a CR value of 0.02, and the alternative is to make BIM legality with a CR value of 0.02. The CR value is less than 0.1, so the data is valid and can be used.

Keywords: Building information modelling, analytic hierarchy process, implementation.

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1. Introduction

The digital era, or industrial revolution 4.0, is a new style of business in Indonesia which is a momentum to revitalize the industrial sector and accelerate the achievement of the goal of becoming the 10th largest economy in the world (Hatmoko et al., 2021.). The transformation of a new business style in the construction sector must be implemented by implementing a Building Information Modeling (BIM) system. BIM is a system that represents a project as a 3 (three) dimensional model. According to (Vass & Gustavsson, 2017) the BIM system is a combination of two important ideas: maintaining data information in digital form, making it easier to update and share data on digital information, and conformity to real-time conditions in carrying out projects planning digitally. This is closely related to technological innovation, so it will impact a company's productivity and quality. Based on this idea, the BIM system is divided into several dimensions and functions according to the information added to a project plan in digital form.

The BIM system serves as a reliable source of information in making a decision during the building cycle, which is used to achieve a specific goal (Sacks, Brilakis, Pikas, Xie, & Girolami, 2020). Data management of a building during the building's life cycle can use 3D, real-time software, and dynamic building modeling, which is useful for increasing the productivity of building design and construction (Abdal Noor & Yi, 2018). BIM implementation has brought changes to new work methods, such as digital survey methods and digital collaboration which can increase company productivity. Productivity measurement provided by the BIM system consists of two aspects, namely the use of 3D models for planning and analysis of design discrepancies or clash detection, the use of the BIM system as a volume and cost reference, scheduling, project management, safety, and project life cycle sustainability (Tauriainen, Marttinen, Dave, & Koskela, 2016).

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The implementation of BIM is in line with the direction of the Minister of Public Works and Public Housing (PUPR) regarding a breakthrough to accelerate sustainable infrastructure development in Indonesia, namely by applying the results of research and technology such as the BIM system which is integrated with lean construction in companies. One of the companies in Indonesia that has implemented the BIM system and was selected as a pilot by the PUPR Ministry is PT Hutama Karya (Persero) General Civil Division (DSU), which is a state-owned enterprise. DSU is one of the divisions or sub-sections of PT Hutama Karya (Persero) under the Operations Directorate I, where DSU handles infrastructure projects such as roads, tolls, dams, docks, airports, bridges, and other types of projects related to infrastructure. DSU began implementing the BIM system in 2019. However, the implementation of the BIM system at DSU is still not optimal; this can be seen from the HK Group's BIM Key Performance Indicator (KPI) implementation assessment score, which is lower than the other divisions based on the 2022 assessment.

This is caused by several inhibiting factors, both internal and external. Factors that cause the implementation of the BIM system to be less than optimal, according to (Amin & Suroso, 2023), are limited Human Resources (HR) in companies that use BIM, changes in work culture from conventional to digitalization, lack of knowledge and understanding of the BIM system and its application to the Common Data communication platform Environment (CDE). Apart from that, (Rizqy, Martina, & Purwanto, 2021) also states that a lot of supporting software is used in implementing BIM. This software has relatively high hardware and license prices, so there is a limit to the value of projects that must use the BIM system. Another thing that affects the implementation of BIM is the lack of support from management in providing, training, and supervision regarding the BIM system and the absence of manuals, procedures, or references in implementing the BIM system according to ISO 19650 (Siebelink, Voordijk, Endedijk, & Adriaanse, 2021).

Based on these factors, it is necessary to conduct research related to the BIM implementation strategy at PT Hutama Karya General Civil Division using the Analytical Hierarchy Process (AHP) method. This method is a decision support model that will describe complex problems in a multi-level structure to the last level of the alternative. The results of these alternatives will then be applied to the company so that productivity in the form of profit for the company will increase.

2. Literature Review

Building Information Modeling (BIM), according to researchers (Borrmann, König, Koch, & Beetz, 2018), is a comprehensive digital technology set that enables the various parties involved to design in an integrated manner, build and operate collaboratively. The BIM system can be used as a development design and construction through modeling technology through collaboration between stakeholders using the Common Data Environment (CDE) communication platform to facilitate scheduling, design, implementation, and facility management (Bui, Merschbrock, & Munkvold, 2016). In addition, the BIM system is also used as a technology that supports company competitiveness to produce efficiency and effectiveness on projects, including modeling, visualization of implementation methods, quantity calculation methods, constructability analysis supported by Digital Survey and Engineering Analysis as well as BIM implementation plans contained in the BIM Execution Plan (BEP).

Meanwhile, according to PT Hutama Karya (Persero) BIM is a project implementation method that is carried out digitally and is integrated, which becomes an integral part of the field construction implementation process. In Non-Joint Joint Operation (KSO) construction service projects, the BIM system is used in two phases of the project life cycle, namely:

2.1. Tender Phase

BIM in the tender phase is used to interpret or visualize between the design and the existing field by carrying out clash detection and calculating major item volume and cost estimates. The application of BIM in the tender phase is expected to assist the engineering team in fulfilling data which is used as one of the requirements in submitting tenders. Documents required for submission include 3D models that include highways and structures so that project methods and visualizations are obtained, pre BIM Execution Plan (BEP), which contains provisions on how BIM is applied to projects, delivery risk assessment related to mitigation of risks that will occur in the project and capacity and capability statements related to resource readiness in implementing BIM in projects. The application of BIM in the tender phase can be seen in Figure 1.

No	Activity Description	Person In Charge				Raw Quality	
		Appointing Party (Owner)	Marketing Dept.	Technic and Design Dept.	Project	Completeness	Output
1	Start						
2	Tender data collection						-Exchange Information Requirement Appointing Party
3	Fulfillment of Tender Data					-Form Collecting Information Requirement; -Capability and Capacity Plan; -Modelling 3D BIM (optional); -Form Rencana Resources BIM; -Form Project Reference and Shared Resources; -Deliverables Item Plan; -Master Information Delivery Plan;	-Pre BIM Execution Plan
4	Data verification						-Pre BIM Execution Plan
5	Submission of Tender Documents					-Post BIM Execution Plan; -Form Document Information; -Protocol BIM (optional); -Completeness of Tender Documents	
6	Announcement of Auction Results						-Contract Documents -Letter of Work Commencement
7	Finish						

Figure 1. Flowchart of the application of BIM in the tender phase

Source: Internal Data of PT Hutama Karya (Persero), 2022

2.2. Construction phase

Lettering and symbols should be clearly defined either in the caption or in a legend provided as part of the figure. Whenever possible, figures should be placed at the top or bottom of a page, as close as possible to the first reference to them in the paper. In the construction phase, BIM is used to produce working drawings, volume and cost references, assist in calculating the volume of work, and collaborate between stakeholders using a common data environment. An explanation of the construction phase can be seen in Figure 2.

The application of BIM in the construction phase positively impacts the company's progress, especially in improving business and engineering processes. One of the positive impacts resulting from implementing the BIM system is speeding up the monthly billing process or Monthly Certificate (MC). The time required for MC billing without using the BIM system or conventionally is approximately 25 days, whereas using the BIM system, it takes approximately 20 days. MC billing speed also affects the company's performance. For MC transfer cycles using conventional methods and the BIM system can be seen in Figure 3 and Figure 4.

3. Research Method and Materials

This study focuses on the implementation of the Analytical Hierarchy Process (AHP) analysis method in the context of Building Information Modeling (BIM) implementation. The AHP method is a decision support model developed by Thomas L. Saaty, which decomposes complex problems into a hierarchical structure. The advantages of the AHP

method include its ability to cover criteria and sub-criteria in depth, consideration of the validity of the decision-making process, and the inclusion of sensitivity analysis. However, there are also disadvantages, such as limitations in terms of respondents' perspectives and the need for expert assessments.

No	Activity Description	Person In Charge				Raw Quality	
		Appointing Party (Owner)	Marketing Dept.	Technic and Design Dept.	Project	Completeness	Output
1	Project Start						
2	Mobilization					-Form Test Methods and Procedures; -Form Test Simulation Deliverables Item; -Form Test Deliverables Item to Appointing Party; -Form Test CDE	
3	Quality Assurance					--Form Quality Assurance	
4	Construction Phase					-BIM Execution Plan -EIR Lead Appointed Party; -Master Information Delivery Plan; -Form Level of Information -3D, 4D, dan 5D LoIN 500 Model BIM; -Draft Berita Acara Serah Terima Dokumen BIM dikeluarkan oleh Appointing Party; -Form Level of Information Need	-3D, 4D, and 5D Model BIM LoIN 350, and LoIN 400
5	Request for Information (RFI) or Issue					-Form Spacial Coordination	
6	Project Closed Out					-Form Lesson Learn; -Form Level of Information Need	-3D, 4D, dan 5D Model BIM LoIN 350, LoIN 400, dan LoIN 500 BIM; -Draft Minutes of Handover of BIM Documents issued by Appointing Party; Form Level of Information Need
7	Finish						-Minutes of Handover of BIM Data issued by Appointing Party

Figure 2. Flowchart of the application of BIM in the construction phase
Source: Internal Data of PT Hutama Karya (Persero), 2022

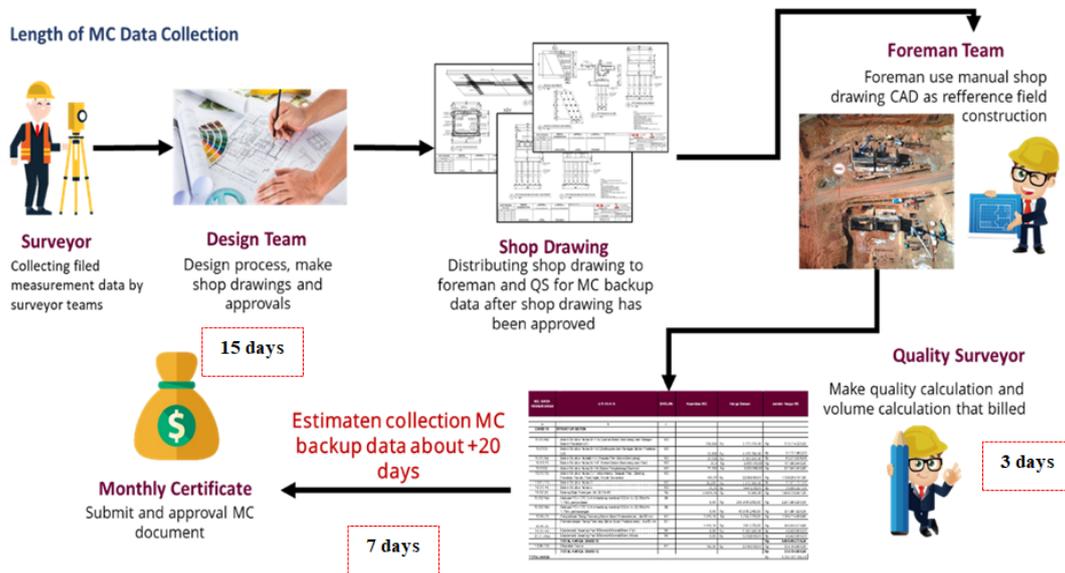


Figure 3. Business Process before the use of BIM system
Source: Internal Data of PT Hutama Karya (Persero), 2022

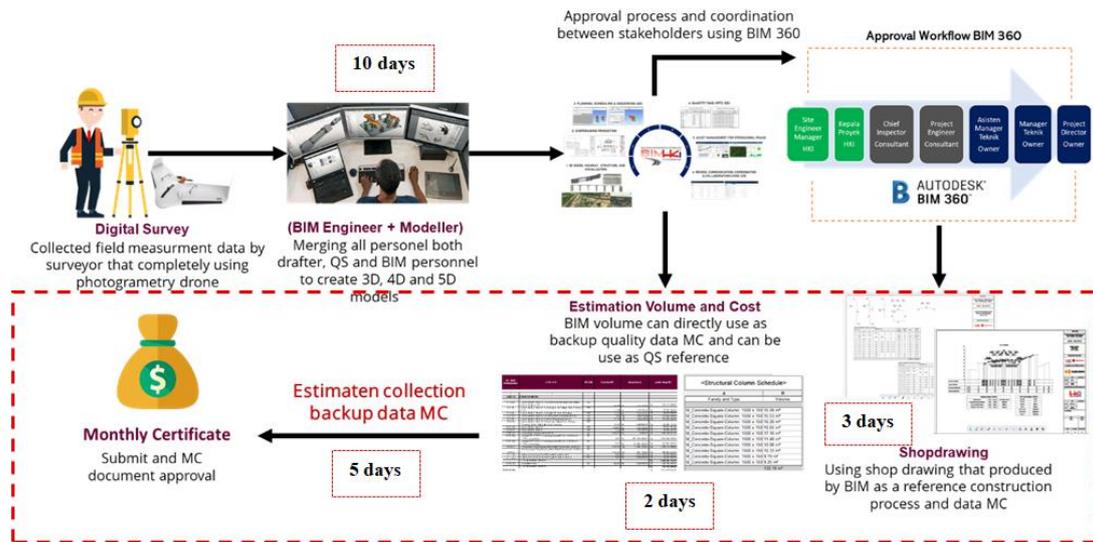


Figure 4. Business Process after the use of BIM system
 Source: Internal Data of PT Hutama Karya (Persero), 2022

The research methodology employed in this study is a quantitative approach, specifically a case study. The study investigates the stages of BIM implementation activities aimed at improving company productivity. The research was conducted at the Hamawas Toll Road Project, General Civil Division of PT. Hutama Karya (Persero) from February 2023 to March 2023. Sections and length of treatment for research locations can be seen in Table 1.

Table 1. Section and Length of Project

No.	Project	Segment	Length (km)
1	Tebing Tinggi Intersection Project	Junction-Tebing Tinggi	7.07
2	Kuala Tanjung–Tebing Tinggi–Prapat Toll Road Projects	Tebing Tinggi–Indrapura Section 1	20.40
		Kuala Tanjung–Indrapura Section 2	18.05
		Jalan Tol Tebing Tinggi–Serbelawan Section 3	30.00
		Jalan Tol Siantar–Serbelawan Section 4	28.00

Source: Research data, 2023

The project selection was carried out based on the HK Group's 2022 KPI assessment results, where the KPI for the Kuala Tanjung - Tebing Tinggi - Prapat Toll Road project is lower when compared to other projects. The research subjects used in each project consist of the project manager (PM), Site Engineer Manager (SEM), and BIM Modeller. Respondents used in this study amounted to 20 (twenty) people consisting of 5 (five) PM, 5 (five) SEM, and 10 (ten) BIM Modellers. The relevance of respondents or research subjects to their positions in this study can be seen in Table 2.

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Data collection techniques included interviews and Focus Group Discussion (FGD). Primary data was obtained through interviews with the research subjects, consisting of project managers, site engineer managers, and BIM modellers. Secondary data was sourced from published journals and previous research.

Table 2. Section and Length of Project

Num	Type	Description	Total
1	Gender	Male	19
		Female	1
		Total	20
2	Position	Project Director	5
		Site Engineer Manager	5
		Officer	10
		Total	20
3	Experinces	0-5 years	10
		5-10 years	5
		>10 years	5
		Total	20
4	Project	<i>Junction</i> - Tebing Tinggi	6
		Kuala Tanjung – Tebing Tinggi – Parapat Toll Road Projects Section 1	3
		Kuala Tanjung – Tebing Tinggi – Parapat Toll Road Projects Section 2	3
		Kuala Tanjung – Tebing Tinggi – Parapat Toll Road Projects Section 3	5
		Kuala Tanjung – Tebing Tinggi – Parapat Toll Road Projects Section 4	3
		Total	20

Table 3. Respondents Data

Num	Type	Description	Total
1	Gender	Male	19
		Female	1
		Total	20
2	Position	Project Director	5
		Site Engineer Manager	5
		Officer	10
		Total	20
3	Experinces	0-5 years	10
		5-10 years	5
		>10 years	5
		Total	20
4	Project	<i>Junction</i> - Tebing Tinggi	6
		Kuala Tanjung – Tebing Tinggi – Parapat Toll Road Projects Section 1	3
		Kuala Tanjung – Tebing Tinggi – Parapat Toll Road Projects Section 2	3
		Kuala Tanjung – Tebing Tinggi – Parapat Toll Road Projects Section 3	5
		Kuala Tanjung – Tebing Tinggi – Parapat Toll Road Projects Section 4	3
		Total	20

Source: Research data, 2023

The AHP analysis method was applied to process the collected data. The AHP method involves decomposition of the problem into a hierarchical structure, comparative judgments, calculation of the geometric mean, synthesis of

priorities using Eigen Vector values, and ensuring logical consistency. The consistency index (CI) and consistency ratio (CR) were calculated to evaluate the logical consistency of the judgments.

4. Results and Discussion

For Based on secondary and primary data validation, the inhibiting factors for BIM implementation are obtained, which consist of level 1 in the form of human resource quality, implementation methods, and implementation costs, level 2 in the form of work culture in companies that are still conventional (manual) and not yet digitized, human resource capabilities human resources in the use of the bim system, lack of top management support in the implementation of the BIM system, the implementation of the bim system is not in accordance with ISO 19650 standards, the utilization of the CDE platform has not been carried out optimally, there are no procedures and manuals for operating the BIM system in the company, BIM software costs, hardware costs BIM, and training costs as well as alternatives in the form of compilation programs related to the BIM system to meet HR needs, validate 2D, 3D BIM output as working drawings and 5D as back up quantity, issue company regulations regarding the application of BIM to be used as a reference for field work implementation, and provide rewards for each project that implements BIM and punishment for projects that do not implement BIM. AHP hierarchical diagram in this study can be seen in Figure 5.

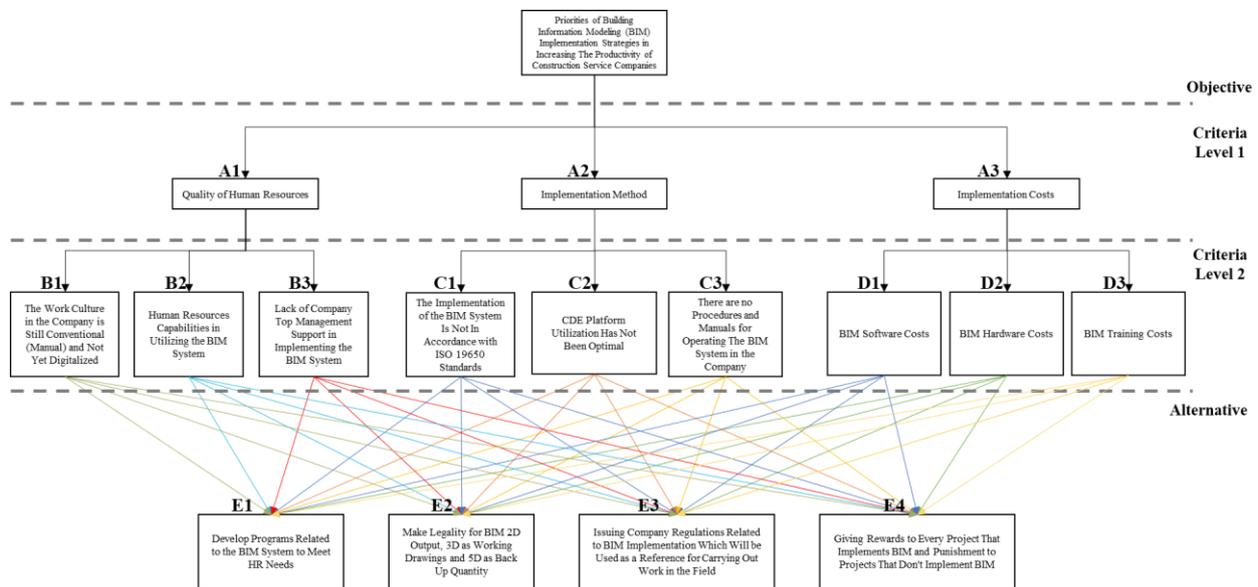


Figure 5. Selection of AHP hierarchy BIM implementation strategy in increasing company productivity

After determining the AHP diagram based on Figure 4.1, calculate the average geometry of each level and the alternatives for filling out the pairwise comparison questionnaires carried out by each research subject and expert. The average geometry level 1 value for factor A12 is 1.51, A13 is 1.647, and A23 is 1.726. The average value of Level 2 geometry (HR Quality) for factor B12 is 0.333, B13 is 0.481, and B23 is 2.291. The geometric mean of Level 2 (Execution Method) for factor C12 is 1.774, C13 is 0.807, and C23 is 0.638. The geometric mean of Level 2 (Implementation Cost) for factor D12 is 3.3253, D13 is 3.7385, and D23 is 2.1946. The geometric mean of the Alternative values for the factor E12 is 0.75, E13 is 0.95, E14 is 1.93, E23 is 1.4, E24 is 2.12 and E34 is 2.84. Level 1, Level 2 (HR Quality), Level 2 (Implementation Method), Level 2 (Implementation Cost) and Alternative Geometry Matrix can be seen in Tables 4, 5, 6, 7 and 8.

Table 4. The geometric mean of the level 1 criteria

Level 1	A1	A2	A3
A1		1.51	1.647
A2			1.726
A3			

Source: Research data, 2023

Table 5. Geometric Average HR Quality Criteria Level 2

Level 1	B1	B2	B3
B1		0.333	0.481
B2			2.291
B3			

Source: Research data, 2023

Table 6. Geometric Average of Level 2 Implementation Method Criteria

Level 1	C1	C2	C3
C1		1.774	0.807
C2			0.638
C3			

Source: Research data, 2023

Table 7. The geometric mean of the criteria for Level 2 Implementation Costs

Level 1	D1	D2	D3
D1		3.3253	3.7385
D2			2.1946
D3			

Source: Research data, 2023

Table 8. Alternative geometric mean

Level 1	E1	E2	E3	E4
E1		0.75	0.95	1.93
E2			1.4	2.12
E3				2.84
E4				

Source: Research data, 2023

After calculating the Geometric Mean, the data is entered into the Expert Choice v.11 software application to obtain the dominant factor based on criteria and alternatives. The dominant factor is obtained based on the order of ranking of the eigenfactor values and CR for each criterion and alternative. Dominant factors based on eigen values and CR for each level and alternatives can be seen in Table 9.

Based on the results of calculating the geometric mean at level 1, it is found that the Quality of Human Resources is the most dominant factor compared to the Method of Implementation and Cost of Implementation. The criterion for Human Resource Capability in Utilizing the BIM System has the highest eigen factor value compared to the other criteria. This factor is in line with the research of (Kusumartono et al., 2018), where efforts to increase human resources or capacity building of the BIM system must be carried out through training and workshops following the mapping plan and adoption of the BIM system in organizations or companies. Based on this literature, the ability of human resources to utilize the BIM system greatly influences the optimization of the application of the system. For example, the BIM system cannot be utilized properly by HR in an organization or company. In this case, the BIM system cannot be felt by the company, which will affect the achievement of company productivity.

Based on the results of calculating the geometric mean at level 2 HR quality, it is known that the ability of HR to utilize the BIM system is the most dominant factor compared to other factors, with an eigenfactor value of 0.557. The inconsistency value of software analysis results is $0.02 < 0.1$ so that the data is valid and can be used. It can be seen that the criterion of Human Resources Capability in Utilizing the BIM System has the highest eigen factor value compared to the other criteria. This factor is in line with the research of (Thangaraj, Suguna, & Sudha, 2022) which states that the optimization of human resources resulting from the implementation of the BIM system compared to conventional is 26.66% due to the streamlined efficiency of BIM personnel. To be able to optimize the implementation of the BIM system, in implementing the BIM system experts or specialists are needed because of the use of the software in the BIM system (Pantiga & Soekiman, 2021) so that the HR capability factor is the main one. supporting factors for the criteria of HR Quality, where if the HR's ability to use the BIM system increases, the application of the BIM system in the company will be more optimal.

Table 9. Dominant factor priority ranking based on Eigen Factor and CR value of each criterion and alternatives

Level 1			Level 2			Alternatives		
Criteria	Eigen Factor	CR	Criteria	Eigen Factor	CR	Criteria	Eigen Factor	CR
1. Quality of Human Resources	0,436	0,02	1. Human Resources Capabilities in Utilizing the BIM System	0,557	0,02	1. Make Legality of BIM 2D Output, 3D as Working Drawings and 5D as Back Up Quantity	0,333	0,05
			2. Lack of Company Top Management Support in Implementing the BIM System	0,284		2. Issuing Company Regulations Related to BIM Implementation which will be used as a reference for carrying out work in the field	0,279	
			3. The Work Culture in the Company is Still Conventional (Manual) and Not Yet Digitalized	0,159		3. Develop programs related to the BIM system to meet HR needs	0,256	
2. Implementation Method	0,337	0,02	1. There are no BIM System Operation Procedures and Manuals in the Company	0,404	0,01	4. Provide Rewards to Every Project that Implements BIM and Punishment to Projects that do not Implement BIM	0,132	0,05
			2. Penerapan Sistem BIM Tidak Sesuai Standar ISO 19650	0,365				
			3. Application of the BIM System Does Not Meet ISO 19650	0,23				
3. Implementation cost	0,227	0,02	BIM Software Costs	0,629	0,05			
			2. BIM Hardware Cost	0,236				
			3. BIM Training Fee	0,135				

Source: Research data, 2023

Based on the results of calculating the geometric average at level 2 of the Implementation Method, it is known that the absence of procedures and manuals for operating the BIM system in companies is the most dominant factor compared to other factors, with an eigenfactor value of 0.404. The inconsistency value of software analysis results is $0.01 < 0.1$ so that the data is valid and can be used. It can be seen that the criteria for Absence of BIM System Operation Procedures and Manual in Companies has the highest eigen factor value compared to other criteria. This factor is in line with (Siebelink et al., 2021), that one of the obstacles to BIM implementation is related to changes and institutionalization of procedures and aspects related to contracts, standards and laws, which creates ambiguity in the implementation of the BIM system. Based on this, the implementation of the BIM system must be based on clear procedures and regulations so that the system can be applied as a new practice in the company's business processes. Based on this, the procedure criteria and manual for the operation of the BIM system are the main factors influencing the implementation method. In order for a method to work properly, procedures and manuals are needed as a reference in its implementation.

The results of calculating the geometric average at Implementation Cost level 2 show that Software Cost is the most dominant factor compared to other factors, with an eigen value factor of 0.629. The inconsistency value of software analysis results is $0.05 < 0.1$ so that the data is valid and can be used. The Software Cost criterion has the highest eigenfactor value compared to other criteria. This factor is in line with the research of (Hutama & Sekarsari, 2018) which states that the use of BIM software relatively requires special hardware specifications that can perform 3D rendering. The hardware needed to use the BIM system is quite expensive because it requires large RAM, graphics cards, and high hardware specifications to work optimally. After the software and hardware are fulfilled, it is necessary to train BIM personnel to operate the software and hardware. Based on this, the Software Cost criterion is the main factor that influences Implementation Costs, where software costs require the highest cost among other criteria.

The results of the alternative analysis in Table 10 show that making legality for the output of BIM 2D, 3D as working drawings, and 5D as the quantity of reserves is the most dominant factor compared to other factors, with an eigenfactor value of 0.333. The inconsistency value of software analysis results is $0.02 < 0.1$ so that the data is valid and can be used.

5. Conclusion

The successful implementation of Building Information Modeling (BIM) in the General Civil Division of PT Hutama Karya (Persero) Hamawas Toll Road Project level 1 heavily relies on the Quality of Human Resources. This factor plays a dominant role in shaping the effectiveness and efficiency of BIM utilization. To ensure a smooth and comprehensive integration of BIM, several strategic priorities have been recommended. Firstly, it is crucial to establish the legality of utilizing BIM output in new projects right from the start. Proposals for BIM output should be presented during the tender stage, allowing them to be incorporated into contracts and clearly defining their functions. Secondly, issuing company regulations dedicated to BIM implementation is essential. This step involves improving BIM manuals, procedures, and overall regulations to provide detailed guidance on utilizing the BIM system. Simultaneously, the development of programs tailored to meet the specific needs of BIM human resources is vital. This encompasses comprehensive BIM software training, coaching sessions, knowledge-sharing initiatives, and even internal competitions aimed at enhancing BIM competencies. Lastly, implementing a system of rewards and punishments is recommended to drive BIM adoption. Projects that successfully implement BIM should be rewarded, while those falling short of implementation targets should face penalties such as warning letters and operational budget restrictions. By focusing on these strategic priorities, the General Civil Division (DSU) of PT Hutama Karya (Persero) can maximize the benefits of BIM implementation so that productivity in the form of profit at these companies will increase.

This research is so that it can be applied to all Construction Service Companies, further research is needed regarding the success rate of Building Information Modeling (BIM) implementation and the need for government policies to instruct all Construction Service Companies involved in government projects to implement BIM both in the tender and construction phases.

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