

Roadmap to Implement BIM and Project Control Integration at Pertamina Refinery Project in Indonesia¹

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Abstract

Building Information Modeling (BIM) is a cutting-edge and cost-effective solution for transforming the Architecture, Engineering, and Construction (AEC) industry. The BIM methodology enables the creation of a digital three-dimensional (3D) model that can be incremented and updated as all disciplines and stages of a building project are developed. The idea of integrating Building Information Modelling (BIM) with Project Controls, which uses the fourth dimension (time) and fifth dimension (cost) of BIM, will be proposed to management as an alternative way to optimize the process of generating Project Schedules and Cost Estimation from BIM software-generated design. By using the MADM method with the non-compensatory and compensatory models, the attributes scoring result from each alternative shows that integrating the combination of BIM 4D and 5D into the company's business process has the highest score compared to partial integration (4D or 5D) and conventional way (not using BIM). This integration will improve the accuracy of the schedule and cost estimate, simplifying the working flow, lowering the risk of miscalculation, and increasing the return on investment for the company.

Keywords: Owner Company, Main Contractor, Subcontractor, Building Information Management, Project Management, Schedule, Progress, Work Breakdown Structure, Cost Breakdown Structure, Refinery Project.

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Introduction

Background of BIM

Building Information modeling (BIM) is an innovative and effective solution for transforming the Architecture, Engineering, and Construction (AEC) sector^{2 3}. Owners from the public sectors in many countries (e.g., the U.K. and Singapore) now increasingly mandate BIM use in their projects⁴, while private owners also exploit BIM use for excess returns. These pressures lead to widespread BIM use and impose new requirements for contractors. "BIM gradually becomes the indispensable qualification criterion for contractor selection, and contractors have no choice but to implement BIM⁵." Even for those small subcontractors, BIM implementation is the determining factor for their survival in the competitive market⁶. Therefore, contractors should select the optimal way to implement BIM efficiently and effectively.

The Building Information Modelling (BIM) methodology allows the creation of a digital three-dimensional (3D) model, incremented and updated throughout the development of all the disciplines and stages related to a building project⁷. The BIM model is generated using the available support tools, and all information is centralized. The model is organized by hierarchical

² Chen, G., Chen, J., Yuan, J., Tang, Y., Xiahou, X., & Li, Q. (2022). Exploring the Impact of Collaboration on BIM Use Effectiveness: A Perspective through Multiple Collaborative Behaviors. *Journal of Management in Engineering*, 38(6), 04022065.

³ Jin, R., Zou, Y., Gidado, K., Ashton, P. and Painting, N. (2019), "Scientometric analysis of BIM-based research in construction engineering and management", *Engineering, Construction and Architectural Management*, Vol. 26 No. 8, pp. 1750-1776

⁴ Jiang, R., Wu, C., Lei, X., Shemery, A., Hampson, K.D., Wu, P., 2021. Government Efforts and Roadmaps for Building Information Modeling Implementation: Lessons from Singapore, the UK and the US." *Engineering, Construction and Architectural Management*. <https://doi.org/10.1108/ECAM-08-2019-0438>

⁵ Mahamadu, A.-M., Mahdjoubi, L., Booth, C.A., 2017. Critical BIM qualification criteria for construction pre-qualification and selection. *Architect. Eng. Des. Manag.* 13 (5), 326–343.

⁶ Saka, A.B. and Chan, D.W.M. (2021), "Adoption and implementation of building information modelling (BIM) in small and medium-sized enterprises (SMEs): a review and conceptualization", *Engineering, Construction and Architectural Management*, Vol. 28 No. 7, pp. 1829-1862. <https://doi.org/10.1108/ECAM-06-2019-0332>

⁷ Sacks R., Eastman C.M., Teicholz P., Lee G. (2018). *BIM Handbook: A Guide to Building Information Modeling for Owners, Designers, Engineers, Contractors, and Facility Managers*, 3rd ed., ISBN: 978-1-119-28755, 2018, 688 pgs Copyright © 2018 by John Wiley & Sons, Inc.

levels, suitable for directed data retrieval by specialty, element, or material⁸. After the elaboration of all components of the building design, the BIM tools most used easily access the model database, allowing its application on the execution of the diverse type of tasks commonly worked out over the project documentation, such as graphic representation, quantification of materials, budgeting⁹, facility management, or construction planning¹⁰. The BIM methodology, based on the centralization of information and the available advanced technological tools, allows the stakeholder involved in the project to collaborate using the same work platform, leading to the reduction of errors and conflicts, which results in cost savings¹¹.

Figure 1 shows the Dimensions of BIM, while the relations between BIM Dimensions with the Asset and Project Phase Gates are shown in Figure 2.

⁸ Ignatov I., Nørkjær-Gade, P. (2019). Data Formatting and Visualization of BIM and Sensor Data in Building Management Systems. 19th International Conference on Construction Applications of Virtual Reality, 13-15 November 2019, Bangkok, Thailand. <https://www.researchgate.net/publication/337274994>.

⁹ Antunes B.M. (2018). Measurement of Work Quantities in Traditional and BIM Environments, Master Thesis in Construction, University of Lisbon, Lisbon, Portugal.

¹⁰ Wang Q., Guo Z., Mintah K., Li Q., Mei T., Peng L. (2018). Cell-based Transport Path Obstruction Detection Approach for 4D BIM Construction Planning, American Society of Civil Engineers, doi: 10.1061/(ASCE)CO.1943-7862.0001583.

¹¹ Han K.K., Golparvar-Fard M. (2015). Appearance-based Material Classification for Monitoring of Operation-level Construction Progress Using 4D BIM and Site Photo-logs, *Automation in Construction*, vol. 53, pp. 44–57, <https://doi.org/10.1016/j.autcon.2015.02.007>

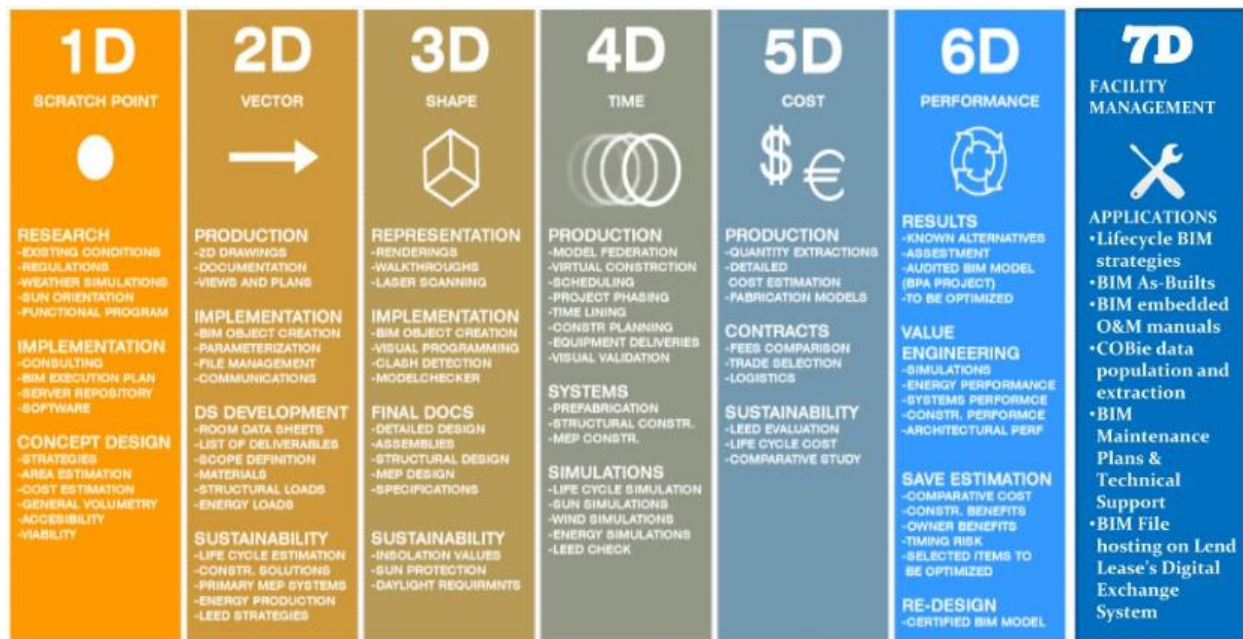


Figure 1. Building Information Management (BIM) Dimensions¹²

¹² SiliconecnzLtd. (2017, August 1). Building information modeling. SlideServe. Retrieved May 14, 2022, from: <https://www.slideserve.com/siliconecnzLtd/building-information-modeling>

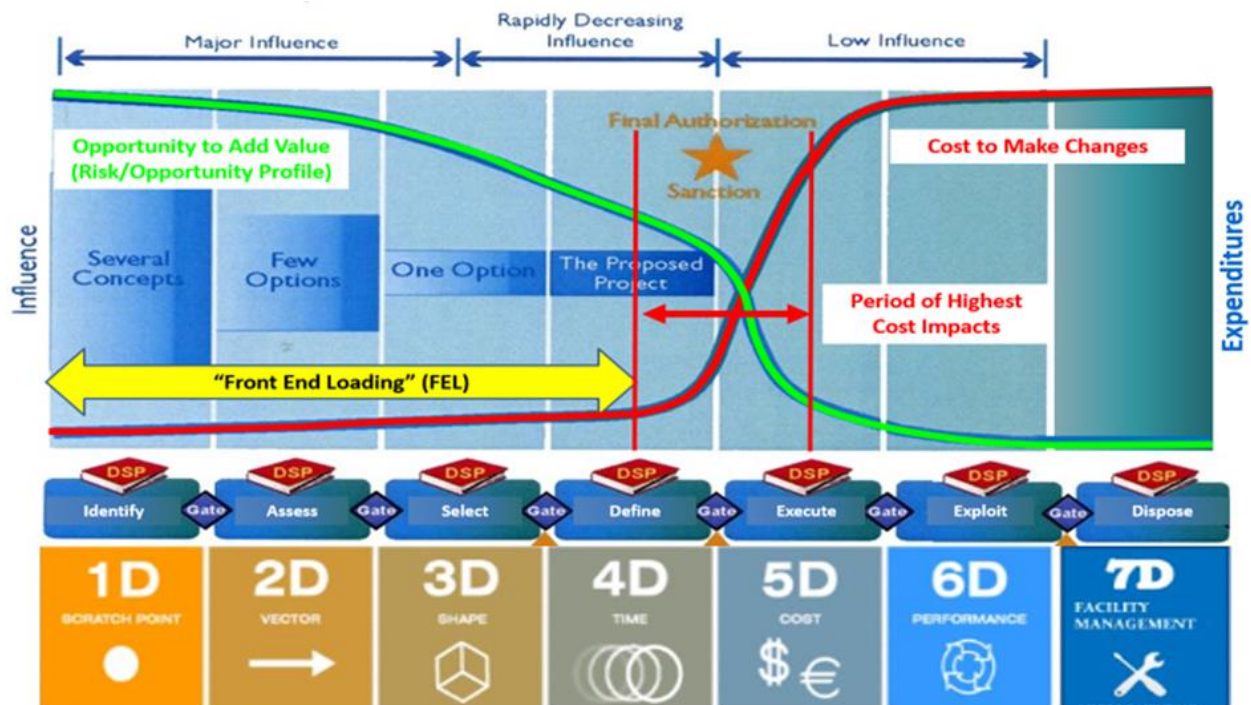


Figure 2. Relationship between BIM Dimensions with The Asset and Project Phase Gates¹³

There are a total of ten (10) dimensions in BIM implementation: 1D (scratch), 2D (vector), 3D (shape), 4D (schedule), 5D (cost), 6D (sustainability), 7D (facility management), 8D (health & safety), 9D (lean construction), and 10D (industrialization process of construction)¹⁴. The research in this paper will be focused on BIM 4D (schedule) and BIM 5D (cost). "The fourth dimension of BIM (4D BIM) brings project management to a whole new level allowing the design team to analyze and monitor construction timing and execution to coordinate the various construction resources and tasks"¹⁵. "5D BIM modeling establishes intelligent links between the 3D digital model (which defines the geometry of the building) and construction cost information.

¹³ Giammalvo, P. D. (2022). Course Materials Contributed Under Creative Commons License BY v 4.0. Retrieved May 14, 2022, from <https://www.slideserve.com/siliconecnzlt/d/building-information-modeling> and <https://planningplanet.com/guild/gpcar/introduction-to-managing-change>

¹⁴ The Dimensions of BIM – 3D, 4D, 5D, 6D, 7D, 8D, 9D, 10D BIM Explained. (2018, April). BibLus. <https://biblus.accasoftware.com/en/bim-dimensions/>

¹⁵ 4D BIM, the Time Dimension of BIM. (2018, September). BibLus. <https://biblus.accasoftware.com/en/4d-bim-the-time-dimension-of-bim/>

The end result is a 5-dimensional (5D) information model with all of the attributes required to estimate the overall project cost."¹⁶.

Even though the advantages of BIM will bring positive impacts to the design of refinery plants, Pertamina still not fully implement the BIM concept into their projects yet. The implementation of BIM requires both a high level of architectural element understanding¹⁷ and regulations to make sure all stakeholders understand the standards of deliverables from a project using BIM. For example, the implementation of BIM in Vietnam was challenged by the availability of BIM objects. The BIM operators in Vietnam need to make them from scratch, and this will lead to more time required to finish the process itself, and the operators need to do interdisciplinary coordination to solve the problems regarding building/equipment positioning¹⁸. In Malaysia, the availability of regulations from the Government to implement BIM as a project's deliverable in Oil & Gas infrastructure contracts has become a challenge there. The Government of Malaysia needs to make regulations, implementation management, and process change strategy to implement BIM in their projects¹⁹.

Problem Statement

There have been many EPC projects in Pertamina refineries in Indonesia in the last four (4) years. The sample of EPC projects can be seen in Table 1 below:

¹⁶ 5D BIM: The 5 Advantages of the Fifth Dimension of BIM. (2019, June). BibLus. <https://biblus.accasoftware.com/en/perspectives-on-5d-bim-the-fifth-dimension-of-bim-linked-to-construction-estimate/>

¹⁷ Park, H. J. (2008). Evolution + BIM: The utilization of building information modelling at an early design stage. CAADRIA 2008 - The Association for Computer-Aided Architectural Design Research in Asia: Beyond Computer-Aided Design.

¹⁸ Nguyen, Q. T., Luu, P. Q., & Ngo, Y. V. (2020). Application of BIM in design conflict detection: A case study of Vietnam. IOP Conference Series: Materials Science and Engineering. <https://doi.org/10.1088/1757-899X/869/2/022038>

¹⁹ Haron, A. T., Marshall-Ponting, A., Mohd Nawi, M. N., & Ismail, M. H. (2014). Building information modelling: A case study approach to identify readiness criteria for process requirement. American-Eurasian Journal of Sustainable Agriculture.

Table 1. Pertamina Refineries Project List in Indonesia²⁰

No	Project Name	Execution Year	Location
1	TPPI Polypropylene Plant	2022	East Java, Indonesia
2	TPPI Polyethylene Plant	2022	East Java, Indonesia
3	TPPI Olefin Plant	2022	East Java, Indonesia
4	Kedung Keris Plant	2019	East Java, Indonesia
5	Suban Compression Plant	2019	South Sumatera, Indonesia
6	Crude Distillation Unit Plant	2018 - 2023	East Kalimantan, Indonesia
7	Vacuum Distillation Unit Plant	2018 - 2023	East Kalimantan, Indonesia
8	LPG Recovery Unit Plant	2018 - 2023	East Kalimantan, Indonesia
9	Residue Fluid Catalytic Cracker Unit Plant	2018 - 2023	East Kalimantan, Indonesia
10	Diesel Hydrotreating Unit Plant	2018 - 2023	East Kalimantan, Indonesia
11	Hydrogen Manufacturing Unit Plant	2018 - 2023	East Kalimantan, Indonesia
12	Naphta Hydrotreating Unit Plant	2018 - 2023	East Kalimantan, Indonesia
13	RFCC Sour Water Stripping Unit Plant	2018 - 2023	East Kalimantan, Indonesia
14	Sulphur Recovery Unit Plant	2018 - 2023	East Kalimantan, Indonesia
15	Cooling Water System Plant	2018 - 2023	East Kalimantan, Indonesia
16	Waste Water Treatment Plant	2018 - 2023	East Kalimantan, Indonesia
17	Air System Plant	2018 - 2023	East Kalimantan, Indonesia
18	Onshore Facilities Plant	2018 - 2023	East Kalimantan, Indonesia
19	Saturated Gas Concentration Unit Plant	2018 - 2023	East Kalimantan, Indonesia
20	Wet Gas Sulphuric Acid Plant	2018 - 2023	East Kalimantan, Indonesia

Table 1 shows that many projects are carried out at Pertamina's refineries every year, and all those projects involve a tight schedule and fixed budget. As a state-owned company, Pertamina should implement OTOBOSOROR (on time, on budget, on specifications, on regulations, and achieving required return) when executing all projects, especially at refineries²¹ since Pertamina's refineries are the primary producer of all kinds of gasoline used in Indonesia. Failing to plan and execute projects at those refineries within schedule and budget could disrupt the gasoline supply chain in Indonesia. It will lead to an investigation by Government/Law.

The objective of this study is to research and find the answer to the following questions:

1. Why is BIM integration with project control not yet implemented at Pertamina?
2. What are the challenges for BIM 4D and 5D integration in the Pertamina refineries project, and could alternative ways be proposed to solve them?

²⁰ Wijoseno. Tangguh. (2022). Modifying the Lang Factor using Process Plant Project Data Cost in PERTAMINA for more Precision, Valid, & Reliable AACE Class 4 Estimation Purpose in Indonesia. AACE Competency Assessments Certification Technical Paper

²¹ Rapat Kerja Direktorat Megaproyek Pengolahan & Petrokimia : Do Smart Beyond Uncertainty. (2019, March). Berita Energia Pertamina. <https://www.pertamina.com/id/news-room/energia-news/rapat-kerja-direktorat-megaproyek-pengolahan-petrokimia-do-smart-beyond-uncertainty>

3. What are the benefits for Pertamina as project owner, which uses BIM integration with project control?

Methodology

"An engineering economy study is accomplished using a structured procedure and mathematical modeling techniques. The financial results are then used in a decision situation that normally includes other engineering knowledge and input"²². The 7 (seven) steps procedure, as shown in Figure 3, can assist decision-making in the engineering management process.

<i>Step</i>		<i>Activity</i>
1.	Problem recognition, definition, and evaluation.	1. Problem/need definition.
2.	Development of the feasible alternatives.	2. Problem/need formulation and evaluation.
3.	Development of the outcomes and cash flows for each alternative.	3. Synthesis of possible solutions (alternatives).
4.	Selection of a criterion (or criteria).	4. Analysis, optimization, and evaluation.
5.	Analysis and comparison of the alternatives.	
6.	Selection of the preferred alternative.	
7.	Performance monitoring and postevaluation of results.	5. Specification of preferred alternative.
		6. Communication.

Figure 3. The 7 Steps Procedure of Engineering Economics Analysis²³

"The scientific process steps had a structure like an hourglass. The structure starts with general questions, then narrows to focus on one aspect, and then designs a study in which we can observe and analyze this aspect. In the end, the hourglass widens, and researchers can conclude and generalize the findings to the real world"²⁴. The scientific process step is similar to an hourglass shown in Figure 4.

²² Sullivan, W. G., Wicks, E. M., & Koelling, C. P. (2014). *Engineering Economy* (16th ed.). Chapter 1 – Introduction to Engineering Economy, pp. 31. Pearson.

²³ Sullivan, W. G., Wicks, E. M., & Koelling, C. P. (2014). *Engineering Economy* (16th ed.). Chapter 1 – Introduction to Engineering Economy, pp. 31. Pearson.

²⁴ What is research? Definition and steps of the scientific method. (2022). Retrieved from <https://explorable.com/what-is-research>

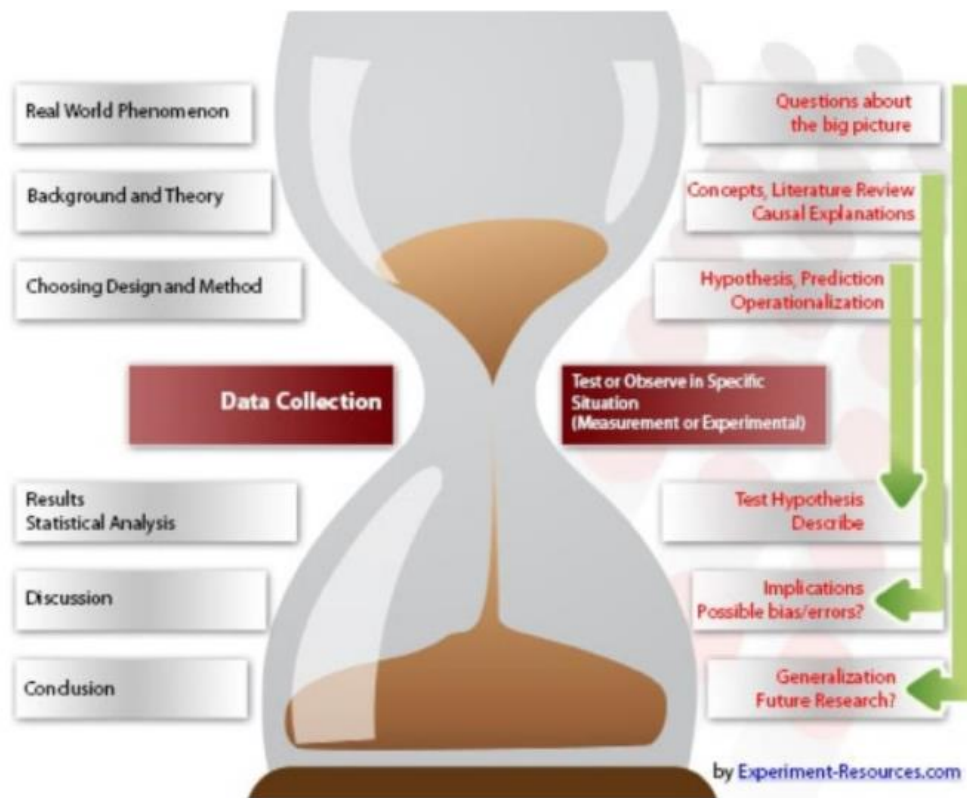


Figure 4. Steps of the Scientific Process²⁵

Each methodology of scientific work must have 4 points that need to be explained in detail:

1. The **Problem Recognition** stage aims for a clear description of real problems. This is followed by the Narrowing Down of the Research Paper Question stage to focus on the core problems.
2. **Feasible Alternative Development** is an evaluation process based on other research. This is so that the results can be reviewed by replicating the experiment and assessing its validity. This aims to prepare alternative plans.
3. **Development of the Outcomes and Cash Flows for each alternative** provides an entirely accurate description of the equipment and techniques used to collect data.
4. The **Selection of a Criterion (or Criteria)** explains how the raw data is compiled and analyzed.

²⁵ What is research? Definition and steps of the scientific method. (2022). Retrieved from <https://explorable.com/what-is-research>

Step 1. Problem Definition

Pertamina, a state-owned National Oil Company, runs six (6) refineries that supply all kinds of gasoline in Indonesia. The technology used in each refinery must be updated periodically following the regulation from the Government of Indonesia (i.e., reducing maximum Sulphur content in Diesel products from 2019 to 2025)²⁶. The capacity of refineries also needs to be increased to fulfill national demand and export overseas.

Table 2. Supply vs. Demand of Fuel Products in Indonesia²⁷

Year	Supply			Demand			Balance (Supply - Demand) (Kilo Liter)
	by Refineries (Kilo Liter)	Import (Kilo Liter)	Total (Kilo Liter)	Domestic (Kilo Liter)	Export (Kilo Liter)	Total (Kilo Liter)	
2011	38,210,000	31,147,000	69,357,000	69,493,296	462,494	69,955,790	(598,790)
2012	37,990,000	31,980,000	69,970,000	72,303,205	342,141	72,645,346	(2,675,346)
2013	37,760,000	32,693,000	70,453,000	72,057,077	962,986	73,020,063	(2,567,063)
2014	39,030,000	33,242,000	72,272,000	70,778,283	625,774	71,404,057	867,943
2015	39,560,000	28,293,000	67,853,000	67,548,378	317,498	67,865,876	(12,876)
2016	42,410,000	23,500,000	65,910,000	68,148,919	348,500	68,497,419	(2,587,419)
2017	42,540,000	27,496,000	70,036,000	70,977,143	478,234	71,455,377	(1,419,377)
2018	44,610,000	28,225,000	72,835,000	74,079,096	322,903	74,401,999	(1,566,999)
2019	44,550,000	24,724,000	69,274,000	74,444,861	126,395	74,571,256	(5,297,256)
2020	39,980,000	20,873,000	60,853,000	65,724,990	568,539	66,293,529	(5,440,529)
2021	40,550,000	22,087,000	62,637,000	70,237,358	167,255	70,404,613	(7,767,613)

For the above reasons, there will be Projects running in each refinery every year, from small maintenance projects to large EPC green-field projects. Due to the high number of projects, while the human resources of the Owner are limited, the need to optimize the method of creation of the Project Schedule and Project Cost Estimation arises inside the organization. The idea of integrating Building Information Modelling (BIM) with Project Controls, which utilizes the fourth dimension (time) and fifth dimension (cost) of BIM, will be proposed to the management as an alternative way to optimize the process to generate Project Schedule and Cost Estimation from design which produced by BIM software (i.e., AutoCAD, Revit, NavisWorks, etc.).

Based on the above reason, the objective of this paper is to research and find the answer to the following questions:

²⁶ Decree of Director General of Oil and Gas (Keputusan Direktur Jenderal Minyak dan Gas Bumi) No. 978.K/10/DJM.S/2013 about Standards and Quality (Specifications) of Diesel Fuel Oil 48

²⁷ Handbook of Energy & Economic Statistics of Indonesia 2021. (2021). Ministry of Energy & Mineral Resources Republic of Indonesia.

1. Why is BIM integration with project control not yet implemented at Pertamina?
2. What are the challenges for BIM 4D and 5D integration in the Pertamina refineries project, and could alternative ways be proposed to solve them?
3. What are the benefits for Pertamina as project owner, which uses BIM integration with project control?

Step 2. Development of the Feasible Alternatives

Conventional Way of Creating Project Schedule & Project Cost

The steps for creating a project schedule and cost, which are the best reference recommended for client and contractor, are taken from GAO and will be shown in Figure 5 and Figure 6. The steps start from understanding the requirement of the user until review and approval from Top Management. In this conventional way, the feed for creating project schedules and costs (drawings, MTO, etc.) are produced separately by different disciplines. This condition will lead to inaccurate Schedules and Costs, and will need more time to coordinate with all disciplines to revise these deliverables.

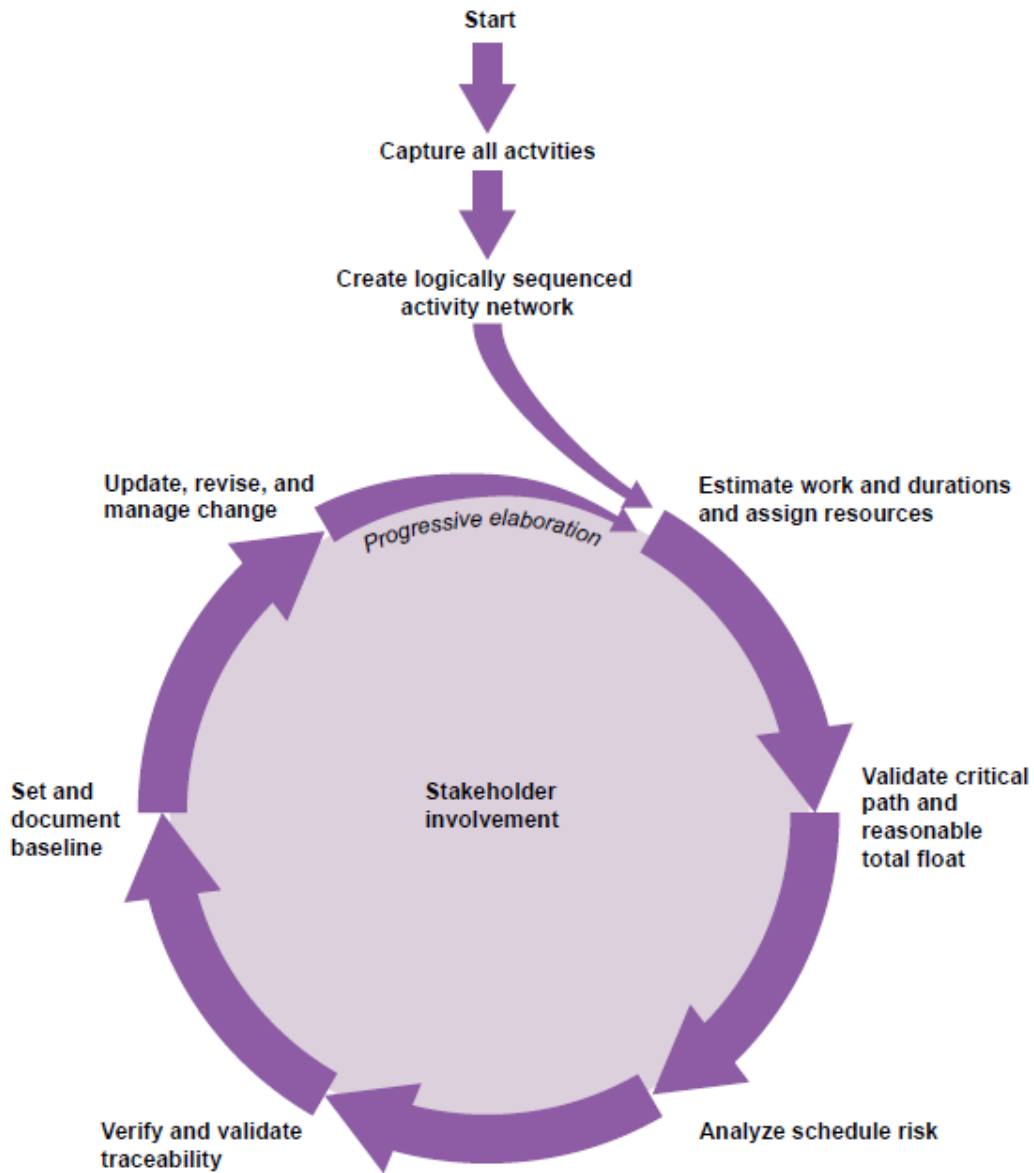


Figure 5. Steps for Creating & Controlling Project Schedule by GAO²⁸

²⁸ United States Government Accountability Office. (2009, March). GAO Cost Estimating and Assessment guide

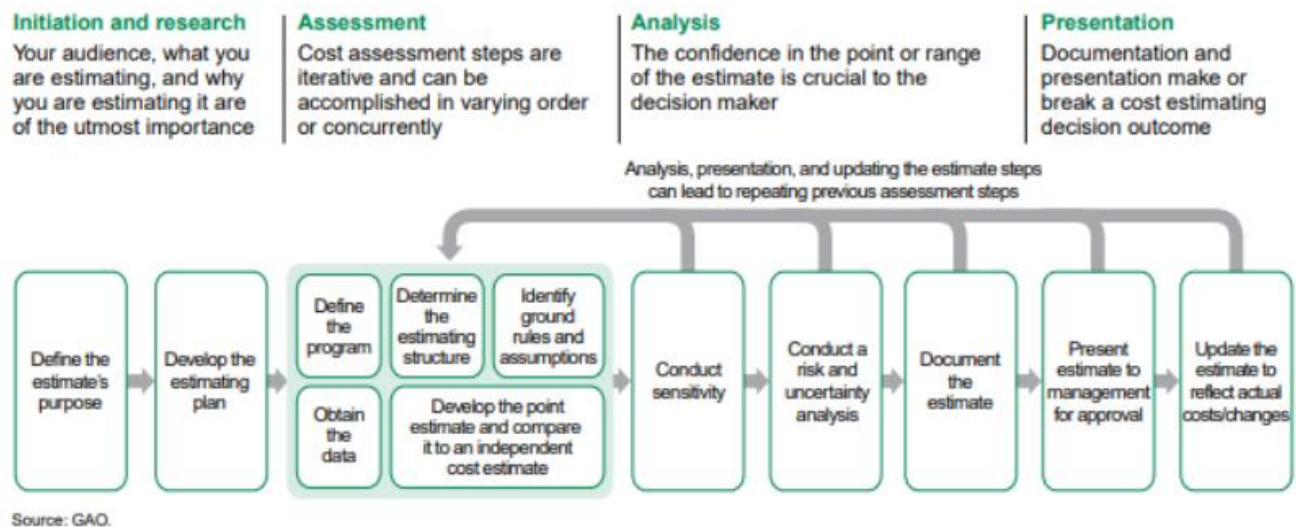


Figure 6. Steps for Creating Project Cost Estimation by GAO²⁹

4D BIM Scheduling

In 4-D BIM, scheduling data is added to different components, creating additional detail as the project progresses. Based on this information, accurate information and visualization for the project's development and flow are developed.

Adding time-related information to a component could include information on the time required to install or construct a component, the lead time, the order in which components were installed (one after another sequence), the time it took for the component to become functional (operational, hardening, curing, etc.) and different dependencies on other projects.

Key points where four-dimensional BIM will enhance the client³⁰:

1. Visualization of 4D Graphical Set
2. Construction Schedules without Clashes
3. Greater coordination among different disciplines
4. Efficient Resource Utilization

²⁹ United States Government Accountability Office. (2009, March). GAO Cost Estimating and Assessment guide

³⁰ Nair, K. (2020, June 30). 4 Ways in Which 4D and 5D BIM Services Will Help Your Clients. www.astechno.com. Retrieved from: <https://web.archive.org/web/20220522204808/https://www.asctechno.com/post/4-ways-in-which-4d-and-5d-bim-services-will-help-your-clients>

5D BIM Cost Estimating

Using 5-dimensional BIM, the cost information is extracted by identifying the most efficient schedule for the project. Such cost information would include costs related to renewal or replacement, capital costs like costs of purchasing and installing components, running costs associated with capital costs, etc.

Data and related information are analyzed to provide cost findings linked to each component represented in a graphical model. With such cost information, the cost managers can easily extrapolate or match the quantities of a given component on a project. Then apply the rates to those quantities to determine the overall cost of the development.

5D BIM is a step ahead of 4D BIM modeling services that integrate design with estimates like cost and includes the generation of Bill of Material (BOM) and Bill of Quantity (BOQ), development of rates, and overall costing of the project.

Key Highlights while using 5D BIM³¹:

1. Higher accuracy and speedy MTO
2. Improved cost estimation and forecast
3. Selection of available options
4. Design modifications have automated quantity take-offs

Step 3. Development of the Outcomes for each Alternative

The expected outcome of the project life cycle after 4D and 5D BIM integration with Project Control can be seen in Figure 7. The project deliverables (including Schedule and Cost) are expected to have a more effective and efficient flow from defining Project Scope/Objectives until As-Built Building Model.

³¹ Nair, K. (2020, June 30). 4 Ways in Which 4D and 5D BIM Services Will Help Your Clients. www.astechno.com. Retrieved from: <https://web.archive.org/web/20220522204808/https://www.asctechno.com/post/4-ways-in-which-4d-and-5d-bim-services-will-help-your-clients>

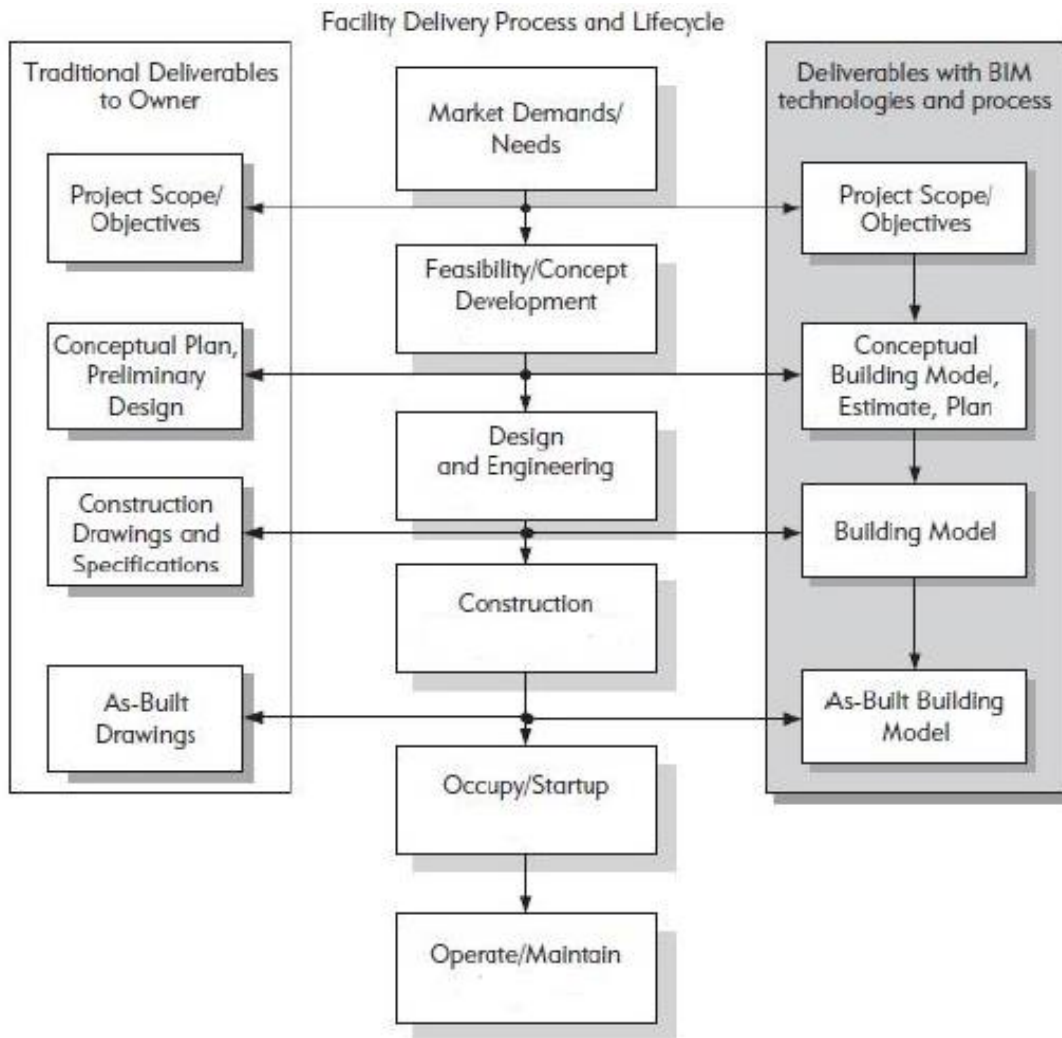


Figure 7. Comparison of BIM vs. Traditional in Project Life Cycle³²

The proposed model of integration of 4D and 5D BIM with Project Control activities (creating schedule and cost estimation) is shown in Figure 8.

³² Sacks Eastman, Charles M., Lee, Ghang, Teicholz, Paul M., R. (2018). BIM Handbook A Guide to Building Information Modeling for Owners, Designers, Engineers, Contractors, and Facility Managers. In Wiley.

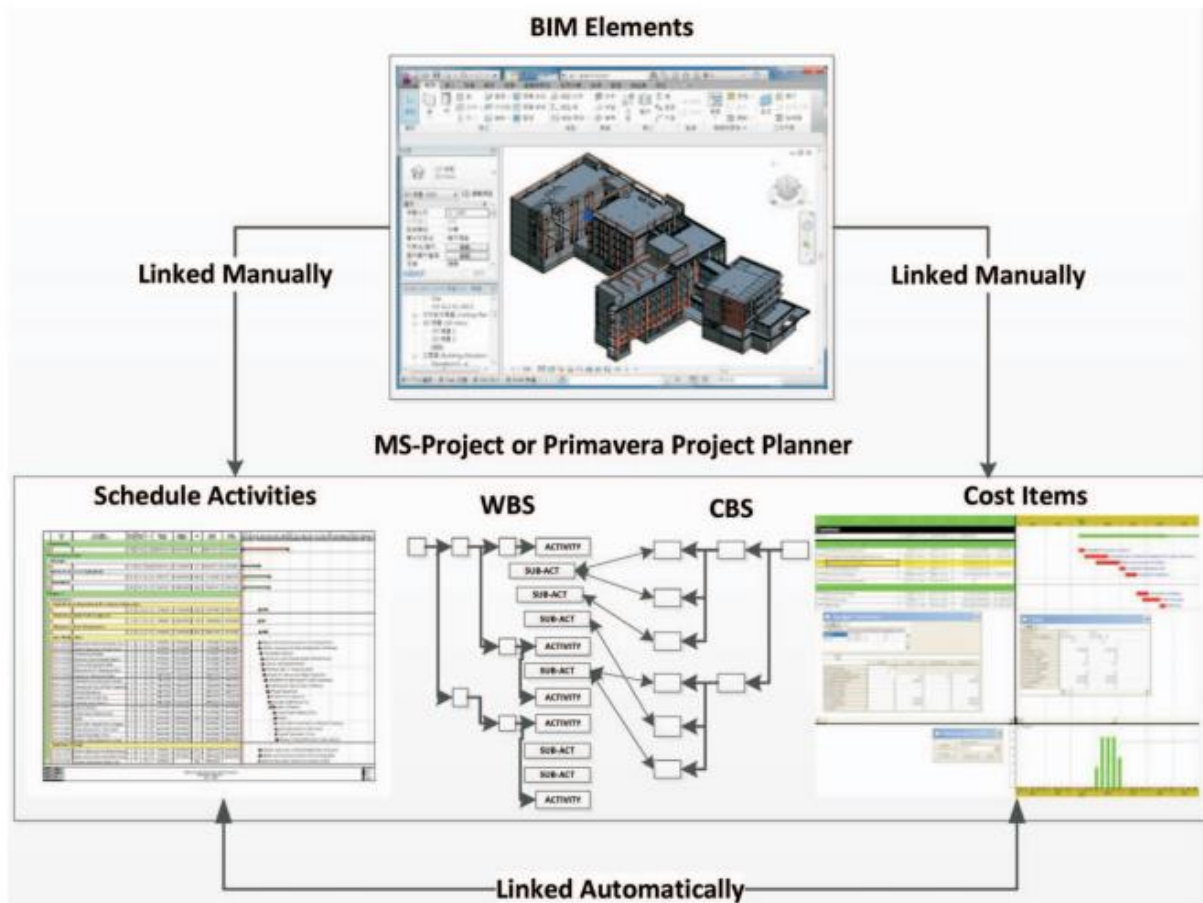


Figure 8. Proposed Integration Model Between 4D and 5D BIM with Project Schedule and Cost³³

When Integration Model in Figure 8 is implemented, potential benefits for Owners are³⁴:

1. Increase building performance through BIM-based energy and lighting design and analysis to improve overall building performance
2. Reduce the financial risk associated with the project using the BIM model to obtain earlier and more reliable cost estimates and improve the collaboration of the project team
3. Shorten project schedules from approval to completion by using building models to coordinate and prefabricate design with reduced field labor time

³³ Fan, S., Wu, C., & Hun, C. (2015). Integration of Cost and Schedule Using BIM. *Journal of Applied Science and Engineering*, 18(No. 3), 223–232. <https://doi.org/10.6180/jase.2015.18.3.02>

³⁴ Sacks Eastman, Charles M., Lee, Ghang, Teicholz, Paul M., R. (2018). *BIM Handbook A Guide to Building Information Modeling for Owners, Designers, Engineers, Contractors, and Facility Managers*. In Wiley.

4. Obtain reliable and accurate cost estimates through automatic quantity take-off from the building model, providing feedback earlier in a project when decisions will have the most significant impact.
5. Assure program compliance through ongoing analysis of the building model against the Owner and local code requirements
6. Optimize facility management and maintenance by exporting relevant as-built building and equipment information to start the systems that will be used over the lifecycle of the facility

Step 4. Selection of a Criterion (or Criteria)

The Author will do the study case using Multi-Attribute Decision-Making methods to find the most beneficial way for the Owner to create a Project Schedule and Cost Estimation. "MADM or AHP methods are most useful when combining qualitative and quantitative attributes rather than purely financial or quantitative attributes alone to consider more common. There are seven approaches to this method, four non-compensatory models that treat all the attributes as equally weighted and the two compensatory models that enable us to weigh the different variables."³⁵

The alternatives to be evaluated are as follows:

1. Conventional way (no integration with 4D nor 5D BIM)³⁶
2. Integrating only 4D BIM with the schedule estimation process
3. Integrating only 5D BIM with the cost estimation process
4. Using full integration (combination of 4D and 5D BIM integrated with Schedule and Cost)

The attributes which will be used are as follows:

1. Easiness of use from the Owner's point of view

The system which will be implemented must be easy to use since the Owner should have tools that a limited amount of people can operate. Owner manpower is not as many as contractor manpower

³⁵ PTMC, & Giammalvo, P. D. (2021). 1.4.1.3 unit 3 – Managing the Business Case. Retrieved from <https://build-project-management-competency.com/1-4-1-3-unit-3/>

³⁶ By Author

2. Cost for investment

In the event of using 4D BIM only, 5D BIM only, or a combination of 4D and 5D BIM, there is some new software that needs to be purchased since currently not available in the company's software list, including training and certification for mastering the software operation will be needed.

3. Reducing time for producing Project Schedule & Project Cost Estimate

For this point, the Author will use secondary data from other publications that researched the correlation between time reduction for producing Schedule and Cost using 4D and 5D BIM.

4. Manpower cost impact

For this point, the Author will also compare the impact of manpower cost if Pertamina decided to implement a transformation of their system by integrating 4D and 5D BIM. The company needs to hire BIM experts to strengthen the team in addition to their original employees, who will have training and certification.

5. Accuracy of Project Schedule Estimation

The Author will compare the accuracy of the project schedule estimation between conventional, 4D BIM integration only, 5D BIM integration only, and complete integration methods. The accuracy of project schedule estimation will increase when integrating with 4D BIM only, while the accuracy for project cost estimation will not improve from the conventional way.

6. Accuracy of Project Cost Estimation

Similar to attribute number 5, cost estimation accuracy will increase when integrating with 5D BIM only, while the accuracy of project schedule estimation will not be affected. The best way to get a maximum score for accuracy is by implementing a combination of 4D and 5D BIM.

7. Project Team Experience

The smoothness of the working flow related to project team experiences in using BIM will impact the decision on whether to implement BIM integration or not.

8. Business Process Working Flow

The business process working flow refers to how the implementation of BIM integration could affect the current workflow at Pertamina. If BIM simplifies the workflow, it will be beneficial for the company.

9. Appropriate Hardware and Software

This attribute refers to the availability of tools required to execute BIM integration, such as workstation (pc) and related software (NavisWork, Revit, Primavera, etc.). Easier access to those tools will increase the odds of BIM integration

10. Return on Investment

This attribute refers to how the BIM implementation could affect the return on investment to the company. It is the main factor that would have a significant impact on the decision to use BIM³⁷

11. Integrated Data Source Availability

This attribute refers to how complete the database of BIM is for interpreting 3D drawings into the sequence of work (schedule) and transforming the drawing to material take-offs that are required for cost estimation. This attribute also shows the importance of data integration in one system rather than using the conventional way, which is not using BIM.

12. Risk and Uncertainty

This attribute used to score how the BIM integration could lower the risk of miscalculation caused by the data used is not synchronizing between disciplines. If BIM could lower such risk, it would gain more points to integrate BIM at the company.

There are two steps for compensatory models for evaluating multi-attribute decision problems: non-dimensional scaling and the additive weighting technique. "A popular way to standardize attribute values is to convert them to non-dimensional form³⁸." Also, "Additive weighting is

³⁷ Ugwu, O. & Kumaraswamy, M., 2007. Critical success factors for construction ICT projects- some empirical evidence and lessons for emerging economies. *ITCON*, 12, pp. 231-249.

³⁸ Sullivan, W. G., Wicks, E. M., & Koelling, C. P. (2014). *Engineering Economy* (16th ed.). Chapter 14 – Decision Making Considering Multiattributes, pp. 608. Pearson.

probably the most popular single-dimensional method because it includes both the performance ratings and the importance weight of each attribute when evaluating alternatives³⁹."

When large numerical values are considered undesirable (when the low value is the best scenario), the Author will use Equation 1. While large numerical values are considered desirable (when the high value is the preferred scenario), use Equation 2.

$$\text{Rating} = \frac{\text{Worst outcome} - \text{Outcome being made dimensionless}}{\text{Worst outcome} - \text{Best outcome}}$$

Equation 1. The Equation for Undesirable Large Numerical Values⁴⁰

$$\text{Rating} = \frac{\text{Outcome being made dimensionless} - \text{Worst outcome}}{\text{Best outcome} - \text{Worst outcome}}$$

Equation 2. The Equation for Desirable Large Numerical Values⁴¹

Findings

Step 5. Analysis and Comparison of the Alternatives

The calculation to determine the dimensionless value with the formula listed in the rating procedure can be seen in Table 3, while Table 4 is the result of the non-dimensional scaling calculation.

³⁹ Sullivan, W. G., Wicks, E. M., & Koelling, C. P. (2014). *Engineering Economy* (16th ed.). Chapter 14 – Decision Making Considering Multiattributes pp. 611. Pearson.

⁴⁰ Sullivan, W. G., Wicks, E. M., & Koelling, C. P. (2014). *Engineering Economy* (16th ed.). Chapter 14 – Decision Making Considering Multiattributes pp. 609. Pearson.

⁴¹ Sullivan, W. G., Wicks, E. M., & Koelling, C. P. (2014). *Engineering Economy* (16th ed.). Chapter 14 – Decision Making Considering Multiattributes pp. 609. Pearson

Table 3. Calculation of Dimensionless Value Using Non-Dimensional Scaling Method⁴²

No	Attribute	Value	Relative Rank	Rating Formula	Rating
1	Easiness of Use from Client Point of View	Easy to Use	3	$(\text{Relative Rank} - 1)$ (3-1)	1.00
		Medium Difficulties	2		0.50
		Difficult/Need Training	1		0.00
2	Additional Cost for Investment per person (Rent new BIM Software)	Low	3	$(\text{Relative Rank} - 1)$ (3-1)	1.00
		Medium	2		0.50
		High	1		0.00
3	Reduced Time to Produce Project Control Deliverables	More than 1 month	3	$(\text{Relative Rank} - 1)$ (3-1)	1.00
		0 (zero) to 1 month	2		0.50
		No Reduce	1		0.00
4	Manpower Cost Impact	No Cost Impact	3	$(\text{Relative Rank} - 1)$ (3-1)	1.00
		Medium Cost Impact	2		0.50
		High Cost Impact	1		0.00
5	Accuracy of Project Schedule Estimation	High accuracy	3	$(\text{Relative Rank} - 1)$ (3-1)	1.00
		Medium Accuracy	2		0.50
		Low Accuracy	1		0.00
6	Accuracy of Project Cost Estimation	High accuracy	3	$(\text{Relative Rank} - 1)$ (3-1)	1.00
		Medium Accuracy	2		0.50
		Low Accuracy	1		0.00
7	Project Team Experience	High Experience	3	$(\text{Relative Rank} - 1)$ (3-1)	1.00
		Medium Experience	2		0.50
		Low Experience	1		0.00
8	Business Process Working Flow	Compact/Simple	3	$(\text{Relative Rank} - 1)$ (3-1)	1.00
		Semi-Compact	2		0.50
		Complicated/Long	1		0.00
9	Appropriate Hardware and Software Availability	Available	3	$(\text{Relative Rank} - 1)$ (3-1)	1.00
		Available but Rare	2		0.50
		Not Available	1		0.00
10	Return on Investment	Increase	2	$(\text{Relative Rank} - 1)$ (2-1)	1.00
		No Change	1		0.00
		Widely Complete	3		1.00
11	Integrated BIM Data Source Availability	Not Complete Data	2	$(\text{Relative Rank} - 1)$ (3-1)	0.50
		Not Available	1		0.00
		Low Risk	3		1.00
12	Risk and Uncertainty	Medium Risk	2	$(\text{Relative Rank} - 1)$ (3-1)	0.50
		High Risk	1		0.00

⁴² By Author

Table 4. Result of Non-Dimensional Scaling Calculation⁴³

No	Attribute	BIM Integration			
		Conventional (No BIM)	4D BIM Integration Only	5D BIM Integration Only	Full Integration (4D and 5D)
1	Easiness of Use from Client Point of View	0.50	0.50	0.00	0.00
2	Additional Cost for Investment per person (Rent new BIM Software)	1.00	0.50	0.50	0.50
3	Reduced time to produce Project Control Deliverables	0.00	0.50	0.50	1.00
4	Manpower Cost Impact	1.00	0.50	0.50	0.00
5	Accuracy of Project Schedule Estimation	0.50	1.00	0.50	1.00
6	Accuracy of Project Cost Estimation	0.50	0.50	1.00	1.00
7	Project Team Experience	1.00	0.50	0.50	0.00
8	Business Process Working Flow	0.00	0.50	0.50	1.00
9	Appropriate Hardware and Software Availability	1.00	1.00	1.00	1.00
10	Return on Investment	0.00	0.00	0.00	1.00
11	Integrated Data Source Availability	0.00	0.50	0.50	1.00
12	Risk and Uncertainty	0.00	0.50	0.50	1.00
TOTAL		5.50	6.50	6.00	8.50

⁴³ By Author

Table 5. *The Ordinal Ranking of BIM Integration to Scoring Attributes*⁴⁴

No	Attribute	Relative Rank
1	Easiness of Use from Client Point of View	6
2	Additional Cost for Investment per person (Rent new BIM Software)	1
3	Reduced Time to Produce Project Control Deliverables	7
4	Manpower Cost Impact	2
5	Accuracy of Project Schedule Estimation	10
6	Accuracy of Project Cost Estimation	11
7	Project Team Experience	3
8	Business Process Working Flow	4
9	Appropriate Hardware and Software Availability	5
10	Return on Investment	12
11	Integrated Data Source Availability	8
12	Risk and Uncertainty	9

By using the Lexicography method, the priority order for implementing BIM integration with schedule and cost estimation can be seen in Table 5. The level of priority for each attribute shall be as follows: Return on Investment > Accuracy of Cost Estimation > Accuracy of Schedule Estimation > Risk & Uncertainty > Data Source > Time Reduction > Easiness of Use > Hardware & Software Availability > Business Process Working Flow > Project Team Experience > Manpower Cost Impact > Additional Cost for Investment New BIM Software. Then, the calculation of weighting factors for each attribute is shown in Table 6 as follows.

⁴⁴ By Author

Table 6. Calculation of Weighting Factors for BIM Integration Alternatives⁴⁵

No	Attribute	Relative Rank	Normalize Weight	
			(I)	
1	Easiness of Use from Client Point of View	6	=6/78	0.08
2	Additional Cost for Investment per person (Rent new BIM Software)	1	=1/78	0.01
3	Reduced Time to Produce Project Control Deliverables	7	=7/78	0.09
4	Manpower Cost Impact	2	=2/78	0.03
5	Accuracy of Project Schedule Estimation	10	=10/78	0.13
6	Accuracy of Project Cost Estimation	11	=11/78	0.14
7	Project Team Experience	3	=3/78	0.04
8	Business Process Working Flow	4	=4/78	0.05
9	Appropriate Hardware and Software Availability	5	=5/78	0.06
10	Return on Investment	12	=12/78	0.15
11	Integrated Data Source Availability	8	=8/78	0.10
12	Risk and Uncertainty	9	=9/78	0.12
TOTAL		78		1.00

Based on the non-dimensional scaling calculation in Table 4 and weighting attributes in Table 6, each BIM integration plan alternative's scores can be calculated by multiplying the dimensionless value and normalized weight to get more clear result for the BIM integration plan. The result of the additive weighting technique score can be seen in Table 7.

⁴⁵ By Author

Table 7. Calculation of Weighting Factors and Dimensionless Value⁴⁶

No	Attribute	Relative Rank	Normalize Weight		Conventional (No BIM)		4D BIM Integration Only		5D BIM Integration Only		Full Integration (4D and 5D)	
			(I)	(II)	(I) x (II)	(II)	(I) x (II)	(II)	(I) x (II)	(II)	(I) x (II)	
1	Easiness of Use from Client Point of View	6	=6/78	0.08	0.50	0.04	0.50	0.04	0.00	0.00	0.00	0.00
2	Additional Cost for Investment per person (Rent new BIM Software)	1	=1/78	0.01	1.00	0.01	0.50	0.01	0.50	0.01	0.50	0.01
3	Reduced Time to Produce Project Control Deliverables	7	=7/78	0.09	0.00	0.00	0.50	0.04	0.50	0.04	1.00	0.09
4	Manpower Cost Impact	2	=2/78	0.03	1.00	0.03	0.50	0.01	0.50	0.01	0.00	0.00
5	Accuracy of Project Schedule Estimation	10	=10/78	0.13	0.50	0.06	1.00	0.13	0.50	0.06	1.00	0.13
6	Accuracy of Project Cost Estimation	11	=11/78	0.14	0.50	0.07	0.50	0.07	1.00	0.14	1.00	0.14
7	Project Team Experience	3	=3/78	0.04	1.00	0.04	0.50	0.02	0.50	0.02	0.00	0.00
8	Business Process Working Flow	4	=4/78	0.05	0.00	0.00	0.50	0.03	0.50	0.03	1.00	0.05
9	Appropriate Hardware and Software Availability	5	=5/78	0.06	1.00	0.06	1.00	0.06	1.00	0.06	1.00	0.06
10	Return on Investment	12	=12/78	0.15	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.15
11	Integrated Data Source Availability	8	=8/78	0.10	0.00	0.00	0.50	0.05	0.50	0.05	1.00	0.10
12	Risk and Uncertainty	9	=9/78	0.12	0.00	0.00	0.50	0.06	0.50	0.06	1.00	0.12
TOTAL		78		1.00	5.50	0.31	6.50	0.52	6.00	0.49	8.50	0.85

Step 6. Selection of the Preferred Alternatives

Using the MADM method, especially non-compensatory and compensatory models, to the selected BIM integration plan alternatives by several attributes, the recommended alternative is using the full integration of 4D and 5D BIM with a total score of 0.85. The return on investment, increasing the accuracy of the schedule, and cost estimate become deciding attributes with the biggest score in the calculation. Based on Table 7, we can summarize that the 4D and 5D BIM integration with project control activity will add more benefit to Pertamina in a lot of aspects, for example, increasing the accuracy of schedule and cost estimation, lowering the risk of miscalculation caused by data not integrated into one system/place, reducing time to produce deliverables, simplifying the business process working flow, and ultimately bring additional Return of Investment for Pertamina due to simple and integrated process by using BIM 4D and 5D integration with Project Control.

⁴⁶ By Author

Step 7. Performance Monitoring and Post-Evaluation of Results

Based on the result, implementing BIM 4D and 5D with project control should be considered beneficial for the company because it can improve many important aspects required by the company. To apply this integration, the company should execute it step-by-step, starting with 4D BIM integration. Referring to Table 7, the integration of 4D BIM only ranked second in the decision-making calculation. However, this rank could be improved by improving several critical factors⁴⁷: increasing the easiness of use⁴⁸ through education and training⁴⁹, re-engineering of business process to adopt BIM⁵⁰, and support from Stakeholders and Top Management⁵¹ also end-user involvement⁵² to adopt BIM, also providing appropriate hardware and software⁵³ which support BIM 4D and 5D. The 4D BIM-only integration could become a first step to implementing full integration of BIM. This integration will produce more accurate schedule estimations for ongoing and future projects at Pertamina. After the 4D BIM can be operated smoothly by Pertamina, the last step is 5D BIM integration to complete the roadmap to use full 4D and 5D BIM for producing a more accurate and reliable schedule and cost estimation.

Conclusion

The objective of this study is to research and find the answer to the following questions:

⁴⁷ Amuda-Yusuf, G. 2018. Critical Success Factors for Building Information Modelling Implementation. *Construction Economics and Building*, 18:3, 55-74. <https://doi.org/10.5130/AJCEB.v18i3.6000>

⁴⁸ Ugwu, O. & Kumaraswamy, M., 2007. Critical success factors for construction ICT projects- some empirical evidence and lessons for emerging economies. *ITCON*, 12, pp. 231-249.

⁴⁹ Woo, H., 2007. Critical success factors for implementing ERP: the case of a Chinese electronics manufacturer. *Journal of Manufacturing Technology Management*, 18(4), pp. 431-443
<https://doi.org/10.1108/17410380710743798>.

⁵⁰ Morlhon, R., Pellerin, R. & Bourgault, M., 2014. Building information modeling implementation through maturity evaluation and critical success factors management. *Procedial Technology*, 16, pp. 1126-1134
<https://doi.org/10.1016/j.protcy.2014.10.127>

⁵¹ Eadie, R., Odeyinka, H. Brown, M. Mckeown, C and Yohanis, M. 2013. An analysis of the drivers for adopting building information modeling. *ITCON*, 18, pp. 338-352

⁵² Bui, N., Merschbrock, C. & Munkvold, B., 2016. A review of Building Information Modelling for Construction in Developing Countries, Budapest, Hungary, s.n., pp. 592-598. <https://doi.org/10.1016/j.proeng.2016.11.649>

⁵³ Panuwatanich, K. & Peansupap, V., 2013. Factors Affecting the Current Diffusion of BIM: A Qualitative Study of Online Professional Network, Budapest, Hungary, Creative Construction Conference, 6-9 July.

1. Why is BIM integration with project control not yet implemented at Pertamina?

BIM 4D and 5D integration with project control at Pertamina face the main challenge, which is a conventional way to create a project schedule and cost estimation separated from engineering drawing and the list of material take-off. This method is already considered "Business as usual" and is commonly used within the organization.

2. What are the challenges for BIM 4D and 5D integration in the Pertamina refineries project, and could alternative ways be proposed to solve them?

The main challenge is, as stated in point 1 above. In addition, the easiness of use also has a significant impact referring to the calculation result in Table 7. The easiness of use will lead to a more effective working flow and reduce the time to produce deliverables. To solve the challenges, the company needs to increase the ease of using BIM by educating and training their engineers, changing the business process, and gaining support from stakeholders, top management, and end-user to accelerate the familiarization of BIM 4D and 5D integration with project control.

3. What are the benefits for Pertamina as project owner, which uses BIM integration with project control?

The benefits⁵⁴ are:

- Increase the return on investment by implementing a more efficient and effective process
- Increase the accuracy of the Project Schedule and Project Cost Estimation
- More efficient working flow and reduced time to produce deliverables
- Upskilling Pertamina's engineers by developing their knowledge following the latest technology.

Based on the answers above, the Author's recommendations for Pertamina are as follows:

1. To start implementation of BIM 4D and 5D integration with project control into the business process since it could bring more benefit to the company.

⁵⁴ By Author

2. Implementation should start by integrating the 4D BIM first and evaluating the impact of this new system by using it in some projects. This step included purchasing new hardware and software that could support BIM 4D, facilitating training sessions with BIM experts continuing with BIM certification for the engineers, hiring experienced personnel in BIM to lead the team, and providing procedure and legal aspects that could help the implementation run smoothly.
3. If the impact is positive, Pertamina should continue with familiarization within the organization and then continue with 5D BIM integration for a cost estimate to complete the BIM integration in Pertamina.
4. The Author recommends not to use partial integration (4D only or 5D only) permanently since it could confuse the team member because of using a dual system (conventional and BIM integration). Partial integration should be used only for evaluation and familiarization purposes; the goal is to use a complete combination of 4D and 5D BIM to get maximum and permanent results.

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No Description

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