PROJECT MANAGEMENT INFORMATION SYSTEM (PMIS) DASHBOARD AS A DIGITAL TWIN TO ENHANCE INFRASTRUCTURE PROJECT DELIVERY: A CASE STUDY OF AMERORO DAM PROJECT

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ABSTRACT: *In supporting the economic growth, Indonesian government has instructed to develop 201 National Strategic Infrastructure Projects, including Ameroro Dam Project. Located in Southeast Sulawesi, the construction process faced many engineering challenges with conventional monitoring methods, such as potentially delayed action plan and hindered decision making due to insufficient progress visualization data, inadequate real-time monitoring data, and unintegrated engineering data. Therefore, Project Management Information System (PMIS) dashboard is utilized as a Digital Twin innovation to overcome these challenges and optimize the project delivery. This study presents a case study approach on how PMIS could optimize the progress monitoring in Ameroro Dam Project. This PMIS Dashboard is integrated with Building Information Modelling, Digital Survey, Geospatial Data, and Project Management Data that supports the decision making as it provides more reliable data. This study illustrates the comparative study between conventional method and PMIS efficiency for a better project management. The effectiveness of PMIS can be seen as the integrated data is utilized to plan a construction working methods, along with monitoring the project schedule. Moreover, the visualization helps the engineers for a risk mitigation with the project performance display. Eventually, the paper concludes by the PMIS dashboard optimization for real-time progress monitoring in dam project, leading to more efficient infrastructure construction project management.*

KEYWORDS: *BIM, Digital Twin, Construction Working Methods, Geospatial Data, Progress Monitoring, Project Management.*

1. INTRODUCTION

As an agricultural country, the presence of Dam has always been considered as one of the most important infrastructures in Indonesia. As one of the most crucial engineering infrastructure, Dam is primarily used for water supply, flood control, agricultural irrigation, and hydroelectric power generation (Kalkan, 2014). Despite its many functions, the construction of Dam project is considered very complex. The construction of Dam project involves a large number of people with various objectives, interest, and disciplines to perform interdisciplinary activities. Moreover, time and physical resources limitations have added another dimension of complexity for dam project (Mahato & Ogunlana, 2011). However, many construction projects in Indonesia still apply traditional methods of project management which frequently caused a low productivity and waste a significant amount of time and resources due to poor prioritization and poor multi-tasking. Not only in Indonesia, but globally, construction is one of the biggest industry in the world that matters for the world economy. However, it has a long record of poor productivity. McKinsey (2020) reports the construction industry represents 13% of global GDP, but the productivity growth in construction only reach 1% annually for the past two decades. As shown in Figure 1, is significantly less than the productivity growth of the global economy, approximately 2.8% a year.

The low productivity in construction caused by many factors, one of which in slow innovation and digitalization. As it can be seen on Figure 2, the digitization index in construction is ranked as the lowest 2 among other industry. Currently, many construction projects are still using traditional monitoring systems which is impossible to implement timely checks and repairs (Woo, 2010). Previous studies also identified several limitations of conventional monitoring methods such as the absence of project visualizations that can hinder the decision making, affected the project quality, time, and costs.

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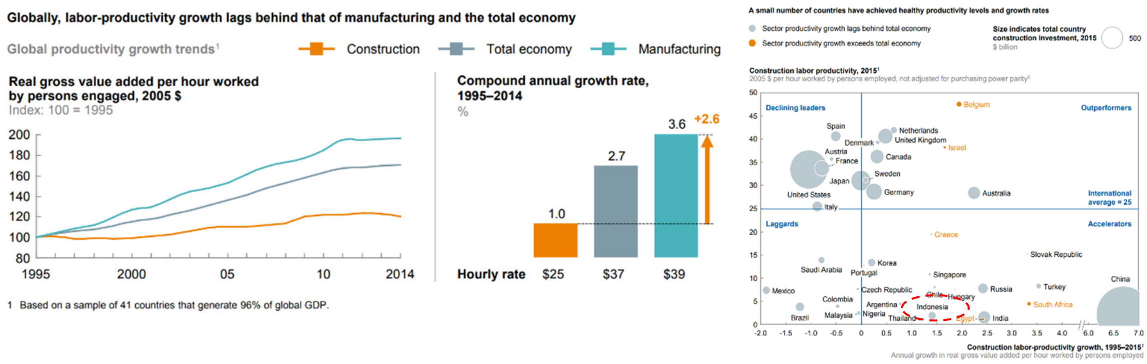

Figure 1. Global Labor Productivity Data (McKinsey Global Institute, 2017)

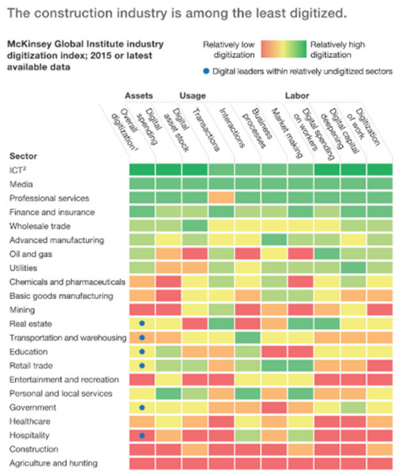

Figure 2. Industry Digitization Index (McKinsey Global Institute, 2016)

As the construction projects are getting more complex, it needs more advanced and integrated tools to improve the construction process. Along with the advancement of information technology (IT) that have been rapidly evolving, Digital Twin and Building Information Modelling (BIM) are some of the latest technologies that are useful in terms of improving project management in construction. Digital Twin can be referred as a concept originated with the Internet of Things (IoT) that represents digital simulation within an IT platform by integrating physical feedback data, artificial intelligence (AI), and machine learning (Bi, 2022). Furthermore, Digital Twin contributes to smart construction in achieving economic and sustainability goals (Istanbullu, Wamuziri, & Siddique, 2022). As it improves the productivity in construction sector through digitalization, many studies discussed about the implementation of Digital Twin and BIM in the construction project. However, the least amount of research discussed the best practices of Digital Twin utilization for infrastructure project management, specifically dam project. Therefore, this paper aims to perform a digital construction innovation namely Project Management Information System (PMIS) dashboard as a Digital Twin platform and analyze the project management effectiveness based on a real case study of a dam project. Finally, some recommendations of PMIS future development are proposed in the conclusion for future infrastructure projects.

2. LITERATURE REVIEW

2.1 Project Management

In order to success in delivering the expected project delivery, a good practice of project management should enable organizations to execute the project effectively and efficiently. Project management can be described as the implementation of knowledge, skills, tools, and techniques to project activities to meet the project requirements. Project management is accomplished through the correct execution and integration of the project management process identified for the project (Project Management Institute, 2017). Especially for construction project which involves many aspects, a good project management practice is required to ensure the project can be delivered on time. Moreover, construction project management can be described as a multidimensional discipline that requires accurate consideration of various crucial aspects, including cost, quality, schedule requirements, as well as social and environmental impacts, and broader stakeholder interests (Ke, Zhang, & Philbin, 2023).

2.2 Project Monitoring

To achieve the project goals, there are several crucial things in practicing project management, one of which is monitoring. Especially for dams construction, monitoring is considered critical since deformation may occurred as a result of erosion, water load, hydraulic gradients, and water saturation (Kalkan, 2014). Besides, monitoring can be described as collecting, calculating, assessing measurement and trends to enhance the process improvements (Project Management Institute, 2017). It can be concluded that project monitoring is fundamental aspect for successful project management and decision-making. However, despite the importance of project monitoring, many construction projects currently constrained by the inadequacy of traditional monitoring system. Traditional monitoring methods are considered inaccurate, time-consuming, and labor-intensive because they rely on large-scale manual operations that will lead into project delays and cost overruns (Nakanishi, Kaneta, & Nishino, 2021). Therefore, a good project monitoring system in a complex construction project is considerably important. For instance, continual monitoring is required to give the project management team with insight into the project's health and indicates any areas that might require special attention (Project Management Institute, 2017). It is because successful construction projects are identified by the level of awareness of project progress or work performance. Moreover, a progress monitoring system should comply the information requirement for real-time progress and decision making (Teizer, Lao, & Sofer, 2007). Ideally, monitoring may fasten the decision makings with its reliable data. The monitoring activities process should enable stakeholders acquire a comprehensive overview of the project's existing condition, identify issues for corrective action, and estimate future performance in terms of time and cost (Project Management Institute, 2017). As numbers of research have been conducted to reduce the gap between traditional monitoring and real-time monitoring, several approaches have been proposed for a better project management in construction monitoring.

2.3 Project Management Information System

Semi or fully automated data collection and analysis process can be a support in making quick and accurate decisions. Fortunately, technological advancement has been striving to improve the construction monitoring system in recent years. Numerous emerging automated data collection, analysis, and visualization techniques also have been utilized to develop systems for digitized real-time progress monitoring (Nakanishi, Kaneta, & Nishino, 2021). Thus, the implementation of PMIS can be considered effective to improve the project management in a complex project. According to Project Management Institute (2017) PMIS required to collect, analyze, and use the information to accomplish the project objectives and realize the project benefits. Moreover, PMIS also provides access to Information Technology (IT) software tools such as scheduling software, that allows stakeholders to track planned dates versus actual dates, report variation between the progress performance against the schedule baseline and estimate the effects of modifications to the project schedule model. Beside the integration between the volume of data and information, PMIS also includes scheduling software that has the capability to help plan, organize, and adjust the sequence of the activities; it also expedites the process of building a schedule model by generating start and finish dates based on the inputs of activities, network diagrams, resources, and activity durations (Project Management Institute, 2017).

2.4 BIM and Digital Twin

As it can fulfill the aspects of the PMIS, the idea of collaborating BIM and GIS shows a great potential as a Digital Twin to improve the project management process. In the last few years, BIM known as a collaborative working method for the creation and management of a construction project (Acebes, Testa, Alonso, & Curto, 2023). BIM can be defined as a three-dimensional view that represents the building data to achieve the summary and integration of various information in construction (Yue, 2023). Furthermore, project progress cost, construction clashes and situation can be accessed through the animation in BIM. These functions are in line with the PMIS which include spreadsheets, simulation software, and statistical analysis tools to assist with cost estimating (Project Management Institute, 2017). However, the utilization of BIM only could not satisfy the PMIS objectives. While BIM tools provide excellent representations for product design, they often lack essential features necessary for construction when it comes to Digital Twins (Bao, Guo, Li, & Zhang, 2018). Digital Twin can be defined as a virtual representation of a physical asset that can reflect its current status. The data is collected through sensors and other monitoring devices embedded within the structure and transmitted to the virtual model in real-time (Ma, et al., 2020). The implementation of Digital twins ensures the final result to be more accurate and reliable. Through accessing to this real-time data, stakeholders can quickly identify and respond to issues as they arise, leading to increased efficiency and productivity (Jiang, Guo, & Wang, 2021). In this case, BIM can be utilized for visual management tools as the base information for Digital Twin to provide a high-level representation of buildings and their assets by integrating the physical and digital world (Hosamo, et al., 2022). Besides, Digital twin construction creates a data-centric way of construction management by combining BIM technology, lean construction thinking, the digital twin concept, and artificial intelligence (Bandara, Ranadewa, Parameswaran, & Eranga, 2023). Hence, the availability of current and historical data on the digital twin enables predictions of future behavior which beneficial for operation and maintenance phase from the infrastructure asset (Sivalingham, Sepuvelda, Spring, & Davies, 2018). Some technologies such as GIS and digital surveying are also utilized to obtain the real-time data of Digital Twin. Moreover, the presence of PMIS as digital twin may improves the overall project management performance as it displays the visualization of current project state, detect the potential risk, shows the project performance, as well as enhance the collaboration between stakeholders. However, as many observers addressed about the development of BIM and Digital Twin, none of the observers discussed about the best practices for dam project. This perspective is important since dam construction is considered very complex and required a good project management system. Hence, the proposed research is to identify the Digital Twin best practice for dam project, as well as analyzing the effectiveness for project management.

3. METHODOLOGY

The methodology used on this research is based on a case study approach of Ameroro Dam from the perspective as the general contractor for project management purposes during the construction. The obstacle inherent in the construction phase is that the monitoring process is still conventional, resulting the data obtained not being real-time, although this phase is critical for monitoring project performance to ensure quality, budget, and schedule. Therefore, the step to overcome this limitation is by doing digitalization with PMIS. The PMIS will automatically collect and process the data such as BIM Model, Digital Survey data, and project data for the input data. As the result, the PMIS platform will present the project data in a more effective way, especially to support the project management and decision-makings.

3.1 Case study description

As an agricultural country, the agricultural sector plays a crucial role and contributes to the country's economy. According to data from Central Bureau of Statistics, Indonesia produces 31,36 million rices in 2021, and the government plans to increase the rice production targets up to 300.000 tons in 2024. Therefore, to support this policy, the Ministry of Public Works mandated to construct 65 priority dams through the National Strategic Project, one of which is Ameroro Dam Project. The Ministry of Public Works assigned the construction of this project to Hutama Karya as one of the Indonesia's leading state-owned enterprises for the main contractor. Ameroro Dam is built as the 2nd dam in South East Sulawesi Province to increase the number of water reservoirs in Indonesia in order to support food security programs and water availability. This dam was designed to be a multipurpose dam, with a total capacity of 54.15 million m^3 and an inundation area of 212.89 Ha. With the project value of 38 million USD, Hutama Karya covers the scope of works namely spillway, access road, bridges, hydromechanical and electrical, and supporting and facility buildings. With a project duration of 945 days, Hutama Karya faces a complex project management to finish Ameroro Dam Project such as targeted to accelerate from the project schedule, remote access to the project, and managing communication with stakeholders in remote area. Therefore, an effective monitoring system is required by the organization to manage this project throughout the project life cycle. The required features to support the project monitoring are collected and combined into a platform to form the PMIS dashboard. The utilization of PMIS dashboard helps Hutama Karya as the main contractor to enhance the project management during the construction process. The PMIS is based on Building Information Modelling (BIM) and Geographic Information System (GIS) and is integrated with other company's strategic platforms, which supports the data requirements for the project to provide a more reliable data, especially during the decision-making process.

Figure 3. Ameroro Dam Project

3.2 Project management information system

The existence of PMIS has significantly improved project management by delivering a more accurate construction process and a better project visualization for construction monitoring. The features available on the PMIS dashboard does not have any specific benchmarks and are developed according to the company's business process needs. The framework in Figure 4 shows the workflow from data collection to processing and output production of PMIS. The primary data such as BIM Model, Digital Survey Data, and Project Data is utilized as the foundation of PMIS dashboard which in this case study is built in the base of a GIS platform, thus geospatial map is becoming the base layer of the information. The production of BIM Model is required and processed with georeferenced coordinate system, inserted to be a raw data for Geo-BIM feature. The Geo-BIM referred to in this paper is the integration of the BIM Model with GIS, hence, to simplify further discussion it will be referred as Geo-BIM. On the other hand, Digital Survey obtained with Photogrammetry methods by using Drone Mapping. This digital surveying operation will produce point clouds and processed into Digital Terrain Model (DTM), Digital Surface Model (DSM), and Orthophoto as a raw data for Geo-BIM. Afterwards, the superimposed BIM Model and Orthophoto in the GIS platform will be beneficial as the progress visualization feature for project monitoring. Moreover, this PMIS dashboard is also equipped with video surveillance from live CCTV that will support the stakeholders for doing construction monitoring remotely. For a better understanding on how PMIS works for the project management process, it will be explained in Figure 4 as shown below.

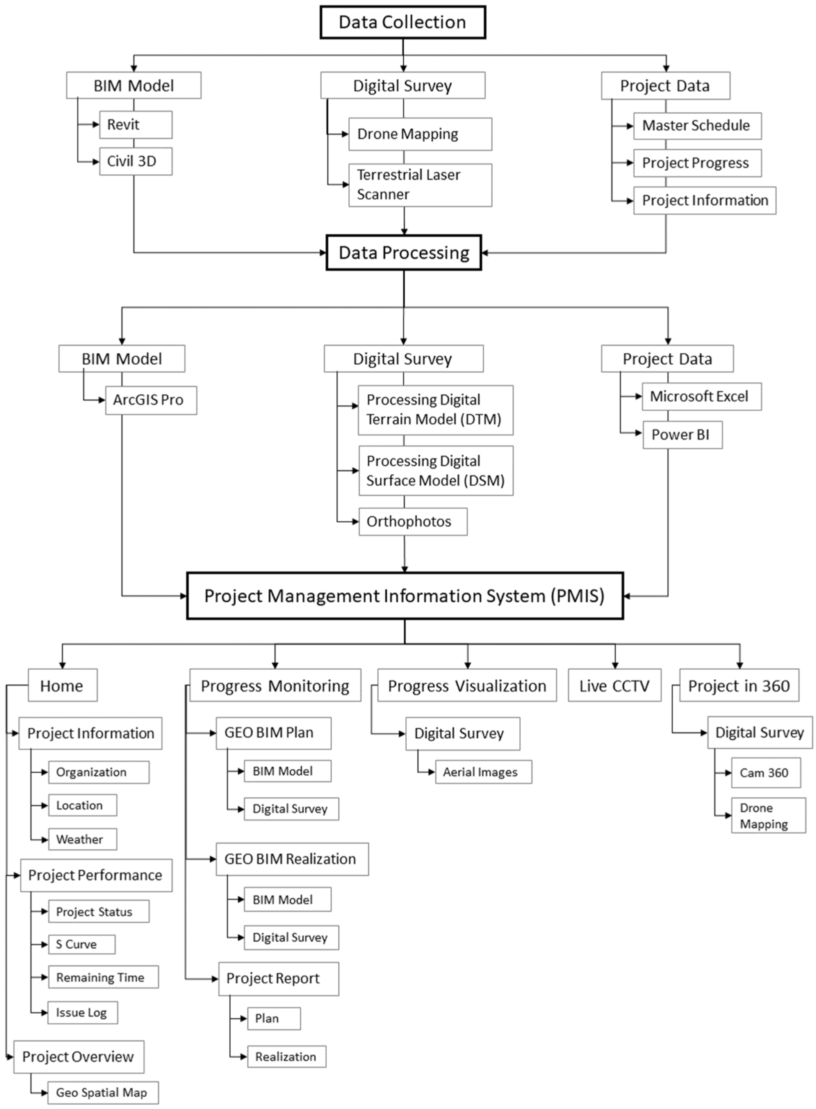

Figure 4. PMIS Flowchart

3.3 Data Collection

As a basis input for PMIS dashboard, data collection is undertaken using two methods namely manual methods with total station and 2-dimensional engineering drawings and digital methods by utilizing digital survey, BIM, and project data. The digital data collection includes Digital Surveying process to obtain the geographic data, real-time data, and making the BIM Model for the visualization and calculation needs.

3.3.1 Manual Data Collection

The conventional method of surveying is undertaken by surveyor using a Total Station Topcon GTS 230 and it took approximately 1,5 hours for 1 hectare. The manual surveying is undertaken by 2-3 surveying engineers. Furthermore, the 2-dimensional engineering drawing usually made at least 1 day for each drawing as shown on Figure 5.

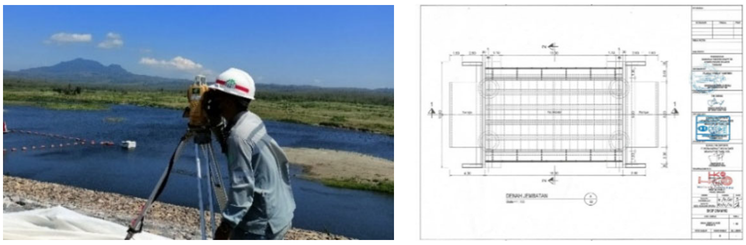

Figure 5. Manual Data Collection with Total Station and 2D Engineering Drawing

3.3.2 PMIS Data Collection

3.3.2.1. Digital Survey

At the earliest stage of the construction, Digital Survey was conducted by BIM Engineer to obtain geographic data to be superimposed with the engineering drawings. The digital surveying process is carried out with Photogrammetry method by using Drone Mapping that will perform aerial surveying and generate a collection of images of the object. The raw data was collected using a drone DJI Phantom 4 Pro V.20 shown in Figure 6. The surveying methods was started by arranging the flying route of the drone and setting up the overlapping rate between each image. Furthermore, Digital Survey method considered effective as it took only 15 minutes approximately for the area of 15 hectares per flight mission with 100 meters of altitude and produced Digital Elevation Model and Orthophotos as the output. This method is conducted regularly, and the data will be embedded on the PMIS dashboard for project monitoring needs.

Figure 6. Digital Survey process with Drone Mapping

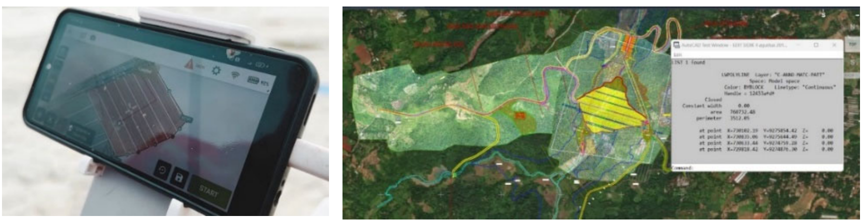

Figure 7. Photogrammetry Flight Mission

3.3.2.2. Building Information Modelling

During the construction process, Building Information Modelling (BIM) plays an important role as the project visualization. Hence, the BIM Model is an important input data for the PMIS dashboard, which can be later integrated with GIS. The data collection process started with the BIM 3D Model creation based on the detailed engineering drawings using BIM Authoring tools. Afterwards, the coordinate points from the digital survey are inputted on the BIM 3D Model, so that this model has georeferenced data that can be integrated with GIS later on the PMIS Dashboard. The process for generating shop drawings from BIM 3D model only requires 4 hours to finish each drawing. This 3D model is also required to provide the design overview for stakeholders, as well as being the basis for decision-making in solving any clash problems.

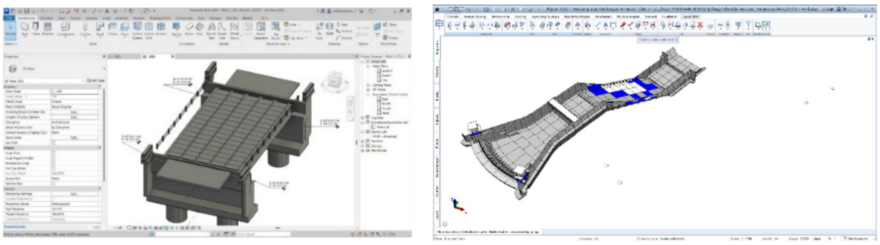

Figure 8. Georeferenced BIM Model

3.3.2.3. Project Data

Besides, the PMIS dashboard also integrated with project data such which compiles stakeholders name, project milestones date, location, and project remaining time to be showed in the project information. Moreover, the PMIS dashboard also integrated with project engineering data such as master schedule, monitoring schedule, 4D scheduling from BIM, plan and realization of project cost that becoming the focal point of the dashboard which will be featured as the project performance.

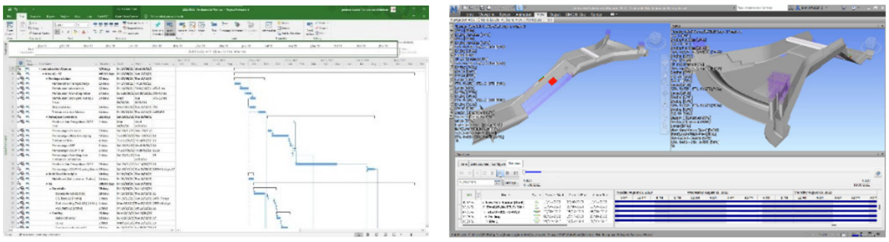

Figure 9. Integrated Project Schedule Data

3.4. Data Processing

3.4.2. Manual Data Processing

For the surveying phase, Total Station obtained RAW data such as distance and elevation level, and the output will be inputted manually on Microsoft Excel and processed in CAD software. Moreover, for the schedule data, the conventional method needs to input manually on Microsoft Excel or Microsoft Project for the monitoring purpose. This process usually requires 6 hours long to produce Cross Section data as a support for Project Monitoring.

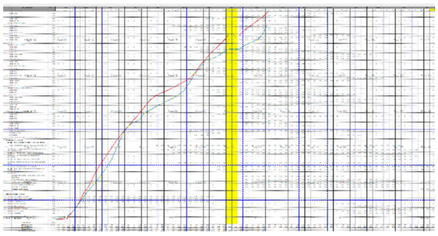

Figure 10. Project Master Schedule

3.4.3. PMIS Data Processing

The graphic visualizations on this dashboard are supported by collaborating platforms and software which data kept in cloud-based or on-premises server. In this case, the company use both, the combination between cloud-based and on premises server because the data is interlinked. Nowadays, digital platforms are build based on collaboration which helps them to grow stronger with the ability on showing other platforms data through open API and interlinked data. As well in this PMIS dashboard, beside using open API to connect the BIM model data, the connector between platforms is developed in spreadsheets that previously arranged with required fields based on each visual requirement. Thus, the information inserted is categorically and historically inputted regarding the visual representation needed in the dashboard then transformed into bar graphs, doughnut graphs or gauge charts.

3.4.4. Project Information

The project information as the basic data, compiles stakeholders name, project milestones date, location, weather condition, and remaining time that becoming the focal point of the dashboard. In the framework of project management, the remaining time shows in countdown to ensure the initial attention of the stakeholders are concerning on how the time and progress are in the right direction, otherwise the rest of information provided in this dashboard will be able to support the necessary decision making to guarantee the timely delivery of the project.

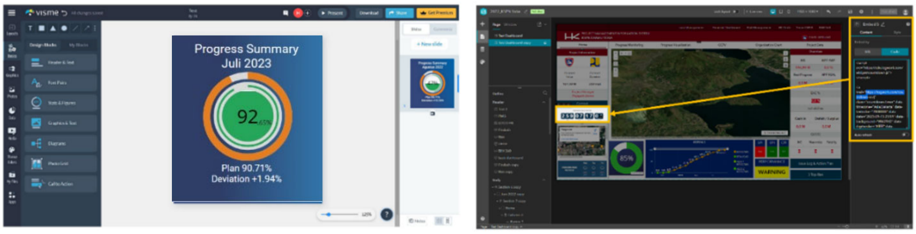

Figure 11. Project Information Data Processing

3.4.5. Project Performance

Project Performance is used to determine if a project is in the Excellent, Warning, or Critical category based on the actual and anticipated project cost value, income realization, and plan. The Project Performance contains many information and integrated with the project engineering data such as master schedule, monitoring schedule, plan, and realization of project cost. Firstly, these databases are inputted in Microsoft Excel and processed on ArcGIS Pro. Then the dashboard is created on ArcGIS Dashboard Enterprise, and these S curve dashboards are inputted in PMIS dashboard through the ArcGIS Experience Builder.

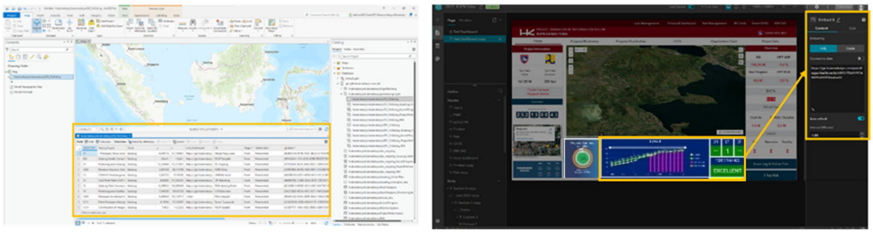

Figure 12. Project Performance Data Processing

3.4.6. Geo-BIM

During the data processing, the Digital Survey data which obtained from Drone Mapping will be processed to be superimposed with the BIM 3D Model. The output produced from the drone mapping were subsequently translated into Orthophoto and Digital Elevation Model (DEM) to be processed in Agisoft metashape. Afterwards, DEM can produce 2 outputs, namely Digital Terrain Modelling (DTM) and Digital Surface Modelling (DSM). DTM could be processed as a contour and can be developed as cross section and top surface in Autocad Civil 3D to produce cut and fill volume calculation for progress monitoring. Meanwhile the DSM or Digital Survey Modelling will be processed as 3D Object. The 3D object will be inputted in ArcGIS and overlayed with the BIM Model to see the construction progress, as shown on Figure 13 and 14.

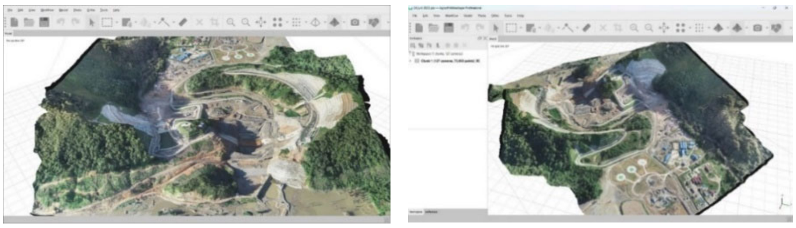

Figure 13. Orthophoto Data Processing

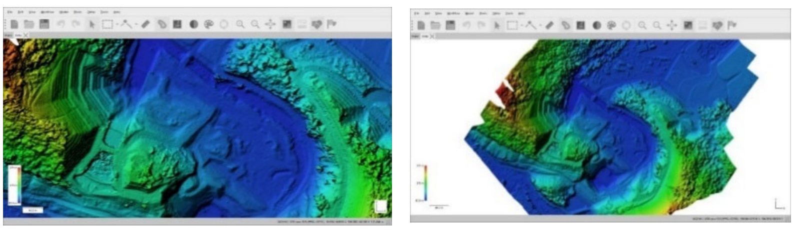

Figure 14. Digital Elevation Model (DEM) Data Processing

3.5. Result and Discussion

After the data processing, many outputs showcased as the result of PMIS. The final output contains project performance, Geo-BIM, and Live CCTV which beneficial as the progress visualization and enhance the decision-makings during the construction progress. This dashboard usually used as project management plan by project stakeholders namely project manager, site engineer manager, engineers, and head-office management team to identify the current project status and regular monitoring purposes during the coordination meeting.

3.5.2. Project Performance

The main page of PMIS dashboard allows us to identify the current project status and project performance. It includes the project information such as project value and time of completion, project remaining time, project location, and the weather. The project performance feature also integrated with the project master schedule, showcasing the S Curve of the project progress. Moreover, it completed with the Schedule Performance Index (SPI), Cost Performance Index (CPI), and Efficiency Performance Index (EPI) which will resulting as the project performance conclusion, as shown on Table 1. Moreover, it also completed with the project data such as financial data, QHSSE data, Issue log and action plan.

Table 1. Project Performance Formula

	SPI	EPI	CPI
EXCELLENT	>1	>1	>1
WARNING	>1	<1	<1
CRITICAL	<1	<1	<1

SPI = Schedule Performance Index

EPI = Efficiency Performance Index

CPI = Cost Performance Index

This formula is referred as Project Forecasting, that is utilized as a monitoring tool that ease the project management team to identify risks and take actions, as well as allocate the resources early. The result can be seen on the PMIS main dashboard which aims to increase the project team's awareness of current project status as shown on Figure 15.

Figure 15. Project Performance

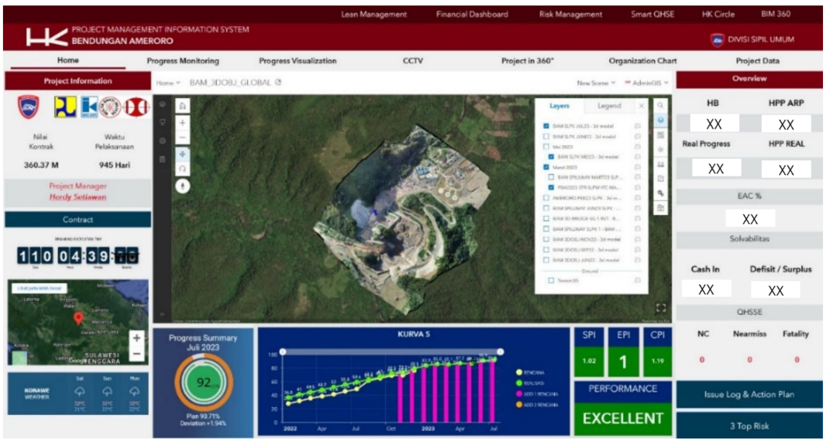

Figure 16. Ameroro Dam Project Performance on PMIS Dashboard

3.5.3. Progress Visualization

The aerial images produced from the Drone Mapping are shown in Progress Visualization feature as an overview of the construction progress. This feature is beneficial for regular monitoring purposes to ensure many points on the site that are difficult to reach manually, so that if there are any construction issues such as initial cracks occur, it can be detected and anticipated immediately.

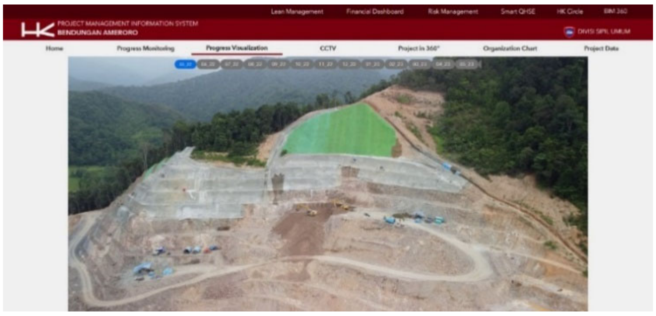

Figure 17. Progress Visualization

3.5.4. Progress Monitoring with Geo-BIM

As a result of the integration between BIM 3D Model and digital data, Geo-BIM was obtained as one of the features of PMIS. In addition, the results from digital survey namely geospatial data, orthophoto, and 3D objects can be superimposed with the BIM Models and site progress data to be integrated in PMIS as digital twin to the existing conformance to the plan accurately with the appropriate coordinates as shown in Figure 18. Moreover, this feature also enables us to make a comparison between the planned construction action plan on the current month versus the realization of construction action plan, which both visualized in BIM overlayed with orthophoto. Manual methods monitoring can only use ms project in terms of scheduling and cannot provide overlay visualization data. Meanwhile, the progress monitoring using PMIS provides Geo-BIM that combined with the project schedule, that can be created for weekly action plan. Each realization progress will be inputted into the Geo-BIM as overlayed data. Then the result of this sumperimposed data can be compared for regular monthly monitoring to identify the deviations. Therefore, if there is any deviations, a strategy can be made to catch up the project schedule. Hence, the integration between photogrammetry with BIM Model accelerates the construction monitoring process as well as making the action plan with the help of the digital twin as the project visualization. Thus, this integration assists stakeholders on decision makings more accurately and quickly.

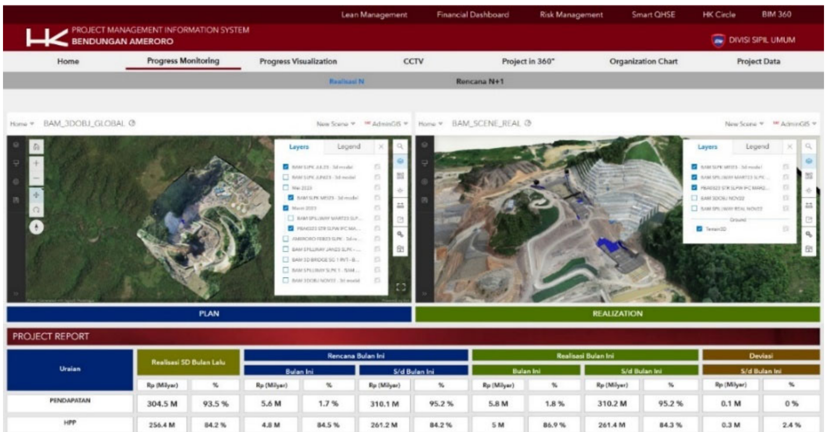

Figure 18. Progress Monitoring with Geo-BIM

3.5.5. Live CCTV

There is a Live CCTV feature which integrated with site project cctv support the progress monitoring purposes. Moreover, this Live CCTV feature enable the stakeholders to do real-time monitoring remotely during the construction process. The CCTV units are strategically placed in the production and construction areas, showing not only the current activities but also assisting safety manager to ensure accident prevention with real time monitoring from the control room.

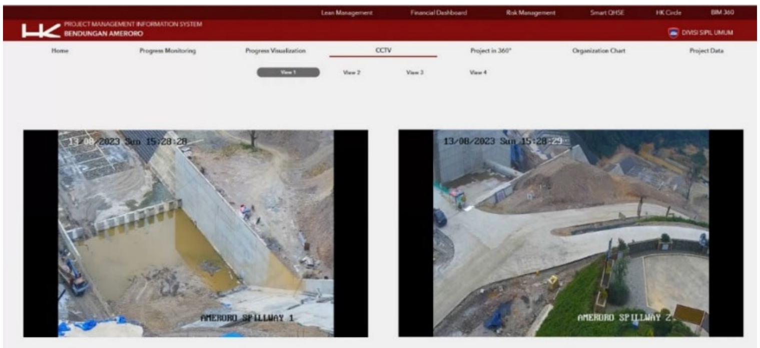

Figure 19. Live CCTV

3.5.6. Comparative Analysis

As we can see from the data above, the manual methods of project monitoring require a lot of time and manhour, rather than the digital monitoring through the PMIS. The comparative analysis below is affected by many factors. On the quantitative side, it affected by manpower and manhour needed during the data collection and processing, with formula as illustrated below:

Data Collection Time Productivity Rate for every 1 hectare

$$Productivity\ Rate = \left|\frac{\sum Manual\ Survey\ time\ (min)}{\sum Digital\ Survey\ time\ (min)}\right|$$

$$Productivity\ Rate = \left|\frac{90\ \ min}{1{,}5\ \ min}\right| = \mathbf{60}\boldsymbol{x}$$

Data Collection Manpower Efficiency

$$Efficiency\ Rate = \left|\frac{\sum Manual -\ Digital\ Survey\ manpower\ (people)}{\sum Manual\ Survey\ manpower\ (people)}\right| x\ 100\%$$

$$Efficiency\ Rate = \left|\frac{(3-2)\ peoples}{3\ peoples}\right| x\ 100\% = \mathbf{33}\%$$

Data Processing Time Efficiency

$$Efficiency\ Rate = \left|\frac{\sum Ms\ Project + BIM\ (hours)}{\sum Ms\ Project\ (hours)}\right| x\ 100\%$$

$$Efficiency\ Rate = \left|\frac{8\ hours}{16\ hours}\right| x\ 100\% = \mathbf{50}\%$$

Data Processing Productivity Rate

$$Productivity\ Rate = \left|\frac{\sum 2D\ Drawings\ time\ (hours)}{\sum BIM\ Drawings\ time\ (hours)}\right|$$

$$Productivity\ Rate = \left|\frac{8\ hours}{4\ hours}\right| = \mathbf{2}\boldsymbol{x}$$

On the other side, the utilization of PMIS also shows significant difference in terms of output quality, especially to support the project monitoring and decision-makings as shown on table 2.

Table 2. Comparative Result of Project Management between using PMIS and non-PMIS

Factors	Project Management without PMIS	Project Management using PMIS
Data Collection	Consisted of single-sourced data. The process requires longer time to collect data from many involved parties	Consisted of integrated data, which more comprehensive between time and visualization. The data automatically updated by the Engineer with a faster time.
Project Monitoring	Manual monitoring requires longer time and cannot be schedule-based since the realization progress from the surveying data is not integrated.	Project Monitoring with PMIS allows the integration between GIS, BIM, and Project Schedule to be superimposed into monthly overlayed data for regular monitoring purpose
Building Information Modelling	It is unintegrated with the geospatial data so clash detection with the site cannot be checked	It can be overlayed with the digital survey data to see the conformance with the existing site as well as beneficial for progress monitoring
Project Performance	The management team in project or headquarter may be unaware with project current status by the unavailability of updated project performance data	Increase the management team awareness of project current status and beneficial to make a corrective action plan
Decision Makings	Requires a longer time by the unintegrated and less updated data and the absence of visualization,	The availability of updated project data and visualization provide more reliable data and fasten the decision-makings
Historical Data	The engineering data are unintegrated and may be lost after the project finished	The historical engineering data are stored and integrated in one platform
Limitation	Requires longer time	Highly dependent to online internet network

4. CONCLUSIONS

The presence of PMIS as a Digital Twin plays a crucial role during the project monitoring in ensuring the timely delivery of a construction phase of a project. It can be concluded from the results above; the quantitative data shows the digital monitoring is more effective than conventional monitoring during the data collection process. In terms of time, digital monitoring improves the productivity by 60x faster than the manual method, with manpower efficiency of 33%. Moreover, the implementation of BIM improves the productivity up to 2x faster than the conventional methods and cut the time efficiency by 50%. From the qualitative side, PMIS consisted of integrated data which more comprehensive between time and visualization, rather than without PMIS that consisted of single-sourced data. In terms of the output quality, the integration of BIM and GIS provide more reliable data to support the decision makings by the presence of updated project data and visualization, that can be overlayed with the digital survey data. Moreover, the project performance feature increase awareness of project current status that ease the project management team to identify risks, take actions, and make the corrective action plan. PMIS is going to be a major difference in asset management aspect, with the collected database from construction phase have been prepared to be handed over to the asset manager as the reference for maintenance activities. Meanwhile with the conventional methods, unintegrated engineering data are subjected to be scattered after the project finished. Therefore, it can be concluded that the utilization of PMIS accelerates stakeholders' decision through data driven decision making while reduce and mitigate risk of cost overruns as early as possible with the findings on project monitoring. Future recommendation of the historical project data which collected in PMIS is expected for future project management plan, especially for project with the same characteristic. Besides, the PMIS utilization is improving collaboration and understanding of the project situation through Digital Twin with the data intensive communication and eliminate the inefficient process with remote monitoring. All in all, the digital twin technology nowadays has shown a significant role on providing the efficiency and optimizing the productivity on construction industry where each stakeholder should spot the benefit for their organization. Likewise, in Hutama Karya, PMIS capabilities currently in use are highly adaptable to future development and updating according to organizational needs and technological advancement. Hence, not only the tools are evolving but also the people need to be agile and adaptive to maintain its effectiveness to support company's business process excellence.

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REFERENCES

Acebes, F., Testa, R., Alonso, J., & Curto, D. (2023). BIM Implementation in Construction Project Management. In *Industry 4.0: The Power of Data.* Springer.

Bandara, D., Ranadewa, T., Parameswaran, A., & Eranga, B. (2023). Lean iceberg model to minimise barriers for digital twin implementation: Sri Lankan construction industry perspective. *11th World Construction Symposium.* Sri Lanka.

Bao, J., Guo, D., Li, J., & Zhang, J. (2018). The modelling and operations for the digital twin in the context of manufacturing. *Enterprise Information Systems, 13*, 534-556.

Bi, R. (2022). A Study of Smart Construction Based on the Digital Twins. *6th International Seminar on Education Management and Social Sciences (ISEMSS 2022).* China.

Delgado, J. D., & Oyedele, L. (2021). Digital Twins for the built environment: learning from conceptual and. *Advanced Engineering Informatics, 49*.

Hosamo, H., Imran, A., Cartagena, J. C., Svennevig, P. R., Svidt, K., & Nielsen, H. K. (2022). A Review of the Digital Twin Technology in the AEC-FM Industry. *Advances in Civil Engineering, 2022*.

Istanbullu, A., Wamuziri, S., & Siddique, M. (2022). BIM Digital twins environment to enhance construction. *IOP Conf. Series: Earth and Environmental Science*.

Jiang, Z., Guo, Y., & Wang, Z. (2021). Digital twin to improve the virtual-real integration of industrial IoT. *Journal of Industrial Information Integration*.

Kalkan, Y. (2014). Geodetic Deformation Monitoring of Ataturk Dam in Turkey. *Arabian Journal of Geoscience*, 397-405.

Ke, Y., Zhang, J., & Philbin, S. P. (2023). Tradition and Innovation in Construction Project Management. *Buildings, 13*(6).

Ma, J., Chen, H., Zhang, Y., Guo, H., Ren, Y., Mo, R., & Liu, L. (2020). A digital twin-driven production management system for production workshop. *The International Journal of Advanced Manufacturing Technology*, 1385-1397.

Madubuike, O., Anumba, C., & Khallaf, R. (2022). A review of digital twin applications in construction. *Journal of Information Technology in Construction*, 145-172.

Mahato, B. K., & Ogunlana, S. O. (2011). Conflict Dynamics in a Dam Construction Project: A Case Study. *Built Environment Project and Asset Management, 1*(2), 176-194.

McKinsey Global Institute. (2016). *Imagining Construction's Digital Future.* McKinsey & Company.

McKinsey Global Institute. (2017). *Reinventing Construction: A Route to Higher Productivity.* McKinsey & Company.

McKinsey Global Institute. (2020). *The Next Normal in Construction.* McKinsey & Company.

Nakanishi, Y., Kaneta, T., & Nishino, S. (2021). A Review of Monitoring Construction Equipment in Support of Construction Project Management. *Frontiers Built Environment, 7*.

Pan, Y., & Zhang, L. (2021). A BIM-data mining integrated digital twin framework for advanced project management. *Automation in Construction, 124*.

Project Management Institute. (2017). *A Guide to the Project Management Body of Knowledge (PMBOK Guide) 6th edition.* Newton Square: Project Management Institute.

Sangyong, K., Yoonseok, S., & Gwang-Hee, K. (2014). Case Study on the Maintenance of a Construction Monitoring Using USN-Based Data Acquisition. *The Scientific World Journal, 2014*.

Sivalingham, K., Sepuvelda, M., Spring, M., & Davies, P. (2018). A Review and Methodology Development for

Remaining Useful Life Prediction of Offshore Fixed and Floating Wind Turbine Power Converter with Digital Twin Technology Perspective. *2nd International Conference on Green Energy and Applications (ICGEA), (197-204).*

Teizer, J., Lao, D., & Sofer, M. (2007). Rapid Automated Monitoring of Construction Site Activities Using Ultra-Wide Band. *24th International Symposium on Automation & Robotics in Construction (p.23-28).* Cochin, India.

The US Geological Survey. (1992). *Publication of The US Geological Survey.* Washington DC: U.S. Government Printing Office.

Wang, X., Wang, Y., Tao, F., & Liu, A. (2020). New Paradigm of Data-Driven Smart Customisation through Digital Twin. *Journal of Manufacturing Systems*.

Woo, J. T. (2010). A study of the present state analysis and development plans about construction monitoring and monitoring industry. *KSCE Journal of Civil and Environmental Engineering Research, 30*(2D), 163-169.

Yue, W. (2023). Research on applications of Building Information Modelling (BIM) in construction project management information systems. *SHS Web Conference. Volume 169, 2023. 4th International Symposium on Frontiers of Economics and Management Science (FEMS 2023).*