Time And Cost Optimization with The Integration of Building Information Modeling (BIM) 4D and Time Cost Trade-Off Methods (Case Study: Pemali Bridge Project)

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Abstract. Time and cost are highly calculated factors as indicators of project success. The presence of the COVID-19 pandemic has had an impact on the process of completing the Pemali Bridge project, a part of the Brebes-Tegal North Ring Road Project, which has stalled for many years. On this study, time and cost optimization using the 4D BIM method and Time Cost Trade-Off. Bridge Modeling in 3D and 4D levels are conducted using BIM 3D and 4D software. Meanwhile, time and cost analysis using spreadsheet and project management software. These results showed that the efficiency of reinforcement and concrete materials had an average value of 5% and an acceleration of the optimum duration of 13 days with the addition of 2 hours of work. These are evidence that the integration of BIM and Time Cost Trade-Off methods are effective for the cost and efficiency of construction project work.

Keywords: Bridge, Construction management, Optimization, 4D BIM, Time cost trade-off.

1 Introduction

Infrastructure is a basic service or social capital in a country that supports transportation activities, health services, education, and other buildings as a means of carrying out community activities (The Routledge Dictionary of Economics, 1995). Increased economic activity in the North Coast region (Pantura) has increased the volume of movement of vehicles crossing the northern coast route, especially during national holidays. This causes traffic jams that often occur along inner-city roads in the City of Brebes and City of Tegal. The construction of the 17.4 kilometer Brebes-Tegal North Ring Road along with seven bridges will also complement the structure of the national road network which can reduce the traffic load on the northern coast by up to 48 percent. The Brebes-Tegal North Ring Road Development Project has been started since 2010 but in the construction process it was stopped and only restarted for completion at the end of 2019.

In implementing a project, factors such as time and cost are very important as indicators of project success. Good project management is needed so that discrepancies that may occur from

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planning can be minimized. However, in its implementation in the field, there were many unexpected conditions that caused work delays. According to Abedi, et.al. (2011) there are nine factors causing delays in construction projects (from the contractor side), namely inaccuracy in construction methods, use of outdated technology, inaccuracies in project planning and scheduling, inaccurate time estimates, lack of project management and supervision, incompetence of the project team, lack of contractor experience , as well as unreliable sub-contractors.

Along with the industrial revolution 4.0, developments in information and communication technology have also had a positive impact in the form of technological breakthroughs on the infrastructure sector. One of these technological breakthroughs is the emergence of the Building Information Modeling (BIM) method. BIM is a modeling technology and a series of related processes for generating, communicating, and analyzing building models (BIM Handbook Introduction, 2011). The information provided by BIM includes detailed structural, architectural, mechanical, electrical items that can be integrated with costs and scheduling in a 3D model. BIM in its use is very adaptive to changes that occur in the continuity of the project. Uncertainty in the field due to various factors makes the management of construction activities in scheduling, financing, and the methods used can change dynamically. The adaptive side of BIM in ensuring the distribution of data and information in real time makes control in projects by various stakeholders better and systematic. In the process of accelerating the implementation of BIM in the country, the government through the Ministry of PUPR issued a regulation in the form of Ministerial Regulation of PUPR number 22/PRT/M/2018 which encourages the implementation of the use of BIM with a focus on non-simple state buildings with criteria of an area of over 2,000 m2 and above 2 floors. Furthermore, the Directorate General of Highways also issued Circular Letter number 11/SE/Db/2021 which regulates the application of BIM in technical planning, construction and maintenance of roads and bridges.

In project planning and scheduling, there are several alternatives that can be used in optimizing the implementation of accelerated project activities which include additional working hours, additional workforce, replacement or addition of equipment, use of more effective construction methods. Determining alternatives to work acceleration requires an analysis of work networks that have a correlation with time and cost, known as the Time Cost Trade Off method. According to Ervianto (2004) the time cost trade off method is a work schedule compression method to gain project benefits in terms of time (duration), costs, and income. The objective is to compress the duration of the project into an optimum state and minimize the total project cost. Reducing the duration of the project is done by selecting certain activities that are on the critical path and then compressing it starting from the critical path that has the lowest cost slope value.

The existence of the COVID-19 pandemic has also affected the construction sector, especially the Pemali Bridge construction project which has been under way since the middle of the first quarter of 2020. In designing this final project, the author tries to solve problems in optimizing the time and cost of the Pemali Bridge construction work using the BIM level method. 4D and methods

2 Design Concept

The research location for this final assignment is in Winduaji Village, Paguyangan District, Brebes Regency, Central Java Province. Literature study is an activity to explore various research references such as journals, scientific articles, papers, standard documents that have

subjects related to Building Information Modeling (BIM) and scheduling using the Time Cost Trade Off method. These references are used as references in completing this Final Project.In a study, primary data and secondary data are two general types of data needed. Primary data is obtained directly by researchers through interviews, experiments, surveys, and so on. While secondary data is data obtained from third parties or previous researchers. The data used in this study is secondary data from the contractor company that implements it
this project.

The data obtained is in the form of shop drawings, S curve data, bill of quantity (BOQ) which will be used in BIM modeling, scheduling, and budget planning calculations. In addition, there is HSPK 2022 data for Brebes Regency provided by the Brebes Regency Public Works Service. At this stage, the data collected from the contractor will be modeled using BIM software, namely Allplan. Shop Drawing and detailed structural information will be modeled into a 3D form so that information such as the volume of the item being reviewed can be obtained.
Collision check is one of the features available in Allplan software to check whether the structural elements being modeled do not collide or overlap with other elements. This check is useful to ensure that the modeling is in accordance with the drawing data listed on the shop drawings.the project budget plan is calculated based on the volume of work multiplied by the unit price based on the standard price in the project construction area. Work items are scheduled systematically by calculating work productivity, dependencies between jobs, critical activities, free float, total float. Using scheduling data from Microsoft Project and financing from Microsoft Excel, things such as crash duration, cost slope, and crash slope are analyzed. From these data then look for the optimum point based on the addition of working hours of 1 hour, 2 hours. and 3 hours of work. The construction process is simulated in 4D using Synchro 4D so that the visualization of the construction process can be seen with modeling that is integrated with work schedules and costs.
By referring to the output of this study, the authors conclude the research results and provide suggestions for the development of similar research that can be carried out by other parties in the future.

Time Cost Trade Off. BIM level 4D modeling is done using BIM Allplan and Synchro 4D software. The implementation of these two softwares is still rarely used in Indonesia because they are not as popular as similar products from Autodesk. Allplan is a product from the Nemetschek company originating from Germany with a function similar to other BIM software such as Autodesk Revit, namely being able to create complex models accompanied by detailed information on each work item and can be accessed in real time by various stakeholders. Meanwhile, Synchro 4D is a product of the British company Bentley. Synchro is a BIM software capable of displaying modeling accompanied by visualization of the construction process that is integrated with scheduling. The use of the BIM method at the 4D level plays a role in reducing the potential for waste materials and evaluating scheduling and work methods so that cost and time efficiencies can be achieved. Furthermore, due to the limited number of available workers and considerations of the spread of the COVID-19 virus due to the addition of workers from outside the project site, an alternative acceleration is carried out in the form of optimum working hours (overtime) using the Time Cost Trade Off method.

2.1 Bridge General Data

The project name Construction of the Pemali Bridge on the Brebes-Tegal North Ring Road Project Project location Winduaji Village, Paguyangan District, Brebes Regency, Central Java Province Bridge Width 9.8 meters Bridge Length 130.4 meters Bridge Type PC-I Girder Bridge

Main Structure Reinforced concrete Bridge Material Data: Concrete Quality 29 MPa for column, pier head, slab 21 MPa for pile caps Steel Quality 400 MPa (U39) and 240 MPa (U24) for ϕ < 13mm
Existing Conditions abutments Partially Built (Backwall and Wingwall continued construction) Piers and Pierheads Pier Column Has Been Partially Constructed (construction will continue with the construction of the pier head). Girders Construction work will be carried out Diaphragm Construction work will be carried out Slab Decks Construction work will be carried out Step Plate CoParapet Construction work will be carried out

2.2 Technical Analysis
The design of the Pemali bridge refers to the regulations in force in Indonesia, which include The calculation of the Budget Plan refers to the Regulation of the Minister of PUPR No. 28/PRT/M/2016 Modeling using the BIM method refers to PUPR Ministerial Regulation No. 22 of 2018.
Equipment and Materials The equipment used in this study includes: Laptops Allplan software Microsoft Project software Microsoft Excel software Synchro 4D Software

3 Results and Discussion

The work on this final project uses data from the Brebes-Tegal North Ring Road Development Project with an overview of the Pemali Bridge Development Project. The following is general data for the Brebes-Tegal North Ring Road Development Project:
The duration of the construction of the Pemali Bridge project is 17 weeks or 117 working days. As for 1 week there are 7 working days, and in 1 working day there are as many as 8 working hours. Job duration is specifically displayed as a result of data processing using Microsoft Project software.
This structural modeling is carried out by referring to the shop drawings of the project. The items include modeling of Abutment, Pier, PC-I Girder, Diaphragm, Deck Slab, Step Plate, Parapet. Due to the absence of elements that specifically regulate the creation of models for several structural items, the drawing is done manually using the 3D line tool, then converting it into a 3D surface, so that it can be extruded.
Abutment modeling refers to the drawings contained in the project shop drawings where the drawings are done manually because there are no elements for making abutments.
Pier and pier head modeling refers to the drawings contained in the project shop drawings where the drawing is done manually for the pier head and directly with cylinder tools for the bridge pier.
The PC-I Girder modeling refers to the drawings contained in the project shop drawings where the drawing is done manually because there are no elements for making abutments. The PC-I Girder items were not modeled for the reinforcement in this study.
Modeling of the Support and Field Diaphragm refers to the drawings contained in the project shop drawings where the drawing is done manually because there are no elements for making abutments.
Deck Slab modeling refers to the drawings contained in the project shop drawings where the drawing is done manually because there are no elements for making Deck Slab with Bondex Plates.
The stamping plate modeling refers to the drawings contained in the shop drawings of the project where the drawing is done manually because there are no elements for
making Deck Slabs with Bondex Plates.

Parapet modeling refers to the drawings contained in the shop drawings of the project where the drawing is done manually because there are no elements for making Deck Slabs with Bondex Plates.
After the structure is modeled, the reinforcement of each bridge structure item is modeled. The reinforcement modeling is done by using tools on the action bar, namely Reinforcement.
Reinforcement modeling is generally carried out using tools, namely Bar Shape where the shape of rebar can be selected according to the presence of families of rebar items. For types of reinforcement that are not available in families, customization can be done using the free form menu.
Making reinforcement in abutments is done by first selecting the abutment modeling items. Then reinforcement modeling is carried out with the Bar Shape tool based on the reinforcement parameters contained in the shop drawing of structural work items.
Making reinforcement on the pier is done by first selecting the abutment modeling item. Then do the reinforcement modeling with the Place Bar Shape tool then select Circular Reinforcement. As for the pier head, the Bar Shape tool is used to model the reinforcement. The entire reinforcement is modeled based on the reinforcement parameters contained in the shop drawings of structural work items.
Making the support and pitch diaphragms is done with the Bar Shape tool. The entire reinforcement is modeled based on the reinforcement parameters contained in the shop drawings of structural work items.
Making reinforcement on the deck slab is done by first selecting the deck slab modeling item. Then do the reinforcement modeling with the Enter Area Reinforcement tool then select Span Reinforcement. The entire reinforcement is modeled based on the reinforcement parameters contained in the shop drawings of structural work items.
Stepping plate making is done with the Bar Shape tool. The entire reinforcement is modeled based on the reinforcement parameters contained in the shop drawings of structural work items.
Making a parapet is done with the Bar Shape tool. The entire reinforcement is modeled based on the reinforcement parameters contained in the shop drawings of structural work items.
All plan results
Structure Volume = 16,231 m3
Rebar Weight = 103,838 kg

Conventional Results
Structure Volume = 17,141 m3

Project Scheduling
Identification of Relationships Between Jobs. Relationships and linkages to each work activity are obtained from the results of project data processing listed in Table 4.2. below this. With the use of Microsoft Project software, these interrelationships are formed in the network in the process of identifying critical activities.

Calculation of Crash Duration
The work plan to be carried out with crash duration in the form of additional working hours is as follows: The duration for normal working hours is 8 hours of work per day (08.00 – 17.00) assuming there is 1 hour of rest (12.00 – 13.00). Meanwhile, overtime hours are carried out after a period of normal working time, namely for a maximum of 3 hours per day.In the addition of 1 hour, 2 hours, and 3 hours of overtime hours, the productivity coefficients are 90%, 80%, and

70%. The following is an example of a calculation along with a table of results from a crash duration analysis for each overtime hour: Crash Duration For Addition 1 Hour Work. The following is an example of the calculation stages for Diaphragm repair work:

Based on the data above, several things that can be concluded include:
The addition of 1 working hour resulted in a reduction in duration of 2 days with an additional direct cost of IDR 117,096.75. The work that experienced compression included the installation of diaphragm formwork.
The addition of 2 working hours resulted in a reduction in duration of 13 days with an additional direct cost of IDR 309,108.11. The works that experienced compression included installation of diaphragm formwork, diaphragm reinforcement, diaphragm casting, floordeck installation, deck slab reinforcement, slab deck casting, deck slab formwork installation, parapet steelwork, stamping plate steelwork.
The addition of 3 working hours resulted in a reduction in duration of 13 days with an additional direct cost of IDR 619,656.62. The works that experienced compression included installation of diaphragm formwork, diaphragm reinforcement, diaphragm casting, floordeck installation, slab deck reinforcement, slab deck casting, slab deck formwork installation, parapet ironing, parapet casting, stamping plate steelwork.

Visualization of work in 4D requires documents including the IFC BIM file obtained from Allplan modeling, then the scheduling document in the form of an .XML Microsoft Project file as shown in **Figure 1**. The two files are inputted so that the monitoring process of project scheduling and financing can be controlled by all stakeholders involved.

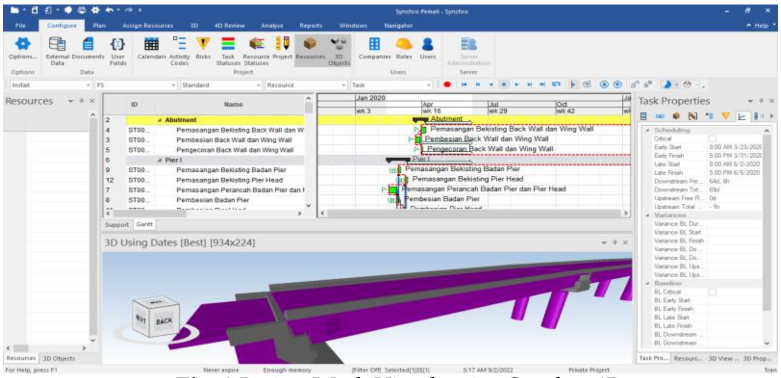

Fig. 1 Project Work Visualization Synchro 4D

4. Conclusion

Based on the results of research that has been carried out using the BIM 4D method and the Time Cost Trade-Off method, it can be concluded that The use of the BIM method is capable of producing an average material efficiency of 5% which has an impact on the total financing of the Pemali Bridge construction project. The use of BIM produces a value of the Planned Budget (RAB) of Rp. 14,604,602,751.62
The total duration that can be accelerated for each additional working hour is as follows In the addition of 1 hour of work, an acceleration of the duration of 2 days is obtained. In the addition of 2 hours of work, an acceleration of the duration of 13 days is obtained. In the addition of 3 hours of work, an acceleration of the duration of 13 days is obtained

Additional costs required as a result of additional working hours are as follows:
The addition of 1 hour of work results in an additional cost of Rp. 117,096.75 so that the total project cost is Rp. Rp14,604,719,848.37
The addition of 2 hours of work results in an additional cost of Rp. IDR 309,108.11 so that the total project cost is IDR 14,604,911,859.73
The addition of 3 hours of work resulted in an additional fee of Rp. Rp. 619,656.62 so that the total project cost is Rp. Rp14,605,222,408.24
Based on the results of the Time Cost Trade-Off analysis, the optimum duration of project completion with additional working hours (overtime) is 13 days with an additional direct cost of Rp. Rp309,108.11.
Using Synchro 4D helps in visualizing work connected to scheduling. This helps stakeholders control the course of work with well-visualized work methods.
In this study, acceleration only focused on increasing working hours because adding workers was a serious consideration during the early days of the pandemic at that time. Therefore, it is very possible to accelerate in the future with a focus on adding tools or using more efficient work methods.
The BIM modeling that was carried out was limited to the work of the bridge superstructure only. Therefore, it is hoped that in the future further research will be able to carry out BIM modeling with the scope of architectural and landscape work in the bridge area.
This research focuses on the consequences of additional costs due to additional working hours. Therefore, it is hoped that in the future there will be a calculation of the consequences of fines due to default in the form of delays in completing work according to the contract. So that the contractor can control losses incurred by taking steps such as adding tools, changing work methods, and adding overtime hours.

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