MULTIPLE IMPACT ANALYSIS OF PILING WORK ON HIGHWAY PROJECTS USING THE EVM METHOD

Mik Wanul Khosiin¹*, Tatang Ary Gumanti², Ali Muktiyanto³, Widi Hidayat⁴

¹ National Taiwan University, ² Indonesia Open University, ³ Airlangga University

*Corresponding author: d10521024@ntu.edu.tw

Abstract
A Toll road is one of the economic growth facilities of a country. In the last seven years, Indonesia has succeeded in building 1900 km, and one of them is Trans-Java. The Gempol-Pasuruan section-2 toll road project is a densely populated route. There are many intersections in the form of roads and rivers, so the project has many overpasses or underpass structures. Although the bridge structure is a sub-project of the main road, if the productivity does not perform well, it will significantly impact the overall progress. Therefore, this study wants to analyze the multiple effects of one of the critical works of the bridge project, such as the pilling work on the total toll road progress through the earned value management (EVM) method. EVM is a widespread technique among practitioners and academics; however, analysis of complex projects (main projects-sub projects) has never been carried out in-depth. It will be a unique challenge in this study. There are four steps in this research; the first step is project scheduling, in which the engineer can use the previous database to prepare the work breakdown structure (WBS), work sequences, and project duration. The second step is the critical path process; at this stage, a slack analysis is carried out for each activity, and setting a network diagram to generate essential paths for the toll-bridge project. Resource management is the third step that involves a lot of documents from the market and internal databases, starting with assigning resources, inputting quantity and unit prices, and doing the leveling process so that the supply chain runs well. The last step is the earn value process; at this stage, the engineer only needs to input the project progress, set the baseline, and finally get the ear value project and project performance index consisting of SPI (schedule) and CPI (cost). Finally, after going through several stages of research, it has been proven that the pilling work is on a critical path, and several scenarios must be carried out to maintain its productivity. Then, the average SPI value is 0.94 < 1, while the SPI value means that the Gempol-Pasuruan section-2 toll road project is experiencing delays and is within the project budget. In conclusion, applying the EVM method to MS. Project 2013 can evaluate complex projects well. Several potential technologies can also be considered in further study to improve performance.

Keywords: Pilling work, Toll Road Project, EVM, SPI, CPI

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INTRODUCTION

Indonesia's economic growth from year to year is quite stable at 5% per year which is an indication of economic stability that can be felt by all Indonesian people such as the stability of the rupiah exchange rate, stable prices of goods, stable transportation, stable exports and imports as well as increasing economic activity in the community [1]. One of the reasons of economic growth is the existence of adequate and equitable infrastructure, especially transportation infrastructure, namely toll roads. The toll road, which is a freeway dedicated to four or more wheeled vehicles, has proven to be able to facilitate the flow of logistics, trade, and reduce city traffic jams. This is what makes toll roads one of the spearheads of Indonesia's economic growth [2].

The construction of toll roads in Indonesia is one of the country's important agendas which has become a national project [3]. Based on the ideals of the founders of the nation that Indonesia consists of several islands and is separated from the sea so that bridges and toll roads must be built to unify the country. Currently, the construction of toll roads is evenly distributed throughout Indonesia, starting from Trans Sumatra to Trans Java, Bali, Nusa Tenggara, Kalimantan, Sulawesi, to Papua. [4].

The construction of toll roads has become popular in developing countries lately, the Indonesian government has established the toll road project as one of the national
strategic programs to support smooth transportation and the country's economic growth. Trans Java toll road with a length of 1167km that stretches from Merak port, Banten to Banyuwangi city, East Java which is still under construction at this time [5]. Java Island has a diverse topography, there are many rivers and mountains. Java is the most populous island in Indonesia and has a variety of mountainous contours so that in the design of toll roads there will be a lot of overpass and underpass bridges to connect the toll road itself as well as to connect existing roads that are passed by toll road projects [6].

Generally, bridge foundations are designed using piles to obtain a stable structure. However, the implementation of piling work on toll road projects is very challenging because in each bridge structure package, the characteristics of the soil are different, access is difficult to reach, bad weather, even contractors often experience equipment damage so that even though the piling work is a minor work, it has an impact. significant and widespread if progress is not achieved. The delay in the piling work causes delays in the completion of the bridge structure and means that the toll road cannot be connected optimally, in other words, the piling work in the toll road project is one of the jobs that are on a critical trajectory which is not allowed to have a pause or experience delays though [7].

Therefore, this study will conduct a multiple impact analysis through earn value management (EVM) to find the relationship between erection work and other work in terms of cost and project implementation time, and in this case the Gempol – Pasuruan project section-II is the case study location (Figure 1), for further evaluation and analysis [8]. The Gempol Pasuruan Toll Road Construction Project Section II is one part of the Trans Java toll road construction program, which connects the Gempol area to the city of Pasuruan. The Gempol Pasuruan Section II Toll Road Construction Project began in February 2017 and must be completed, handed over and operational in the second week of June 2018 (homecoming Eid 2018) by PT. Jasa Marga.

![East Java map and the design of Gempol-Pasuruan toll road](Source: Kompas, HK-Gorip KSO)

**Figure 1.** East Java map and the design of Gempol-Pasuruan toll road (Source: Kompas, HK-Gorip KSO)

**RESEARCH METHODS**

EVM technique has been applied to assist several construction activities such as project monitoring [9]–[13], performance measurement [10], [13]–[15], prediction process [14], risk analysis [16], project controlling [9]–[13], [15]–[17], cost control [9], [11]–[13], [15], etc. Previous studies have also carried out the use of project control methods involving EVM and critical buffer management (CBM) methods to improve analysis performance to make it more reliable [17]. However, so far, multiple impact analysis through EVM has never been applied comprehensively for multiple complex projects such as analyzing the impact of delaying one critical work (e.g. pilling work) on a bridge project on a toll road project (sub-project to main project). In this case, the contractor's expertise is very demanding to be able to develop mitigation of performance failures. So that through the EVM method the contractor can predict the value of CPI and SPI to see project performance and ensure that the work continues according to the targets set by the stakeholders [18].

The EVM technique is a method used by construction managers to measure project performance in terms of time and cost, therefore the EVM method is becoming very popular. The implementation of the EVM system begins with the preparation of a work breakdown structure (WBS) for all work items involved in the toll road project and highlights the erection work and its relationship to the project as a whole [19]. On the MS program. The next project, each work item is given a project schedule and sequence of work. The next stage, a critical path analysis will be carried out using the CPM technique, to ascertain whether the erection work is a fundamental work or not. The project is continued by including all types of resources involved along with their unit prices such as materials, materials, tools, labor, etc. Then the data that has been inputted is analyzed using the EVM method. This method is broadly obtained from the budget at completion multiplied by the percentage of actual progress which must be entered after the resource input process is complete. Then the comparison between the earn value (1) or budgeted cost of work performed (BCWP) with the actual cost (ACWP) will get the cost performance index (CPI) (3) and when compared with the planned value (PV) or
budgeted cost of work scheduled (BCWS) will get the value schedule performance index (SPI) (2) [14].

\[ EV = \text{Actual} \% \text{ Complete} \times BAC \]
\[ EV : \text{Earned Value} \]
\[ BAC : \text{Budget at Completion} \]
\[ SPI = \frac{BCWP}{BCWS} \]  
(1)
\[ CPI = \frac{BCWP}{ACWP} \]  
(2)

- Finish to Start (FS), meaning that job B can start after job A is finished
- Finish to Finish (FF), meaning that both jobs A and B are completed simultaneously.
- Start to Start (SS), meaning that jobs A and B are started simultaneously.
- Start to Finish (SF), meaning that job A can only start when job B has started

The third step is to determine the length of time for the work, and the determination of the start and completion date of the work is carried out after the work item relations are completed [22].

**Critical Path Method (CPM)**

This phase is part of the first time control analysis in a series of application of the EVM method so it must be carried out carefully and carefully. The critical path is a work network that has the longest duration, or a network in which each work item has a slack value equal to zero, which means there is no lag time between jobs. So that if the work at the beginning is delayed, it will slow down the performance of the work at the end [23].

**Resources Management**

After the schedule is formed, the next step is to enter resources or so-called assign resources used in the bridge project, both in the form of materials and labor [24]. In this stage, the volume of work and the unit price of work are also included, so that the outputs at this stage are project costs, resource management, and time control of implementation.

a. Project costs, based on input volume and unit price of work.

b. Resource management, the volume of resources that we have included in each job, where the work schedule is tight so that the use of resources will accumulate on certain days and exceed the capacity of the resources that have been determined, so that in the MS. In the 2013 project, to overcome this problem, resource leveling was carried out, so the result was that there were no working days with the use of resources exceeding the maximum capacity that had been set. [25].

c. Controlling implementation time, the impact of the process of equalizing resources, one of which is delaying work and putting on work days that are relatively more ready to receive additional work, in other words, the duration of work is extended or moving the working day backwards, this stage is part of controlling project time.

**Earned Value Analysis**

After distributing resources, the next step is the process of running the project or entering the project progress, if the status of the bridge project is measured at the end of May 2018, the bridge project has been completed 100% based on the work in the field, but to

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**Figure 2.** The diagram of Earn Value mechanisms

**Scheduling Process**

Piling work is the first stage of the construction of the bridge foundation, while the bridge foundation is one part of the bridge building (Figure 2). In addition, there is a link between the first bridge to the ninth bridge of the Gempol-Pasuruan Section II Toll Road construction project, especially due to the piling work. So it is necessary to make a schedule that integrates all work items and the relationship between bridges. The process of making schedules, and controlling time for all work items is used by the MS program. Project 2013. The first step is to enter the type of bridge that uses a pile structure along with a breakdown of the work items for each bridge [20]. After entering the list of work items, the next step is to determine the relationship between the work items [21]. In the MS program. Project 2013 job relationships are called predecessors which have four kinds of relationships between jobs, namely:
compare the planned costs to the actual costs achieved requires a separate analysis.

The earn value method or the yield value method is a cost control concept, which can answer the efficiency or loss experienced by the project, besides that this method can determine whether the project status is running on schedule, sooner or later than the predetermined schedule. MS. Project 2013 in the system is equipped with an analysis of the Earn value method.

Table 1. WBS, CPM, and assigning resources result

To carry out the analysis process in this program, you must follow the procedure according to Figure 1 or in the following order [22].

1. Project progress
   The first step is to include job performance according to the conditions in the field, in the MS program. project 2013 to enter work performance using the "% Complete" column. By entering work performance into the program, the system will calculate the actual costs incurred by the project based on the actual achievements entered [24].

2. Baseline management
   After doing a series of planning, both time, resource and cost planning. Then the next step is to determine the baseline or reference in project planning. This reference can be used as a reference and project control tool in the cost control process.

3. Determining the project period
   Before the Earn value method analysis process begins, it is necessary to set the period or time span that will be processed in the Earn value method analysis. The determination of this period will determine the accuracy of the assessment of the status of the bridge project being studied. The best period is from the project start date to the end of the field implementation work date.

   4. Earn value management
   Basically, after carrying out a series of previous steps correctly and completely, indirectly the Earn value method analysis process is automatically processed by the Microsoft Project 2013 program. The next step is to ensure that the analysis process is running or not, by selecting the Earn value method table in menu available in MS. Project 2013. Finally, at the end of the process, a table of EVM, SPI, CPI values will be obtained automatically to determine the performance of the project being evaluated. [25].

RESULTS AND DISCUSSIONS

Table 1 shows that the erection work for all bridges on the Gempol-Pasuruan section II toll road project is in the critical network (red color) so that if the erection work is interrupted or has low productivity, it will be able to affect the completion target of bridge construction and main road overall.

Table 2. Earn value management (EVM) result

<table>
<thead>
<tr>
<th>Bridges</th>
<th>BCWS (IDR)</th>
<th>BCWP (IDR)</th>
<th>ACWP (IDR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wetan B.</td>
<td>3.37B</td>
<td>3.36B</td>
<td>3.36B</td>
</tr>
<tr>
<td>Welang B.</td>
<td>10.45B</td>
<td>9.71B</td>
<td>9.33B</td>
</tr>
<tr>
<td>Tidu B.</td>
<td>3.94B</td>
<td>2.92B</td>
<td>2.92B</td>
</tr>
<tr>
<td>Legowok B.</td>
<td>2.77B</td>
<td>2.73B</td>
<td>2.73B</td>
</tr>
<tr>
<td>Parasrejo-1 B.</td>
<td>3.31B</td>
<td>2.97B</td>
<td>2.97B</td>
</tr>
<tr>
<td>Parasrejo-2 B.</td>
<td>3.44B</td>
<td>3.25B</td>
<td>3.25B</td>
</tr>
<tr>
<td>Pedestrian B.</td>
<td>1.52B</td>
<td>1.52B</td>
<td>1.52B</td>
</tr>
<tr>
<td>Interchange B.</td>
<td>7.15B</td>
<td>7.15B</td>
<td>7.15B</td>
</tr>
<tr>
<td>Parasrejo-3 B.</td>
<td>8.90B</td>
<td>8.90B</td>
<td>8.90B</td>
</tr>
</tbody>
</table>
Table 3. The project performance indexes

<table>
<thead>
<tr>
<th>Bridges</th>
<th>SPI</th>
<th>CPI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wetan B.</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Welang B.</td>
<td>0.93</td>
<td>1.04</td>
</tr>
<tr>
<td>Tidu B.</td>
<td>0.74</td>
<td>1.00</td>
</tr>
<tr>
<td>Legowok B.</td>
<td>0.98</td>
<td>1.00</td>
</tr>
<tr>
<td>Parasrejo-1 B.</td>
<td>0.90</td>
<td>1.00</td>
</tr>
<tr>
<td>Parasrejo-2 B.</td>
<td>0.94</td>
<td>1.00</td>
</tr>
<tr>
<td>Pedestrian B.</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Interchange B.</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Parasrejo-3 B.</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Index Average</td>
<td>0.94</td>
<td>1.00</td>
</tr>
</tbody>
</table>

The CPI value is equal to 1, so it can be concluded that the project is experiencing delays and also suffers from inefficiency (Table 3).

**CONCLUSION**

Based on the critical path method (CPM) analysis of the MS. Project 2013 has found that the pilling work is on a critical path and has an important influence in determining the duration of the bridge project implementation and the overall progress of the main road. Thus, according to the earned value method analysis, it can be concluded that the bridge project has a CPI value of 1 = 1 and an SPI of 0.94 < 1, so the bridge project is experiencing delays and is working according to a predetermined budget.

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**REFERENCES**


