Project Schedule Evaluation Using Project Management Software: A Case Study in an Electric Steam Power Plant in Indonesia

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Abstract. Project scheduling plays an important role among knowledge areas according to Project Management Body of Knowledge (PMBOK). There are six constraints to be considered in managing a project: scope, cost, schedule, quality, risk, and human resource. In project scheduling, a schedule baseline must be determined properly in order to meet all deliverables presenting schedule milestones, the activities, and network diagram. Each process within project scheduling management (inputs-tools and technique-outputs) are: (1) plan schedule management; (2) define activities; (3) sequence activities; (4) estimate activity duration; (5) develop schedule; (6) control schedule. According to the data obtained, the shelter at ash disposal was accomplished 19 days behind the target set of 38 days. This condition is evaluated using project scheduling process. One constraint involved are 18 human resources assigned into the project. A new schedule is proposed by interviewing the project sponsor to identify the dependencies among activities and simulated using a project management software called Microsoft Project 2016. It can highlight the critical path as well as leads and lags of all activity. The new schedule result shows that project completion can increase 9 days from 57 days to 48 days.

1. Introduction
Projects are required to balance the constraints; time, budget, quality, risk, scope, and human resources. The implementation of a project often does not work properly as it was planned. In order to execute the project according to the plan, scheduling becomes one of the basic requirements of project management planning and analysis. The scheduling is integrated with other constraints such as budget, scope, and resources. The activities within a project can be conducted faster when a project can provide more budget to hire several resources. Vise versa, it can be longer if there is only limited budget that the human resources can be limited as well. However, the constraints must be managed in order to meet the project deliverables. Project scheduling is a tool for communication, managing stakeholders’ expectation, and as a basis performance reporting that provides a detailed plan how and when the project will deliver the products, services, and results [1].

More companies are clearly seeing the benefits of managing project in order to build organizational project management expertise: lower costs, greater efficiencies, improved customer and stakeholder satisfaction, and greater competitive advantage [2]. Project management performance, which evaluates success mostly based on budget, schedule, and requirement goals, becomes an indicator to project success. Benefits evaluation of a project performance through Benefits Realisation Management method
shows a positive correlation to project success on the creation strategic value for the business [3]. According to [4], a project success is measured by product and project quality, timeliness, budget compliance, and degree of customer satisfaction. Project management focuses on the ability to deliver the project’s product in scope, time, cost and quality known as the traditional iron triangle. Even though this iron triangle can not only be the main measurement of project success, most project managements still believe that time and cost are they key of it [5].

According to [6], the project management tools for project management success are several including WBS (work breakdown structure), PDM (Precedence Diagram Method), and Resource Leveling. Accordance with the results of [6], the precedence diagram method (PDM), Critical Path Method (CPM), and Critical Chain which is based on CPM the most common scheduling methods [1]. Project management software is also one of project management success factor [6]. Based on survey of 497 participants, project management software is a measurement of success [7]. Project management software (PMS) is required to support organizing, planning and managing resource in project management. They are capable of dealing with estimation, project scheduling, budget management, resource assignment, cooperation, communication, decision-making, quality management and administration system. Spreadsheet program Microsoft Excel 2016 and Microsoft Project 2016 are used for cost optimal time scheduling in construction [8]. Excel’s add-in solver was allowed to execute the cost optimization of example project time schedule applying the developed model. Afterwards, Microsoft Project software was employed for further organizing and presentation of optimized time scheduling solution [9].

Ash Disposal is a place or area of waste disposal in the form of dust from coal combustion processing. Ash Disposal itself is located on an artificial hill south of the power plant. On Ash Disposal, waste dust is processed to be more environmentally friendly and does not cause pollution. Whereas Shelter at Ash Disposal is an open building that is used to store drum oil as fuel for processing waste dust on Ash Disposal. Because of consideration of distance and cost efficiency, it was necessary to build a Shelter at the Disposal. Yet, the real project was completed in 57 days while the planned target was initially finished within 38 days. The project was 19 days behind the planned schedule. Therefore, this study aims to evaluate the real project using Project Management Software, Microsoft Project 2016 based on Project Scheduling Management steps in Project Management Body of Knowledge (PMBOK) 6th edition. The proposed schedule was introduced to compare to what company has carried out.

2. Methods

2.1 Schedule data

The data was obtained from the third party who conducted Shelter at Ash Disposal construction project in an electrical steam power plant in Indonesia for almost 3 months observing and interviewing. Shelter at Ash Disposal was selected as the research object since it had just been completed several months before our study started. The data collection were activity attributes and identified constraints. We also gathered relevant information related to the project by interview the Project Manager and supervisor as well. In this study, man power or human resource was treated as the constraint since the third party employed fixed number of human resource during the project. While other constraints, risk and cost, were excluded.

2.2 Data analysis

According to project schedule management explained in Project Management Book of Knowledge (PMBOK) 6th edition, there are 6 processes required in order to manage the completion of the project. The real project schedule was evaluated based on each process, they are: plan schedule management, define activities, sequence activities, estimate activity durations, develop schedule, and control schedule as can be seen on the conceptual model Figure 1. Plan schedule management. The output is schedule management plan consisted of project schedule model development, release and iteration length, level
of accuracy, organizational procedures links, and so forth. Project schedule model management provides project description.

1. Define activities. It means that decomposing WBS (work breakdown structure) into schedule activities in order to provide a basis for estimating, executing, monitoring, and controlling the project work. In this part, milestone list is one of the outputs.

2. Sequence activities. We identified the relationships among activities both predecessor and successor using Precedence Diagram Method (PDM) together with leads and lags analysis. There are 4 relationships of activities according to PDM: Finish-to-Start; Finish-to-Finish; Start-to-Finish; Start-to-Start. These relationships will assist the project team to assign resources including human resources and materials. It will be treated differently.

3. Estimate activity durations. We documented the duration of each activity that had been defined by the project team.

4. Develop schedule. The data was analysed using Critical Path Method (CPM) and resource levelling. Software was applied to process both methods considering schedule constraints. This study treated resource limitation as the constraint inputed into software processing.

5. Control schedule. It helps project to monitor and manage the changes.

A new schedule using Project Management Software was proposed due to the delay of 19 days so there was a comparison for the schedule evaluation and review. Microsoft Project 2016 was employed because it inform us the critical path of the project, the leads and lags, and overallocated human resources employed for the project. Furthermore, the auto mode schedule option was set for the proposed schedule in the software while the real schedule was applied manually. We studied whether or not the human resources provided were enough to conduct the project. If it is found an overallocated signal on the software, the levelling item will be used to overcome the problems. It is an iterative action to check and action until a fixed schedule is determined for a project baseline.

3. Results and Discussion
Before evaluating the scheduling, work breakdown structure was required as a baseline for project team because it provided a clear framework of the project in order to communicate with all stakeholder involved as well as to effectively manage and control the project. WBS was determined in the project scope management (it is the second knowledge according to PMBOK). The work packages of the project consist of foundation, floor, wall, roof, and finishing spread into 23 activities. The detail of each work package is shown in Figure 2. There are 3 level of WBS (level 1 is vision of end product; level 2 is parent elements; level 3 is child elements).
3.1 Plan schedule management

One output of plan schedule management is schedule model management. In this schedule model, project description and project calendar (start-end) have to be explained. Shelter at Ash Disposal project was carried out by third party (a contractor company) sponsored by the electric steam power plant. The working hour is 07.00-16.00 with an hour for lunch time from Monday to Sunday. The real schedule started on 4 December, 2017 and finished on 29 January, 2018 for 57 days. However, after software processing using Ms. Project 2016, it supposed to be completed 2 days earlier which is 55 days completion. For the new schedule, it was assumed to be started on the same date, 4 December 2017. Yet they have different completion time. According to data, the real schedule ended on 29 January, 2018. While the new schedule finished earlier on 20 January, 2018.

3.2 Define activities

In this activity, there are several output to be performed such as milestone, activity calendar, and activity code. According to the real schedule, it was stated the start and end date of each activity. Then we assumed the milestones were every deliverable on level 2: foundation, floor, wall, roof, and finishing. Meanwhile, we did not define the completion date until the processing ended for the new schedule. It was found that the project could finish 9 days earlier due to the changes of activity dependencies. The milestones are listed below:

| Milestone Description | The real schedule          | The new schedule          |
|-----------------------|-----------------------------|----------------------------|
| Begin the project     | Monday, 12/4/2017           | Monday, 12/4/2017          |
| Complete Foundation   | Friday, 12/15/2017          | Friday, 12/15/2017         |
| Complete Floor        | Thursday, 1/4/2018          | Monday, 1/1/2018           |
| Complete Wall         | Monday 1/22/2018            | Thursday, 1/11/2018        |
| Complete Roof         | Saturday 1/27/2018          | Wednesday, 1/17/2018       |
| Finish the project    | Monday, 1/29/2018           | Saturday, 1/20/2018        |

3.3 Sequence activities

In the sequence activities step, the activities were defined each relationship using Precedence Diagramming Method (PDM) followed by leads and lags determination. According to the data given by
the company, it was not written explicitly any relationship among those activities of the real schedule. Yet, we could conclude it by reading the data obtained. Most activities had predecessor but digging footplate in foundation and inspection in finishing. Based on Gantt chart in software, all activity was finish-to-start relationship (F-S) explained in figure 3 below. For example, shoring for footplate in foundation could not be started unless digging footplate finished. Backfill and levelling were conducted after install formwork for pedestal and install anchor bolt m24 were completed. It is showed that install formwork for pedestal was Start-to-Start (SS) relationship with shoring for footplate. While install anchor bolt m24 was a Finish-to-Finish relationship with 2 activities, pouring concrete for footplate and install formwork for pedestal. However, leads and lags did not find in this real schedule. It did not explained the dependencies among the activities as well whether they are mandatory, discretionary, internal, or external.

3.3.1 Leads and lags. Actually leads and lags did not determine for both real and new schedule. They were found after processing the data in software shown in figure 3. The leads and lags were occured in new schedule since we changed the dependencies based on the interview with project sponsor. The real schedule presented that most of the activities were Finish-to-Start relationship while there were various relationships found in new schedule after simulated using the software (figure 3). According to the interview with project sponsor, install anchor bolt m24 had Finish-to-Finish dependencies with pouring concrete footplate. It was a Finish-to-Start with pouring concrete footplate in the real schedule. Another change was the predecessor of install anchor bolt m24 which was 2 predecessors in the real schedule reduced to 1 predecessor in the new schedule.

In work package 2 (floor), the predecessors of install formwork sloop and floor were pouring concrete pedestal and backfill and levelling. It represented 2 days leads with install formwork sloop and floor, and Start-to-Start relationship with backfill and levelling. They were not found in the real schedule. However, install anchor bolt m24 in the real schedule was replaced with backfill and levelling. Install flashing and gutter in work package 4 (roof) informed another leads. It had a Finish-to-Start relationship with install roofing but the install flashing and gutter activity could begin oneday earlier before install roofing finished. Install rafter (wall work package) was shifted to Finish-to-Finish relationship with install and welding coloumn whereas they were in Finish-to-Start based on the real schedule data.

As we mentioned before that these leads were incurred since some relationships modified. It could be more optimized if other informations or constraints added into the software such as cost, risk, and resource provided. In this case, the resources was inputted to the schedule calculation. Nevertheless, it showed a better scheduling which it was 9 days faster than before which was close to the target set of 38 days completion. There is a possibility that the constraints can conflict each other. By simulating the scheduling using project management software, we can determine the best scenario for the project.

3.4 Estimate the activity duration
Activity duration is required in order to estimate the number of work periods to complete the project. It produces the overall duration estimation of the project. There are several information used to estimate the activity duration such as scope of work, estimated resource quantities, resource requirement related to skill levels, and resource calender (Monday-Friday working days or including Saturday and Sunday, 8 hours work time, etc). These can be treated as constraints when estimating the duration as well as any risk related to each activity and advances in technology. Since the data obtained was very limited, the only information gained was the resources provided, not the resource requirement, and working hour. Therefore, we assumed that the real project data given had been calculated each constraints. There are 18 workers involved in the project consisted of a supervisor, a foreman, 3 welders, 2 painters, 3 scaffolders, 2 semi-skilled persons, and 6 helpers. They work Monday to Sunday started from 7 o’clock in the morning until 4 o’clock in the afternoon with an hour for lunch time (12.00-13.00). This information was also employed in processing the new schedule.

There were 5 major activities comprised foundation (12 days), floor (20 days), wall (18 days), roof (5 days), and finishing (2 days). The longest activitie duration was 7 days for each of install formwork
for pedestal and install and welding column while the shortest duration was 1 day: pouring concrete for pedestal, install flashing and gutter, and inspection. The duration of each activity was shown in Figure 3.

![Table: Schedule Comparison](image)

**Figure 3.** Comparison of real and new schedule

### 3.5 Develop schedule

In developing schedule, we used one tool called Critical Path Method (CPM). Both schedule highlighted different activities in critical path as seen in Table 1. Most all of activities were critical in the real schedule but 3 activities foundation work package: digging footplate, shoring for footplate, and pouring concrete for footplate. There were only 10 activities in critical path spread into 3 work packages (foundation, floor, and finishing) compared to 20 activities in the real schedule. Roof work package did not in the critical of the new schedule. However, it was found the resource overallocated in this work package for both install roofing and install flashing and gutter (roof work package). If the levelling option in software was run, both activities became critical with 0 float. The project completion was still 48 days without any changes due to levelling option.

The activities in floor and finishing work package remained the same for both real and new schedule. It can be concluded that those activities were critical even though a few dependencies turned. Install formwork for sloof and roof was the only replacement of relationship while others remained the same. Foundation consisted of 4 critical activities decreased to an activity in the new schedule, pouring concrete pedestal with the same predecessor.
Table 1. Critical path of real and new schedule

| Real schedule                  | New schedule                      |
|-------------------------------|-----------------------------------|
| Task Name                     | Task Name                         |
| Shelter Ash Disposal          | Shelter Ash Disposal              |
| **Foundation**                | **Foundation**                    |
| Install Formwork Pedestal (IFP)| Pouring Concrete for Pedestal (PCP)|
| Install Anchor Bolt m24 (IAB) |                                   |
| Backfill and Levelling (BL)   | Floor                             |
| Pouring Concrete Pedestal (PCP)| Install Formwork for Sloof and Floor (IFSF)|
| **Floor**                     | Ground Levelling (GL)             |
| Install Formwork Sloof and Floor (IFSF)| Install Wiremesh (IW)           |
| Ground Levelling (GL)         | Install Rebar (IR)                |
| Install Wiremesh (IW)         | Floor Concrete (FC)               |
| Install Rebar (IR)            | Install Concrete Ramp (ICR)       |
| Floor Concrete (FC)           | Grinding Concrete Surface (GCS)   |
| Install Concrete Ramp (ICR)   |                                   |
| Grinding Concrete Surface (GCS)|                                   |
| **Wall**                      | **Finishing**                     |
| Install and Welding Coloumn (IWC)| Painting (P)                    |
| Install Rafter (IR)           | Inspection (I)                    |
| Install Beam, and Purlin (IBP)|                                   |
| Install Wall from Brickstone and Plestering (IWBP)|       |
| Install Ring Balk and Concrete Wall (IWRCW)|                   |
| **Roof**                      |                                   |
| Install Roofing (IR)          |                                   |
| Install Flashing and Gutter (IFG)|                                   |
| **Finishing**                 |                                   |
| Painting (P)                  |                                   |
| Inspection (I)                |                                   |

Regarding the resource overallocated, it was not found in the real schedule. It could be caused by the Finish-to-Start relationship that every resource was assigned to do their work without any conflicting. After finishing an activity, the resources continued to conduct the next step. The new schedule indicated the overallocated on 2 activities. The same resources were assigned to both activities: foreman, helper 1, helper 2, and helper 3. Moreover, install flashing and gutter was conducted 1 day earlier (FS-1) before install roofing finished. According to the new schedule (table 1), install roofing was done between 14 – 17 January, 2018 for 4 days duration. Meanwhile, install flashing and gutter was conducted on 17 January, 2018. Based on the date, install flashing and gutter was started on the day install roofing finished. If we levelled the overallocated, install flashing and gutter turned to 2 days duration (17-18 January, 2018). We assumed that the company did not hire more resource to finish the project, then the levelling option was chosen to fix the overallocated.

4. Conclusions
The project scheduling management based on PMBOK consists of 6 major processes to be followed in order to create a good schedule baseline for a project. They are define activities, sequence activities,
estimates activity durations, develop schedule, and control schedule. Each process has tools and techniques such as Critical Path Method (CPM) in develop schedule process. The case study regarding project scheduling was evaluated by the processes of project scheduling including the dependencies of each activities listed on WBS, the duration, critical path, and the milestones list as well. In order to have a better understanding, the project management software (Microsoft Project 2016) was employed to simulate the data obtained. Then, the new schedule was proposed compared to the real schedule particularly in the activity relationship. Both schedule presented different project completion time that the new schedule was faster 9 days from 57 days to 48 days. Besides changing the relationship, another important information added to the software was resource provided. Other consideration such as risk and cost were excluded. Even though it was still behind the target set of 38 days, however, it showed a better scheduling. Eventually, the schedule baseline is integrated to all knowledge area in order to meet customer demand under uncertainties occurred.

For further research, risk and cost estimation can be added into software simulation. The dependencies can also perform different result whether it is Finish-to-Start, Start-to-Start, or Finish-to-Finish. Yet, it is required an expert judgement to validate the relationships among project activities. Leads and lags must be identified as well so that each tools and techniques provided by PMBOK can be followed properly for the best scenario of project scheduling. Another project management software can be applied for comparison even though each has strength and weaknesses. Project scheduling plays an important role among other knowledge areas according to PMBOK. Therefore, it must be planned well so the six constraints of scope, cost, schedule, quality, risk, and human resource can be managed in order to meet all project deliverable.

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