A COMPARISON OF APPLICATION OF THE PROJECT SCHEDULING USING PRECEDENCE DIAGRAM METHOD (PDM), LINE OF BALANCE (LOB), AND POSITION WEIGHT METHOD (RPWM) TO CONSTRUCT CIRCULATING CLOSE COOLING WATER SYSTEM

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ABSTRACT
Project is activity that does not happen at any time and has specific purpose. There must be a time limit on a project work, so project scheduling is needed to prevent delays. In this paper, the focus is about scheduling Circulating Close Cooling Water System construction project using Precedence Diagram Method (PDM), Line of Balance (LOB), and Position Weight Method (RPWM). The result from different methods will be compared to determine the most precise completion for Circulating Close Cooling Water System construction project. Applying PDM method, duration of the project is 210 days and its critical path is clearly visible in the PDM network.
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diagram. Contrast to the LoB method, the duration is 244 days and can’t display critical path nor invisible logic connection between activities. Meanwhile, the RPW method duration is 213 days and capable of displaying critical paths. Based on the analysis for each method, the ability to display critical paths, the logic relationships, obstacles, and usage; the suitable method to complete Circulating Close Cooling Water System construction project is Precedence Diagram Method.

Key words: Critical, Diagram, Duration, Network, Scheduling


1. INTRODUCTION

The maritime industry of the world is now experienced a rapid progress. Indonesia as archipelagic country is expected to improve its maritime industry through project work related to maritime.

Project activity itself has been known since thousand years ago. The construction of a temple or kingdom by a royal family is one of the examples. It needs planning and serious execution, since it’s not a usual task. Other human activities such as planting rice and lecture implementations are not categorized as project. An activity is called project if it took place within a certain time and had certain results. It also has uniqueness that only happened once, the same thing never repeats again, and it’s not permanent (Santosa, 1997). According to (Soeharto, 1997), project is a temporary activity that lasts for a limited time, with certain allocation of resources and is intended to carry out clearly outlined tasks.

Based on those characteristics, a project cannot be done carelessly without preparation and careful planning. Because there will be problems that may happen during project implementation, including:

- Difficulty to complete the project on time
- Frequent project implementation needs greater cost than the plan
- Difficulty to use resources as efficiently as possible (Kalangi, 2015).

Therefore, good and proper management is required to make the project done and meet the expectations. Management is a science, art of leading an organization consisting of planning, organizing, implementing and controlling limited resources in order to achieve effective, efficient goals and objectives (Husen, 2009). Management project has been widely used to make sure the project run smooth and finish on time (Silvianita., 2018a, Silvianita., 2018b). In order to achieve the goals of a project AHP can be the solution (Shafiq, 2010, Silvianita, 2013). Meanwhile, according to (Amsyah, 2003), management is the art getting things done through the people.

As (Lock, 1992) pointed out, project management is required to face the challenges caused by industrial development. So it is essential to manage time, materials, and labor in the project to avoid the problems mentioned above. Because the purpose of management is getting the best method or technical way so that with limited resources, maximum results in
terms of accuracy speed, saving, and comprehensive safety of the work can be obtained (Husen, 2009).

One of the things that must be examined closely in project management is how to arrange work schedules (scheduling) in order to avoid work delay. The lateness of a project may reduce production and, of course, decrease company's revenue. Scheduling determines when the activity is started, postponed and finished, so that the financing and resources usage can be adjusted according to predetermined needs (Mertha, 2007).

One of the usual scheduling methods used in a project is Precedence Diagram Method (PDM). PDM basically focuses on the equilibrium of cost and project completion time. PDM emphasizes the relation between the application of an amount of labor to shorten the project completion time and increase in costs as the result of additional labor (Ngurah, 2011). Dummy activity is not required on its network planning, thus become its advantage (Soeharto, 1997). In PDM, there is an important calculation to determine how long an activity can be delayed. Time delay or better known as float is the tolerance limit for the delay of an activity that can be utilized for time optimization and resource allocation (Husen, 2009). Total Float (TFi) is the total grace or maximum delay allowed for an activity without causing delays in project implementation. Total float is useful to determine the critical path. Systematically, total float (TFi) is formulated according to table 1. PDM has been used to improve the information available in computer printouts of PDM networks (Wiest, 1981). PDM has been used to explore the modeling possibilities of point to point relations (Hajdu, 2015). PDM has been used to relate between liaisons or logical combinations of liaisons in a mechanical product (George, 2016).

In addition to PDM, there is another method with a particular characteristic that can be used for repetitive projects, in example, the Line of Balance (LoB) method. LoB was first introduced by the Goodyear company in the 1940s. LoB is a linear scheduling method that can be combined with network methods, because this method is able to display information about project progress that cannot be displayed by network methods (Husen, 2009). According to Arianto (2010), LoB itself is a method that uses operation balances, each activity is a continuous performance.

The Weight Map Method was introduced by W.B. Helgeson and D.P. Birnie in 1961. This method is famous for its accumulation base which can find solutions quickly by identifying failures in production process and determining the weights of production process (Helgeson, 1961). Ranked position weighted method has been used to solve a problem of line balancing for engine production (Krantikumar, 2015). Ranked position weighted method also has been discussed to resolve problem of line balancing in cashew nut shelling machine production (Santosh, 2013).

Each methods, either network or linear method has its own advantages and disadvantages in solving problems on a project scheduling. Therefore, there will be comparative analysis of 3 methods: Precedence Diagram Method (PDM), Line of Balance (LoB), and Weight Position Method (RPWM) toward the development of Circulating Close Cooling Water System in one of the shipyard company in Indonesia.

Circulating Close Cooling Water System or commonly called CCCW system is a system for cooling equipment which exists on working components of machine in a structure or company by using heat exchangers to exchange heat of hot fluid flow (passing through the equipment) with cold fluid / sea water. This system is used when the engine is heated and needs to be cooled, as in ship engines and equipment components at power plants.
2. MATERIAL AND METHODS

2.1. Literature Study
Conducting literature study through books, journals, and internet related to project scheduling, CCCW system etc.

2.2. Data Collection
Data collection is needed in relation to the required time analysis that is project planning and design scheduling, project execution time, and project implementation location. Data obtained from the said company.

2.3. Creating Precedence Network
Networks are created to ease monitoring activities and arrange each activities so that it become more details. Before doing the calculations, it is important to create a WBS and determine the logic relationship between activities at first. Next is the calculations:

*Calculate the forward pass*
Steps in calculating the forward pass are calculating ES and EF for each activities. The forward pass calculation has to be done to determine the earliest time to start, the quickest time to finish, and total duration of the project.

*Calculate the backward pass*
Steps in calculating the backward pass are calculating LS and LF of each activities. The backward pass calculation is performed to find the longest time to start the project and the longest time to finish the project.

*Determine the critical path*
The critical path is determined by counting the float. Float can be calculated after the backward and forward pass are done. The critical path has a float equal to zero.

2.4. Creating LoB Diagram
Here are the steps of preparing LoB diagram according to (Prawira, 2014):

- Plan the implementation of each works in the form of a complete diagram with estimated time.
- Determine the length of time/duration for the implementation of each activities component.
- Determine the delivery program. In this case, can be the duration of the works.
- Determine the buffer time which is the approximate amount of required time to avoid activity conflicts.
- Illustrate the LoB diagram.

2.4. Calculating RPWM
Because this RPW method requires precedence diagram, and has been created earlier in the procedure of making network precedence, the step that needs to be done is to continue the calculation according to positional weight.

- The positional weight of each operations calculated
- based on the number of operating times and the following operations.
- Sort the operations from the largest operational weight to the smallest.
Enter priority data in MS Project.
Obtain project duration from the MS Project calculation.

2.5. Conducting a Comparison Analysis
Comparison is done based on 5 aspects:

Duration
In this aspect, we will find out which method can shorten project work time the most from 3 methods used.

Ability to display critical paths
In this critical path aspect, we will analyze which method can display critical path clearly.

Ability to display logical relationships
Of the 3 methods, ability to show dependency logic relation will be analyzed.

Ability to display obstacles
Of the 3 methods, we will see which method can display obstacles of project implementation.

Usage
In this aspect, efficiency analysis of each aspects and the most suitable method for Circulating Close Cooling Water System development will be decided.

3. RESULT AND DISCUSSION
3.1. Dependency Relation Analysis on Circulating Close Cooling Water System Project
Circulating Close Cooling Water System or commonly called CCCW system is a water filler cooling system to cool down equipments in the steam power plant using heat exchangers to exchange the heat from hot fluid flow (passing the equipments) with cold fluid / sea water. CCCW system development project is done by one of the shipyard company in Indonesia. Figure 1 shows the overview of CCCW system creation process.

Preliminary data were obtained in the form of a gantt chart in MS Project software. The block chart is constructed in order to identify the time and sequence elements in activity planning, which consists of start time, completion time, and reporting time (Nugraha, 1986).
From the data, it can be seen that the only dependency relation of project data is finish to start (FS), there is no other dependency relationships (start to finish, finish to finish, and start to start). According to (Soeharto, 1999 ), finish to start constraint explains that new successor activities can be started after predecessor activities have been completed. If there is a waiting time between predecessor and successor activities, then the time is called a lag. The project is expected to be free from lag or lag = 0, unless certain things such as climate change and chemical / physics processes take more time. This constraint is formulated with FS (i-j) = a. a is the waiting time of activity j to start after the activity i is done (lag).

3.2. Scheduling Using Precedence Diagram Method

PDM is a scheduling Activity On Node (AON) method, which its connecting line is an explanation of dependency relation between activities. Of the 4 logical dependency relations in the precedence diagram method, only one will be used, that is finish to start according to field condition and available data.

![Figure 2 Node Precedence Diagram](source)

Basically, the node shape in the precedence diagram is square with columns containing these following informations as shown in Figure 2:

- ES : Earliest Start, which is the very first start of an activity
- ID : Identification number
- EF : Earliest Finish, which is the very first end of an activity
- LS : Latest Start, which is the slowest start of an activity
- D : Activity duration
- LF : Latest Finish, which is the slowest end of an activity
- Label : Activity name

Precedence diagram is also called the node diagram or construction block diagram. On the precedence diagram, dummy activity is no longer needed. Dummy activity exists on CPM and PERT, so that the diagram becomes clean (Soeharto, 1995). The projects start with the main drawing and follow with other activities as seen in Figure 3.
MS Project 2007 is originally designed for PDM network which has 4 constraints namely FS (Finish to Start), SS (Start to Start), SF (Start to Finish), and FF (Finish to Finish). However, the network created with MS Project 2007 does not contain detailed information of ES (Erliest Start), EF (Erliest Finish), LS (Latest Start), LF (Latest Finish) and TF (Total Float) calculations. It will require network conversion from MS Project 2007 to AutoCAD to make the network not taking too much space and loading required informations.
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Figure 4 shows critical path marked with red line, and critical activity marked with a red node. The critical path is the pathway formed by the interrelated critical activities. To know the critical path, forward and backward calculations are needed. The forward calculation will produce ES, EF, and the overall project duration, then the initial time considered as zero. Meanwhile, the backward calculation is useful to complete LS, LF, and TF.

In accordance with the formula in Table 1, then the calculation toward 108 existing works elements can be done, with the information of each activities duration. If TF = 0, then the activity is critical. If it was indicated that after and or before the critical activity has TF = 0, then the critical path is formed. Activities on critical path should not be delayed and should take precedence when a resource conflict occurs, to ensure that the overall project is not running late.

<table>
<thead>
<tr>
<th>FORWARD</th>
<th>BACKWARD</th>
</tr>
</thead>
<tbody>
<tr>
<td>( ES_{(i)} = ) (Choose the largest number from)</td>
<td>( LF_{(i)} = ) (Choose the smallest number from)</td>
</tr>
<tr>
<td>( ES_{(i)} + SS_{(i-j)} ) or ( ES_{(i)} + SF_{(i-j)} - D_{(j)} )</td>
<td>( LF_{(j)} - FF_{(i-j)} ) or ( LS_{(j)} - FS_{(i-j)} ) or ( LF_{(j)} - SF_{(i-j)} + D_{(j)} ) or ( LS_{(j)} + SS_{(i-j)} + D_{(j)} )</td>
</tr>
<tr>
<td>( EF_{(i)} + FS_{(i-j)} ) or ( EF_{(i)} + FF_{(i-j)} - D_{(j)} )</td>
<td></td>
</tr>
</tbody>
</table>

Description:
- SF : Start to Finish
- SS : Start to Start
- FS : Finish to Start
- FF : Finish to Finish
- \( (i) \) : predecessor activities
- \( (j) \) : successor activities

In the same activity ID, the MS Project and manual calculations have different results. In figure 5 (section marked by a red line) the fabrication activity, MTO, shop drawing, and CPS are not counted as critical activities and have no longer paths (the line is disconnected). Meanwhile, according to (Aronto, 2010) activity items that have disconnected the links, creating imperfect network diagram because it is not closed at one end point. So improvements are needed on the calculation and PDM network diagram.

The forward and backward calculations are listed on the network diagram manual (AutoCAD), then the analysis will be done on the diagram. The path that will be analyzed is a path with ID 1-2-3, ie ID 1 as start (assumed ES = 0) and ID 3 as finish.

Improvements are done by performing forward and backward calculations. The forward count will produce ES, EF, and the overall project duration with the initial time considered zero. The backward calculation is useful to complete LS, LF, and TF. Using the forward formula, ES and EF will be calculated. ES (1) is 0, as the initial activity. Next, earliest start of the next activity which is the number of earliest finish of predecessor activity plus duration lag (waiting time) on FS relation will be calculated. For example, on the calculation of earliest start ID 2, FS (1-2) is 0 because after activity 1 is completed, activity 2 immediately follows without pause. If there is a pause in the day, then the value of FS is no longer 0, but as many
as the interval days between the predecessor and successor activities. Then the calculation of earliest finish is earliest start coupled with work duration. With forward calculation, we will know the earliest start and earliest finish on the line 1-2-3. The duration of the 1-2-3 line can be determined, that is the earliest finish from the whole circuit of three activities. Calculations can be seen in Table 3.

![Networks diagram with ID lines 1-2-3 were analyzed](image)

Figure 5: Networks diagram with ID lines 1-2-3 were analyzed.

Next is the backward calculation that determines LS, LF, and total float. The backward calculation cannot be performed before the forward calculation is completed, as the latest finish is taken from the duration of path which previously determined through the forward calculation. As the name implies, backward calculations are performed from the most recent activity. In Table 3 the latest finish line 1-2-3 is earliest finish ID 3 that is 41 days. After that, the latest start is calculated according to the formula. The calculations are listed in Table 4.

The total float calculation is obtained after the forward and backward calculations are completed. Here is the result of the total float calculation where all the IDs on line 1-2-3 have TF = 0. That means the three IDs are critical activities, and path 1-2-3 are critical paths as seen in Table 2.

<table>
<thead>
<tr>
<th>ID</th>
<th>DURATION</th>
<th>ES</th>
<th>LF</th>
<th>TF</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>15</td>
<td>0</td>
<td>15</td>
<td>LF-ES-D = 15-15-0 = 0</td>
</tr>
<tr>
<td>2</td>
<td>20</td>
<td>15</td>
<td>35</td>
<td>LF-ES-D = 35-15-20 = 0</td>
</tr>
<tr>
<td>3</td>
<td>6</td>
<td>35</td>
<td>41</td>
<td>LF-ES-D = 41-35-6 = 0</td>
</tr>
</tbody>
</table>

According to critical path definition, the path that is experiencing delays in activity, there will be delays in the running process of project as a whole. Then the case on the line ID 1-2-3 is a contradiction. If it was viewed as a whole running project, ID 2 and 3 does not affect the duration of the project. Because these two IDs are not successors for other activities. Unlike
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ID 1 which is a successor for all other activities, it is correct if ID 1 was included in critical activity.

This was happened because the ID did not end at the same point (the link was disconnected) and did not form a perfect network. According to (Husen, 2009) an event like this is called dangling, where there are some activities that do not have predecessor activities or successor activities. So between the calculation and reality conditions in field is not appropriate.

Improvements are made by changing the network diagram that have cut off his links to form a perfect network. For IDs which do not have successors, the links will be continued until finish. This added link is called dummy finish, which serves to connect a dangler activity with a finish.

### Table 3 Forward Calculation to Determine ES, and EF

<table>
<thead>
<tr>
<th>ID</th>
<th>Relation Dependency</th>
<th>Predecessor</th>
<th>Duration (Days)</th>
<th>Forward</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>ES</td>
</tr>
<tr>
<td>1</td>
<td>FS (0)</td>
<td>-</td>
<td>15</td>
<td>ES₁ = 0</td>
</tr>
<tr>
<td>2</td>
<td>FS (0)</td>
<td>1</td>
<td>20</td>
<td>EF₁+FS₁ = 15+0 = 15</td>
</tr>
<tr>
<td>3</td>
<td>FS (0)</td>
<td>2</td>
<td>6</td>
<td>EF₂+FS₂ = 35+0 = 35</td>
</tr>
</tbody>
</table>

Duration = EF latest activity = 41 days

### Table 4 Backward calculation to Determine LS, LF

<table>
<thead>
<tr>
<th>ID</th>
<th>Relation Dependency</th>
<th>Predecessor</th>
<th>Duration (Days)</th>
<th>Backward</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>LS</td>
</tr>
<tr>
<td>1</td>
<td>FS (0)</td>
<td>-</td>
<td>15</td>
<td>LF₁-D₁ = 15-15 = 0</td>
</tr>
<tr>
<td>2</td>
<td>FS (0)</td>
<td>1</td>
<td>20</td>
<td>LF₂-D₂ = 15-0 = 15</td>
</tr>
<tr>
<td>3</td>
<td>FS (0)</td>
<td>2</td>
<td>6</td>
<td>LF₃-D₃ = 41-6 = 35</td>
</tr>
</tbody>
</table>

Therefore, there will be one additional node, the node ID 109 which is the end point of all activities. Thus, no more disconnected links and floating activities (dangler) as well as calculations according to reality in the field. ID 109 (later referred as finish) has no duration, therefore the latest finish, latest start, earliest finish, and earliest start are the same, 210.

### 3.3. Scheduling Using Line of Balance Method

Line of balance method is actually a common method used for repetitive projects. In this CCCW development project, it is reviewed in advance which repeatings activities are going to be elaborated using LoB method. After reviewing all activities, there are several similar activities in sub fabrication activities as can be seen in Table 5. That means those activites are repetitive.
Table 5 List of the same activities on sub fabrication activities

<table>
<thead>
<tr>
<th>NO</th>
<th>ACTIVITY</th>
<th>SHELL, NOZZLES, FLANGE, &amp;SADDLE (A)</th>
<th>REAR CHANNEL (B)</th>
<th>FRONT CHANNEL (C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>ES</td>
<td>EF</td>
<td>ES</td>
</tr>
<tr>
<td>1</td>
<td>Material Identification</td>
<td>108</td>
<td>109</td>
<td>109</td>
</tr>
<tr>
<td>2</td>
<td>Marking &amp; cutting hole for nozzle</td>
<td>115</td>
<td>118</td>
<td>118</td>
</tr>
<tr>
<td>3</td>
<td>Marking &amp; cutting hole for nozzle</td>
<td>118</td>
<td>120</td>
<td>120</td>
</tr>
<tr>
<td>4</td>
<td>Fit-up pipe + flange nozzle</td>
<td>120</td>
<td>122</td>
<td>122</td>
</tr>
<tr>
<td>5</td>
<td>Welding pipe + flange</td>
<td>122</td>
<td>124</td>
<td>124</td>
</tr>
<tr>
<td>6</td>
<td>NDE (RT+MT)</td>
<td>124</td>
<td>125</td>
<td>125</td>
</tr>
<tr>
<td>7</td>
<td>Fit-up/install nozzle to shell</td>
<td>125</td>
<td>129</td>
<td>129</td>
</tr>
<tr>
<td>8</td>
<td>Welding nozzle to shell</td>
<td>129</td>
<td>133</td>
<td>133</td>
</tr>
<tr>
<td>9</td>
<td>NDE (UT+MT)</td>
<td>133</td>
<td>134</td>
<td>134</td>
</tr>
</tbody>
</table>

After calculating, LoB diagram will produce 9 lines that represent each activities. In the LoB diagram as shown in Figure 6, there are intersecting activities that is the activity of welding nozzle to shell, Fit-up / install nozzle to shell with the activity of NDE (UT + MT), and Welding pipe + flange with NDE (RT + MT). NDE activity (RT + MT) and Fit-up / install nozzle to shell are almost tangent because they both have the same earliest start and almost simultaneously earliest finish. Close-knit activities do not need to be given buffer time. Buffers are only given to intersecting activities to avoid conflict.

![LoB Diagram](image)

Figure 6 LoB Diagram

Giving buffer results in increasing the amount of project duration. Initially, to complete 9 activities in 3 stages takes 34 days. Then after adding buffer, it takes 43 days. As in previous explanation, the dependency relationship of all activities in this project is finish to start, then the addition of duration in activities directly affects the addition of the entire project duration. Previously, by using PDM method it takes 210 days after elaborating. Using LoB method, the duration became 244 days. Please note that the elaborated activity using LoB method was only 27 (9 activities multiplied by 3 stages). Of all 109 activities, the remaining 82 still with the result of PDM method calculation.
3.4. Scheduling Using Ranked Position Weight Method

RPW method has specificity that is using positional weight as the priority of the activities, concentrating on work efficiency by reducing idle time. The common work using this method is the one that runs continuously like a paper manufacturer, a bicycle factory, or a shirt where the product is produced in large quantities and sustainable.

RPW method also cannot be separated from network diagram. So the network diagram on the PDM method can be used as a reference in the next work. Furthermore, to calculate the required position, a predecessor matrix is needed with a predefined format. The positional weight of an activity is the sum of activity durations that follow it. The less the number of following activity durations, the smaller the positional weight.

Table 6 Predecessor Matrix

<table>
<thead>
<tr>
<th>Predecessor Operation</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>...</th>
<th>...</th>
<th>8</th>
<th>9</th>
<th>Positional Weight</th>
<th>Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-</td>
<td>20</td>
<td>6</td>
<td>...</td>
<td>...</td>
<td>0</td>
<td>5</td>
<td>0</td>
<td>942</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>-</td>
<td>6</td>
<td>...</td>
<td>...</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>69</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>0</td>
<td>-</td>
<td>...</td>
<td>...</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>...</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-</td>
<td>...</td>
<td>0</td>
<td>0</td>
<td>73</td>
<td>25</td>
</tr>
<tr>
<td>...</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-</td>
<td>0</td>
<td>5</td>
<td>129</td>
<td>3</td>
</tr>
<tr>
<td>108</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-</td>
<td>0</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>109</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 6 shows the areas with shading should be filled with a duration number according to its activity. Example for predecessor operation 1, the successor operation is ID 2 to 109 later filled by the ID duration. Number 0 could appear if the ID is not a following activity from activity ID that has been being calculated. For example in ID 2, the successor operation is only ID 3, then the other IDs are filled with the number 0. Afterwards, the number of following durations is summed (towards right). The higher the weight, will be regarded as priority 1 and so on.

Figure 7 Calculation of RPW method by entering priority

The next step will be done in MS Project by entering a new column that is priority column, then putting the priority number instead of positional weight number. For example,
the Main Drawing activity has 923 positional weight as priority 1 as seen in Figure 7. In MS Project, this ID is prioritized 1. Calculating duration by its priority is done by using level resources with standard levelling order priority. The project duration was generated initially 210, after leveling it became 213 days.

3.5. Comparison between 3 Methods
Based on the 3 methods PDM, LoB and RPWM the project completion for Circulating Close Cooling Water System is summarized in Table 7.

<table>
<thead>
<tr>
<th>Comparative Parameter</th>
<th>PDM</th>
<th>LoB</th>
<th>RPWM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duration (days)</td>
<td>210</td>
<td>244</td>
<td>213</td>
</tr>
<tr>
<td>Ability to display Critical Path</td>
<td>Can display</td>
<td>Cannot display</td>
<td>Can display</td>
</tr>
<tr>
<td>Ability to display Logic Dependency Relation</td>
<td>Clearly visible and able to display 4 dependency relations</td>
<td>Not seen</td>
<td>Visible, but only able to display one relation, finish to start.</td>
</tr>
<tr>
<td>Ability to display Obstacles</td>
<td>Cannot display</td>
<td>Can be displayed, with the intersection between activities</td>
<td>Cannot display</td>
</tr>
<tr>
<td>Usage</td>
<td>Easier to read and suitable for overlapping activities</td>
<td>For overlapping activities, it is not readable on the chart</td>
<td>Easy to understand and suitable for overlapping activities</td>
</tr>
</tbody>
</table>

4. CONCLUSIONS
After analyzed scheduling comparison between Precedence Diagram, Line of Balance, and Position Weight method toward CCCW system development, it can be concluded:

- Using PDM as scheduling method, the duration of project is 210 days. Precedence Diagram method can display critical paths, overlapping activities and accurate calculations.
- Using LoB as scheduling method, the duration of project is 244 days. LoB method cannot display critical path and it is hard to understand if the amount of activities are too much. The line diagram generated in the LoB method cannot display overlapping activities as well.
- Using RPWM as scheduling method, the duration of project is 213 days. RPW method focused on the calculation of positional weight that becomes priority reference for the calculation of project duration. This method can display critical paths in the network diagram.
- The most precise method for Circulating Close Cooling Water System work project is PDM, with 210 days duration which is the fastest among the three methods and has the ability to display critical paths and overlapping activities.

REFERENCES
A Comparison of Application of the Project Scheduling using Precedence Diagram Method (PDM), Line of Balance (LOB), and Position Weight Method (RPWM) to Construct Circulating Close Cooling Water System


