Analysis of project work using earned value management and precedence diagram methode in manufacturing system projects

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ABSTRACT

PT. Weiss Tech has received a project order for the fabrication and installation of coffee packaging production machines from PT. XYZ, scheduled to start on June 19, 2023, with a deadline of June 24, 2024, spanning 54 weeks. The project has been ongoing for 16 weeks with an update indicating that only 20% of the planned progress has been achieved, which suggests that it may not be completed on time. To evaluate the project's performance, the Earned Value Management method will be used to identify critical tasks and reduce the project duration using the Precedence Diagram Method with the help of MS Project software. The evaluation shows negative values for CV and SV variances, as well as performance index SPI < 1 and CPI < 1, indicating poor project performance. The critical tasks identified include electrical & instrument installation, machine & utility installation, trial work, assembly, quality control, polishing, milling, turning, cutting, and design. Design work has been identified as the most influential on the critical path. By rescheduling the project plan, positive values for CV and SV have been achieved. With the SPI value of 1.13 and CPI value of 1, it can be concluded that future project performance will be completed faster and within budget

1. Introduction

PT Weiss Tech is a company engaged in services that include consulting, design, fabrication, and installation in improving production processes in the manufacturing industry. The manufacturing industry itself is a product planning or design, in the selection of materials, and performs stages in making these products from raw materials into finished products using manual labor or machine assistance (Caintan & Suwarno, 2022). One of the projects featured by PT Weiss Tech is an industrial automation system project, where automation itself is a process of automatically controlling operations and controlling systems using mechanical and electronic equipment that can replace human tasks in observing and making decisions (Wisesa & Purwandari, 2021). The automation system itself has the advantage of being able to increase the productivity of a manufacturing company with the use of an automated production system that allows production to continue without stopping (Dinata et al., 2020).

One of the main issues faced in project execution is the occurrence of delays in project completion. PT. Weiss Tech has received a project order for the fabrication and installation of machines for the production of packaged coffee from PT. XYZ. The production system project for packaged coffee is based on a Bill of Quantity (BoQ) list, which is a list containing various equipment in a project or construction unit taken from the reference design or drawing of a project. The list includes the quantity

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and price of each equipment (Farrel Ghiffary et al., 2023). This project was planned to start on June 19, 2023, with a deadline set for June 24, 2024, with a project duration of 54 weeks. The project has been running for 16 weeks with a progress update indicating completion of only 20% of the work. Comparing this progress with the time required to complete the entire project (or the project makespan time), it is unlikely that the project will be completed on time (Ginting et al., 2023). Looking at the baseline, which is the initial condition of a scheduling model or form that has been agreed upon as the basis for the timing or planning of an activity, the current progress update has already exceeded the previous baseline schedule. Therefore, it is expected that the project will experience delays in the future (Supardi et al., 2021).

Based on the current progress percentage and estimated delay, it seems unlikely that we will be able to complete the project as per the target. Therefore, we need to conduct an evaluation of the project to analyze, measure, and assess its performance and any deviations from the initial plan. This will be done using the Earned Value Management (EVM) method to provide a more detailed and accurate validation of whether the project is indeed experiencing delays or deviations from the original plan (Nabil et al., 2023).

Previous research by Meliya serves as a supporting reference for studies on Earned Value Management (EVM). EVM is an efficient method in project management that allows for assessing project performance and preventing potential obstacles and challenges (Reski Meliya et al., 2022). Meanwhile, research by Veronika indicates that the use of Earned Value Management aims to avoid the risks of failure and excesses in upcoming projects (Veronika & Ginting, 2020). Additionally, Proboretno's research highlights the importance of Earned Value Management (EVM) for construction service providers to prevent project delays. Furthermore, the analysis of EVM data is enhanced by using MS Project software (Proboretno et al., 2024).

Based on the issues at hand, the Earned Value Management (EVM) method was chosen as the best alternative for analyzing the problems. Additionally, the Precedence Diagram Method (PDM) was selected as the best alternative for resolving the issues using scheduling techniques in the form of network planning – to ensure the project is completed as initially planned, with the assistance of the Ms. Project application (Luntungan et al., 2023). Ms. Project is recommended as a tool for creating project scheduling systems and for cost analysis using the Earned Value Management (EVM) method (Mantovani & Beatrix, n.d.).

Research Objectives: (1) To identify deviations in time and cost performance of the project from the planned schedule that have occurred in the field, and to calculate more valid using the Earned Value Management method and applied using MS Project software. (2) To determine critical tasks using scheduling applied in MS Project with the Precedence Diagram Method. (3) To reduce makespan or remaining work time that may not be completed on time or experience delays, using the Precedence Diagram Method.

2. Methods

Research activities were conducted for six months at PT. Weiss. The research method involved observational techniques, which included direct observation, note-taking, and identification of the research subjects to obtain the necessary data. Both primary and secondary data were used, obtained from a project leader involved in the fabrication and installation of packaged coffee production machines, as well as an expert in the fields of PPIC and Estimator Engineering. The types of data to be used include:

a. Timeline schedule / Plan schedule
b. Bill of Quantity (BoQ)
c. Actual Cost
d. Project weekly report (16 week)

Earned Value Management (EVM)

Earned Value Management is a method used to measure and assess the performance of a project by combining schedule, scope, and resource capacity to evaluate the progress status of a project. It also serves as a tool to identify deviations from the schedule by employing a forecasting concept to estimate project completion (Ahadis et al., 2020). Before conducting an assessment analysis, Earned Value Management has fundamental parameters, including the following :

a. Actual Cost of Work Plan (ACWP) or Actual Cost (AC) represents the precise estimated value of work completed from the start to a specific point in time (Nalawade et al., 2019).

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b. Budgeted Cost of Work Plan (BCWP) or Earned Value (EV) is an estimate of the value that has been earned on the work that has been performed (Nalawade et al., 2019).

c. Budgeted Cost of Work Schedule (BCWS) or Plan Value (PV) is the amount of budget allocated to scheduled work (Nalawade et al., 2019).

In project performance evaluation using the Earned Value Management (EVM) method, there are certain terms that need to be analyzed or identified in order to determine the values that may indicate any deviations in the project. When applying the Earned Value Management (EVM) method, it is crucial to understand the basic terms or indicators associated with project performance assessment, including Cost Variance, Schedule Variance, Cost Performance Index, and Schedule Performance Index (Veronika & Ginting, 2020).

a. Cost Variance (CV) is the the the difference between the value obtained after completing a work package and the actual cost incurred during project implementation. A positive value indicates that the value obtained for a work package is greater than the amount spent. On the other hand, a negative value indicates that the value obtained is less than the amount spent (Reski Meliya et al., 2022).

$$CV = BCWP – ACWP \quad (1)$$

(Project Management Institute & Agile Alliance, 2017).

b. Schedule Variance (SV) is the the the difference between the work that has been completed and the work that was planned. In simple terms, if the value is positive, it means the work is ahead of schedule, and if it's negative, it means the work is behind schedule (Reski Meliya et al., 2022).

$$SV = BCWS – BCWP \quad (2)$$

(Project Management Institute & Agile Alliance, 2017).

c. The Cost Performance Index (CPI) is a comparison between the value received from completing work and the actual cost incurred to complete that work. If the CPI value is > 1, it indicates good performance as there is a cost saving. Conversely, if the CPI value is < 1, it indicates poor performance due to excessive cost incurred (Reski Meliya et al., 2022).

$$CPI = BCWP / ACWP \quad (3)$$

(Project Management Institute & Agile Alliance, 2017).

d. The Schedule Performance Index (SPI) is a comparison between the actual work progress and the planned budget expenditure based on the scheduled work over a certain period of time. If the SPI value is > 1, then the performance is considered good because the work is being completed faster than the set target. Conversely, if the SPI value < 1, then the performance is considered poor because the work is taking longer than the set target (Reski Meliya et al., 2022).

$$SPI = BCWP / BCWS \quad (4)$$

(Project Management Institute & Agile Alliance, 2017).

In estimating the projected project, we will use several reviews based on the search results of budget and temporary time values. By considering these reviews, the project stakeholders can anticipate the project creation steps to avoid any failures during the project's execution until its completion. Therefore, the prediction formulation of time and cost usage until the completion of the project is Estimate at Complete and Estimate to Complete (Veronika & Ginting, 2020).

a. Estimate at Completion (EAC) is the total estimated cost of the entire expenses incurred from the beginning of the work to the end of the project, obtained from the remaining estimated cost plus the actual cost (Reski Meliya et al., 2022).

$$EAC = ((Total\ Cost - PV) + AC) / ((CPI \times SPI)) \quad (5)$$

(Project Management Institute & Agile Alliance, 2017).

b. Estimate to Completion (ETC) is an estimated cost required to complete the remaining work on a project (Reski Meliya et al., 2022).

$$ETC = EAC – AC \quad (6)$$

(Project Management Institute & Agile Alliance, 2017).

The research flow is a general overview of the entire research process that will be carried out from start to finish. Research flow involves data processing from the collected data for identification and obtaining results for conclusion. The entire research process can be depicted through a flow diagram as seen in Figure 1.

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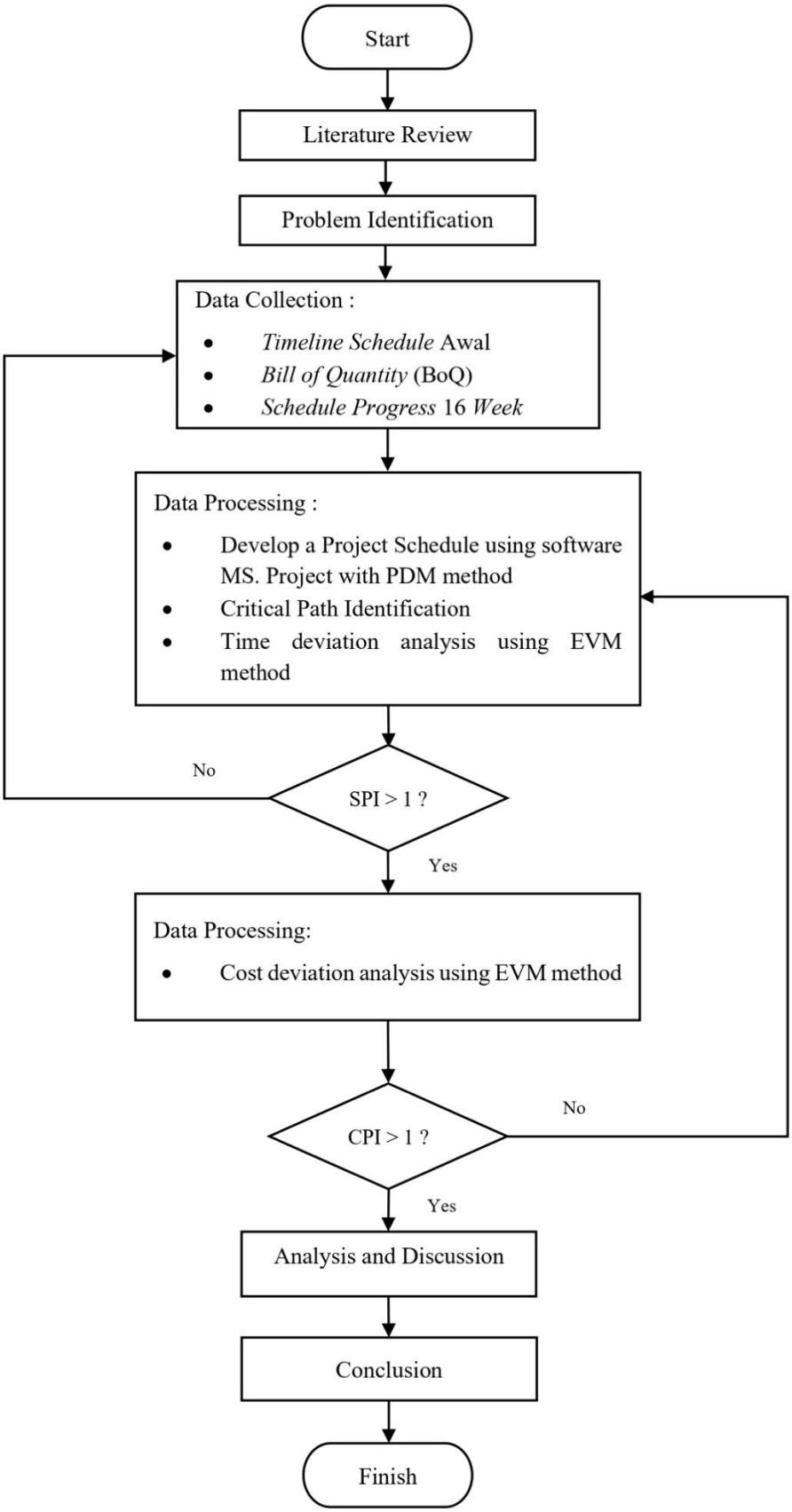

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Fig. 1 Research Flow.

3. Results and Discussion

After data collection, the next step is data processing. During this stage, project performance deviations are evaluated, critical path task identification is carried out, and project work schedule is rescheduled by modifying or reducing job makespan.

3.1 Timeline Schedule S-Curve

During the first phase, the timeline schedule is prepared using Ms. Project software and the Precedence Diagram Method (PDM). It is then transformed into an S-curve in the Ms. Project programming results and used as the baseline schedule, as shown in Figure 1 below.

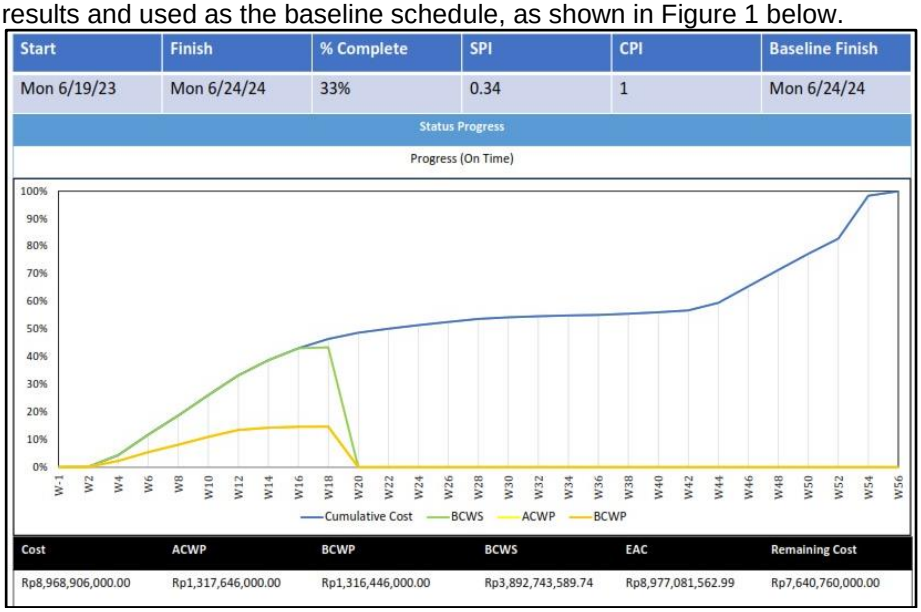

Fig. 2 Dashboard Ms. Project timeline schedule.

After the schedule is arranged and the dashboard is generated as shown in Figure 2, we can see that the completion percentage is currently at 33% during the 16-week working process. The project is projected to be completed on June 24, 2024, with a total working period of 54 weeks. The total budget for the project is Rp 8.968.906.000,00.

3.2 Progress 16 Weeks S-Curve

Progress 16 weeks S-Curve is the next stage after creating the timeline schedule. At this stage, any remaining unfinished work that does not align with the previous plan or timeline is rescheduled. The start date is adjusted according to the updated project schedule.

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Fig. 3 Dashboard Ms. Project progress 16 week.

Based on figure 3, it is found that the project will be completed on August 23, 2024, which exceeds the planned or baseline date. In the 16-week progress report, the completion percentage is simulated as 100% to enable the calculation of variance and performance index for future completion analysis. Furthermore, an analysis of the project's variance and performance index based on the Ms. Project programming result on the S-curve progress for 16 weeks using the Earned Value Management (EVM) method can be provided.

3.1.1 Variance Value of Project Performance

Here are the details for calculating the project performance variance in week 8 using the Earned Value Management (EVM) method as follows :

a. Cost Varians (CV)

CV = BCWP – ACWP

CV = Rp 947.974.133,33 – Rp 948.574.133,33

CV = -Rp 600.000,00

Based on the calculation of the Cost Variance (CV), obtaining a negative value indicates that the actual cost is lower than the budgeted cost.

b. Schedule Varians (SV)

SV = BCWS - BCWP

SV = Rp 2.340.206.707,69 – Rp 947.974.133,33

SV = -Rp 1.392.232.574,36

Based on the Schedule Variance (SV) calculation, a negative value indicates that the task is being completed more slowly than planned. For further calculations, the same method as the example above can be used to obtain the results, as shown in Figure 4, based on the programming results in Ms. Project.

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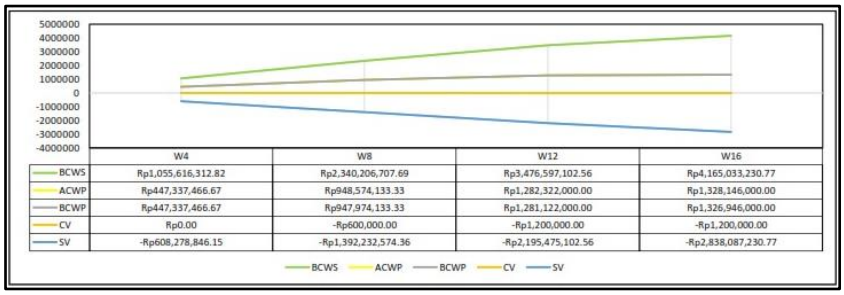


	W4	W8	W12	W16
BCWS	Rp1,055,616,312.82	Rp2,340,206,707.69	Rp3,476,597,102.56	Rp4,165,033,230.77
ACWP	Rp447,337,466.67	Rp948,574,133.33	Rp1,282,322,000.00	Rp1,328,146,000.00
BCWP	Rp447,337,466.67	Rp947,974,133.33	Rp1,281,122,000.00	Rp1,326,946,000.00
CV	Rp0.00	-Rp600,000.00	-Rp1,200,000.00	-Rp1,200,000.00
SV	-Rp608,278,846.15	-Rp1,392,232,574.36	-Rp2,195,475,102.56	-Rp2,838,087,230.77

Fig. 4 Dashboard Ms. Project progress 16 week varians value.

Based on the analysis of the project performance variance on the timeline schedule, it can be concluded that up to week 16, the cost variance (CV) and schedule variance (SV) were both negative. This indicates that the actual values were lower than expected and the work was completed at a slower pace.

3.1.2 Performance Index Value Project Performance

Please take note of the following details regarding the calculation of the project performance index in week 8 using the Earned Value Management (EVM) method :

a.) Schedule Performance Index (SPI)

SPI = BCWP / BCWS

SPI = Rp 948.574.133,33 / Rp 2.340.206.707,69

SPI = 0.405081367

Based on the Schedule Performance Index (SPI), a value of SPI < 1 indicates poor performance, signifying that the work is taking longer to complete than the set target.

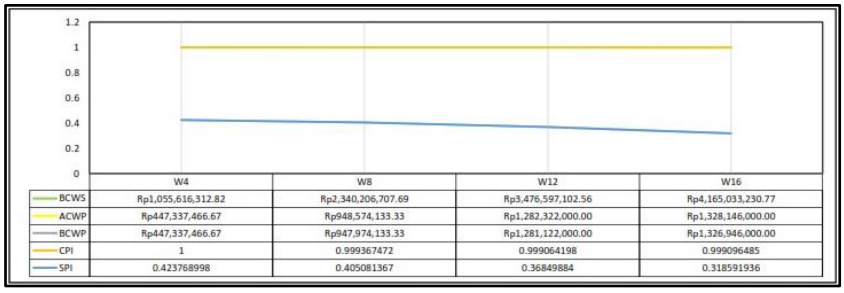
b.) Cost Performance Index (CPI)

CPI = BCWP / ACWP

CPI = Rp 948.574.133,33 / Rp 948.574.133,33

CPI = 0,999367472

Based on the Cost Performance Index (CPI) result, a CPI value < 1 indicates poor performance as the implementation costs are considered to be extravagant. Further calculations can be performed using the same method as the example above, and the results can be found in figure 5, as shown by the programming results in Ms. Project.



	W4	W8	W12	W16
BCWS	Rp1,055,616,312.82	Rp2,340,206,707.69	Rp3,476,597,102.56	Rp4,165,033,230.77
ACWP	Rp447,337,466.67	Rp948,574,133.33	Rp1,282,322,000.00	Rp1,328,146,000.00
BCWP	Rp447,337,466.67	Rp947,974,133.33	Rp1,281,122,000.00	Rp1,326,946,000.00
CPI	1	0.999367472	0.999064198	0.999096485
SPI	0.423768998	0.405081367	0.36849884	0.318591936

Fig. 5 Dashboard Ms. Project progress 16 week performance index.

The analysis of the project's performance index on the project timeline shows that up to week 16, the SPI value is < 1, indicating that the project's performance is slower than the set target. Additionally, the CPI value is < 1, suggesting that the project costs are higher than planned. Therefore, it can be concluded that the project's performance index is poor.

3.3 Critical Path Diagram

Critical path diagram, also known as the critical path method, is the sequence of project tasks that determines the shortest possible duration for completing the project.

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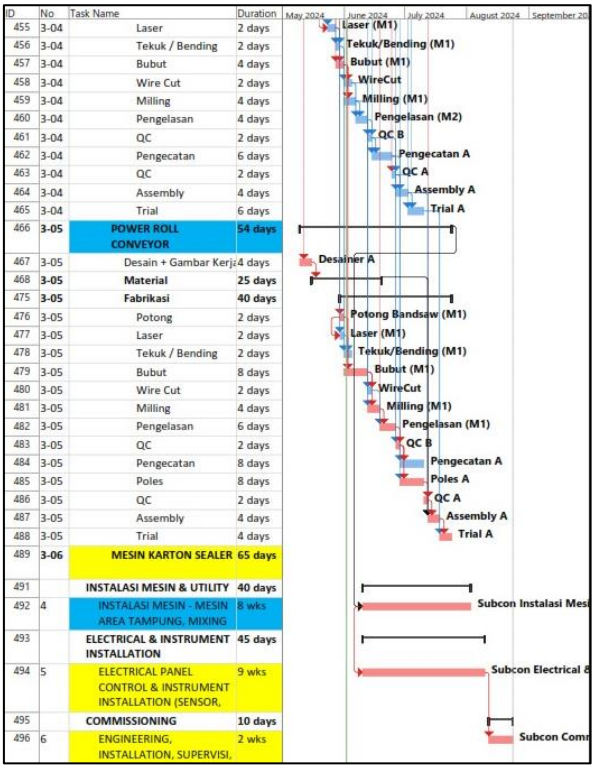
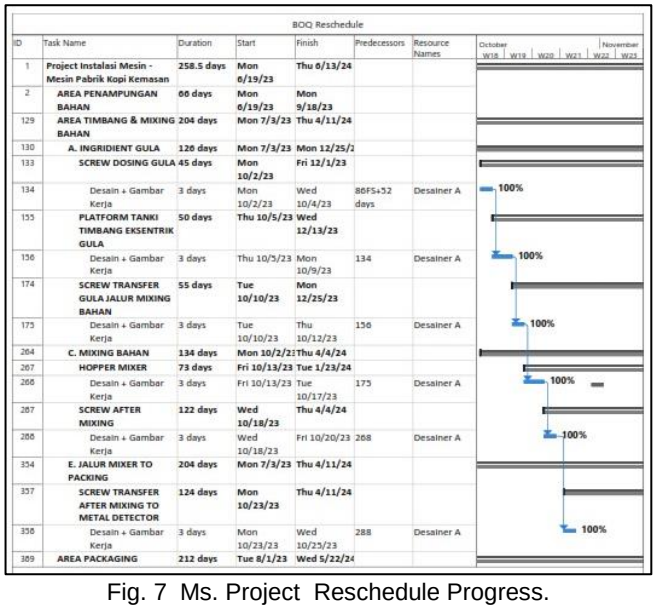


ID	No	Task Name	Duration
455	3-04	Laser	2 days
456	3-04	Tekuk / Bending	2 days
457	3-04	Bubut	4 days
458	3-04	Wire Cut	2 days
459	3-04	Milling	4 days
460	3-04	Pengelasan	4 days
461	3-04	QC	2 days
462	3-04	Pengecatan	6 days
463	3-04	QC	2 days
464	3-04	Assembly	4 days
465	3-04	Trial	6 days
466	3-05	POWER ROLL CONVEYOR	54 days
467	3-05	Desain + Gambar Kerja	4 days
468	3-05	Material	25 days
475	3-05	Fabrikasi	40 days
476	3-05	Potong	2 days
477	3-05	Laser	2 days
478	3-05	Tekuk / Bending	2 days
479	3-05	Bubut	8 days
480	3-05	Wire Cut	2 days
481	3-05	Milling	4 days
482	3-05	Pengelasan	6 days
483	3-05	QC	2 days
484	3-05	Pengecatan	8 days
485	3-05	Poles	8 days
486	3-05	QC	2 days
487	3-05	Assembly	4 days
488	3-05	Trial	4 days
489	3-06	MESIN KARTON SEALER	65 days
491		INSTALASI MESIN & UTILITY	40 days
492	4	INSTALASI MESIN - MESIN AREA TAMPUNG, MIXING	8 wks
493		ELECTRICAL & INSTRUMENT INSTALLATION	45 days
494	5	ELECTRICAL PANEL CONTROL & INSTRUMENT INSTALLATION (SENSOR,	9 wks
495		COMMISSIONING	10 days
496	6	ENGINEERING, INSTALLATION, SUPERVISI,	2 wks

Fig. 6 Ms. Project Critical Path Diagram.

After identifying that the project's performance is inefficient and progressing slower than planned based on the assessment of the S-curve progress over 16 weeks, the next step is to identify the work packages on the critical path based on Figure 8. The critical path is depicted in red on the bar chart, and the last work package that affects the project's completion target is the commissioning work. On the critical path, it is evident that several work packages affect the commissioning work, including electrical and instrument installation, machine and utility installation, trial work, assembly, quality control, polishing, milling, turning, cutting, and design. It can be concluded that the design work is the initial stage before proceeding to other tasks and has a significant impact on the critical path.

3.4 Makespan Reduction



BOQ Reschedule

ID	Task Name	Duration	Start	Finish	Predecessors	Resource Names
1	Project Instalasi Mesin - Mesin Pabrik Kopi Kemasan	258.5 days	Mon 6/19/23	Thu 6/13/24		
2	AREA PENAMPUNGAN BAHAN	66 days	Mon 6/19/23	Mon 9/18/23		
129	AREA TIMBANG & MIXING BAHAN	204 days	Mon 7/3/23	Thu 4/11/24		
130	A. INGRIDIENT GULA	126 days	Mon 7/3/23	Mon 12/25/2		
133	SCREW DOSING GULA	45 days	Mon 10/2/23	Fri 12/1/23		
134	Desain + Gambar Kerja	3 days	Mon 10/2/23	Wed 10/4/23	86FS+52 days	Desainer A
155	PLATFORM TANKI TIMBANG EKSENTRIK GULA	50 days	Thu 10/5/23	Wed 12/13/23		
156	Desain + Gambar Kerja	3 days	Thu 10/5/23	Mon 10/9/23	134	Desainer A
174	SCREW TRANSFER GULA JALUR MIXING BAHAN	55 days	Tue 10/10/23	Mon 12/25/23		
175	Desain + Gambar Kerja	3 days	Tue 10/10/23	Thu 10/12/23	156	Desainer A
264	C. MIXING BAHAN	134 days	Mon 10/2/23	Thu 4/4/24		
267	HOPPER MIXER	73 days	Fri 10/13/23	Tue 1/23/24		
268	Desain + Gambar Kerja	3 days	Fri 10/13/23	Tue 10/17/23	175	Desainer A
287	SCREW AFTER MIXING	122 days	Wed 10/18/23	Thu 4/4/24		
288	Desain + Gambar Kerja	3 days	Wed 10/18/23	Fri 10/20/23	268	Desainer A
354	E. JALUR MIXER TO PACKING	204 days	Mon 7/3/23	Thu 4/11/24		
357	SCREW TRANSFER AFTER MIXING TO METAL DETECTOR	124 days	Mon 10/23/23	Thu 4/11/24		
358	Desain + Gambar Kerja	3 days	Mon 10/23/23	Wed 10/25/23	288	Desainer A
369	AREA PACKAGING	212 days	Tue 8/1/23	Wed 5/22/24		

Fig. 7 Ms. Project Reschedule Progress.

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In the rescheduling stage of the project plan after the 16th week's progress, based on figure 7, there will be a reduction or change in the makespan of certain work packages that are part of and affect the critical path. Before making changes to the makespan, the results of the previous critical path identification have been obtained, and one of the mentioned work packages is the design work. As the design work is the starting point before other tasks, it becomes the initial test for changes in the makespan.

3.5 Kurva S Reschedule

Results of changes in makespan of design work packages in the previous stage are then accumulated into an S-curve Reschedule from the programming results using Ms Project.

Fig. 8 Dashboard Ms. Project progress reschedule

Based on the figure 8, the project is scheduled to be completed on June 13, 2024, which is earlier than the planned/baseline date. In the rescheduling of the planning schedule, the completion percentage is simulated to be 100%, with the aim of ensuring that when analyzing the variance and performance index values, they can be calculated according to the future completion results.

3.6 Variance Of Project Perfomance

Next are the project performance variance results for weeks 16 to 54 using Earned Value Management (EVM) method.

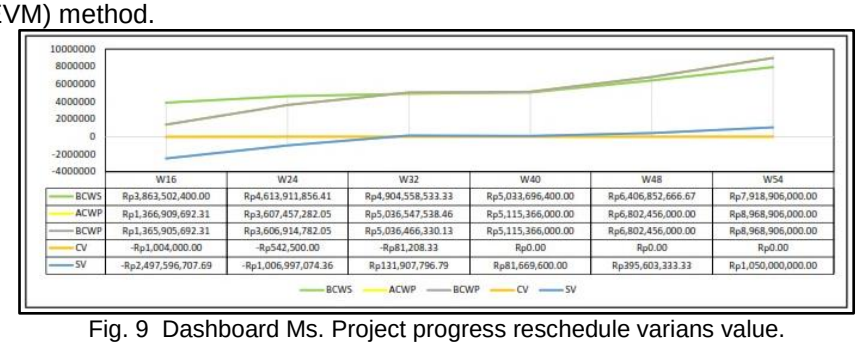

Fig. 9 Dashboard Ms. Project progress reschedule varians value.

The following is the result of the project performance variance from week 16 to week 54 using the Earned Value Management (EVM) method. The analysis of the project performance variance on the schedule timeline indicates that based on the assessment up to week 54, the cost variance (CV) value is 0, and the schedule variance (SV) value is positive. This suggests that the value obtained is in line with the budget spent and that the work is being completed ahead of schedule.

3.7 Performance Index Project Performance

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Here are the earned value management (EVM) performance index results for project performance from week 16 to week 54.

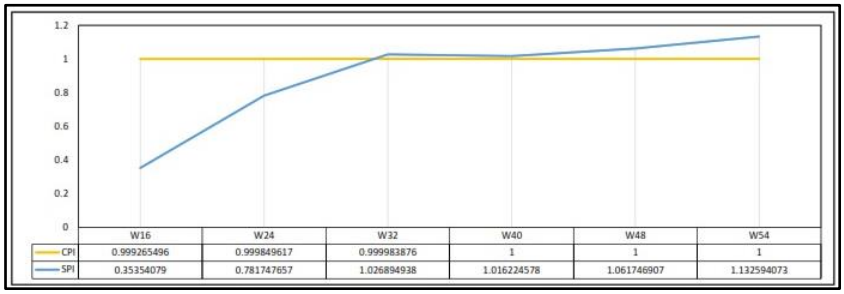

Fig. 10 Dashboard Ms. Project progress reschedule performance index.

Based on the analysis of the project performance index on the timeline schedule, it can be seen that in week 54, the SPI value < 1.13 which indicates that the project is running ahead of the targeted schedule. In addition, the CPI value < 1, which indicates that the implementation cost matches or meets the set target. In conclusion, the project performance index shows good and efficient performance going forward. Comparison of the results of research conducted by Proboretno's (Proboretno et al., 2024), the SPI value > 1, namely 0.78 and CPI < 1, namely 1.11, which means that it shows that the project performance is delayed with a smaller cost than budgeted.

4. Conclusion

After conducting an analysis and evaluation using Earned Value Management (EVM) on manufacturing system project work has been successfully applied. The initial step of the application is to collect data on the timeline schedule, bill of quantities, progress 16 weeks. then the data is processed by compiling the timeline into Ms. Project programming using the Precedence Diagram Method (PDM). Producing project work evaluation data that has a deviation, where there is a deviation in the value of the project performance variance and the value of the project performance index resulting in a negative CV and SV variance value, then the performance index value SPI < 1 and CPI < 1, where the project performance value is declared poor. Then the critical path diagram or critical path identification is carried out on the work package, it can be seen that the work packages include electrical & instrument installation, machine & utility installation, trial work, assembly, QC, polishing, milling, lathe, cutting, and design. From the results of the identification of the design work package that has the most influence on the critical trajectory. Furthermore, a reschedule is carried out by reducing the makespan of the design work package by reducing the waiting time in the predecessor setting in Ms. Project. The final results of the reschedule system in the form of variance values and performance index project performance are obtained accordingly and faster. So it can be concluded that the Earned Value Management method is more accurate in calculating the project performance index.

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