# Critical Path Method to Accelerate Automotive Maintenance Duration

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**Abstract:** Maintenance activities need to be carried out appropriately. This study aims to speed up maintenance duration as expected. The duration of maintenance activities has an impact on decreasing customer loyalty. In this study the scheduling of maintenance activities is evaluated using the Critical Path Method (CPM) using the POM program. In the CPM method scheduling is done by determining the details of activities, adding duration to each activity, identifying previous activities, determining the sequence of activities and describing in network form, arranging the duration of completion for each activity, entering each data into the POM program so that the activity was identified wether it is on critical path or not.In this research, maintenance activities are classified into 2: 1) Lightweight injection and CVT service package; 2) oil and spare parts replacement. The results are compared before and after the improvement. The results showed that the CPM method can speed up maintenance duration. The efficiency of accelerating injection and CVT service package duration is 57.89% while oil and spare part replacements is 22.72%.

**Keywords:** Automotive, critical path, efficiency, maintenance, scheduling.

## 1 INTRODUCTION

In a business, scheduling plays an important role in planning and managing work assignments. If the arrangement and planning is not right then there is a buildup of work between work stations that is not balanced with the speed of work duration, this also results in long queues. There are several scheduling methods used to manage duration and resources. Each method has advantages and disadvantages. The use of these methods is considered based on needs and the results to be achieved on scheduling performance. The bar chart method is informative so it is easy to make and understand, but the relationship between activities is not clear and the critical path cannot be known [1]. The network method are Critical Path Method (CPM), Precedence Diagraming Method (PDM), and The Program Evaluation and Review Technique (PERT) can show in detail the relationship of activity dependency and critical path, but this method cannot see disturbed activities, the CPM has the goal of getting an estimate of the duration of efficient maintenance and knowing the critical path [2], [3], [4]. Line of Balance (LOB) is simple and easy to understand but cannot show in detail the dependency relationship between activities [5]. The curve s method is able to show the progress of the project by comparing the planning schedule, but the information delivered is not detailed and requires another scheduling method to improve the renewal of resources or duration [6]. Apart from the inaccurate regulation and planning, another thing that can cause queues is the increase in the number of motorized vehicles. Maintenance queues trigger customer complaints on company performance and adversely affect customer loyalty [7]. This condition is the background of the need to schedule maintenance activities using the critical path method because it can show critical and non-critical activities, this method also looks at maintenance activities that can be done simultaneously. Some studies only discuss one service package such as aircraft overhaul maintenance [8], types of HGPI gas turbine maintenance classified as preventive maintenance [9], overhaul maintenance of Meyer 78/18 bottle filling machine [10], maintenance scheduling of a fleet of fighter aircraft [11], types of aircraft maintenance classified as preventive maintenance [12], major of overhauling of a modern bulldozer [13] Meanwhile, services for automotive may consisted of several maintenance. This paper studies combination for both services, they are 1) lightweight injection and CVT service packages and 2) oil and spare parts replacement.

## 2 SYSTEM DESCRIPTION

The way mechanical works affect the smooth running of the system. In the old system, every mechanic worked on maintenance without help from other mechanics. Mechanics work on lightweight injection and CVT service packages as well as oil and spare parts replacements based only on experience without scheduling activities. This causes a long duration in every automotive maintenance. The duration of maintenance has an impact on queue length and service capacity. System improvement using CPM method can control activities with a long duration, increase the compactness of the mechanical team, increase mechanical productivity.

## 3 METHODOLOGY

There are 6 prinsif maintenance scheduling namely (1) identifying skill level. In this case if there are 2 mechanics in maintenance, one mechanic does not need to have special skills (helper). (2) adhere to scheduling and prioritizing work activities that are on the critical path. (3) schedule work activities according to mechanical skills. 4) all work hours are scheduled. 4) Supervisors can match mechanical tasks according to skills. 5) measure labor efficiency in accordance with the effectiveness of planning and scheduling [14].

The basic steps of the critical path method are (1) identifying and preparing fractions of work activities, (2)


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building relationships between activities and determining which activities are performed first, (3) drawing a network that connects all activities, (4) Estimating the length of duration each activity, (5) calculating the longest time path with critical paths, and (6) planning, scheduling, and controlling projects using a network [15].

### 3.1 Research Stages

The research stages can be seen in Figure 1 below:

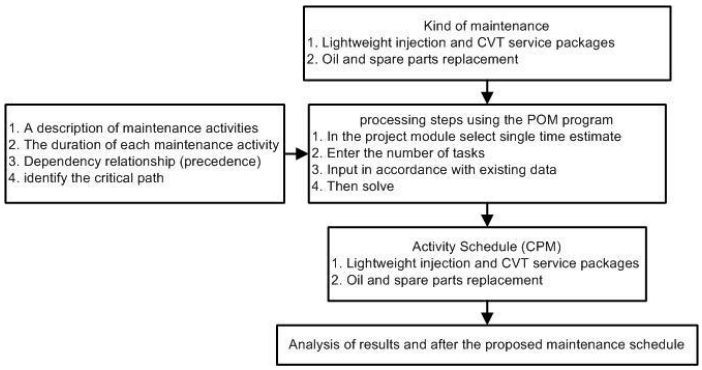



**Fig. 1**. *Research stages*

### 3.1 Light Injection and CVT Service Packages

Data collection of lightweight injection and CVT service packages before processing can be seen in Table 1, Table 2, Table 3.

**TABLE 1**
DATA MAINTENANCE ACTIVITIES DESCRIPTIONS OF LIGHTWEIGHT INJECTION AND CVT SERVICE PACKAGES

| AC (1) | A (2) |
|---|---|
| 1 | Light Check |
| 2 | Horn Check |
| 3 | Removal of Cover Body |
| 4 | Engine Oil Inspection |
| 5 | Oil Filter Check |
| 6 | Spark Plug Inspection |
| 7 | Spark Plug Adjustment |
| 8 | Injector Cleaner |
| 9 | Cleaning the Fuel Filter |
| 10 | Fuel Filter Replacement |
| 11 | Air Filter Cleaning |
| 12 | Air Filter Replacement |
| 13 | Valve Check |
| 14 | Valve Adjustment |
| 15 | Clutch Check |
| 16 | Clutch Adjustment |
| 17 | Brake Check |
| 18 | Brake Adjustment |
| 19 | Brake Light Switch Adjustment |
| 20 | Battery Checkup |
| 21 | Tire Pressure Checks |
| 22 | Tire Pressure Addition |
| 23 | Shock Beaker examination |
| 24 | Steering Handlebar Check |
| 25 | Steering Handlebar Adjustment |
| 26 | Wheel Bearing Inspection |
| 27 | CVT examination |
| 28 | Mounting Cover |

**TABLE 2**
DATA COLLECTION OF LIGHTWEIGHT INJECTION AND CVT SERVICE PACKAGES

| AC (1) | A (2) | AD (Minute) (3) |
|---|---|---|
| 1 | Light Check | 0,5 |
| 2 | Horn Check | 0,5 |
| 3 | Removal of Cover Body | 7,0 |
| 4 | Engine Oil Inspection | 1,0 |
| 5 | Oil Filter Check | 1,0 |
| 6 | Spark Plug Inspection | 0,1 |
| 7 | Spark Plug Adjustment | 0,9 |
| 8 | Injector Cleaner | 10,0 |
| 9 | Cleaning the Fuel Filter | 0,8 |
| 10 | Fuel Filter Replacement | 0,2 |
| 11 | Air Filter Cleaning | 0,8 |
| 12 | Air Filter Replacement | 0,2 |
| 13 | Valve Check | 0,8 |
| 14 | Valve Adjustment | 4,2 |
| 15 | Clutch Check | 0,3 |
| 16 | Clutch Adjustment | 1,7 |
| 17 | Brake Check | 0,1 |
| 18 | Brake Adjustment | 0,9 |
| 19 | Brake Light Switch Adjustment | 1,0 |
| 20 | Battery Checkup | 2,0 |
| 21 | Tire Pressure Checks | 0,3 |
| 22 | Tire Pressure Addition | 1,7 |
| 23 | Shock Beaker examination | 1,0 |
| 24 | Steering Handlebar Check | 0,1 |
| 25 | Steering Handlebar Adjustment | 0,9 |
| 26 | Wheel Bearing Inspection | 1,0 |
| 27 | CVT examination | 15,0 |

**TABLE 3**
RELATIONSHIP RELIABILITY OF LIGHTWEIGHT INJECTION AND CVT SERVICE PACKAGES

| AC (1) | A (2) | AD (Minute) (3) | P (4) |
|---|---|---|---|
| 1 | Light Check | 0,5 | |
| 2 | Horn Check | 0,5 | |
| 3 | Removal of Cover Body | 7,0 | |
| 4 | Engine Oil Inspection | 1,0 | 3 |
| 5 | Oil Filter Check | 1,0 | 3 |
| 6 | Spark Plug Inspection | 0,1 | 3 |
| 7 | Spark Plug Adjustment | 0,9 | 6 |
| 8 | Injector Cleaner | 10,0 | 3 |
| 9 | Cleaning the Fuel Filter | 0,8 | 3 |
| 10 | Fuel Filter Replacement | 0,2 | 9 |
| 11 | Air Filter Cleaning | 0,8 | 3 |
| 12 | Air Filter Replacement | 0,2 | 11 |
| 13 | Valve Check | 0,8 | 3 |
| 14 | Valve Adjustment | 4,2 | 13 |
| 15 | Clutch Check | 0,3 | 3 |
| 16 | Clutch Adjustment | 1,7 | 15 |
| 17 | Brake Check | 0,1 | |
| 18 | Brake Adjustment | 0,9 | 17 |
| 19 | Brake Light Switch Adjustment | 1,0 | |
| 20 | Battery Checkup | 2,0 | 3 |
| 21 | Tire Pressure Checks | 0,3 | |
| 22 | Tire Pressure Addition | 1,7 | 21 |
| 23 | Shock Beaker examination | 1,0 | 3 |
| 24 | Steering Handlebar Check | 0,1 | |
| 25 | Steering Handlebar Adjustment | 0,9 | 24 |

The activity components are rearranged in the order of dependency logic. Dependency logic is obtained from observations and direct observations in the field.

The total duration needed for the lightweight injection and CVT service packages before scheduling is 65 minutes. There was a queue in the service of light injection and CVT service packages because all this time the workshop only determined scheduling based on experience.

### 3.1 Oil and Sparepart Replacement

Data collection of oil and sparepart replacement before processing can be seen in Table 4, Table 5, Table 6.

**TABLE 4**
DATA MAINTENANCE ACTIVITIES DESCRIPTIONS OF OIL AND SPARE PART REPLACEMENT

| AC (1) | A (2) |
|---|---|
| 1 | Light Check |
| 2 | Horn Check |
| 3 | Removal of Cover Body |
| 4 | Engine Oil Inspection |
| 5 | Oil Filter Check |
| 6 | Spare Parts Replacement |
| 7 | Mounting Cover |

**TABLE 5**
DATA COLLECTION OF OIL AND SPARE PART REPLACEMENT

| AC (1) | A (2) | AD (Minute) (3) |
|---|---|---|
| 1 | Light Check | 0,5 |
| 2 | Horn Check | 0,5 |
| 3 | Removal of Cover Body | 7 |
| 4 | Engine Oil Inspection | 1 |
| 5 | Oil Filter Check | 1 |
| 6 | Spare Parts Replacement | 0,5 |
| 7 | Mounting Cover | 0,5 |
| | Total | 11 |

**TABLE 6**
RELATIONSHIP RELIANCE OF OIL AND SPAREPART REPLACEMENT ACTIVITIES

| AC (1) | A (2) | AD (Minute) (3) | P (4) |
|---|---|---|---|
| 1 | Light Check | 0,5 | |
| 2 | Horn Check | 0,5 | |
| 3 | Removal of Cover Body | 7 | |
| 4 | Engine Oil Inspection | 1 | 3 |
| 5 | Oil Filter Check | 1 | 3 |
| 6 | Spare Parts Replacement | 0,5 | 3 |
| 7 | Mounting Cover | 0,5 | 4,5, 6 |

The total duration for oil and spare part replacement before scheduling is 11 minutes. There was a queue in oil and spare part changes because all this duration the workshop only determines scheduling based on experience.

## 4 RESULT AND DISCUSSION

### 4.1 Lightweight Injection and CVT Service Package

Critical pathway for lightweight injection and CVT service package can be seen in Figure 2

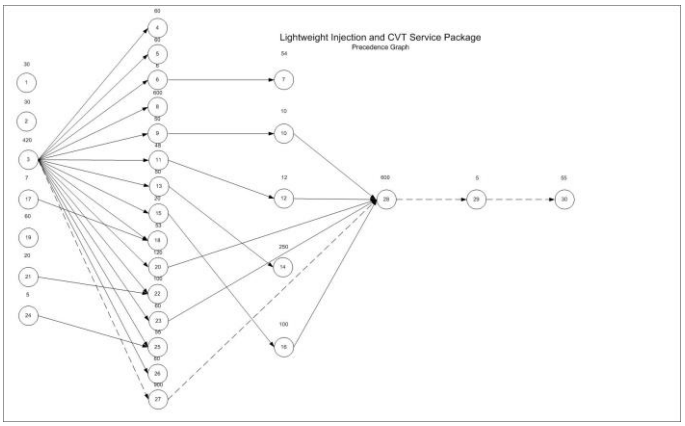



**Fig. 2**. *The Critical Path of Lightweight Injection and CVT Service Package Activity*

Critical route for lightweight injection and CVT service packages in activities (3) Cover Body Removal, (27) CVT examination, (28) Covering installation, (29) Nuts and Bolts examination and (30) Nuts and Bolts tightening. This path must be prioritized so that other activities continue to run smoothly.

Processing of lightweight injection and CVT service packages scheduling using CPM method can be seen in Table 7 and Table 8.

**TABLE 7**
SCHEDULING OF LIGHTWEIGHT INJECTION AND CVT SERVICE PACKAGES

| AC (1) | AD (2) | ES (3) | EF (4) | LS (5) | LF (6) |
|---|---|---|---|---|---|
| **Project** | 33,00 | | | | |
| 1 | 0,50 | 0 | 0,50 | 32,50 | 33,00 |
| 2 | 0,50 | 0 | 0,50 | 32,50 | 33,00 |
| 3 | 7,00 | 0 | 7,00 | 0,00 | 7,00 |
| 4 | 1,00 | 7,00 | 8,00 | 32,00 | 33,00 |
| 5 | 1,00 | 7,00 | 8,00 | 32,00 | 33,00 |
| 6 | 0,10 | 7,00 | 7,10 | 32,00 | 32,10 |
| 7 | 0,90 | 7,10 | 8,00 | 32,10 | 33,00 |
| 8 | 10,00 | 7,00 | 17,00 | 23,00 | 33,00 |
| 9 | 0,83 | 7,00 | 7,83 | 21,00 | 21,83 |
| 10 | 0,17 | 7,83 | 8,00 | 21,83 | 22,00 |
| 11 | 0,80 | 7,00 | 7,80 | 21,00 | 17,83 |
| 12 | 0,20 | 7,83 | 8,00 | 21,80 | 22,00 |
| 13 | 0,83 | 7,00 | 7,83 | 17,00 | 17,83 |
| 14 | 4,17 | 7,83 | 12,0 | 17,8 | 22,0 |

The total duration of Lightweight injection and CVT service package after scheduling is 33 minutes.

**TABLE 8**
CRITICAL ACTIVITY OF LIGHTWEIGHT INJECTION AND CVT SERVICE PACKAGE

| AC (1) | ES (3) | LS (5) | ST (7) | CA (8) |
|---|---|---|---|---|
| 1 | 0 | 32,50 | 32,50 | No |
| 2 | 0 | 32,50 | 32,50 | No |
| 3 | 0 | 0,00 | 0 | Yes |
| 4 | 7,00 | 32,00 | 25,00 | No |
| 5 | 7,00 | 32,00 | 25,00 | No |
| 6 | 7,00 | 32,00 | 25,00 | No |
| 7 | 7,10 | 32,10 | 25,00 | No |
| 8 | 7,00 | 23,00 | 16,00 | Yes |
| 9 | 7,00 | 21,00 | 14,00 | Yes |
| 10 | 7,83 | 21,83 | 14,00 | No |
| 11 | 7,00 | 21,00 | 14,00 | No |
| 12 | 7,83 | 21,80 | 14,00 | No |
| 13 | 7,00 | 17,00 | 10,00 | No |
| 14 | 7,83 | 17,83 | 10,00 | No |

From Table 8 it can be seen that maintenance activities carried out simultaneously are activities (1) inspection of lights, (2) inspection of horns, (3) removal of cover bodies, (17) inspection of brakes, and (24) checking of steering handlebar with the time the activity starts in seconds 0.

While in 420 seconds the activities carried out together are the activities of (4) checking of engine oil, (5) checking of oil filters, (6) checking of spark plugs, (8) injector cleaner, (9) cleaning of fuel filters , (11) cleaning the air filter, (13) checking the valve, (15) checking the clutch, (20) checking the battery, (23) checking the shock beaker, (26) checking the wheel bearings and (27) checking the CVT.

At 470 seconds the activities carried out together are (10) fuel filter replacement, (12) air filter replacement and (14) valve adjustment.

Table shows that both critical and non-critical activities can be carried out simultaneously which can speed up maintenance time.

In Table 2 and Table 7 it can be seen that the time taken on a lightweight injection and CVT service package, which initially took 65 minutes to 33 minutes. Acceleration duration for lightweight injection and CVT service packages is 37 minutes.

### 4.2 Oil and Spare Part

Critical path for oil and spare part replacement activities can be seen in Figure 3.

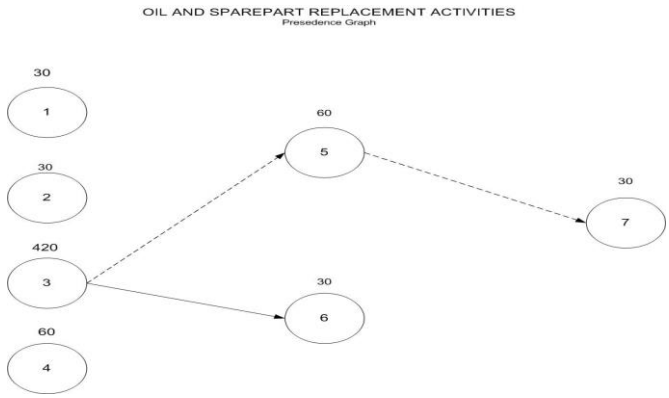



**Fig. 3**. *The Critical Path of Lightweight Injection and CVT Service Package Activity*

The critical path for oil and spare part changes in activities (3) Cover Body Removal, (5) Oil Filter Inspection, (7) Cover Installation. This path must be prioritized so that other activities continue to run smoothly.

Processing of oil and sparepart replacement scheduling using CPM method can be seen in Table 9 and Table 10.

**TABLE 9**
RESULT OF OIL AND SPAREPART REPLACEMENT SCHEDULING

| AC (1) | AD (2) | ES (3) | EF (4) | LS (5) | LF (6) |
|---|---|---|---|---|---|
| **Project** | 8,5 | | | | |
| 1 | 0,5 | 0 | 0,5 | 8 | 8,5 |
| 2 | 0,5 | 0 | 0,5 | 8 | 8,5 |
| 3 | 7 | 0 | 7 | 0 | 7 |
| 4 | 1 | 0 | 1 | 7,5 | 8,5 |
| 5 | 1 | 7 | 8 | 7 | 8 |
| 6 | 0,5 | 7 | 7,5 | 8 | 8,5 |
| 7 | 0,5 | 8 | 8,5 | 8 | 8,5 |

*AC= activity code, AD= activity duration, ES= earliest start, EF= earliest*

**TABLE 10**
CRITICAL ACTIVITY OF OIL AND SPAREPART REPLACEMENT

| AC (1) | ES (3) | LS (5) | ST (7) | CA (8) |
|---|---|---|---|---|
| 1 | 0 | 8 | 8 | No |
| 2 | 0 | 8 | 8 | No |
| 3 | 0 | 0 | 0 | Yes |
| 4 | 0 | 7,5 | 7,5 | No |
| 5 | 7 | 7 | 0 | No |
| 6 | 7 | 8 | 1 | No |
| 7 | 8 | 8 | 0 | No |

*AC= activity code, ES= earliest start, LS= latest start, CA= critical activity*

The total duration of oil and sparepart replacement after scheduling is 8,5 minutes.

Critical activity on the network has the same amount of time between Earliest Start (ES) and Latest Start. Activities on the Critical Path must be on time because they do not have a duration difference.

From Table 10 it can be seen that maintenance activities can be carried out simultaneously on the activities of (1) checking the lights and (2) examining the horn and (3) removing the body cover and (4) checking the engine oil with the activity

starting at the second to 0.

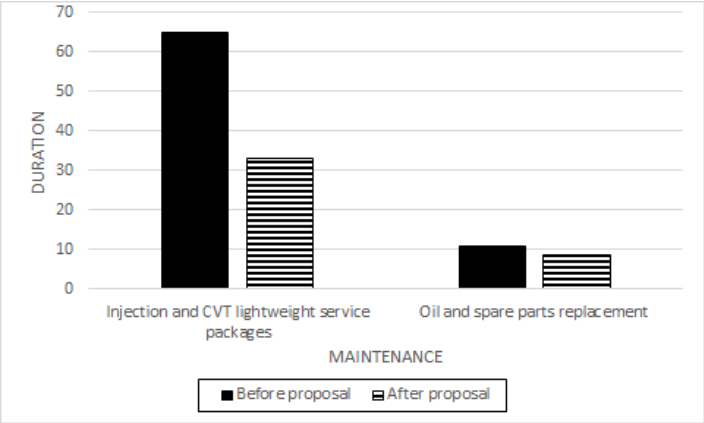
seconds 420 activities carried out together are activities (5) checking the oil filter and (6) replacing spare parts.

In Table 4 and Table 5 it can be seen that the duration required for oil and spare parts replacement which was originally 11 minutes to 8.5 minutes. the acceleration of oil and spare part change duration is 2.5 minutes.

A comparison of before and after the proposed improvement in scheduling of 1) lightweight injection and CVT service packages and 2) oil and spare parts replacement can be seen in Table 11 and Figure 4.

**TABLE 11**
COMPARISON BEFORE AND AFTER IMPROVEMENT

| Type of maintenance | Before improvement (minute) | After improvement (minutes) |
|---|---|---|
| lightweight injection and CVT service packages | 65 | 33 |
| Oil and spare parts replacement | 11 | 8.5 |




(1) $E\% = \frac{D_0 - D_1}{D_0}$ (1)

Where: $\%E$= Percentage of Efficiency, $D_0$ = Maintenance duration before proposed improvement, $D_1$= Maintenance duration after proposal improvement.

The results of the percentage efficiency of the lightweight injection and CVT service packages are as follows:

$$E\% = \frac{65-33}{65} \times 100\ \% = 49{,}23\ \%.$$

The results of the percentage efficiency of oil and spare part replacement are as follows :

$$E\% = \frac{11-8{,}5}{11} \times 100\ \% = 22{,}72\ \%.$$

Activities with longer duration occupy a critical path. The critical path is marked without slack time on ES with LS. The critical path slack work is equal to 0 (zero). This can relocate resources from non-critical work to critical work. This critical path must be prioritized because it affects the smooth running of other activities. when maintenance time is accelerated the capability of work station service capacity increases. the faster the maintenance process is completed, the faster the other automotives occupy the slots at the work station. The availability of work stations results in increased customer loyalty.

## 6 Conclusion and Suggestion

### 6.1 Conclusion

Studies show there is an acceleration of duration when the critical path method is carried out, this is achieved by carrying out critical and non-critical activities simultaneously.

The lightweight injection and CVT service packages get 37 minutes acceleration with 57.89% efficiency, oil and spare parts changes get 2.5 minutes acceleration with 22.72% efficiency.

### 6.3 Suggestion

From the results of research and discussion, it is recommended to mechanics to pay more attention to activities that are on the critical path. Delays that occur in critical paths can disrupt overall maintenance. The Critical pathway method will provide sufficient time to complete maintenance if used effectively.

## 7 References

[1] Rolfsen, Christian Nordahl. Merschbrock, Christoph, "Acceptance of construction scheduling visualizations: bar-charts, flowline-charts, or perhaps BIM?," in Procedia Engineering, pp. 558-566, doi.org/10.1016/j.proeng.2016.11.658. 2016

[2] Suherman and Ilma, Amarina., "Analisa Penjadwalan Proyek Menggunakan PDM dan Pert Serta Crash Project," Jurnal Teknik Industri, vol. 2, pages 31-45, available at https://ejournal.uin-suska.ac.id, 2016. [in Bahasa]

[3] Nursanti, Ellysa. Avief, Suaidy. Handoko, Fourry. "Overhaul Maintenance Scheduling Optimization of Indonesian Air Force Hawk MK-209 Aircraft Using CPM/PERT," International Journal of Advanced Industrial Engineering, vol. X, pages 1-12, available at https://inpressco.com/category/ijaie, 2017.

[4] Nursanti, Ellysa. Avief, R. M. Suaidy. Sibut. Kertaningtyas, Mariza, "Peningkatan Efisiensi Waktu dan Biaya Pemeliharaan Overhaul Pesawat Tempur," *Jurnal Teknologi dan Manajemen Industri*, vol. 4, pages 1-6, available at https://pdfs.semanticscholar.org, 2018. [in Bahasa]

[5] Wahdiat, Irwan Sutirman, "Analysis of Lean Accounting, JIT and Balance Scorecard in The Company's Lean Manufacturing," *International Journal of Scientific & Technology Research*, vol 5, pages 213-220, available at http://www.ijstr.org

[6] Zulia Manalu and Yuliani Dwi Lestari, "Project Effectiveness Improvement: A Case Study in PT.X," *Journal of Bussiness and*

*Management*. vol. 4, pages 587-593, available at https://journal.sbm..itb.ac.id, 2015.

[7] Heizer, Jay and Render, Barry, "Operations Management. Administration Texas Lutheran University and Crummer Graduate School of Business Rollins College. New Jersey," New Jersey: Prentice Hall, 2009.

[8] Nursanti, Ellysa. Avief, R.M. Suaidy, Sibut, Kertaningtyas, Mariza, "Parallel Series Scheduling for Aircraft Overhaul Maintenance," *Advances in Economics, Business and Management Research*, pp. 640-644, https://download.atlantis-press.com, 2019

[9] Sari, Nur Kumala. Puryani. Soepardi. "Penjadwalan Kegiatan Pemeliharaan untuk Memaksimalkan Availabilitas Mesin," Jurnal Optimasi Sistem Industri, vol. 11, pp. 105-111, http://jurnal.upnyk.ac.id/, 2018. [in Bahasa]

[10] Nwadinobi C. P. Mejeh K.I. Eti P. E. "Development of Network Model for Overhaul Maintenance of Meyer 78/18 Bottle Filling Machine," International Journal of Engineering and Modern Technology, vol. 3 No. 3, pp. 08-21. www.iiardpub.org,

[11] Mattila, V. Virtanen, K. "Maintenance Scheduling of A Fleet of Fighter Aircraft Throught Multi-objective Simulation Optimization". Simulation, vol. 9, pp. 1023-1040. doi:10.1177/0037549714540008, 2014

[12] Junqueira, V.S.V. Nagano, M.S. Miyata, H. H. "Procedure Structuring for Programing Aircraft Maintenance Activities". *Revista de Gestão. Vol 27, pp. 2-20,* www.emeraldinsight.com/2177-8736.htm, *2018*

[13] Selvan, M. Muthamil. Ahuja, Sangeeta. Parray, Roaf Ahmad. Rajaiah, P. Rangasamy, K. " Overhaul Maintenance of Modern Bulldozer with Software-Based Management Techniques (PERT/ CPM). Indian Journal of Agricultural Science 85 (4), https://www.researchgate.net, 2015.

[14] Midas, Matt, "Best Practices of Maintenance Planning and Scheduling," *Inspectioneering Journal,* vol. 21, issue 2, pp. 1-6, https://inspectioneering.com/, 2015

[15] Agyei, Wallace. "Project Planning and Scheduling using PERT and CPM Techniques with Linear Programming: Case Study," vol . 4, issue 08, https://www.ijstr.org, 2015