Jurnal Teknologi Kedirgantaraan (JTK)
Vol. 10, No 2, August 2025, page. 122 - 129
ISSN: 2528-2778 (Print); 2684-9704 (Online)
https://doi.org/10.35894/jtk.v10i2.245

JTK
Jurnal Teknologi Kedirgantaraan
(Journal of Aeronautical Engineering)

Analysis of The Removal and Installation Stages of The RR Trent 700 Engine on an Airbus A330 Aircraft Using the Critical Path Method

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Article Info

Article History:
Submitted: March 6, 2025
Revised: July 20, 2025
Accepted: July 24, 2025

Keywords:
MRO;
Removal and Install ;
RR Trent 700;
Critical Path Methods Efficiency.

ABSTRACT

The lifting of the Restriction of Community Activities (PPKM) in January 2023 was the beginning of the aviation industry in Indonesia starting to rise marked by the emergence of new Maintenance Repair and Operations (MRO). Limited hangar space at MRO is a challenge in scheduling aircraft maintenance, setting the order of task cards that have been submitted by the airline and must be done in the maintenance project will be an illustration of how long this project will be done. MP item number 7122410504 contains Detailed Inspection of Aft Engine Mount Fail-Safe link is a maintenance job that can be done after the removal of Engine. The engine removal and installation process often takes more time and effort, potentially causing delays in the overall maintenance time. The purpose of this research is to make efficiency in the removal and installation process of the RR Trent 700 engine using the critical path method. The critical path method in analysing the stages of work in the maintenance process aims to identify and optimise resource allocation, so that maintenance time can be minimised and overall efficiency can be improved. The results showed that the application of the critical path method in the stages of engine removal and installation work resulted in a time efficiency of about 1,655 Hours so that the delay in work on the critical path became the main factor affecting the total duration of the engine removal and installation process.

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INTRODUCTION

The airline industry is gradually recovering and experiencing a surge in demand following three years of disruption caused by the Covid-19 pandemic. The lifting of the Public Activity Restrictions (PPKM) in January 2023 has marked a turning point for the aviation sector in Indonesia, reflected in the rising number of both domestic and international passengers [1]. This recovery is further evidenced by the emergence of new Maintenance, Repair, and Overhaul (MRO) facilities, indicating an increase in operational aircraft that require scheduled maintenance. However, the existing MRO hangar capacity remains limited, making it necessary to implement alternating maintenance schedules. The accurate estimation of spare parts also plays a critical role, as it directly influences the duration of aircraft downtime during the maintenance process [2].

Maintenance task cards submitted by airlines to MROs are typically organized according to a defined process flow. Efficient management of these tasks not only ensures optimal maintenance quality but also helps maximize hangar throughput, enabling MRO providers to accommodate more aircraft and increase overall profitability [3]. One aircraft model that exemplifies the complexity of this process is the Airbus A330-300, introduced in 1993 and equipped with several engine options, including the Rolls-Royce Trent 700 [4]. The A330 undergoes several levels of maintenance, such as the A-Check performed every 1,000 flight hours, and more comprehensive heavy maintenance like the C-Check and D-Check, which are scheduled every two and six years, respectively [5].

Among the components requiring special attention during heavy maintenance is the aircraft engine. For instance, Maintenance Programme (MP) item number 7122410504, titled "Detailed Inspection of Aft Engine Mount Fail-Safe Link," necessitates engine removal prior to inspection. This task, while routine, is notably labor-intensive, time-consuming, and often inefficient. Moreover, it can delay other maintenance procedures, extend aircraft downtime and result in operational and financial losses for MRO providers [6].

Given these challenges, this study aims to analyze and optimize the engine removal and installation process by applying the Critical Path Method (CPM). CPM is a project management tool that identifies the sequence of interdependent activities that determine the minimum time required to complete a process. In the context of aircraft maintenance, CPM provides a structured approach to map all relevant activities, identify the most time-sensitive tasks, and determine their logical dependencies. The goal is to uncover the critical path within the engine maintenance workflow, allowing for a more precise understanding of which stages directly affect total maintenance duration.

Through this analysis, the study seeks to achieve several key objectives. First, it aims to identify critical activities whose delays would impact the overall turnaround time. Second, it endeavors to optimize the sequence of tasks and the allocation of resources—such as manpower, tools, and hangar space—so that maintenance operations can be carried out more efficiently. Third, the application of CPM is expected to reduce aircraft ground time, thus improving aircraft availability for operations. Ultimately, these improvements contribute to better scheduling decisions, reduced operational costs, and increased competitiveness of MRO providers in a post-pandemic recovery era [7][8].

Each airline develops a tailored Maintenance Programme (MP) for every aircraft type in its fleet, based on the standardized Maintenance Planning Data (MPD). While an MP may impose more stringent requirements than the MPD, it must never be more lenient, and implementation requires approval from the relevant aviation authority in the airline's country of operation. During the D-Check stage, licensed Aircraft Maintenance Engineers (AMEL holders) at MRO facilities are responsible for conducting inspections on critical systems, including engines. MP item 7122410504, which involves a detailed inspection of the Aft Engine Mount Fail-Safe Link, is categorized as a Detail Inspection (DET) task, requiring specific access provisions, specialized tools, and skilled personnel to execute properly.

METHODS

Critical Path Method

The Critical Path Method is a project management tool used to schedule, organize and coordinate the parts of work in a project. The use of the critical path method aims to identify crucial stages in the maintenance process, as well as determine the optimal sequence and allocation of resources to minimize overall maintenance time. Critical path scheduling uses a two-pass process consisting of forward pass and backward pass to determine the time schedule for each activity, then produces float/slack, where the relationship is formulated [9]. Early Finish (EF) is calculated by adding the Early Start (ES) of an activity to its Duration (D). This gives the earliest time an activity can be completed. Late Finish (LF) is found by adding the Late Start (LS) to the Duration (D). This indicates the latest time an activity can finish without delaying the project. Float (F) or slack is the amount of time an activity can be delayed without affecting the project's overall timeline. It is the difference between Late Start and Early Start, or between Late Finish and Early Finish. In this research there are several steps taken, as in the flowchart presented in **Figure 1.**

$$EF = ES + D \tag{1}$$

$$LF = LS + D \tag{2}$$

$$F - EF = LS - ES \tag{3}$$

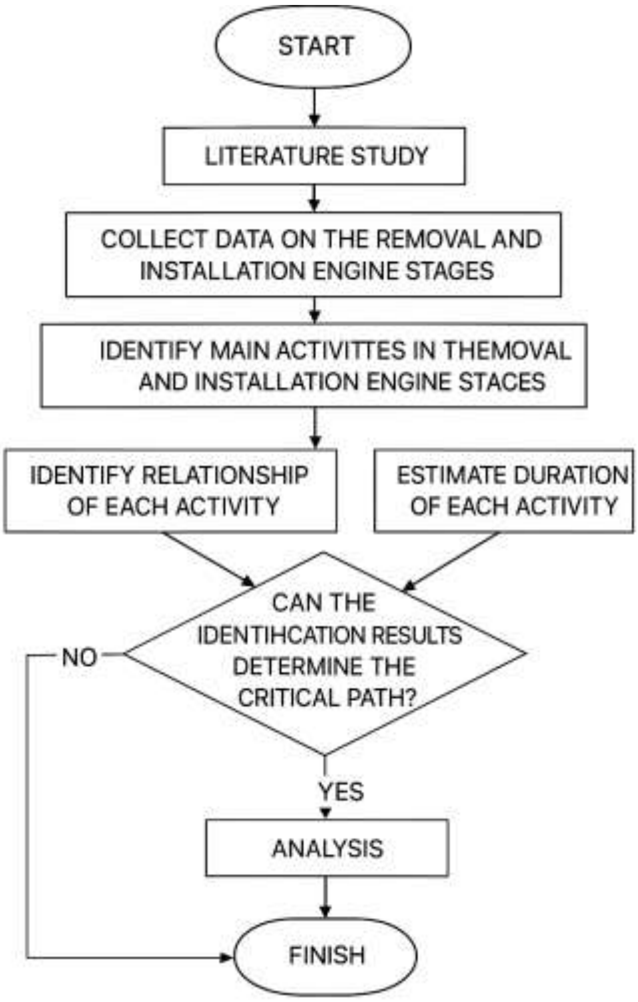

Figure 1 Research flowchart

In the implementation and completion of this research, it starts from collecting data on the stages of engine removal and installation. After that, the data is processed by identifying the main activities in the engine removal and installation stage, identifying the relationship between each activity and estimating each activity. After the data is processed and calculated, the critical path analysis that has been made before will be carried out.

In the research process, the critical path calculation method is used, which is one of the techniques used in project management to plan, organise, and control the sequence of activities in a project. The critical path helps project managers identify the critical path, which is a series of activities that have the longest completion time and have the potential to affect the overall completion time of Engine Removal and Installation activities.

Here are the steps in using the critical path method:

RESULT AND DISCUSSION

Removal and Installation Engine A330

The first stage was the collection of data on the time required to complete each of these stages from work experience and field observations. This time data was then analysed using the critical path method to identify critical paths and stages that require special attention.

Table 1 Work data of engine removal and installation

No	Step	System	Deskripsi Pekerjaan	Total Man Power	Man Power	Working time (minutes)	Working time (hour)
1	Removal	Preparation	Document and Tools Preparation	7	2	15	0,25
2			Aircraft Maintenance Configuration		2	15	0,25
3			Safety Precaution		2	10,2	0,17
4			Install the Thrust Reverser Safety Strut		2	22,5	0,375
5			Check The Storage Requirements		2	10,2	0,17
6			Drain The Engine LP Fuel System		2	36	0,6
7		Remove	Disconnection Of The Fluid Tubes		3	21	0,35
8			Disconnection The Electrical Connection		3	13,2	0,22
9			Disconnect The Air Ducts		3	24	0,4
10			Remove The IP8 Air Tube		3	9,96	0,166
11		Inspect	Inspect The Holes and Baseplates of the Engine Mount		2	16,2	0,27
12			Close-up		2	12	0,2
13	Lower	Engine	Perform installation of the Bootstrap	7	4	30	0,5
14			Install the Fan Cowl Doors Brace-Hold Open Cowls		4	20,4	0,34

No	Step	System	Deskripsi Pekerjaan	Total Man Power	Man Power	Working time (minutes)	Working time (hour)
15	Hoist		Perform Installation of the Multi- Purpose Transportation	7	4	24	0,4
16			Removal of the Engine		4	40,8	0,68
17		Cowl	Perform removal of the air intake cowl		3	42	0,7
18			Assemble the parking-stand common nozzle Assy		3	18	0,3
19			Perform removal of the common nozzle assembly		3	26	0,43
20		Begin	perform preparation of the engine for installation		2	20	0,33
21		Main	Installation Engine to the pylon		5	150	2,5
22			Attachment of the Engine to the Pylon		5	50,4	0,84
23	Installation	Clean	Remove The Multi-Purpose Cradle Stand From The Engine	7	3	32	0,53
24		Install	Connect the Air Duct		2	20	0,33
25			Connect the Electrical Connection		2	14	0,23
26		Closing	Connection of the Fluid Tubes		2	20	0,33
27			Install the IP8 Air Tube		2	15,6	0,26
28			Finishing		2	16,8	0,28

Network Path

Engine removal and installation job data obtained from Maintenance job card engine change A330 PK-ABC aircraft at PT XYZ, then we form a network path that connects all activities[10].

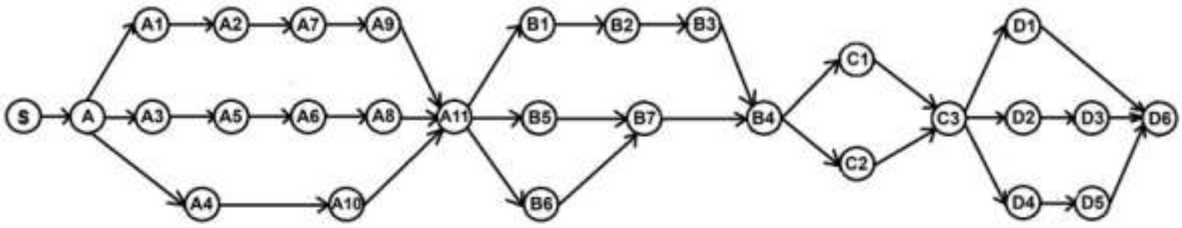

Figure 2 Network path

The network path that connects all jobs will be analysed by performing several calculations.Forward Pass. In identifying the critical path, a method called forward calculation is used. In the process of identifying the critical path of forward calculation, several formulas are known ES = earliest start time of an activity (Earlier Start Time) EF = earliest finish time of an activity (Earliar Finish Time) D = time needed to do the work..

Earliest Start Time (ES)	*MAN HOURS*	*Earliest Finish Time (EF)*
	SIMBOL	

Figure 3 Symbol of forward pass critical path method

From the results of the critical path method work network analysis, forward pass occupies the top box which means ES and EF. The calculation is done through formula (1), on activity code A has a calculation: EF = 0 + 0.125 = 0.125.

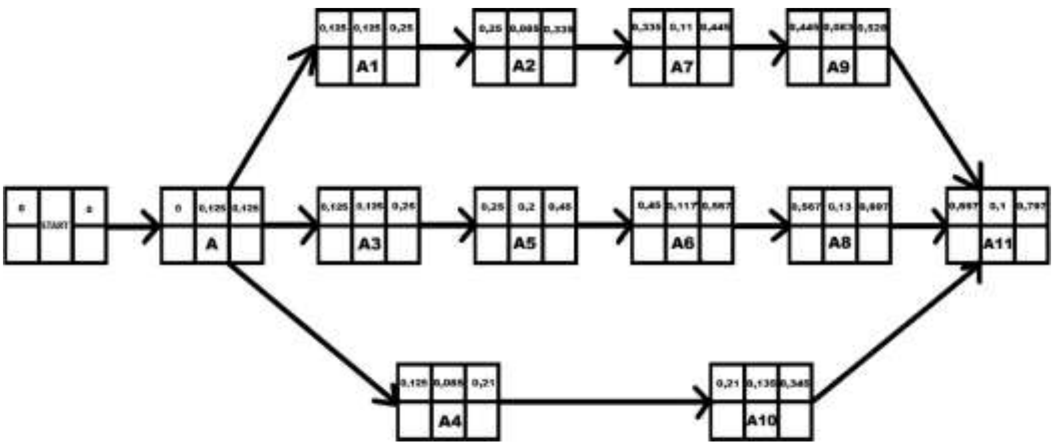

Figure 4 Initial calculation of forward pass

Backward Pass

The countdown is intended to determine the latest time that each activity can start and end without delaying the overall engine removal and installation time, which has been generated from the forward count. The countdown starts from the far right (the last hour of engine removal and installation completion) of a work network. In the process of identifying the countdown, several formulas are known LF = Latest Finish Time, LS = the latest time the activity starts, D = time required to do the work.

	MAN HOURS	
Latest Start Time (LS)	SIMBOL	*Latest Finish Time (LF)*

Figure 5 Symbol of backward pass critical path method

From the results of the critical path method work network analysis, backward pass occupies the top box which means ES and EF. The calculation is done through formula (2), on activity code D6 has a calculation: LF = 2.303 + 0.14 = 2.443

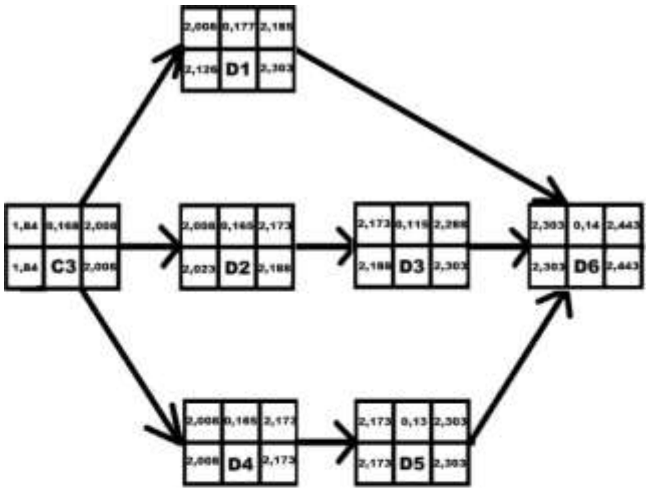

Figure 6 Initial calculation of backward pass

Float

the critical path, meaning that it cannot be delayed and on the critical path it takes the longest completion time. Once the forward and backward calculations have been completed, the float can be calculated. In planning and organising the engine removal and installation process, the importance of float is that it indicates the amount of time that can be used to postpone an activity, without affecting the overall schedule for completion of the removal and installation process. Overall work network path analysis has been published

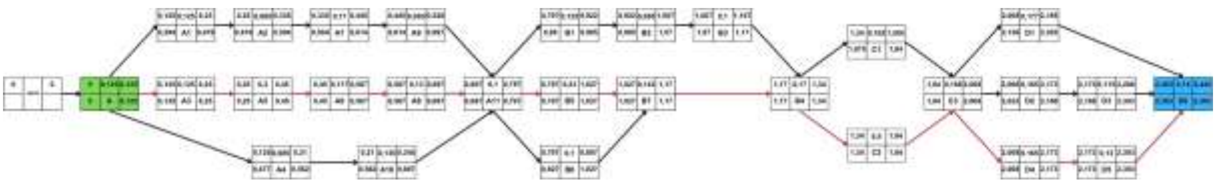

Figure 7 Engine removal and installation work network path calculation

CONCLUSION

The Conclusion section of a scientific journal article should provide a clear and concise summary of the key findings without introducing new information. It should restate the main objectives of the study and highlight the most significant results while avoiding excessive repetition of data from previous sections. Additionally, the conclusion should explain how the findings contribute to existing knowledge and discuss their practical, theoretical, or methodological implications. If relevant, real-world applications of the study can also be mentioned. Furthermore, it is important to acknowledge any limitations that may affect the interpretation of the results, providing an honest assessment of the study's constraints. Lastly, the conclusion should offer recommendations for future research by suggesting areas for further investigation or improvements in methodology. Overall, the conclusion should be concise, well-structured, and written in a formal academic tone to reinforce the importance of the research and leave a lasting impression on the reader.

ACKNOWLEDGEMENTS

The authors would like to express their sincere gratitude to the Department of Aeronautical Engineering, Universitas Dirgantara Marsekal Suryadarma, for the valuable support and assistance provided throughout the preparation and completion of this research. The guidance, resources, and facilities made available by the department were instrumental in the successful execution of this study.

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