Line balancing of aircraft IDG part maintenance process line balance using line balancing and promodel

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Abstract. *Aircraft have thousands of components that must be maintained to remain functional. Components on aircraft have a high enough price that maintenance is required. The power source on an airplane can be divided into 2 types, namely AC and DC. One source of AC electricity is the Integrated Drive Generator (IDG) which is one of the important components of an aircraft that functions as a generator of electricity. If IDG experiences a problem, it will disrupt aircraft operations. For this purpose, IDG must receive good care with effective services. The processing time for maintenance services takes 42.8 hours for one IDG part unit. This study aims to balance the trajectory. The IDG part maintenance process is carried out by Pro-model simulation. The results of the IDG maintenance simulation are the maintenance time in operation (Average time in Operation) which is 42.61 hours and the IDG parts handled are 11 IDG parts. The results of this simulation scenario can estimate the possible number of IDG parts that will occur annually and can estimate the total service capacity that handles the planned number of incoming entities. The best scenario results when the capacity of 1 service group per unit will result in the number of IDG maintenance services of 11 units per year, by increasing the service capacity to 2 service groups per unit will result in the number of IDG maintenance services of 23 units per year. And by increasing the service capacity to 4 service groups per unit, the number of maintenance services will be 46 units per year.*

Keywords: line balancing, modeling, pro-model, simulation.

1. Introduction

To support the transportation business, periodic maintenance is needed to maintain transportation performance. The reliability and availability of aircraft services must have the highest required level of safety and security. The need for maintenance has increased with the increasing intensity of flights and the number of aircraft operating in Indonesia. For this purpose, maintenance and repair services for aircraft components must be provided with effective and efficient services. The role of the aircraft maintenance industry is to provide aircraft maintenance services that are expected to maintain the longevity of the aircraft itself. One of them is in the field of aircraft maintenance, repair, and overhaul services which includes aircraft frames, engines, components, and their supports. PT GMF Aero Asia is very concerned about the quality of its services along with the number of aircraft maintenance service companies that have sprung up. Aircraft have thousands of components that must be maintained in order to remain functional. Components on aircraft have a high enough price that routine maintenance up to the provision of a safety system or prevention of component damage is also required. Domestic airplanes with passengers between 100 – 200 people are generally served by Boeing 737 series and Airbus 320 series (Aviatren, 2021).

Based on Boeing data, around 10,600 737 aircraft have been successfully delivered to their customers. Meanwhile, based on Airbus data, around 10,000 A320 aircraft have been successfully delivered to their customers (Aviatren, 2021). It is very important to prepare aircraft maintenance and repair services to maintain the reliability and availability of aircraft that operate safely and securely. The government as a regulator has regulated aviation security and safety through PP No. 3 of 2001. Aircraft must have an aircraft maintenance company certificate, which is proof of compliance with standard procedures in aircraft maintenance, aircraft engines, aircraft propellers, and other components. by a maintenance company (Phanden et al., 2021).

It was recorded from the Company's Maintenance Operations, in general, the stages of aircraft engine maintenance and its supporting components are carried out based on the implementation time interval. Disassembly and disassembly in maintaining aircraft are grouped into routine maintenance and non-routine maintenance. For routine maintenance, the set intervals must be repeated within these time intervals. While non-routine maintenance will be carried out based on the findings obtained during the operation of the aircraft. On average, routine maintenance of Boeing 737-class aircraft is divided into daily maintenance which is carried out in the Before Departure Check (BDC) phase, during a stopover at an airport or transit check, and daily inspection or daily inspection/24-hour check. Periodic maintenance is carried out at certain time intervals according to the maintenance inspection schedule.

One of the important parts of an airplane is the reliability and availability of the electrical system. The electrical system on an airplane is the main energy system which is very basic for the operation of an airplane. The power source on airplanes can be divided into 2 types of sources, namely AC power sources and DC power sources. One source of AC power is the Integrated Drive Generator (IDG) which functions as a generator of electricity. If IDG experiences a problem, it will disrupt aircraft operations. For this purpose, IDG must receive good care with effective services. On the experience data of the Care Service Facility of PT. GMF Persero in 2022 that the maintenance service process takes 42.8 hours for one IDG part unit and has provided a total of 42 IDG parts in the last 3 years.

The focus of this research is to design a trajectory model for the maintenance process of aircraft IDG parts, calculate the estimated balance of the trajectory of the maintenance process for aircraft IDG parts and create improvement scenarios to optimize the productivity of the aircraft IDG part maintenance process. From the results of this simulation scenario, it is hoped that it will be possible to estimate the possible number of entities that will occur annually and be able to provide the total service capacity that handles the planned number of entities (Weckenborg & Spengler, 2019).

Simulation models, new modeling approaches, decision support systems (DSS), and their integration can make decisions in companies that have industrial applications (Hizar, 2019). The optimization problem is divided into several general sub-problems to increase the convergence rate and avoid falling to the local optimal value by using hybrid methods (Deng, 2019). To increase production efficiency, achieve optimal production capacity, and calculate the right number of operators at workstations, a line balancing analysis is carried out (Pratama, 2019). Simulations can be carried out to optimize industrial services (Boydon, 2020). Typical problems faced by garment manufacturers are long production lead times, bottlenecks, and low productivity (Yemane, 2020). Line balancing can be utilized to achieve the required production level and to optimize objectives (Eghtesadifard, 2020). Modeling the path of the maintenance process line using the pro-model simulation program provides suggestions for the most optimal track conditions so that the company can review the line balance and production capacity currently owned by the company (Septiadi, 2023).

2. Method

The step for determining maintenance layout modeling, there are stages in the IDG maintenance process. These stages include the cleaning stage and the leakage current insulation resistance test stage. The following are the stages in building a simulation model (Anugerah et al., 2016)

- Step 1: Describing the process stages.

This stage is the initial stage before checking the IDG components. Prior to performing this work, it is necessary to search for the latest documents related to the cleaning stage as shown in Table 1.

Table 1 Maintenance Model

No.	Process	Working Time (in hours)
1.	Preliminary Inspection	0.3
2.	Testing, Disassembly, Cleaning	16
3.	Check	2
4.	Repair, Assy, Final, Test	24
5.	RTS	0.5

The treatment process design can be seen in the Operation Process Chart (OPC) which is presented in Figure 1.

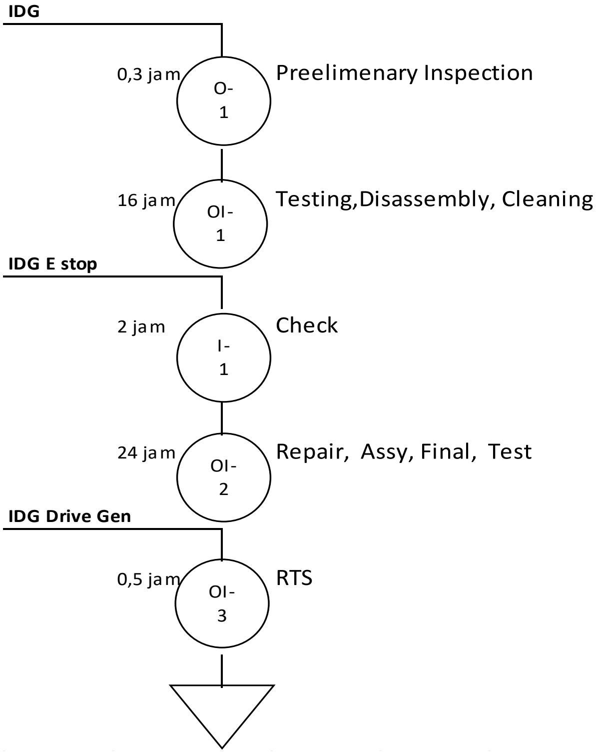


Figure 1 IDG Part Treatment Process.

- Step 2: Defining the technical parameter terminology in the output of Pro-model program.

Parameter terminology can produce output that can be analyzed consisting of:

Entity States

- % In Move Logic: the percentage of time the entity spends traveling between locations, including any delays that occur in the move logic.
- % Waiting: the percentage of time spent by an entity waiting for resources, Wait Until Condition, other entities to join or merge, or behind other entities. (100% - Sum of % for all other parts)
- % In Operation: the percentage of time the entity spends processing at a location or traveling on conveyors/queues. If an entity is on a conveyor behind another entity that is obstructed because the next location is unavailable, the time spent by the entity behind the other entity is considered % in Operations.

Location States (Multiple Capacity)

- Scheduled Time: the total number of times a scheduled location will be available. The value is now in decimal format, untruncated (Excludes off-shit time, break time, and scheduled downtimes)
- % Empty: the percentage of time the location has no entity.
- % Partially Occupied: the percentage of time that location has an entity but is not fully occupied (100% time - %Full Time - %Free Time).
- % Full: the percentage of time the location is full to entity capacity.
- % Down: the percentage of time the location was down as a result of unscheduled downtime. This does not exclude the possibility of overlapping with any of the three states.
- % Blocked: the percentage of time the entity spent waiting to the next available location.

Locations

- Scheduled Time: the amount of time the location is scheduled to be available. The value is now in decimal format, untruncated. (Excludes off-shit time, break time, and scheduled downtimes.)
- Capacity: the capacity specified in the location module for this location.
- Total Entries: the total number of entities that enter the site, excluding entities that come to join and are loaded. Entities that are separated, disassembled, or separated from other entities in a location are not counted as additional entries. Entities that came before have been grouped or loaded to form a single entity that only counts as one input/entry.
- Average Time Per Entry: the average time each entry spends at the location. This time can include partial times from the start and end of the actual running time.
- Average Contents: the average number of entries in locations.
- Maximum Contents: maximum number of entries occupying a location during the simulation.
- Current Contents: the number of entities remaining in the location when the simulation ends.
- % Utilization: The percentage of capacity filled, on average, during the simulation.

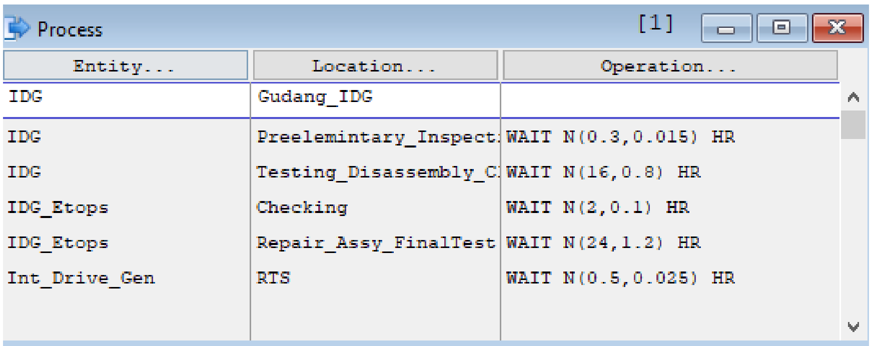
$$\frac{\text{Cumulative Occupancy Time x 100}}{\text{Capacity x Schedule Time}} \quad (1)$$

- Cumulative Occupancy Time: refers to the number of hours each entity spends at the processing location.

3. Result and Discussion

Identifying and determining inputs:

Entities: 3 consisting of IDG, IDG Estop, and IDG Drive
Process: 6 consisting of IDG Warehouse to finish (EXIT)
Therefore, Process Time = Actual Time $\pm$ 5% x Actual Time
The following results of the input made to the Pro-model software can be seen in Figure 2.



Process [1]

Entity...	Location...	Operation...
IDG	Gudang_IDG	
IDG	Preelemintary_Inspect:	WAIT N(0.3,0.015) HR
IDG	Testing_Disassembly_C:	WAIT N(16,0.8) HR
IDG_Etops	Checking	WAIT N(2,0.1) HR
IDG_Etops	Repair_Assy_FinalTest	WAIT N(24,1.2) HR
Int_Drive_Gen	RTS	WAIT N(0.5,0.025) HR

Figure 2 Entity, Location, and Operation Input.

Creating process flow model in Pro-model

After inputting each entity and process, the next step is to build a model framework in the Pro-model software. The following is a simulation model framework that can be seen in Figure 3.

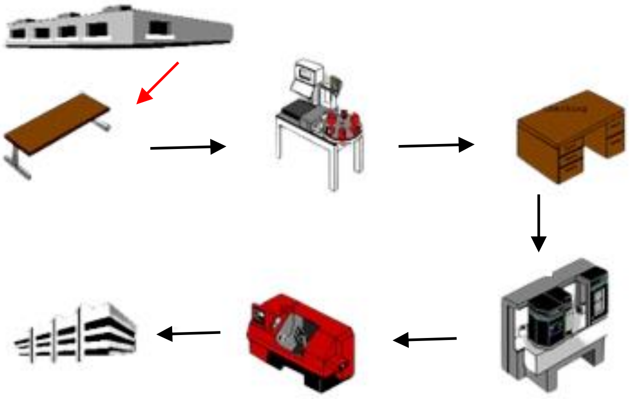


Figure 3 Disassembly Model of IDG Components.

Results of the Process Balance Modeling Execution

The conditions applied in the modeling were adjusted to the field conditions obtained over the last 3 years, which were published in the technical data of the annual report. The assumed input data are as follows:

- Service Operation Time: 1 year (365 days)
- IDG Arrival Time: 1 month (4 weeks or 28 days)
- Available Capacity: 1 job in 1 service unit

The results obtained are shown in Figure 4.

Entity Summary							
Name	Total Exits	Current Quantity In System	Average Time In System (Hr)	Average Time In Move Logic (Hr)	Average Time Waiting (Hr)	Average Time In Operation (Hr)	Average Time Blocked (Hr)
IDG	0,00	1,00	0,00	0,00	0,00	0,00	0,00
IDG Etops	0,00	1,00	0,00	0,00	0,00	0,00	0,00
Int Drive Gen	11,00	0,00	43,03	0,42	0,00	42,61	0,00

Figure 4 Entity Output.

The total number of IDGs that have been maintained in a year is 11 units with an average maintenance time during operation of 42.61 hours. The difference between actual and simulation results is obtained from = (42.80-42.61)/42.8 = 0.44%. The confidence level obtained from the created model simulation is 99.56%.

Based on maintenance orders

Based on the average maintenance orders from 2019, 2020, and 2021, the average obtained is 14 orders. The number of orders in 2019 was 17, in 2020 it was 11 and in 2021 it was 14.The following results can be seen in Table 2.

Table 2 Number of IDG Maintenance Orders

Year	Number of Orders
2019	17
2020	11
2021	14
Average	14

Based on the simulation of the maintenance process with an arrival of 28 days, it was obtained that IDG Product Outputs. The result can be seen in Figure 5.

Entity Summary		
Name	Total Exits	Current Quantity In System
IDG	0,00	1,00
IDG Etops	0,00	1,00
Int Drive Gen	11,00	0,00

Figure 5 Table of IDG Product Outputs.

The total exit produced was 11 IDG Drives and there was still 1 unit each of IDG and IDG Etop in the process. The difference between the actual and simulated average is (14-11)/14 = 27.3%. In actual condition, it occurred in 2019 when the Covid-19 pandemic had not yet happened, while in 2020-2021 the pandemic had started, and the actual average was 12 units. The difference would then become 8.3% [(12-11)/12].

Based on the validation and verification of the two conditions by comparing the actual and simulated conditions, the difference ranges above 90%, meaning that the modeling and simulation of the maintenance process can be declared valid and verified correctly.

Designing Scenarios

The next simulation scenario is to vary the number of IDGs received in terms of arrival time (Arrival) and the quantity of service capacity in terms of units (Capacity in Unit). The arrival time is in days, namely 7, 14, 21, 28, 35, 42, and 49, and the simulated capacities are 1, 2, 3, and 4 per unit.

Scenario 1:

The assumed input data are as follows:

- Duration of service operation: 1 year (365 days)
- Available capacity: 1 job in 1 service unit
- IDG arrival time (days): 7, 14, 21, 28, 35, 42, and 49.

The simulation results obtained from Scenario 1 can be seen in Table 3.

Table 3 Simulation Results Obtained from Scenario 1

	Entity			Average Time		Percentage of Schedule Time			
Arrival	**IDG Drive**	**IDG**	**IDG Estop**	**in Operation (Hr)**	**in System (Hr)**	**Moving Logic**	**Waiting**	**Operation**	**Blocked**
7	14	36	2	42.65	154.55	0.27	32.83	27.60	39.31
14	13	11	2	42.87	106.97	0.39	9.73	40.08	49.81
21	13	2	2	42.29	57.94	0.72	0	72.98	26.30
28	11	1	1	42.61	43.03	0.96	0	99.04	0
35	9	1	0	42.57	42.99	0.97	0	99.03	0
42	7	0	1	42.37	42.78	0.97	0	99.03	0
49	6	0	1	43.11	43.53	0.95	0	99.05	0

Based on Scenario 1, the optimal simulation is when the Operation Percentage is close to 100%, Waiting Percentage is close to 0%, and there is no blockage. This optimal simulation occurs at an arrival time of 28 days with 11 units of IDG Drive produced. This scenario is also known as the Basic Scenario, which is in line with the data and facts in the field.

Scenario 2:

The assumed input data for this scenario is as follows:

- Service Operation Time: 1 year (365 days)
- Available Capacity: 2 jobs per unit of service

- IDG Arrival Time (days): 7, 14, 21, 28, 35, 42, and 49.

The simulation results obtained from Scenario 2 can be seen in Table 4.

Table 4 Simulation Result Obtained from Scenario 2

	Entity			Average Time		Percentage of Schedule Time			
Arrival	**IDG Drive**	**IDG**	**IDG Estop**	**in Operation (Hr)**	**in System (Hr)**	**Moving Logic**	**Waiting**	**Operation**	**Blocked**
7	27	21	4	42.80	105.67	0.39	29.73	40.50	29.37
14	23	2	1	42.59	43.01	0.96	0	99.04	0
21	15	1	1	42.19	42.60	0.97	0	99.03	0
28	11	1	1	42.61	43.03	0.96	0	99.04	0
35	9	0	1	42.57	42.99	0.97	0	99.03	0
42	7	0	1	42.37	42.78	0.97	0	99.03	0
49	6	0	1	43.11	43.53	0.95	0	99.05	0

Based on Scenario 2, the optimal simulation is when the Operation Percentage is close to 100%, Waiting Percentage is close to 0, and there is no blocking. This optimal simulation occurs at arrival of 14 days with 23 IDG Drives produced. This scenario suggests that the service capacity should be available in 2 parallel groups.

Scenario 3:

The assumed input data for this scenario are as follows:

- Service Operation Time: 1 year (365 days)
- Available Capacity: 3 jobs per unit of service
- IDG Arrival Time (in days): 7, 14, 21, 28, 35, 42, and 49.

The simulation results obtained from Scenario 3 can be seen in Table 5

Table 5 Simulation Result Obtained from Scenario 3

	Entity			Average Time		Percentage of Schedule Time			
Arrival	**IDG Drive**	**IDG**	**IDG Estop**	**in Operation (Hr)**	**in System (Hr)**	**Moving Logic**	**Waiting**	**Operation**	**Blocked**
7	39	7	6	42.95	42.95	0.67	15.22	68.95	15.17
14	23	2	1	42.59	42.59	0.96	0	99.04	0
21	15	1	1	42.19	42.19	0.97	0	99.03	0
28	11	1	1	42.19	42.19	0.96	0	99.04	0
35	9	0	1	42.57	42.57	0.97	0	99.03	0
42	7	0	1	42.57	42.57	0.97	0	99.03	0
49	6	0	1	43.11	43.11	0.95	0	99.05	0

Based on Scenario 3, the optimal simulation is achieved when the Operation Percentage is close to 100%, Waiting Percentage is close to 0, and there are no blocks. The optimal simulation occurs on the 14th day of arrival with 23 units of IDG Drives produced. This scenario indicates that service capacity must be available in 3 parallel groups.

Scenario 4:

The assumed input data are as follows:

- Service Operation Time: 1 year (365 days)
- Available capacity: 4 jobs in 1 service unit
- IDG Arrival Time (days): 7, 14, 21, 28, 35, 42, and 49

The simulation results obtained from Scenario 3 can be seen in Table 6

Table 6 Simulation Result Obtained from Scenario 4

	Entity			Average Time		Percentage of Schedule Time			
Arrival	**IDG Drive**	**IDG**	**IDG Estop**	**in Operation (Hr)**	**in System (Hr)**	**Moving Logic**	**Waiting**	**Operation**	**Blocked**
7	46	3	3	42.57	43.00	0.97	0	98.98	0.05
14	13	11	2	42.87	106.97	0.96	0	99.04	0
21	15	1	1	42.19	42.60	0.97	0	9903	0
28	11	1	1	42.61	43.03	0.96	0	99.04	0
35	9	0	1	42.57	42.99	0.97	0	99.03	0
42	7	0	1	42.37	42.78	0.97	0	99.03	0
49	6	0	1	43.11	43.53	0.95	0	99.05	0

Based on Scenario 4, the optimal simulation is where the Operation Percentage is close to 100%, Waiting Percentage is close to 0, and there is no one blocked or delayed. The optimal simulation occurs at the arrival of 7 days with 46 units of IDG Drive generated. This scenario suggests that service capacity must be available in 4 parallel groups.

Analyzing the Comparison Results

The results obtained from the simulation scenarios can be compared in the following Table 7 and Figure 6.

Table 7 Comparison of Operational System Process Results for Each Scenario

Arrival	Achieved System Operation Process (%)			
(Day)	Scenario 1	Scenario2	Scenario 3	Scenario 4
7	28	41	69	99
14	40	99	99	99
21	73	99	99	99
28	99	99	99	99
35	99	99	99	99
42	99	99	99	99
49	99	99	99	99
Total Exit	11	23	23	46

Based on Table 7 and Figure 6, it can be analyzed that having 1 service group per unit will result in 11 units of IDG maintenance service per year while adding the service capacity to 2 groups per unit will result in 23 units of IDG maintenance service per year. Finally, increasing the service capacity to 4 service groups per unit will result in 46 units of maintenance service per year.

The performance of the optimization process can reduce processing time and passenger waiting time with line balancing and simulation methods that can be used to optimize the departure terminal system at the airport (Novrisal, 2015). Application of management pro-model simulation analysis of PT. XYZ can make decisions to increase productivity by considering the percentage of the workload of all resources used and providing opportunities for recommendations for improvement with the topic of improvement methods such as line balancing to balance lines (Suwandi, 2019).

A simulation model of the actual line and the improvement result line by providing a simulation of each result (Kharuddin, 2020). Like previous research using process trajectories with pro-model simulations that seek optimal results such as Haekal (2021) uses the Helgerson Bernie approach, namely the line balancing method simulation so that the line efficiency value is 95.76%. The improvements made were effective in eliminating waste and increasing productivity with an improvement of 25.0% (Abdurrahman, 2022).

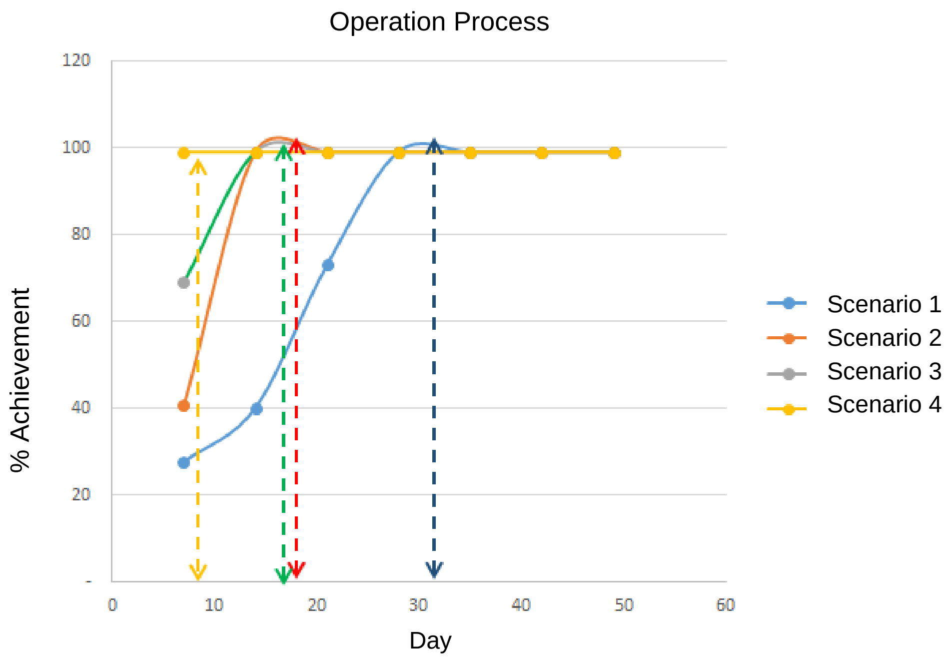


Figure 6 Operation System Processes Against Arrival Time

4. Conclusion and Suggestion

The process flow model of aircraft IDG part maintenance using discrete event simulation with Pro-model yielded a result of a total of 11 IDG parts that were serviced in one year with an average maintenance time of 42.61 during its operation. Pro-model simulation is highly reliable as evidenced by two conditions, namely the Maintenance Time and the Output units that can be serviced, which closely match actual maintenance conditions. The actual total maintenance process time is 42.80 hours, while the maintenance process time in operation (Average time in Operation) is 42.61 hours. The difference between the actual and simulated results is 0.44%. The confidence level obtained from the simulation model is 99.56%. Meanwhile, from the output of units maintained, the difference will be 8.3%. Thus, comparing the actual conditions and simulation results, the difference range is above 90%, meaning that the modeling and simulation of this maintenance process can be considered valid and correctly verified. The proposed process improvement scenario is to vary the number of IDGs received in terms of arrival time (Arrival) and the quantity of service capacity in terms of the number of units (Capacity in Units). The arrival time is in days, namely 7, 14, 21, 28, 35, 42, and 49, and the simulated capacities are 1, 2, 3, and 4 per unit. The best scenario result is achieved when the capacity is 1 service group per unit, which will result in 11 units of IDG maintenance per year. Increasing the service capacity to 2 groups per unit will result in 23 units of IDG maintenance per year. And increasing the service capacity to 4 groups per unit will result in 46 units of IDG maintenance per year.

IDG part maintenance process modeling provides the best scenario as a suggestion for companies to be able to increase the output of treated IDG products by considering the length of service, capacity, and arrival of IDG. Further research can be continued by detailing the activities of the treatment process.

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