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Estimating The Necessity For Brake Spare Parts at PT XYZ Using The Monte Carlo Method

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ABSTRACT

Companies often experience serious challenges related to the availability of aircraft spare parts. This research was conducted at PT XYZ with the aim of estimating the need for aircraft brake parts in the future using historical replacement data. Brake replacement data is random because it is not a scheduled replacement, so a Monte Carlo model is used. The Monte Carlo method has advantages, one of which is that it is easily understood by non-mathematicians and can generally be easily expanded and developed as needed. The results showed that brake replacement in 2022 was 405 and in 2023 was 481. Linear regression estimated the spare parts requirements for 117 aircraft (A320, B737-900ER, and B737-9 MAX) in 2024. The actual number of replacements over 2 years was 886, with Monte Carlo simulation yielding 922 and linear regression 945. Comparison with actual data for 6 months in 2024 shows a difference of 7% for Monte Carlo and 23% for linear regression. The Monte Carlo method has a smaller percentage difference than linear regression, making it more effective to use. This shows that the smaller the percentage difference, the more accurate the forecasting.

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INTRODUCTION

Aircraft is a means of transportation that has the highest interest among the Indonesian people until now. This transportation tool has many advantages including being able to reach long distances with short travel times, having sophisticated technology, having a high level of comfort and safety[1]. On an airplane there is one of the main components, namely the brake which functions to slow down, hold, and stop the speed of the aircraft during landing, taxing, and parking. Inventory and planning of brake spare part requirements are the main challenges at PT XYZ. Where the company is engaged in Maintenance Repair and Overhaul (MRO)[2].

Spare part inventory management is one of the factors that can affect service quality. Where it demands that aircraft maintenance be completed on time accompanied by quality work results in accordance with existing flight standards, therefore it is important to manage inventory in the company[3]. In this analysis, a simulation of forecasting methods based on PT XYZ data will be tried to predict and determine the need for accurate brake spare parts so that there is no shortage of stock. One method that can be used is the Monte Carlo method because brake replacement data includes random data. This replacement is not known when it should be replaced and cannot be ascertained because it is not included in the scheduled replacement. This method uses historical data from aircraft brake damage, thus providing accurate information on spare parts inventory planning[4]. The use of the Monte Carlo method that will be tried at PT XYZ aims to be able to predict the need and supply of brake spare parts in the future so that there is no shortage. If the spare part inventory is not controlled properly, it can cause flight delays and can even cause Aircraft On Ground (AOG). This is the background of research with the title "Estimating the need for brake spare parts at PT XYZ using the Monte Carlo Method".

Based on the explanation and background above, the analysis that will be discussed is how to predict the need for brake spare parts in the future using historical data for 2022-2023 by applying the Monte Carlo method and comparing it to actual data for 6 months in 2024 and not calculating the cost of procuring brake spare parts. This analysis is carried out with the aim of knowing whether the Monte Carlo method can be used to predict the need for brake spare parts.

METHODS

Based on Civil Aviation Safety Regulation (CASR) part 43 concerning Maintenance, Preventive Maintenance, Rebuilding and Alteration, maintenance is all activities carried out to maintain aircraft, aircraft components and equipment in an airworthy state including inspection, repair, service, overhaul and component replacement. To perform maintenance on the aircraft there is such a thing as a Maintenance Program which contains the time when the aircraft maintenance must be carried out and what processes must be carried out[5]. Maintenance programs are divided into two broad outlines which include preventive maintenance and Corrective maintenance. Aircraft maintenance is also divided based on work package intervals (Clustering) which aims to facilitate maintenance so that maintenance becomes more effective and efficient. The types of aircraft maintenance intervals include Flight Hours, Flight Cycle, and Calendar time[6].

Inventory is useful for determining the level of inventory to be maintained, when backorders should be placed, and how many orders should be placed. Some of the functions of inventory control are as a backup so that there are no delays when there is unexpected demand, anticipating surges in consumer demand[7]. The Monte Carlo method is a mathematical technique that generates random variables to model risk or uncertainty in a system[8]. The Monte Carlo method has the advantage of being easily understood by non-mathematicians. It also has the disadvantage that calculations can take longer than analytical models[9].

Brake is an important component used to reduce speed on a vehicle. Brakes on aircraft also have the same function which slows, holds, steering, and stops the speed of the aircraft. In this case the brake also has a role in supporting the aircraft during landing, taxing and parking. The carbon brake is an update of the Multiple-Disc Brake. Therefore for modern aircraft today many use this type of brake, especially on high-performance aircraft[10]. In this research there are several steps taken, as in the flowchart presented in **Figure 1**.

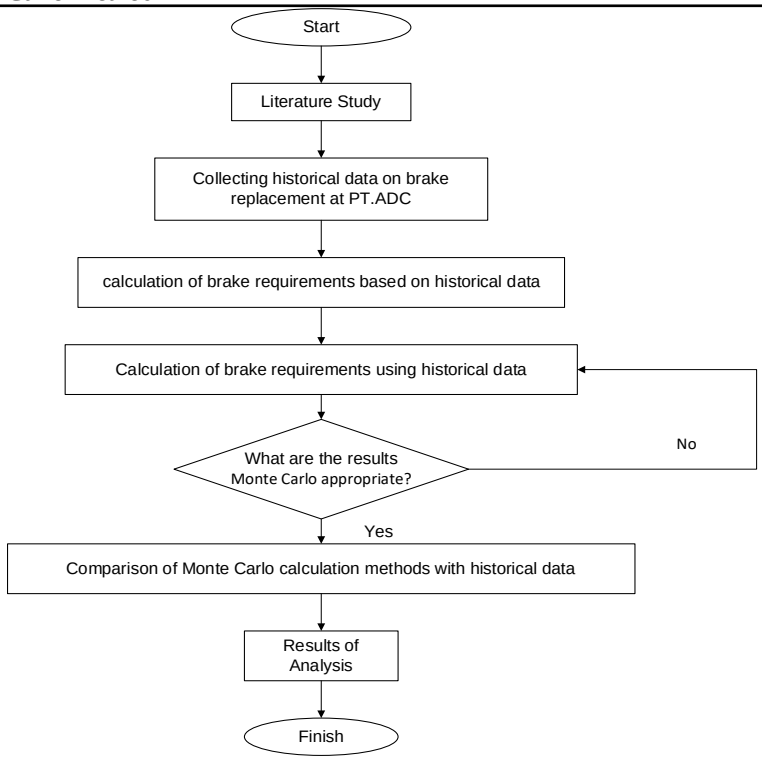

Figure 1 Research flowchart

According to **Figure 1** Flowchart of the research, this analysis begins with the collection of historical brake replacement data. This historical data then became the basis for calculating brake requirements conventionally. To obtain more accurate and comprehensive results, calculation simulations using the Monte Carlo method were also carried out. The simulation results were then compared with the latest historical data. The comparison is done to get a value of how well the simulation model developed in describing the actual conditions. The results of this analysis are expected to provide predictions of spare part inventory in the future.

Simulation with Weekly Data in 2022 - 2023

Monte Carlo simulation can be done by observing the following steps. The data used is data in two years where the data is grouped into weeks accompanied by the number of brake changes in each week. Fisrt calculate the frequency of the number of brake usage. The frequency shows how often the number of uses appears in the data as found in Table 1.

Table 1 frequency

NUMBER OF USE	F
1	1
2	5
……	……
15	3
19	2
n	**104**

Table 1shows the brake usage that has been categorized on a weekly basis. The rare brake replacement is 1 in each week, with a damage frequency of 1 brake damage.The next step is to find the opportunity value as found in **Table 2**

Table 2 Chance

NUMBER OF USE	F	P
1	1	0,009615
2	5	0,048077
……	……	……
15	3	0,028846
19	2	0,019231
n	**104**	

To find the opportunity value, divide each turnover by the total turnover. Get the calculation as follows:

$$\boldsymbol{P} = \frac{F}{n} = \frac{1}{104} = 0{,}009615 \quad (1)$$

The next step is determine the Cumulative Probabilities, determine the cumulative odds obtained by summing the odds with the cumulative odds. Since the first cumulative chance is unknown, the first cumulative chance is taken from the first chance number, so that the second cumulative chance is obtainedshown in Table In **Table 3**

Table 3 Cumulative Probabilities

NUMBER OF USE	F	P	P CUMULATIVE
1	1	0,009615	0,009615
2	5	0,048077	0,057692
……	……	……	…….
15	3	0,028846	0,980769
19	2	0,019231	1,000000
n	104		

Get the calculation as follows :

$$\boldsymbol{P\ Cumulative} = P\ Number + P\ Cumulative = 0{,}009615 + 0{,}048 = 0{,}057692 \quad (2)$$

In this step, determine the Interval Random Number by taking a number from 0 to an integer from the result of multiplying the cumulative probability by 1000.

$$\textbf{Interval Random Number} = P\ Cumulative \times 1000 = 0{,}009615 \times 1000 = 9 \quad (3)$$

Table 4 Interval Random Number

NUMBER OF USE	F	P	P cumulative	Interval
1	1	0,009615	0,009615	0 – 9

2	5	0,048077	0,057692	10 – 57
……	……	……	…….	…….
15	3	0,028846	0,980769	952 – 980
19	2	0,019231	1,000000	981 - 1000
n	104			

In Table 4 shows that each column is interconnected which is needed to simulate the Monte Carlo method. Interval Random Number data will be a reference to bring up demand simulation data. In this step, determine the Random Number with the aim of obtaining demand simulation data obtained from the formula in Ms. Excel, namely (=RANDBETWEEN) functions in generating numbers within certain limits. In this analysis, the range of numbers used to generate random numbers is 1 for the lowest limit and 1000 for the highest limit. The random numbers that have been obtained from Ms. Excel are used to predict the future demand for brake spare parts by determining which interval corresponds to the random number. Each random number that falls into a certain interval will represent the simulation results as shown in **Table 5**

Table 5 Monte Carlo Simulation

NO	WEEK	RANDOM NUMBER	REQUEST (SIMULATION)
1	1	806	12
2	2	622	10
……	……	……	…….
103	103	35	2
104	104	903	13
		n	922

Result and discussion

Monte Carlo Simulation Results With Weekly Data In 2022 – 2023

This chapter begins by displaying data that has been processed in tabular form regarding the number of brake changes in several aircraft for 2 years, namely January 2022 to December 2023 which are grouped weekly. The following is the weekly brake change data contained in **Table 6**

Table 6 Two years of weekly brake data and result of calculation

NO	DATE	TOTAL BRAKE REPLACEMENT	SIMULATION	DEVIATION (%)
1	01/01/2022 - 01/07/2022	9	12	……
2	01/08/2022 - 01/14/2022	12	10	……
……	……	……	……	……
103	11/04/2023 – 11/10/2023	9	2	……
104	11/11/2023 – 11/17/2023	6	13	……
	n	**886**	**922**	**4%**

Based on **Table 6**, the number of brake replacements can be calculated for each week. For example, on 01/01/2022 - 01/07/2022 there were 9 brake replacements. It is from the weekly data for a period of two years that is used in the application of the Monte Carlo method. **Table 6** also shows a comparison based on the results of the Monte Carlo analysis calculation with actual data. The comparison aims to determine the difference in total replacement. The difference in total replacement is calculated and expressed as a percentage. The percentage of this difference is obtained by dividing the actual data by the analyzed data, then multiplying by 100%. In this case, it means that the smaller the percentage difference, the more accurate the Monte Carlo forecast. It can be seen that the total brake change is 886 while the total brake change based on Monte Carlo analysis is 922, there is a difference of 4% between the actual data and the results of the Monte Carlo calculation. Based on the calculations that have been carried out, it shows that the Monte Carlo simulation can fulfill the inventory of brake spare parts for two years with a fairly small difference. The following is a comparison diagram of brake replacement generated based on data for 2 years. In this case, the brake replacement data in **Table 6** is used.

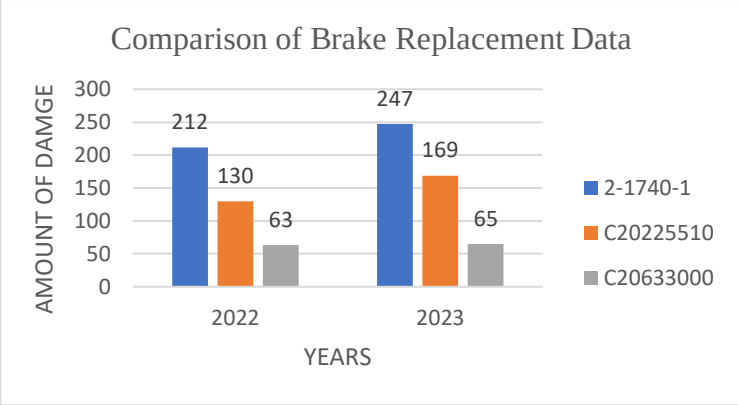

Figure 2 Brake replacement data

Figure 2 shows a comparison diagram of brake replacement in 2022-2023. In 2022 there were 405 brake replacements In 2023 there was an increase of 481 brake replacements.. In **Table 7** there is a comparison of data between the results of Monte Carlo simulation calculations and actual data from 2022-2023 as a whole. This analysis begins by presenting actual data in 2024 starting from week 1 on 01/01/2024 to week 26 on 06/24/2022. The following is the brake data contained in **Table 7**

Table 7 26-week brake data in 2024 and result of calculation

NO	DATE	TOTAL BRAKE REPLACEMENT	SIMULATION	DEVIATION (%)
1	01/01/2024 - 01/07/2024	6	12	……
2	01/08/2024 - 01/14/2024	9	10	……
……	……	……	……	……
25	06/17/2024 - 06/23/2024	7	6	……
26	06/24/2022 - 06/30/2022	4	6	……
	n	**201**	**216**	**7%**

In **Table 7** the actual data is used to compare with the results of the Monte Carlo simulation calculations that have previously been carried out. **Table 7** also shows a comparison based on the results of the Monte Carlo analysis calculation with actual data, where there is a difference in total. The difference is obtained by dividing the actual data with the analysis data which is then multiplied by

100%. In this case, it means that the smaller the percentage difference, the more accurate the Monte Carlo estimate. Based on the calculations that have been carried out, it shows that the Monte Carlo simulation can fulfill the inventory of brake spare parts for twenty-six weeks with a fairly small difference. It can be seen that the total brake replacement in 2024 is 201 while the total brake replacement based on Monte Carlo analysis is 216. There is a difference of 7%, this difference is quite small because brake damage rarely occurs and the number of replacements is not as much as other components such as aircraft tires, thus indicating that Monte Carlo analysis can be used to estimate future brake replacement requirements. If the weekly simulation calculation is compared with the actual data in the form of a graph, it can be seen as in Figure 4.9.

Monte Carlo Simulation Results With Monthly Data In 2022 – 2023

This chapter begins by displaying data that has been processed in tabular form regarding the number of brake changes in several aircraft for 2 years, namely January 2022 to December 2023 which are grouped monthly. The following is the monthly brake change data contained in **Table 8**

Table 8 Two years of monthly brake data and result of calculation

NO	MONTH	TOTAL BRAKE REPLACEMENT	SIMULATION	DEVIATION (%)
1	JANUARY 2022	40	46	……
2	FEBRUARY 2022	19	56	……
……	……	……	……	……
103	NOVEMBER 2023	30	34	……
104	DECEMBER 2023	39	39	……
	n	**886**	**957**	**8%**

Based on **Table 8**, the number of brake replacements can be calculated for each month. For example, on January there were 40 brake replacements. It is from the monthly data for a period of two years that is used in the application of the Monte Carlo method. **Table 8** also shows a comparison based on the results of the Monte Carlo analysis calculation with actual data. The comparison aims to determine the difference in total replacement. The difference in total replacement is calculated and expressed as a percentage. The percentage of this difference is obtained by dividing the actual data by the analyzed data, then multiplying by 100%. In this case, it means that the smaller the percentage difference, the more accurate the Monte Carlo forecast. It can be seen that the total brake change is 886 while the total brake change based on Monte Carlo analysis is 957, there is a difference of 8% between the actual data and the results of the Monte Carlo calculation. Based on the calculations that have been carried out, it shows that the Monte Carlo simulation can fulfill the inventory of brake spare parts for twenty-six weeks. This analysis begins by presenting actual data in 2024 starting from month 1 on January 2024 to June 2024. The following is the brake data contained in **Table 9**

Table 9 Comparison of actual data with 6-month monte carlo and result of calculation

NO	MONTH	TOTAL BRAKE REPLACEMENT	SIMULATION	DEVIATION (%)
1	JANUARY 2024	30	46	……
2	FEBRUARY 2024	41	56	……
……	……	……	……	……
103	MEI 2024	47	56	……
104	JUNE 2024	27	33	……
	n	**201**	**256**	**22%**

In **Table 9** the actual data is used to compare with the results of the Monte Carlo simulation calculations that have previously been carried out. **Table 9** also shows a comparison based on the results of the Monte Carlo analysis calculation with actual data, where there is a difference in total. The difference is obtained by dividing the actual data with the analysis data which is then multiplied by 100%. In this case, it means that the smaller the percentage difference, the more accurate the Monte Carlo estimate. Based on the calculations that have been carried out, it shows that the Monte Carlo simulation can fulfill the inventory of brake spare parts for six month. It can be seen that the total brake replacement in 2024 is 201 while the total brake replacement based on Monte Carlo analysis is 256. There is a difference of 22%, Based on the calculations that have been carried out, it shows that the Monte Carlo simulation can fulfill the inventory of brake spare parts for six month.

Estimation of Brake Spare Part Requirements Based on Linear Regression

Based on **Figure 3** displays data on the number of aircraft used at PT XYZ for 2 years which will be used to predict using the linear regression method. In this case, the brake replacement data in **Table 6** is used.

	2022	2023	2024
AMOUNT OF AIRCRAFT	171	199	117
BRAKE CHANGE	405	481	201

Figure 3 Aircraft Data

In this analysis, the Linear Regression method is also used in estimating the need for brake spare parts in order to compare with the prediction results using the monte carlo method. The following is the linear regression line equation generated based on the number of aircraft in **Figure 4**

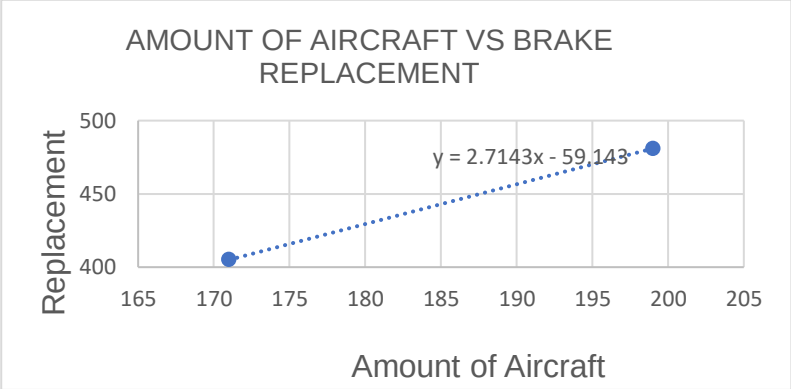

Figure 4 Regresi linier

Based on **Figure 4** shows the relationship between the number of aircraft in operation and the number of brake changes. There is a positive correlation and linear regression line shown in Figure 4.3 in this case an increase in the number of aircraft followed by an increase in the number of brake changes. And there is a regression line equation produced, namely y = 2.7143x - 59.143, in which case it can be used to predict the number of brake changes based on the number of known aircraft. y = 2.7143×117-59.143 = 258.4301 the result of y is the predicted number of brake changes in 2024 with the value of x obtained from the number of aircraft in 2024 which amounts to 117. y=2,7143×370-59,143 = 945,148 the result of y is the predicted number of brake changes for 2 years, namely 2022 and 2023 with the value of x obtained from the number of aircraft in 2024, which is 370.

Analisys

Based on the analysis that has been carried out using the Monte Carlo method which aims to estimate the future need for brake spare parts at PT XYZ, the use of weekly data is more accurately used to estimate the need for brake spare parts. This is because when the analysis is carried out using monthly data the resulting percentage difference is greater than using weekly data. In this case, it means that the smaller the percentage difference, the more accurate the Monte Carlo forecast. In this analysis, estimates are also not made using daily data because brake damage rarely occurs. If data in the form of daily data is used, it is not possible to perform calculations in estimating the need for brake spare parts because it

is not certain that on that one day there is an aircraft brake replacement. Therefore, to be able to know exactly the number of ups and downs of brake needs, data from each week is used.

In the Monte Carlo analysis conducted weekly for 2 years based on the overall unit, airline, and Part Number shows that the total number of brakes required based on the results of Monte Carlo calculations is smaller than if a monthly Monte Carlo calculation is performed. For the amount of simulation difference on a weekly basis is 4% while if a monthly simulation is carried out, a difference of 8% is obtained. The Monte Carlo analysis also compares the actual data for 26 weeks and 6 months in 2024 with the Monte Carlo simulation results that have been obtained based on overall units, airlines, and part numbers. This analysis also shows that the total number of brakes required based on the results of Monte Carlo calculations is smaller when using weekly data compared to monthly Monte Carlo calculations. For the number of simulation differences on a weekly basis is 7% while if a monthly simulation is carried out, a difference of 22% is obtained.

In this study, predictions were also made using Linear Regression which aims to compare the accuracy of the number of brake replacement predictions. When compared to using the monte carlo method, the number of predictions when using linear regression has a considerable percent difference compared to the monte carlo percent. Also, when predictions are grouped by airline and part number, the estimates do not meet the actual data. The need for brakes can change every time, so it is necessary to do regular calculations to estimate brake needs, especially if there are significant changes in brake usage. The use of the Monte Carlo method can help companies to plan brake inventory, ensure brake inventory is always sufficient so as to increase operational efficiency. For comparison specifications can be seen in **Table 10**

	ACTUAL	WEEKLY	DEVIATION (%)	MONTHLY	DEVIATION (%)	Linear Regressi	DEVIATION (%)
Overall Unit 2 Years	886	922	4%	957	8%	945	7%
Overall Unit 6 Month	201	216	7%	256	22%	258	23%

Table 10 Summary

CONCLUSION

Based on brake turnover data in 2022 as much as 405 and in 2023 as much as 481. With linear regression of the number of aircraft in operation and brake replacement, the equation y = 2.7143x - 59.143 results in an estimated need of 258,4301 for 117 aircraft with all three types used in 2024, namely aircraft using three types of aircraft, namely A320, B737-900ER, and B737-9 MAX. The number of brake replacements for 2 years in a week, namely January 2022 to December 2023 based on actual data amounted to 886 while the results of the Monte Carlo simulation of brake replacement for 2 years amounted to 922. The comparison of brake replacement obtained from Monte Carlo simulation results with actual data for 6 months in 2024 amounted to 7%.

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