Preventive maintenance policy on leasing by considering the usage rate

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Abstract. The needs of the consumers about the functionality of a product and increase maintenance costs of equipment caused the prices of products and treatments to be expensive. Therefore, the company considers the lease rather than buy it. Leasing provides interesting strategy when dealing with expensive equipment. Policy maintenance that is done to the product that has decreased performance. Minimum repair done to fix failed equipment in order to return to operational condition, while imperfect preventive maintenance to improve the operational conditions of the equipment to avoid failure. Time duration for a minimum repair neglected. The lessor will charge a penalty (penalty cost) if the lease equipment failure. Mathematical model built for the minimization cost of maintenance policy. In the final part, the numerical experiment are given to show the maintenance policy taking into account the rate of usage (usage rate) by knowing the minimization the resulting costs.

1 Introduction

Some of the conditions encountered at this time where the consumer needs will be a function of products with increasingly diverse (multifunction), more expensive production equipment, as well as the existence of a rise in the cost of production, equipment maintenance activities be the cause manufacturers are starting to think that being uneconomical again if buy equipment production. So to overcome this, manufacturers are choosing to lease a production equipment rather than buy it [1]. Leasing has become a widely used business strategy. Increasingly attractive leasing options mainly deals with complex equipment in the form of expensive production equipment, medical tools, means of transportation, and others [2].

In the leasing contract between lessor and lessee also determined the policy of maintenance rent equipment if you experience against failure. Policy maintenance provided by the lessor of leasing contracts that have been agreed upon by the lessee on the basis of a leasing period of equipment lease. Policy maintenance that is done to reduce the number of failures and applied on the equipment during the lease period the lease [2]. Research [1] said that preventive maintenance can be divided into two, namely the action perfect PM and Imperfect pm. Perfect PM return the equipment to its original condition (new) and Imperfect PM bring the equipment back to its original condition and are among the current conditions.

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In previous research about leasing i.e. Research [3], using FRRM the periodic maintenance policy to get optimal equipment for rent. Research [4], acquiring the number and optimal degree of PM for equipment leased by combining minimal corrective repairs. Research [5], investigated the limit value threshold of failure rates for products rent with Weibull distribution in lifetime and get the value of the threshold and optimum maintenance policy during the period of the lease.

Research on the usage rate is found in the case of warranty. The concept of the usage rate is based on two-dimensional where this concept is based on age (age) of the item and the other representing the usage (usage) of the item. Research on two-dimensional about little-known in the study of warranty. As for the discussion of two-dimensional research on warranty are: Research [6], examines some strategies to repair-replacement for the sale of goods by administering the warranty for free in case of equipment failure, where the failure of the equipment based on the concept of two-dimensional. Research [7], researching on granting a warranty on equipment if failure based on the concept of two-dimensional, where the repair tools in use is minimal and imperfect repair for find the total cost of the guarantee minimum expectations. Research [8] and research [9] are researching about model of costs to determine warranty program PM optimally applied to extended warranty with the concept of two-dimensional.

Research [10], researching on optimisation strategy to repair the product based on the concept of two-dimensional warranty. In the concept of two-dimensional used based on two categories of age (age) and usage (usage). In his research investigations about the strategy of imperfect PM periodically on a product with a combination at the time base warranty and extended warranty from the perspective of the company. Repairs performed using minimal repair. In this paper would like to know the policy of maintenance during the period of leasing by considering the usage rate. In this case would be known by looking at the minimum of the costs incurred in maintenance policy during the period of leasing. Time PM and repair in minimal time, and ignore any failure will be given a cost penalty.

2 Problem Description

In previous research about the lease, did not consider the usage rate in determining policy maintenance for equipment lease. Usage rate is important in the use of equipment lease. The more equipment is used then the great rate semaki damage the equipment, since the equipment reliability decline. The use of the equipment sometimes exceeds the limits of use specified in the contract during the period of the lease. The more damage will certainly lead to higher repair costs and the total expenses will be high as well, thus causing harm to the lessor. With the existence of a usage rate then helps the lessor knowing the level of maintenance well in low to high usage during the period of the lease.

On the development of models for policy maintenance on leasing by considering the usage rate, using research from leasing i.e. research [1] and research on the case of warranty i.e. research [10]. On the research of research [1], researching on optimum period of lease and maintenance on equipment leasing. In looking at the results of his experiments using the total profit. In the calculation of total profit expectations consists of total revenue, total costs of expectations, and the total cost of maintenance. However, in his research did not consider the usage rate. On the research of Wang et al. research [10], researching on the strategy of product warranty with the premier in the concept of two-dimensional, which consider the usage and time. The goal is to determine the total cost of the minimum expectations of the given maintenance policy.

From the deliberations of the research that has been described, it is in this paper would like to develop a research policy maintenance on leasing by considering the usage rate. The concept of the development of this model uses research from research [1] at a total cost of

expectations which consists of minimal cost to repair, the cost of the penalty, the amount of damage to the equipment, and the total cost of maintenance, in addition also of the research research [10], where the amount of damage considering from the usage rate and the total cost of maintenance which consists of fixed costs, marginal costs and the degree of maintenance. Model development policies can be seen in Figure 1 below:

Fig. 1. Policies conceptual model maintenance on leasing by considering the usage rate.

3 Model and Algorithm

The following is a mathematical notation used in this study :

Table 1. Mathematical notations and description.

Notations	Description
x	Actual age
r	Usage rate
n	The total number of actions PM
L	The time limit of lease
$\lambda_0(x r)$	Conditionals failure intensity function on items in the absence of PM
$\lambda_j(x r)$	Conditionals failure intensity function in the item after kth PM action, $1 \leq j \leq n$
τ_0	Time interval PM
δ	Degree preventive maintenance, have a value range between 0 to 1
T_j	Time instant for performing the jth PM, $j=1, \dots, n$
C_m	Minimal cost to repair
C_f	Penalty cost
$C_p(\delta)$	$C_p(\delta) = a + b\delta$ for $a > 0$ and $b \geq 0$, $C_p(\delta)$ is a function of cost am with maintenance degree δ
$E[TC]$	Total expected cost within the lease period

In this paper in assume that $\lambda(x|r)$ are polynomial functions of x and r, and can be formulated as follows:

$$\lambda_0(x|r) = \theta_0 + \theta_1r + (\theta_2 + \theta_3r)x \tag{1}$$

Then conditionals failure intensity function of the items at the time of age (x) be as follows:

$$\lambda_j(x|r) = (1 - \delta)\lambda_{j-1}(x|r) + \delta\lambda_0(x - T_j|r) \tag{2}$$

Step 1: Calculate the cost of repair

Equipment failure is repaired by using minimal repair. Process equipment failure on the interval $[T_i, T_{i+1}]$, follow the non-homogeneous poison process. The average time interval

of PM ($\tau_0 = L/n$). T_i for $i = 0,1,2,\dots,n-1$. Where $T_i = i\tau_0$ dan $T_{i+1} = (i + 1)\tau_0$. Then the expected number of failure as follows:

$$\sum_{i=0}^{n-1} \int_{T_i}^{T_{i+1}} \lambda_j(x|r) \, dx \tag{3}$$

$$\sum_{i=0}^{n-1} \int_{i\tau_0}^{(i+1)\tau_0} \lambda_j(x|r) \, dx \tag{4}$$

Then expected the total cost of repair during the period of lease is as follows:
 = (minimal repair cost + penalty cost) x the number of failures during the period of lease

$$= [C_m + C_f] \left[\sum_{i=0}^{n-1} \int_{i\tau_0}^{(i+1)\tau_0} \lambda_j(x|r) \, dx \right] \tag{5}$$

Step 2: Calculate cost Maintenance

PM actions carried out during the period PM lease with maintenance of the same degree of δ . The cost of the notation i.e. $C_p(\delta)$, who has non-negative and non-decreasing function of maintenance degree. $CP(\delta) \geq 0$, for the value δ of values from 0 to 1. PM is done at the time of T_i , where $i = 1,2, \dots n$. The cost of maintenance during the period of leasing are as follows:

$$\begin{aligned} &= (\text{number of PM actions during the period of leasing cost} \times \text{PM Cost}). \\ &= \sum_{i=0}^n C_p(\delta) = nC_p(\delta) \end{aligned} \tag{6}$$

Step 3: Calculate the total expected cost within the lease period

Then the total pembiayaan over the period of lease by considering the rate of usage (usage rate) i.e. by summing the total cost of the repair with the total cost of maintenance Here is an expected of the total costs during the period of leasing (L):

$$\begin{aligned} E[TC] &= \text{Total cost of repair} + \text{Total cost of maintenance} \\ E[TC] &= [C_m + C_f] \left[\sum_{i=0}^{n-1} \int_{i\tau_0}^{(i+1)\tau_0} \lambda_j(x|r) \, dx \right] + nC_p(\delta) \end{aligned} \tag{7}$$

4 Numerical Experiment and Result

This numeric experiment using a case study on moving companies in leasing with attention to the usage rate of its users. The company made a numerical experiment cases because in accordance with the model of research developed with consideration of the usage rate. The data used is the data usage rate is the company-owned vehicle with other types of commercial vehicles and the long-term contract (long-therm). The object of the vehicle taken is Pick up L300 has 1493 CC engine capacity and transport capacity of 2 tons. Data usage rate used to have the unit kilometres per year, i.e., the distance traveled (u) by vehicles for one year (t). In this case one year and users (usage) = 10000 km. the Data is divided into 3 categories by category usage rate is low, normal and high and the data taken during the use of average time limit one year i.e. leasing. As for the data usage rate as follows :

Table 2. Data usage rate Pick up L300.

Pick up L 300	
The average Usage of low Category	24091
The average Usage of normal Category	35970
The average Usage of high Category	41382

In this paper a numerical experiment values that will be used during the initial values of the intensity function failure conditionals are given below :

$$\begin{aligned} \lambda_0(x|r) &= \theta_0 + \theta_1 r + (\theta_2 + \theta_3 r)x \\ &= 0.1 + 0.2r + (0.5 + 0.5r)x \end{aligned}$$

For a minimal repair cost of Rp 600 and the Pinalty cost of Rp 20. at the cost of PM, $C_p(\delta) = 15 + b\delta$, And the action for the number of PM (n) is given a range of values from 1 to 12. Then the results of numerical experiments as follows :

Table 3. Results of numerical experiment

b	δ	Low Usage		Normal Usage		High Usage	
		n	E[TC]	n	E[TC]	n	E[TC]
30	0.1	3	897.3433	7	1202.507	9	1334.312
	0.2	6	846.1321	10	1104.899	11	1217.09
	0.3	6	802.3195	9	1041.345	9	1145.811
	0.4	6	770.0527	7	998.1824	8	1097.584
	0.5	5	745.8711	7	965.6884	7	1061.954
	0.6	5	725.8311	6	939.3215	6	1033.896
	0.7	4	709.9498	5	917.869	6	1010.579
	0.8	4	694.2743	5	898.9808	5	989.1589
	0.9	4	682.0335	4	882.7522	5	971.9517
50	0.1	3	903.3433	5	1214.772	7	1350.542
	0.2	5	868.4498	8	1139.01	9	1256.051
	0.3	5	836.0644	7	1087.269	8	1196.853
	0.4	5	812.2604	6	1051.532	7	1156.746
	0.5	4	793.1901	5	1025.106	6	1126.239
	0.6	4	777.4563	5	1002.857	5	1101.732
	0.7	4	765.9498	4	984.7588	5	1082.037
	0.8	3	753.532	4	967.4398	4	1062.734
	0.9	3	741.5244	4	954.7522	4	1046.198
	0.1	3	909.3433	4	1223.86	5	1363.312
	0.2	4	885.7181	6	1166.666	7	1288.311
	0.3	4	862.9247	6	1125.315	6	1239.667
	0.4	4	845.5474	5	1095.918	6	1205.904
	0.5	4	833.1901	5	1075.106	5	1179.544
	0.6	3	820.5928	4	1055.244	4	1159.933
	0.7	3	809.8882	4	1040.759	4	1140.447
	0.8	3	801.532	3	1028.21	4	1126.734
	0.9	3	795.5244	3	1012.791	3	1111.777
90	0.1	3	915.3433	3	1230.81	4	1372.883
	0.2	3	898.8962	5	1189.109	6	1314.831

0.3	3	884.7976	5	1156.727	5	1275.484
0.4	3	873.0475	4	1133.849	5	1246.926
0.5	3	863.6459	4	1115.429	4	1225.791
0.6	3	856.5928	4	1103.244	4	1207.933
0.7	3	851.8882	3	1088.795	4	1196.447
0.8	3	849.532	3	1076.21	3	1179.483
0.9	2	843.3542	3	1066.791	3	1165.777

From Table 3 can be explained on examples of the value of the marginal costs (b) = 30 = 0.1 maintenance degree and obtained a low usage to PM action (n) = 3, the expected total cost (E [TC]) = 897.34. PM actions to normal usage (n) = 7, the total expected cost (E [TC]) = 1202.507. PM action to high usage (n) = 9, the expected total cost (E [TC]) = 1334.31. The higher of usage, then PM action is higher and the expected total cost is higher too. The higher of marginal cost (b), then the higher value of the expected total cost (E [TC]).

5 Conclusion

Maintenance policy on leasing by considering the usage rate is then divided into 3 categories comprise usage is low, normal and high by taking the average usage rate of vehicles. For research in the future can use specific distributorship for conditions of usage rate and also the limitations of usage in the extension of the lease either at the beginning or end of the period. In addition, it can set up cost (minimal repair and applied) for testing other vehicles.

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