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OPTIMUM SOLUTIONS OF HOSTEL FACILITY MAINTENANCE BASED ON COST-DOWNTIME MODEL TECHNIQUE

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Abstract: This paper is part of an on-going research on the development of maintenance cost and down time model for Higher Education Institution Hostel facility maintenance in Malaysia where the case study is conducted at Universiti Melaka (UNIMEL). The model is developed to analyse the total cost and downtime curve for various values of the uncertain parameter and noting the effect of this variation on the optimal solution. The decision areas addressed based on the replacement action that are assumed to be known with certainty. This is due to the item not being subject to failure but considering the operating cost and downtime with use. The study is aimed to assist Development Maintenance Unit deciding an appropriate replacement policy. This is usually useful to plot the total cost of downtime per unit time curve. The advantage of the curve is that, along with giving the optimal value, it shows the total cost around the optimum. If the curve is fairly flat around the optimum, it is not really very important that engineers should plan for the replacements exactly at the optimum. The model is proposed to guide and facilitate when dealing with optimization problems. If there is uncertainty about the value of the particular parameter required during the analysis, then the replacement cost downtime is uncertain. Furthermore, the evaluation of the total cost and downtime curve for various values of the uncertain parameter could in consequence affect the optimal solution and show the graph in 3 Dimensional (3 D). from this study will get the optimum between cost and downtime model for Hostel Facility Maintenance techniques at Unimel

Keywords: Replacement Cost and Downtime model, Three-Dimensional Cost - Downtime Model

1. Introduction

Some equipment operates with excellent efficiency when it is new. But as it ages, the performance deteriorates. An example is the door components in Universiti Melaka (UNIMEL) hostel facilities maintenance [1]. When new, it is considered as the equipment is in good condition [2}. However, if there has a small crack, it will affect the quality of the equipment, is it economically justifiable-to repair or replace the Door, thus reducing the operating cost downtime of the Hostel building? In general, replacements will cost money in terms of component and a balance is required between the money spent for replacements and savings obtained to reduce the operating cost [3] and [4]. Thus, this study aimed to determine an optimal replacement policy that will minimize the sum of operating and replacement costs downtime per unit time [5] and [6]. The goal of this research is to present model that can be used to optimize component replacement decision. The interest in this decision area is initiated by a common approach to improve the reliability of the system or the building [7] and [8].

Equipment has followed through preventive replacement of critical component within the system. Thus, it is necessary to be able to identify which component should be considered for preventive replacement and which should be left to run until they fail. If the component is selected for preventive replacement, then the subsequent question to be answered is-: What is the best time to perform maintenance? Bases the fact primary goal addressed in this study is that to make a system more reliable through preventive replacement [8] and [9].

Replacement problem (and maintenance problem in general) can be classified as either deterministic or probabilistic (stochastic). Deterministic problem is those in which the timing and outcome of the replacement action are assumed to be know with certainty. For example, we may have an item that is not subject to failure but whose operating cost increases with use [10]. To reduce this operating cost, a replacement can be performed. After the replacement, the trend in operation cost downtime is decreased. This is a kind of example of component replacement problem that can be treated with a deterministic model. Probabilistic problem is those where the timing and outcome of the replacement action depend on chance. In the common situation the equipment may be described as being good or breakdown. The probability law describing changes from good to fail is described by the distribution of time where completion failure is a random variable whose distribution is termed as the equipment's failure distribution [13], [14].

2. Optimal Replacement Time for Component

Some component/equipment operates with excellent efficiency when new as it ages the performance deteriorates. When on the increasing cost trend, is it economically justifiable to replace the equipment? In general, a balanced replacement cost downtime in term of material and wages-is required between the money spent on replacement and saving obtained by reducing the operating cost. Thus, to determine an optimal replacement policy is essential to minimize the sum of operating and replacement cost per unit time [13] and [14].

When dealing with optimization problem, in general, we wish to optimize some measure of performance over a long period. This is equivalent to optimizing the measure of performance per unit time. This approach is easier to deal with mathematically when compared to developing a model for optimizing a measure of performance over a finite horizon [11].

Usually, the cost is conflicted and associated with optimization problem. It should be stressed that this class of problem can be termed as short term deterministic since the magnitude of the interval between replacements is weeks or month, rather than years. If the interval between replacements was measured in years, then the fact that money changes in value over time would need to be taken into account in the analysis. Such problem can be term as replacement [11] and [12].

3. Stochastic Preventive Replacement

Before proceeding with the development of component replacement models, it is important to note that preventive replacement action is taken before equipment reaches a failed state. This requires two necessary conditions:

1.The total cost of the replacement must be greater after failure than before (if cost is the appropriate criterion, otherwise an appropriate criterion such as downtime is substituted in place of cost). This may be caused by a greater loss of production since replacement after failure is unplanned or failure of one piece of plant may cause damage to other equipment [12].

2. The hazard rate of the equipment must be increasing. To the illustrate this point, consider an equipment with a constant hazard rate. The failures occur according to the negative exponential distribution or equivalent with the Weibull distribution, where the shape parameter $\beta = 1.0$. When this is the case, replacement before failure does not affect the probability that the equipment will fail in the next operation, given that it is good now. Consequently, money and time are wasted if preventive replacement is applied to equipment that fails according to the negative exponential distribution. Obviously, when equipment fails according to the hyper exponential distribution or the Weibull whose β value is less than 1.0, its hazard rate is decreasing and again component preventive replacement should not be applied. Examples of component where a decreasing hazard rate has been identified include quartz crystals, medium – and high-quality resistors and capacitors and solid.

– state device such as semiconductors and integrated circuits [12] and [13].

4. Optimal Preventive Replacement

An item, sometimes termed a line replaceable unit or part, is subject to sudden failure and when failure occurs, the item has to be replaced. Since failure is unexpected, it is not unreasonable to assume that failure replacement is more costly than a preventive replacement [14]. For example, a preventive replacement is planned, and arrangements are made to perform it without unnecessary delays, or perhaps a failure may cause damage to other equipment. In order to reduce the number of failures, preventive replacement can be scheduled to occur at specified intervals. However, a balance is required between the amount spent on the preventive replacement and their resulting benefits, that is reduced failure replacements [14]. The conflicting cost downtime consequences and their resolution by identifying the total cost and downtime curve. The replacement policy is one where preventive replacement occurs at fixed intervals of time. Failure replacement occurs whenever necessary and to determine the optimal interval between the preventive replacement to minimize the total expected cost downtime of replacing the equipment per unit time [11] [12].

4.1 Cost Model

When dealing with optimization problems, in general, this study aimed to optimize some measure of performance over a long period. In many situations, this is equivalent to optimize the measure of performance per unit time [11]. This approach is easier to formulate mathematically when compared to develop a model in optimizing a measure of performance over a finite horizon [11] [12]. The model construction is as follows.

Construction of the Model:

1. *c(t)* is the operating cost per unit time at time *t* after replacement

2. *C*, is the total cost of a replacement.

3. The replacement policy /to perform replacements at interval length

4. The objective is to determine the .optimal interval between replacements to . minimize the total cost of operation and replacement per time

The total cost per unit *C (t)* for replacement at time *t*, is

C(t)= total cost in interval (0,t) length of interval

To use the equation $c(t_r) = C(\quad t_r)$, it requires that the trend in operating costs be an increasing function, which in practice is a very reasonable assumption. In practice, it is often not unreasonable to disregard the replacement time since it is usually small when compared to the interval between the replacements []. Any costs, such as production losses incurred due to the duration of the replacement which need to be incorporated into the cost of the replacement action. Otherwise, a numerical solution is required as in Equation (1):

$$C\left(t_r\right) = \frac{\int_0^{t_r} c\left(t\right) dt + C_r}{t_{r+T_r}} \qquad (1)$$

Models are developed whereby, for particular assumptions, the optimal interval between the replacements can be obtained. In practice, there may consider difficulty in scheduling replacements to occur at their optimal time, or in obtaining the values of some of the parameters required for the analysis [11].

4.2 Case Study – (Cost Model)

The hostel building maintenance data is gathered from ICYM in certain period of time. By using Eq. (1), in discrete form, Table I is obtained from which it is seen that the optimal replacement age is 10 months, and the associated cost per month is MYR 17.14 .Table also show the deterioration trend from month 1 to 12 and increase again from 10 to 11 .The associated graph of cost per month versus time is provided in Fig. 1, which includes the calculation of the optimizing criterion $c(t) = C(f_r)$ when the trend in operating cost is discretized. Therefore, by replacing at the end of month 10, since next period's do operations and maintenance cost, c (t = 10), is higher than the average cost to date (MYR 17.19).

Table 1: Replacement Cost for Door

Month	MYR
1	17.99
2	17.81
3	17.71
4	17.64
5	17.54
6	17.38
7	17.35
8	17.27
9	17.23
10	17.19
11	17.20
12	17.25

*MYR- Malaysia Ringgit

B) Sample numerical Calculation

The simplified after referring to Eq. (1) is:

C(tr)=(1/t) *(((600.44/30) *t+((22172.94/30) *EXP(-X*(t))/X)- ((600.44/30)/X) +(200)/30)) Where t = 24 hours (1 Day), And X = Exponent / days

X = 5,357/30 days = 0.178567 = (1/24) *(((600.44/30) * 24+((22172.94/30) *EXP(-X*(24))/X) -((600.44/30)/X) +(200)/30))

= 17.99

Cost Vs. Time Model

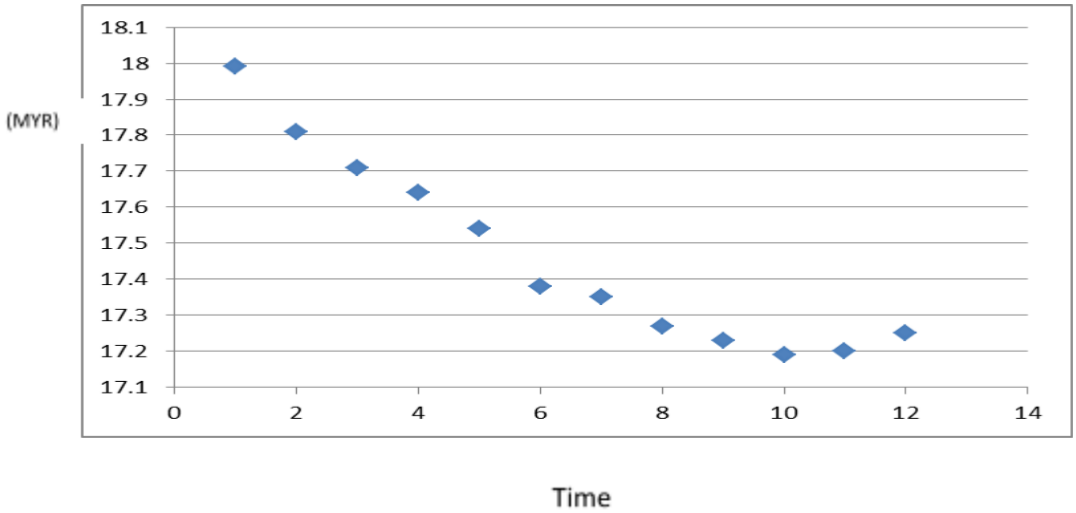

Fig. 1 Replacement cost for door

5. Downtime Model

The purpose of downtime model is to minimize the total downtime per unit time. In some cases, due to difficulties in costing or the desire to get maximum throughput or utilization of equipment, the replacement policy required may be one that minimizes total downtime per unit time or, equivalently, maximizes availability [15]. The problem is to determine the best times at which replacements should occur to minimize total downtime per unit time. The basic conflict is that as the preventive replacement frequency increase, there is an increase in downtime due to this replacement, but a consequence of this is a reduction of downtime due to failure replacements, and the aim is to get the best balance between them.

The model is developed to determine the optimal replacement interval between preventive replacements in order to minimize total downtime per unit time. The policy is illustrated in Figure 1.

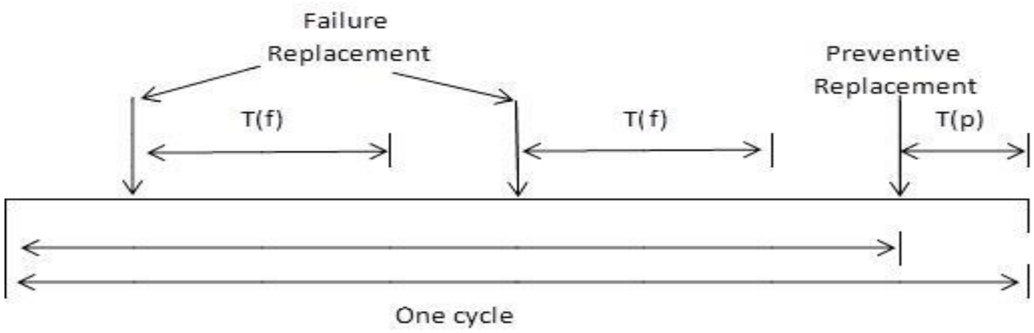

Fig. 2. Downtime minimization: optimal interval.

The total downtime per unit time, for preventive replacement at time , denoted as D( ) is in Equation (2)

$$D(t) = \frac{\underline{Expected\ downtime\ due\ to\ failures + downtime\ due\ to\ preventive\ replacement}}{Cycle\ length} \quad \textbf{(2)}$$

Downtime due to failures = number of failures in interval (0, t) Time required to make a failure p × replacement = H(t) × $p\ Tf$

Downtime due to preventive replacement = Tp

Therefore Equation (3)

$$D(t) = \frac{H\ tp\ (t)Tf + Tp}{tp + Tp} \quad \textbf{(3)}$$

This is a model of the problem relating replacement interval t to total downtime D( ). $p\ tp$

5.1 Case Study (Downtime Model)

The method applied from the downtime model, the corresponding curve of *D(T)* in table 2 for the preventive replacement and presented graphically in Figure 2. The remarks that can be concluded are that the assumption verified by the curve that the preventive replacement plotted above the best time to the replacement of component hostel facility maintenance [16]. It also shows that when the 18 values increased the curve will go nearer to perfect replacement from 6.6 value downtime, if the quality of preventive replacement downtime, means that the more downtime detected, the downtime will reduce due to fewer breakdowns occurred during operations. Details of the percentage of the expected downtime to fit the status quo point are also shown in Table 2 and Fig.2.

Table 2: Replacement Downtime for Door

t	Tf	Tp	lambda	f(t); if exponent	H(t); if exponent	Downtime
	7	0.035	5.309	lambda*EXP (-la mbda*t)	lambda*t	
1	25	0	5.309	0.026262939	5.309	132.725
2	34	3	5.309	0.000129919	10.618	72.8024
3	18	5	5.309	6.42694E-07	15.927	36.46075

4	14	12	5.309	3.17933E-09	21.236	19.3315
5	5	7	5.309	1.57277E-11	26.545	11.64375
6	3	7	5.309	7.7803E-14	31.854	7.889385
7	4	18	5.309	3.84881E-16	37.163	6.66608
8	11	60	5.309	1.90396E-18	42.472	7.752824
9	15	85	5.309	9.41864E-21	47.781	8.528883
10	31	120	5.309	4.65928E-23	53.09	13.583
11	40	90	5.309	2.30489E-25	58.399	24.01941
12	65	90	5.309	1.1402E-27	63.708	41.48059

Downtime Vs. Time Model

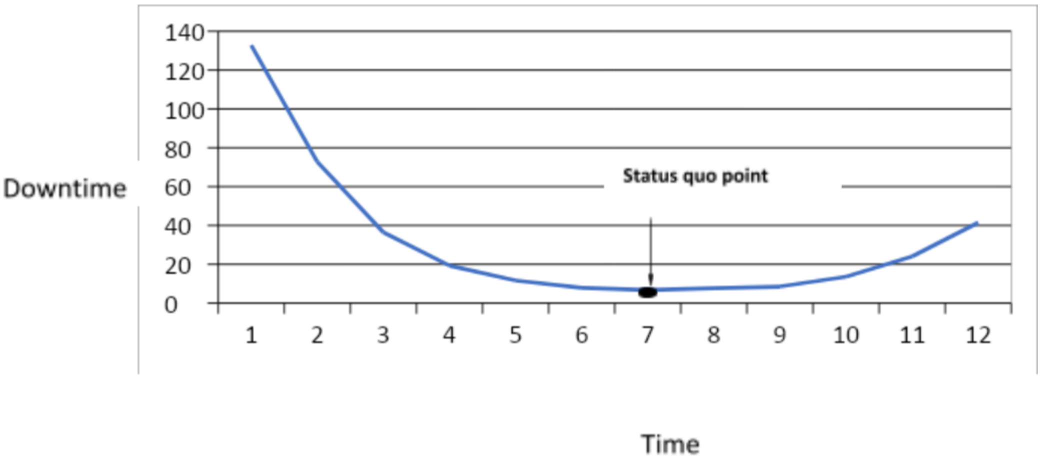

Fig.2. Replacement Downtime for door

6. Three-Dimensional (3D) Graph: Cost - Downtime Replacement Model

Three-dimensional space is a geometric three-parameter model of the physical universe in which all known matter exists. These three dimensions can be labelled by a combination of cost, Downtime and time. Any three directions can be chosen, provided that they do not all lie in the same plane [17]. In physics and mathematics, a sequence of *n* numbers can be understood as a location in *n*-dimensional space. When $n = 3$, the set of all such locations is called three-dimensional cost & downtime replacement space. It is commonly represented by the table 3 and Fig 3 and 4.

Table 3: Three Dimensional (3D) Graphs: Cost Downtime Replacement Model

Time	Cost	Downtime
1	17.99	132.725
2	17.81	72.8024
3	17.71	36.46075
4	17.64	19.3315
5	17.54	11.64375
6	17.38	7.889385
7	17.35	6.66608
8	17.27	7.752824
9	17.23	8.528883
10	17.19	13.583
11	17.2	24.01941
12	17.25	41.48059

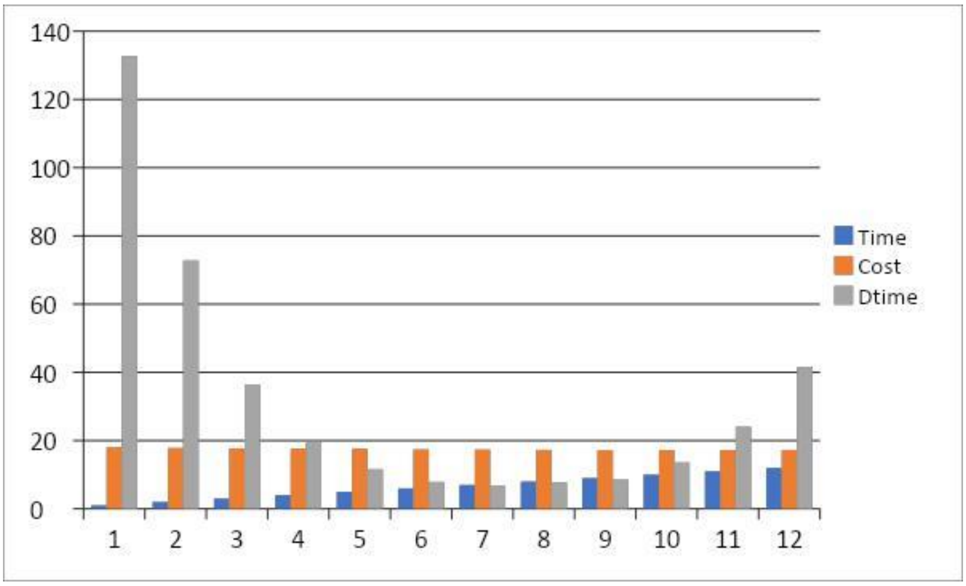

Fig. 3. Three Dimensional (3D) Graphs: Cost - Downtime Replacement Model

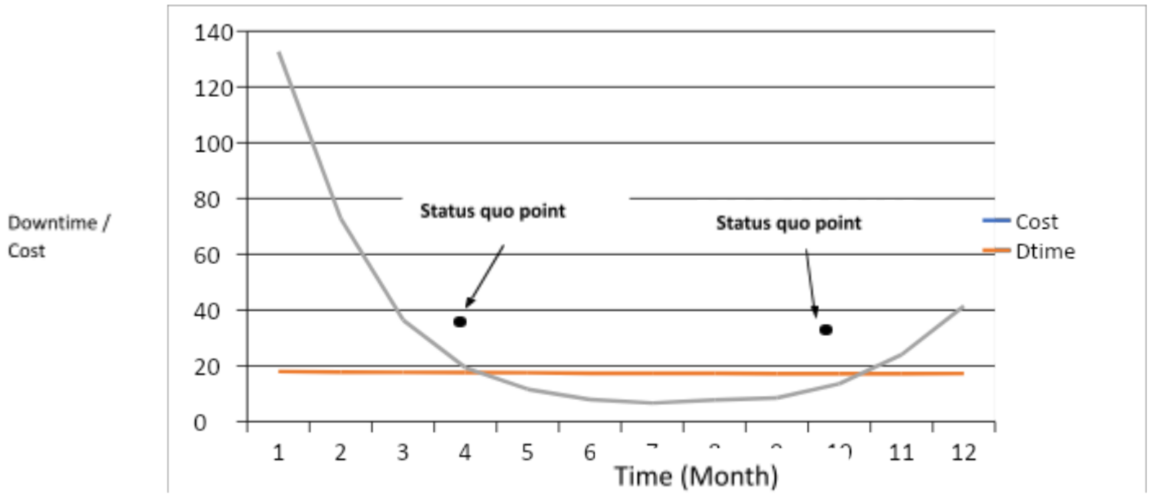

Fig. 4. Three Dimensional Graphs (3 D): Cost - Downtime Replacement Model

The cost and downtime model, the corresponding curve of *D(T)* in Table 3 for the cost and downtime replacement the graphically show in Figure 3and 4. The remarks that can be concluded are that the assumption verified by the 3 D curve that the best time to replacement cost and downtime plotted above the perfect replacement [18]. It also shows that when the *r* value from 19.33 to 17,64 and 13.583 to the curve will go to status quo point. If the quality of downtime is meet the more faults detected, the downtime will reduce due to fewer breakdowns occurred during operations [19][20]. Details of the percentage of the expected downtime to fit the status quo point are shown in Table 3.

7. Conclusion

The hostel facility maintenance model shows that the total cost downtime curve is not fairly flat around the optimum and rising rapidly on both sides. This is then the optimal interval should be adhered to all possible circumstances. If there is uncertainty about the value of the particular parameter required in the analysis and, then the evaluation of the total cost downtime curve for various values of uncertain parameter, could affect the optimal solution. In order to further assist engineers in deciding what appropriate replacement policy should be, it is useful to plot the total cost downtime per unit time curve. The advantage of the curve is that, along with giving the optimal value of t, it shows the total cost downtime around the optimum value. If the curve is fairly flat around the optimum, it is not really very important that engineers should plan for the replacements to achieve the optimum value, thus giving some leeway in scheduling the work. The goal is to develop a model that related inspection frequency to profitable cost. The way in which the model was developed a such that to establish the optimal inspection frequency to minimize total cost, then the same result would have been obtained. The most important point from this problem is that it is concerned with identifying the best level of preventive maintenance (in the inspections and replacement) when the failure rate of equipment is constant. When necessary, the replacement duration can be incorporated into the replacement model, as is required when the goal is the minimization of total downtime or equivalent and the maximization of item availability. This research has presented a model that can be used to establish the optimal time-based which discard decision if the goal is to identify the interval of preventive replacement policy for future improvement, the model can be hybrid that with Artificial Intelligence (AI) and data mining technique to increase its accuracy.

8.Acknowledgements

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