Development of Repair versus Replacement Model for Deteriorating Mid - Term Life Equipment

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ABSTRACT

The aim of any industrial organization is to optimize the maintenance to increase the profit margin . The optimization of maintenance cost is defined as minimization of the maintenance cost while sustain the required level of the performance. The optimization of maintenance cost is achieved by finding the point "optimum point" at which the repair became uneconomical option and replacement should be done.

To determine this point , a repair versus replacement model is developed that balance between the cost of carrying on with repair and the cost of doing replacement. The decision for either carrying with repair or doing replacement is based on the average cost "(cost of repair plus the cost of replacement) per unit time". The model is limited to mid-term life deteriorating and repairable equipment whose repair cost increase and the value of money remain constant with time.

Keywords: Authors are advised to writes 3-5 keywords related to the article. These keywords will be used for indexing p

1. Introduction

The maintenance has always been an important function in industrial facilities and represent from 10- 40% of the total production cost [2]. Companies all over world spend billions of dollars per year on maintenance to achieve the required level of performance. Thus, the maintenance represent a potential area for product unit cost reduction to increase the profit margin. A small percentage in cost reduction would amount to millions of dollars. Also, the maintenance cost minimization approach supersede cost reduction approach and increase in production to boost the revenues approach. The last two approaches may reduce the spending or increase in the production but it is not guaranteed that the product unit cost would be reduced. More ever, Any cost reduction must take into account two elements, the losses associate with the reduction must not exceed the saving and the reduction must not affect the quality and performance. Also , increase in production should not cause increase in the stock and subsequently decrease in sales price and increase in stock cost. The challenge is how to reduce the product unit cost without affect the quality and performance. The answer is by adopting a maintenance cost optimization approach that aims at minimization of maintenance cost while sustaining required level of performance. When equipment or item fail to provide the required performance, repair is carried out to restore the equipment to the condition prior to failure without affect the age of the equipment. The cost of repair as the equipment ages increase and replacement to restore the

equipment to as new condition become an ecumenical option. This paper deals with developing a model to find the point at which the repair should be stopped and replacement should be done.

2. Maintenance Policy

In early days , most industrial facilities adopted a breakdown maintenance policy that runs the equipment breaks down and then decide on its repair or replacement . This policy may increase the utilization of equipment in some case or may end up in excessive delays of the operation . however the maintenance cost and loss of operation time gets very high as result of repair and replacement during the time allocated for production.. After that , the focus is shifted to periodic preventive policy that replace the equipment before it reach " failure state" . This policy may prevent a breakdown and the negative impact on quality and performance but the item maybe replaced while still in good condition. Nowadays , optimum policy is being adopted that aim at optimum utilization without have any negative impact on performance or quality. The aim of optimum policy is achieved by balancing between the cost of carrying with repair and cost of doing replacement . The trend of repair and replacement cost is shown in figure (1). As can be seen from figure (1), the repair cost is low when the equipment is a new and start to increase as the equipment ages while the value of equipment decrease. Thus , the point at which the repair should be stopped and replacement should be carried out is known as optimum replacement point.

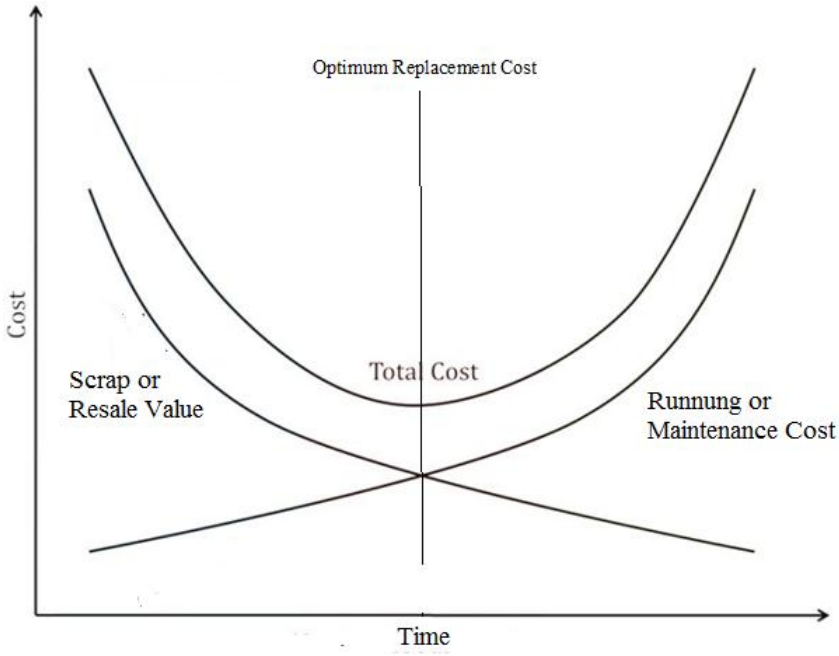

Figure 1 trend of equipment maintenance cost [4]

3. Maintenance Theory

Replacement Theory is Concerned with the Prediction of Replacement Costs and determinations of the most economic replacement Policy [4]. The replacement problem rise when equipment require replacement because of its deteriorating condition which associate with decrease in efficiency and increase in the repair and maintenance costs. The objective of replacement is to achieve cost minimization by finding the optimal replacement policy instead of carrying on with higher repair cost. In other ward , it is the balance between cost of doing replacement and the cost of carrying with repair. The decision for carrying on with repair or doing replacement is based on the analysis of the relevant costs. The relevant cost for either repair and replacement are [2] :

- Constant costs if they differ between alternative.
- The avoidable cost that are eliminated if replacement done.

The irrelevant costs are:

- Unavoidable costs are not eliminate by doing replacement**.**
- Same costs for alternatives .
- Sunk costs and incurred not accrued costs**.**

4. Replacement modeling Techniques

There are various replacement techniques to find the optimum that depend on failure pattern and the expected life of the items .The modeling techniques for deteriorating items.

- Replacement of Items whose maintenance costs Increases and value of money changes with time.
- . Replacement of Items whose repair and maintenance costs increases with time and the value of Money remains constant. .

They are other replacement techniques and will not mentioned here because they are not within the scope of this paper. Also, the paper will deal with case "Replacement of Items Whose Repair and Maintenance Costs Increases with time and the Value of Money remain constant. And , a model will be developed to find the solution for this case which is " optimum replacement point"].

5. The Proposed Modeling approach

This section The replacement model would simply be defined as the formal ways of determining replacement decision criteria [3] . The cost that should be considered for finding the optimum replacement are :

- The cost of items or equipment including the installation cost.
- The stoppage cost
- The material and installation cost for repair.
- The cost associated with continuation of repair that includes :Increase in energy consumption, Low quality cost, Decline in performance, and Penalty costs (risks and unavailability).

5.1 The Method for Finding the Solution

Authors The method used for finding the optimum replacement point by calculating the total maintenance cost during time (t) which is given by equation [7].

$$T(t) = \mathrm{D} + \int_0^i R_t \mathrm{dt} \quad (1)$$

Where :

T(t) ; the total cost incurred during time (t)

R_t : the total repair cost incurred during (t)

D: the depreciation cost which equal to:

D = C - SV

Where :

C: replacement cost

SV: resale value or scrap value ,or

D = C if the equipment has no salvage value

The time variable can be continuous or discrete variable

i- Time is Continuous variable case

The equation for total maintenance cost when the time is a continuous variable

$$\mathrm{T(t)} = \mathrm{D} + \int_0^i Rt \ \mathrm{dt}$$

And the average maintenance cost is:

$$\mathrm{Ta(t)} = \frac{1}{i} [\mathrm{D} + \int_0^i R_t \ \mathrm{dt}\ ] \quad (2)$$

The replacement is done when the average maintenance cost is equal the maintenance cost.

ii- The time is discreet variable

The equation for total maintenance cost when the time is a discrete variable is:

$$\mathrm{T}(t) = \mathrm{D} + \sum_0^i R_t \, dt$$

(3)

And the average total maintenance cost is:

$$T_a(t) = \tfrac{1}{\mathrm{i}}[\mathrm{D} + \sum_0^i R_t \, dt] \quad (4)$$

The replacement is done when the average maintenance cost for time (t) is greater than the average total cost for time (t-1). As can be seen , the model focus on point at which the maintenance cost is optimum rather than the actual cost.

5.2 Model consideration

The method used for The proposed model should take into consideration the following:

- It is a general model for repair versus replacement for deteriorating equipment or items with no change in value of the money.
- The existing equipment considered as defender and the new equipment as the challenger.
- The change of the input data in the future.
- The life of equipment should divide into equal periods .
- It should be flexible to cope with any change in the input data.

5 .3 Model limitation

The model limited to the following cases:

- Replacement with identical items.
- Items that deteriorate not prone to fail and have no salvage value which implies the depreciation cost is equal to full replacement cost and to the equipments that have salvage value.
- The time variable is discrete variable and decision for either carrying on with repair or doing replacement is taken at the end of period.
- The repair cost increasing as the equipment ages.
- No change in value of money which implies the effect of interest rate will not be taken into account

5.4 The Algorithms of Proposed Model

Algorithms are sets of mathematical rules for solving a particular class of problem or model. An algorithm consists of a set of logical steps that can be input into the computer in a specific format [6]. The steps are shown in figure 2.

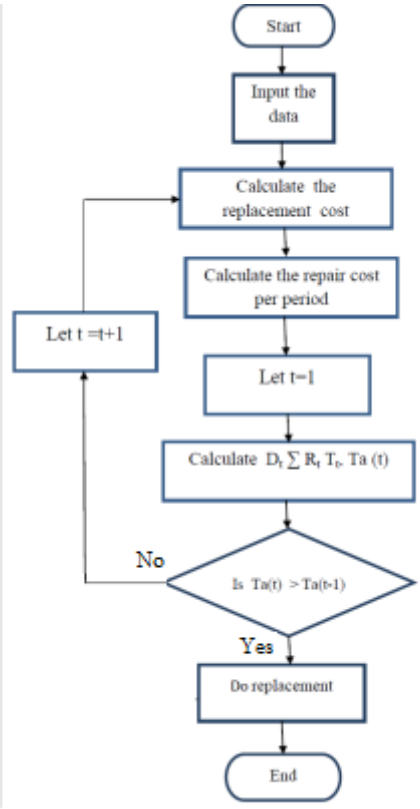

Figure 2 the algorithm logical steps

6. Model formulation

The model formulation is based on replacement technique known as repair versus replacement in which the analytical formulation of the model is done in a table form [8]. Basically . the aim of formulation is to convert the steps of the algorithm into manipulations in excel work sheet. The formulation and the decision criteria are illustrated in Table 1 and 2 respectively.

Table 1**:** *model formulation*

	Basic variables		Evaluating variables			Decision variable
1	2	3	4	5	6	7
				5= ∑ 3	6= 5+4	7= 6/1
Period	Replacement cost	Repair cost	*Depreciation cost	Cum repair cost	Total cost	Average total cost
t	C	Rt	Di	∑ Rt	T(t)	Ta (t)
0	C	0	0	0	C	- -
1	-	R1	D1	∑R1	∑R1 + Di	Ta(1)/1
2	-	R2	D2	∑(R_2 + R1)	∑(R_2 + R1) +D2	Ta(2)/2
↓	↓	↓	↓	↓	↓	↓
i	-	Ri	Di	∑(Ri-1+Ri)	∑(Ri-1 +Ri) + Di	Ta(i)/i

Table 2**:** *model decision criteria*

The end of period	Average total cost	Decision criteria (true or false)	Optimum point (yes or no)
t	Tt	Ta(t > Ta(t-1)	-
1	Ta(1)	FALSE	NO
↓	↓	↓	↓
i	Ta(i)	true	yes

Tables (1) and (2) show the pattern of the manipulation toward reaching the optimum replacement point. It starts with the basic variable then goes through the evaluating variables and ends with the decision variables that determine the optimum replacement point based on the model decision criterion. Thus, the model variables are:

- The decision variable is the average total cost.
- The evaluating variables are the accumulation of the repair cost , depreciation cost and total cost. They are used to obtain the average cost.
- The basic variables are repair and replacement costs that are used to obtain the evaluating variables.

7. Sensitivity analysis

The aim of the sensitivity analysis is to determine the cost that influence the optimum point. It is done by varying one cost while the other costs remain the same . if the variation of the cost cause shift in optimum either to left or right , then the cost has impact on replacement decision. If the variation cause no shift , then the cost has no impact on the replacement decision.

8. Conclusions

A repair versus replacement for deteriorating equipment whose maintenance cost increase with time is developed to find the optimum replacement point. The model limited to short and mid-term life equipment and to the case when the time variable is discrete and the effect of inflation and interest rate is neglected. The model take into consideration the change of input data and entering the data without prior calculation. The focus on finding the point where the optimum maintenance cost occur rather than the actual maintenance cost.

6. Recommendations

- The model should be tested and compared with validated results
- Sensitivity analysis should be carried to determine the cost that have impact on the

replacement decision**.**

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