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Power Tiller and Technical Replacement Policy by Optimization

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Abstract There are multiple misconceptions about preventive maintenance; one such misconception is that preventive maintenance is unduly costly. This research work dictate that it cost more for regular scheduled down time and maintenance than it will normally cost to operate equipment's until repair is absolutely necessary one should compare not only the cost but the long term benefits and saving associated with preventive maintenance. The data generated for this study are presented in tables. This simplified the arrangement of the data in sequential order for easier analysis and interpretation. The table presented shows the running cost per year and resale prices of certain make (Power Tiller Machine). The result indicates that the average total cost ATCnis minimum during 5th year. There is the need to look at the mathematical approaches in this system through which replacement policy could assist agricultural mechanization to tackle problems of preventive maintenance.

Keywords Power Tiller, Maintenance Schedule, Optimization, Replacement, Average Total Cost

1. Introduction

The problem of replacement is felt when the job performing units such as men, machines, equipment's, parts, etc. become less effective or useless due to either sudden or gradual deterioration in their efficiency, failure or breakdown. By replacing those with new ones at frequent intervals, maintenance and other overhead costs can be reduced. However, such replacements would increase the need of capital cost for new ones. Economic decision analysis is a useful tool, offering individuals and organizations the techniques to model economic decision-making problems, such as maintenance and replacement decisions, and determine an optimal decision. However, the accuracy of the model determines the validity of the conclusion. In many cases, the assumption of certainty in many models is made not so much for validity but the need to obtain simpler and more readily solvable formulations. Essentially, the tradeoff is between an inaccurate but solvable model and a more accurate but potentially unsolvable one.

In most real-world systems, however, there are elements of uncertainty in the process or its parameters, which may lack precise definition or precise measurement, especially when the system involves human subjectivity. When developing a model of a system with uncertainty, the decision-maker can ignore the uncertainty, implicitly acknowledge it, or explicitly model it. Ignoring the uncertainty usually results in the deterministic model of the process with precise values for all parameters. Implicitly acknowledging the uncertainty may still result in a deterministic model which sensitivity analysis or discount factors can be used to get an idea of how this uncertainty affects the outcome. Lastly, the decision-maker can explicitly model the uncertainty using specific paradigms such as interval analysis, possibility theory, probability theory, or evidence theory [2]. A new economically sound methodology for assisting with equipment replacement at Texas DOT is presented. This new method takes full advantage of Texas DOT's comprehensive equipment operating system database, can prioritize the units on the basis of comparisons among all units within any desired class of equipment and uses life-cycle cost trends as a replacement criterion. This methodology was implemented through the Texas

Equipment Replacement Model; a menu driven software that allows the fleet manager to efficiently apply the methodology [6]. A comprehensive dynamic programming (DP) based optimization solution methodology is then proposed and implemented to solve the ERO problem. The developed ERO software consists of three main components: 1) A SAS Macro-based Data Cleaner and Analyzer, which undertakes the tasks of raw data reading, cleaning and analyzing, as well as cost estimation and forecasting; 2) A DP-based optimization engine that minimizes the total cost over a defined horizon; and 3) A Java based Graphical User Interface (GUI) that takes parameters selected by and inputs from users and coordinates the Optimization Engine and SAS Macro Data Cleaner and Analyzer. The first component (i.e., the SAS macro based Data Cleaner and Analyzer) is presented in detail. Preliminary numerical results of the SAS data analysis, estimation and forecasting of several costs are also discussed. Then, in a following paper, the DP-based optimization engine and ERO software development (including the Java GUI) are presented in detail [8]. TxDOT uses the Texas Equipment Replacement Model [4] to identify equipment items as candidates for equipment replacement one year in advance of need (This one year allows sufficient time for the procurement and delivery of a new unit). TxDOT's Equipment Operations System (EOS), in operation since 1984, captures extensive information on all aspects of equipment operation. This system is used to provide historical data in a computerized approach. EOS historical cost data is processed against three preset standards/benchmarks for each identified equipment class. The criteria used for replacement in the approach are: 1) Equipment age, 2) Life usage expressed in miles (or hours), and 3) Life repair costs (adjusted for inflation) relative to original purchase cost (including net adjustment to capital value). In other words, TERM uses threshold values for age, use of an equipment unit and repair cost as inputs for replacement. For example, current threshold values for dump trucks with tandem rear axles (referred to as class code 540020 within TxDOT) for age, use and repair cost are 12 years, (150000) miles and 100%, respectively. As a result, a dump truck with tandem rear axles, 43000+ lb. GVWR, State Series 990d, that is 12 years old, has accumulated 150000 miles of usage and whose life repair costs have exceeded one hundred percent of the original purchase cost, including net adjustments to capital value, meets all three criteria [4]. Starting in 1997, UTSA created a SAS decision analysis tool to be used by the TxDOT in its equipment replacement process. The equipment replacement approach developed includes a multi-attribute priority ranking combined with a life-cycle cost trend analysis. It allows the manager to select the attributes used to compare the challenged unit with all other active units within a desired class or group, the life-cycle costs and multi-attribute ranking methodologies for equipment replacement.

Weismann et al. [7] summarized the computerized equipment replacement methodology in a paper as a condensed version of these three research reports. While the UTSA-TERM analysis tool met project scope within the data limitations existing at the time of its delivery, an improved vehicle cost data base has been developed and will now allow a more normative decision support tool for fleet replacement optimization. It is known that there are several issues with the current UTSA-TERM model. First, it looks at individual pieces of equipment and does not track unit costs for use and replacement. Second, it is still very labor intensive, heavily depends on the fleet managers' experience and is not automated since it is based on units - 1 piece of equipment at a time, replaces equipment based on classes of equipment. TxDOT needs a new, more robust fleet optimization system that must use these class codesrather than individual pieces of equipment, can automate the process and optimize the equipment keep/replacement decision based on that class of equipment age, mileage, resale value and the cost of replacement equipment. The future TxDOT TERM developed as a result of our work will be an advanced and fully automated equipment replacement optimization system that incorporates robust mathematical optimization models and reliable statistical cost estimation and forecasting models. With a click of the mouse button, the "one-stop shopping" seamless software system can/will automatically recommend robust optimization solutions based on the built-in cost statistical analysis. To accomplish this task, Java is carefully chosen as the programming language and DP as the designed optimization solution approach. A significant number of software programs currently exist to assist in fleet management .One of the major fleet management software manufacturers is Asset Works. Their programs and services are offered to a number of state DOTs and other public organizations. DOT users of Asset Works' software include Arizona, Minnesota, California (Caltrans), Delaware, Georgia, Maine, Michigan, Nevada, New Hampshire, New Jersey, New York, Virginia and Washington [3]. The renewal theory can be applied in modeling the machine replacement problem.

We begin with a deterministic model to illustrate the concept of a machine cycle, and then follow by a stochastic model with a general cost. We then compare two popular replacement policies: the quantity-based replacement policy and the time-based replacement policy for a single machine replacement problem. We also prove an interesting result that the optimal costs of both policies are the same under certain assumptions [1]. Organized the concurrent pursuit of many goals, guaranteeing structural safety, maintaining traffic and calling for bids while developing a design to replace the entire suspension system at the earliest possible time [5].

Operations research provides a methodology for solving replacement problems. The steps adopted for solving such replacement problems in OR have been discussed. Kapoor [9] Identified the items to be replaced and also their failure mechanism. There are two types of failure; i.e. gradual failure and sudden failure. Items such as machines, equipment… etc. follow the gradual failure mechanism and they deteriorate with time. Such type of failure accounts for increased expenditure in the form of operating costs, decrease of productivity of the equipment and decrease in the values of the equipment; i.e., salvage value. The items which follow the sudden failure mechanism may fail any time, thus precipitating the cost of failure. The cost of failure of an item may be quite high as compared to the value of the item itself. Sudden failure may cause loss of production and may also cause faulty product. This type of failure may cause safety risk to workers/road users. The item should be replaced before it actually fails. The maintenance schedule of power tiller record is found that the cost per year of running a car whose purchase price is #320,000 and the resale value are as follow:

Table 1: Shows the running cost and resale value of power tiller

YEAR	RUNNING COST(#)	RESALE VALUE(#)
1	50,000	200,000
2	60,000	130,000
3	70,000	70,500
4	90,000	30,750
5	110,000	20,000
6	160,000	20,000
7	180,000	20,000

Sources: Habgito Nigeria Limited

2. Model Formulation of Problem

The mathematical approach to this problem is given by:

$$TC = C - S + \int_0^n R(t)dt$$

When time‘t’ is a continuous variable and

$$TC = C - S + \sum_0^n R(t)$$

When‘t’ is discrete variable

3. Solution of the problem

When operational efficiency of an item deteriorates with time (gradual failure), it is economical to replace the same with a new one. For example, the maintenance cost of a machine increases with time and a stage is reached when it may not be economical to allow machine to continue in the system. Besides, there could be a number of alternatives on the basis of the running costs (average maintenance and operating cost) involved. In this section, we shall discuss various techniques for making such comparisons under different conditions. While making such comparisons it is assumed that suitable expressions for running costs are available.

MODEL I: Replacement policy for items whose running cost increases with time and value of money remains constant during a period.

THEOREM 1: The cost of maintenance of a machine is given as a function increasing with time and its scrap value is constant.

If time is measured continuously, the average annual cost will be managed by replacing the machine when the average cost to date becomes equal to the current the average cost to date becomes equal to the current maintenance cost. (Bhopal Umv. Msc (stat) 1985; indore Univ., Msc (maths), 1985; sambalpuruniv.Msc (maths), 1986)

If time is measured in discrete units, then the average annual cost will be minimized by replacing the machine when the next period's maintenance cost becomes greater than the current cost.

Symbols and Variables

C= capital or purchase cost of new equipment

S= scrap (or salvage) value of the equipment at the end of t years

R(t)= running cost of equipment for the year t

n= replacement of the age of the equipment.

When time't' is a continuous variable: if the equipment is used for t years, then the total cost incurred over the periods is given by

TC= capital (or purchase) cost – scrap value at the end of t years + running cost for t years

$$TC = C - S + \int_0^n R(t)dt$$

Therefore, the average cost per unit time incurred over the period of n years is:

$$ATC_n = \frac{1}{n}\left\{C - S + \int_0^n R(t)dt\right\}$$

Policy: Replace the equipment when the average annual cost for n years becomes equal to the current annual running cost. That is,

$$R(n) = \frac{1}{n}\left\{C - S + \int_0^n R(t)dt\right\}$$

When time't' is a discrete variable: the average cost incurred over the period n is given by

$$ATC_n = \frac{1}{n}\left\{C - S + \sum_{t=0}^{n} R(t)dt\right\}$$

If $C - S$ and $\sum_{t=0}^{n} R(t)$ Are assumed to be monotonically decreasing and increasing respectively, then there will exist a value of n for which ATC n is minimum. Thus we shall have inequalities

$$ATC_{n-1} \succ ATC_n \prec ATC_{n+1} \text{ or } ATC_{n-1} - ATC_n \succ 0 \quad \text{and}$$

$$ATC_{n+1} - ATC_n \succ 0$$

Policy 1: if the next year running cost R(n+1) is more than average cost of n^{th} year, ATC $_n$ is economical to replace at the end of n years that is

$$R(n+1) \succ \frac{1}{n}\left\{C - S + \sum_{t=0}^{n} R(t)\right\}$$

Policy 2: if the present years running cost is less than the previous year's average cost, ATC_{n-1} do not replace that is,

$$R(n) \prec \frac{1}{n-1}\left\{C - S + \sum_{t=0}^{n-1} R(t)\right\}$$

4. Result and Discussion

All computations and analysis were done using software package and the statistical package for social sciences (SPSS).

Table 3 Indicates that the total average cost ATC_n is minimum during 5^{th} year

The red color representing 136,100. Hence, the vehicle should be replaced every 5^{th} year

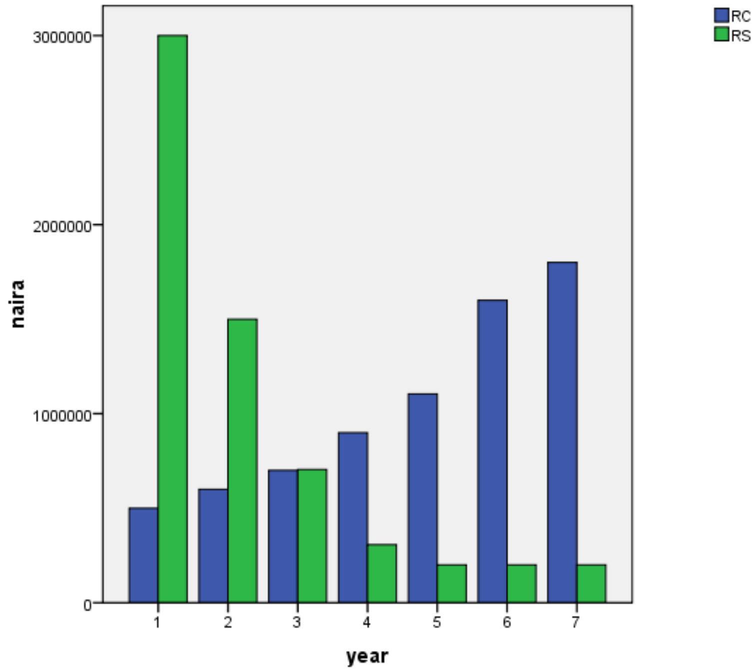

Figure1: Display of running cost and resale values in a bar chart

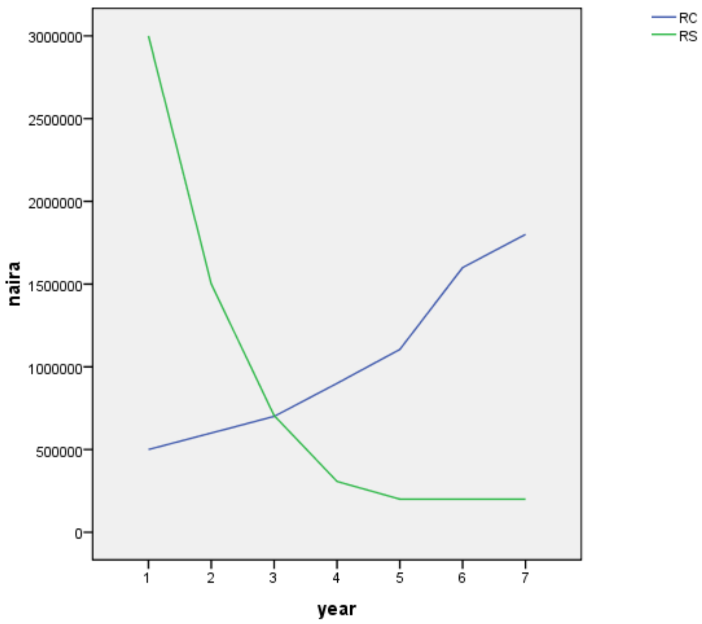

Figure2: Display of running cost and resale values in a line graph

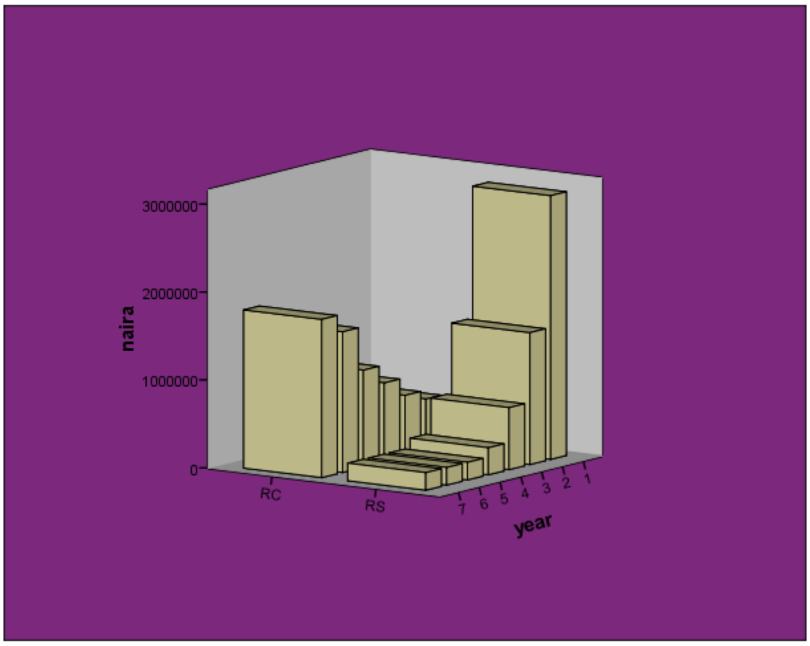

Figure 3: Display of running cost and resale values in 3D

Table 2: Represent the total running cost

Year (n)	**Running cost R(n)(₦)**	**Cumulative** $\sum R(n)$ **(₦)**	**Purchase Cost(C)(₦)**	**Resale Value(S)(₦)**	**Depreciation C-S(₦)**	**Total cost (₦)**
(1)	(2)	(3)	(4)	(5)	(6)=(4)-(5)	(7)=(3)+(6)
1	50,000	50,000	320,000	200,000	120,000	170,000
2	60,000	110,000	320,000	130,000	190,000	300,000
3	70,000	180,000	320,000	70,500	249,500	429,500
4	90,000	270,000	320,000	30,750	289,250	559,250
5	110,500	380,500	320,000	20,000	300,000	680,500
6	160,000	540,500	320,000	20,000	300,000	840,500
7	180,000	720,500	320,000	20,000	300,000	1,020,500

Table 3: Represent the average total running cost

Year (n)	**Running cost R(n)(₦)**	**Cumulative** $\sum R(n)$ **(₦)**	**Purchase Cost(C)(₦)**	**Resale Value(S)(₦)**	**Depreciation C-S(₦)**	**Total cost (₦)**	**Average Total Cost** ATC_n**(₦)**
(1)	(2)	(3)	(4)	(5)	(6)=(4)-(5)	(7)=(3)+(6)	(8)=(7)÷(1)
1	50,000	50,000	320,000	200,000	120,000	170,000	170,000
2	60,000	110,000	320,000	130,000	190,000	300,000	150,000
3	70,000	180,000	320,000	70,500	249,500	429,500	143,167
4	90,000	270,000	320,000	30,750	289,250	559,250	139,813
5	110,500	380,500	320,000	20,000	300,000	680,500	136,100
6	160,000	540,500	320,000	20,000	300,000	840,500	140,083
7	180,000	720,500	320,000	20,000	300,000	1,020,500	145,786

Table 3 indicates that the average total cost ATC_n is minimum during 5^{th} year.
The red color representing 136,100. Hence, the power tiller should be replaced every 5^{th} year.

5. Conclusion and Recommendation

The replacement or servicing of most part of an item that deteriorate with time is schedule in the manual in terms of working hours. When operational efficiency of an item deteriorates with time, it is economical to replace the same with a new one. Beside there could be number of alternative choices and one may like to compare available alternatives on the basis of the running cost (average maintenance and operating cost).

In order to arrive in this model an assumption is made, that is, the value of money is constant.

If the next year running say, R(n+1) is more than average cost of the nth year, ATC_n then it is economical to replace at the end of n years that is

$$R(n+1) \succ \frac{1}{n}\left\{C - S + \sum_{t=0}^{n} R(t)\right\}$$

If the present year running cost is less than the previous year's average total cost ATC_{n-1} then do not replace, that is

$$R(n) \prec \frac{1}{n-1}\left\{C - S + \sum_{t=0}^{n-1} R(t)\right\}$$

Based on the results and findings of this study, I recommend to the management responsible in Economic decision analysis such as maintenance and replacement decisions, offering individuals and organizations the techniques to model economic decision-making problems and determine an optimal decision. However, the accuracy of the model determines the validity of the conclusion. In many cases, the assumption of certainty in many models is made not so much for validity but the need to obtain simpler and more readily solvable formulations.

Habgito Nigeria Limited to seek to the application of mathematical theories into their operations as a necessary tool when it comes to decision making, not only in the area logistics(the Maintenance and Replacement Problem), but in production as well as administration.

This study employed mathematical technique to solve management problems and make timely optimal decisions. If the Items users are to employed the proposed replacement model it will assist them to efficiently plan out its maintenance scheduled at a minimum cost.

References

[1]. Allen, H.T. and Ching, W.K. 2005. On the Use of Renewal Theory in Machine Replacement Models. International Journal of Applied Mathematical Sciences, 2 (2): 240247.

[2]. Behrens, A. and Choobineh, F. (1989). Can Economic Uncertainty always be described by randomness? In proceedings of the 1989 International Industrial Engineering Conference.

[3]. State Government: State Customers. 2009. Asset Works, Inc. Available at http://www.assetworks.com/page/ state-government.

[4]. TxDOT Equipment Replacement Model-TERM. 2004. Accessed on January 20, 2009, ftp://ftp.dot.state.tx.us/ pub/txdot-info/gsd/pdf/txdoterm.pdf.

[5]. Virlogeux, M. 2003. Replacement of the Suspension System of the Tancarville Bridge. Journal of Transportation Research Record, 1654: 113-128.

[6]. Weissmann, J., Jannini, A., Weissmann, A.J. and Gona, S. 2006. Computerized Equipment Replacement Methodology. Journal of Transportation Research Record, (1824): 77-83.

[7]. Weissmann, J., Weissmann, A.J. and Gona, S. 2003. Computerized Equipment Replacement Methodology, Journal of the Transportation Research Board, (1824): 77-83, Washington, D.C.

[8]. Fan, W., Machemehl, R.B., Randy, B. and Kortum, K. 2011. Equipment Replacement Optimization: Part I. Solution Methodology, Statistical Data Analysis and Cost Forecasting. Published in: Transportation Research Record and Presentation at the 90th Annual Meeting of the Transportation Research Board, Washington, D.C., January 23-27.

[9]. Kapoor, V.K. 1999. Operation Research. Sultan Chand and Sons, Educational Publisher, New Delhi, India.