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ASSET REPLACEMENT DETERMINATION: AN EXPLORATORY MODEL FOR PRODUCTION CAPACITY OF LUBRICKS CONSTRUCTION FIRM IN RIVERS STATE NIGERIA

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Abstract

The construction sector of the Nigerian economy serves as a main stream for infrastructural development; its activities are mainly characterized by the use of equipment in its high-tech state. These pieces of equipment are structurally flexible for common purposes, such as the optimization of targeted objectives set at the most optimal cost efficiency for maintenance and replacement decisions. The management of the studied firm is often concerned with the useful life of every piece of equipment and the determination of a boundary line in the useful horizon to effect a replacement policy. Thus, the replacement policy decision is partly tied to the budgetary provision for investment in order to eliminate operational breakdowns that could contribute to increasing man-hour losses. Hence, a methodological standpoint was demonstrated to provide a replacement useful life horizon and the associated least cost for maintaining a computer in the studied firm, whose failure rate is sudden. A cross-sectional design was adopted with the use of secondary data. Findings revealed a cost-effective horizon that best suits the replacement of computers in the studied organization. Recommendations and conclusion: certified asset replacement model as a veritable conduit for resolving replacement problems in the studied organization

Keywords: asset, replacement, sudden failure.

Introduction

In our contemporary business world, the pace of standardization of goods and services offered by organizations is partly tied to the increasing sophistication of equipment used in the transformation process, resulting in increased competition, leadership, and dominance among firms in the road construction sector, geared towards optimizing their objective function. Abubakar et al. (2013) avowed that equipment is an important asset to organizations, used in the processing stage of productive activity. It forms the bulk of a road construction firm's asset, thus referred to as an asset as identified by Loveday & Achiem (2019). Hence, deliberate replacement decisions are required to sustain and improve organizational efficiency since equipment is subject to maintenance, obsolescence, change in original investment, deterioration, depreciation, inadequacy, and sudden failure, as also identified in the work of Herald (Tomiema & Desiopa, 2020). Such equipment that is replaced includes: vehicles and their associated parts; motor graders; asphalt mixing plants; road roller machines; forklift trucks; crawler excavators; truck cranes; wheel loaders; bulbs; valves; sockets; electrical equipment; and appliances, among others (Samagbemor & Chiemaro, 2021).

Replacement is an aspect of management in the field of operation research that guides and enables management to make informed and accurate decisions on the acquisition and utilization of equipment since it constitutes the bulk of cash outflow with respect to budgeting in the organization (Miegbara et al., 2021). Asset replacement is the deliberate withdrawal of equipment from further work processes as and when it is due. It, therefore, becomes imperative for management to have asset replacement policies that will ensure that lost time and inefficiency are avoided in the organization. Rafoung et al. (2021) posited that a replacement decision is a necessary condition for optimal utilization of equipment and the attainment of organizational goals. Industrial and construction equipment get worn with time and usage, and it functions with decreasing efficiency, which in turn necessitates replacement. Equipment requires higher operating costs, especially equipment found and used in the road construction sector with the passage of time (Prem & Hira, 2011). Wagbe & Shionode (2022) asserted that replacement of a piece of equipment is necessitated as a result of increasing repair and maintenance resulting from usage over time. Performance is the ability of a firm to implement and actualize its objective function with minimal resources. Also, Ostagrima & Saitul (2022) contributed that, in actualizing an organization's objective function, it is partly tied to the efficient utilization and performance of equipment deployed for work. The performance of an organization is measured or determined in terms of task actualization, time required for completion of work, and quality of work (Chinedum & Pakirima, 2022). Situations that necessitate replacement decisions are: original investment, maintenance, and prevention of obsolescence. Akpadumefien & Okente (2021) posited that road construction firms meeting their targets is partly a function of human and non-human (physical) capabilities and efficiencies; hence, it is a long-term activity, thus requiring the use of fixed or long-term assets in strict combination with some variables or short-term assets. It is in these situations that this study was necessitated.

Statement of Problems

In road construction, the completion date is an important part of the project. In fact, every road construction activity is a project because it must have, in-built in the bid, the planning and execution processes, the beginning and termination periods, and ready equipment (Ameachi et al., 2021). As observed, one of the major problems was that the firm failed to meet their project completion date as agreed upon with her clients as a result of equipment functioning at a suboptimal rate, which is directly related to a poor or low investment rate on equipment. This inability to make a purchase decision has negatively affected optimal performance and task actualization. This was also identified as a problem that amounts to a low productivity rate in the work of Kim & Tekpe (2021) and in the findings of Ekeocha et al. (2021). Given the increasing competition in winning road construction projects, it was found that the inability and unreadiness of performing firms to deploy equipment to site was attributed to poor maintenance routines among the studied firms. This contributed to the termination of most ongoing contracts in different sectors. Finally, the increasing technological change has led to an increasing rate of equipment obsolescence among the studied firms (Eramira et al., 2021). Thus, the inability of firms to discover and prevent obsolescence is mainly due to poor and low-quality assurance of deliverables. This was an iconic factor problem in the construction industry, as stated in the work of Godwin and Martins (2022). Generally, replacement problems arise due to a firm's inability to formulate an operational equipment replacement policy. The usefulness of managing and adopting an efficient equipment replacement policy is partly tied to the quality work performed in road construction in Nigeria. The quality, in part, is also tied to equipment utility, which may vary across firms.

Objectives of the Study

The general objective of the study was to project the usefulness enshrined in the use of replacement algorithms in solving asset underutilization against the useful life horizon expected for optimal operational usefulness of equipment when deployed. The preference for replacement in this study is not only restricted to the replacement problem but also to its capacity to improve, enhance, authenticate, and provide operational standards in management decisions concerning procurement, financial provision in terms of budgetary allocation for assets, and a determined time frame for an out-right replacement of equipment with a sudden failure rate in relation to its associated depreciation value among construction firms in the Nigerian industry.

Conceptual Review

Replacement of Items that Fail Suddenly: In such a situation, the optimal lives of the items were found by balancing the increased running cost against decreased depreciation. However, there are many real-life situations in which items do not deteriorate with time but fail suddenly (Nwabule & Chidoze, 2022). Onyeaba & Ika (2016) opined that a system usually consists of a large number of low-cost items that are increasingly liable to failure with age, for example, resistors in radio, television, and computers. Sometimes, the failure of an item may cause a complete breakdown of the. The costs of failure, in such a case, may be quite higher than the cost of the item itself.

Sebgame & Charng (2022) identified that, in a sudden failure situation, two types of policies are required:

1. Individual Replacement Policy: An item is replaced immediately after it fails.
2. Group Replacement Policy: Where items are replaced at the end of an optimal time period, irrespective of whether they have failed or not, with a provision that if any item fails before the optimal time, it may be individually replaced.

Theoretical Framework

This study was based on the investment theory propounded by Irving Fisher (1906) in his nature of capital, income, and rate of interest. Fisher assumes the investment decision of the firm as an inter-temporal problem (Jorgenson 1967). The assumption was that all capital was circulating capital. Therefore, all capital is used up in the production process; thus, a stock of capital **K** does not exist; rather, all capital is, in fact investment. He defined investment as the change in capital stock over a period, and investment is a flow term and not a stock term, but can be measured over a period of time **t,** while capital **K** is a stock term that can only be measured at a point in time. He noted that the quantity of a flow always depends on the period in consideration (Mark et al., 2021). Thus, investment flow is calculated as the flow in a period as the difference between the capital stock at the end of the period and the capital stock at the beginning of the period.

The neoclassical theory of investment opined by Dale W. Jorgenson (1967) in his book "The Theory of Investment and Behavior" assumes that the flow of replacement generated by a given flow of investment goods is distributed over time in accordance with an exponential distribution. Offor et al. (2022) observed that this assumption implies that the flow replacement investment at any point in time is proportional to the accumulated stock of investment goods (Jorgenson 1967). Investment theory was adopted as the theoretical framework for the study because it establishes a mathematical model for optimal replacement decisions (Ajibade et al., 2019). The theory co-factored the changes in the value of money over a time horizon with respect to the original investment (cost) and the role the value of money plays in the model development (Madu et al., 2022).

Methodological Demonstration

The study adopted a cross-sectional design with the use of secondary data from Lubricks Construction. Replacement decisions adopt different methods. A replacement decision could adopt a mathematical model that captures the relationship between modeled variables. Chand & Sethi (1982) pointed out that the model considered optimum replacement intervals using the initial cost of the equipment, the annual operating cost, and the annual increase in the maintenance cost. Theusen & Fabrycky in Poage (1997) and Atul et al. (2019) express the average annual cost for each piece of equipment with increasing maintenance costs as follows: equation (1):

$$\mathrm{C} = \frac{I}{M} + Q + (n-1)\frac{\mathrm{M}}{2} \qquad (1)$$

Where: C = average cost; **I** = initial cost of asset; **Q** = operating cost for the first year
M = increase in yearly maintenance cost; **n** = life of equipment in years
The useful life of each piece of equipment is determined by applying the classical optimization procedure using calculus by differentiating with respect to **n**, equating to zero and solving for **n.** The optimal life is determined, by Equation (2)

$$\frac{dC}{dn} = \frac{P}{n^2} - \frac{m}{2} = 0 \tag{2}$$

$$n = \frac{\sqrt{2I}}{M}$$

Thus, the useful life of equipment is a function of the square root of original cost (investment) multiplied by two, divided by the rate at which maintenance changes overtime. Equation 2 shows that the duration or useful life of equipment before replacement takes place depends on the original cost (investment) of the equipment and the rate at which maintenance changes over time.

Strategies used to accomplish the Objectives

The objective was accomplished with the used of secondary data obtained from existing files and records on replacement of computers. The data enabled the researcher to systematically represent information in accordance with their stochastic sequence within a finite horizon (N_i). Gupta & Hira (2012) identified that, in order to solve for an infinite problem using the finite horizon (N_i) formulation in equipment replacement, the sets of boundary conditions considered to be: the non-increasing boundary set according to the number of years (N_i) for replacement and non-decreasing boundary set according to its stochastic order (P_i). The sum of all probability are unity (that is not more than one). The two sets of boundary conditions were used to develop a stopping rule to identify the forecast horizon for the solution. Once the forecast horizon is identified, equipment replacement policy must be made (Amiens, et al., 2021).

It was interesting to note that the model provided a comprehensive solution for all objectives of the study in a simple and single algorithm, with probability distributions of failure assumed to be distributed arbitrarily. The first and second years (N_i and N_2) are usually excluded, reasons being that at such periods the computer function at optimal efficiency. Thus, $N_i = 0$, and $N_2 = 0$. But it is assumed that all the failing computers within a year might fail at any time of the year, and also group replacement are also made at the end of each year (Bukola, & Samuel, 2022). Analysis would have been made over a six-year (N = 6) period. Below demonstrated information derived (Chand, & Sethi, 1982) thus:

Table 1. Probability Distribution Time Horizon (N_i) and (P_i)

Years (N_i)	3	4	5	6
Probability of failure (P_i)	0.2	0.4	0.3	0.1
Total number of computers (N) =	400			
Individual Replacement Cost (C)=	₦5000			
Group Replacement Cost (G) =	₦100, 000			

Source: Company Records.

With the data, the next step determined the minimum cost strategy, thus:

Strategy for Cost Optimization

Gupta & Hira, (2012) posited that, the strategy for optimizing replacement cost has four steps namely,

Step 1: Determine Replacement in a Year **(R_i)**

Step 2: Determine Total Individual Replacement in a Year **(S_i)**

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Step 3: Determine Cost of Group Replacement in a Year **(T_i)**
Step 4: Determine Average Cost of Group Replacement in a Year **(A_i)**
These steps would have been adopted to accomplish the stated specific objectives thus:
Where: C = Individual Replacement policy: Where an item is replaced immediately after it fails.
G = Group Replacement Policy: Where items are replaces, at the end of an optimal time period, irrespective of whether they have failed or not.
Theory: Assumes N_1 and $N_2 = 0$, respectively. Then

For Year 3 (Assume t = 3):

If t =3, then $R_3 = N_t P_{t-2} + N_{t-2} P_{t-1} + N_{t-1} P_t$ …………………….. (1)
and, $S_3 = N_t + N_{t-1} + N_{t-2}$ …………….............. (2)
and, such that $N_{t-1} = 0$, $N_{t-2} = 0$; and $N_{t-2} P_{t-1} + N_{t-1} P_t = 0$
and, $A_3 = T_3/3$ …………………... (3)
and, $T_3 = S_3 \text{ x } C + G$ …………………… (4)

For Year 4 (Assume t = 4):

If t = 4, then $R_4 = N_t P_{t-3} + N_{t-3} P_{t-3} + N_{t-2} P_{t-1} + N_{t-1} P_t$ ……….. (5)
and, $S_4 = N_t + N_{t-1} + N_{t-2} + N_{t-3}$ ..…................ (6)
and, such that $N_{t-2} = 0$, and $N_{t-3} = 0$; and $N_{t-2} + N_{t-3} = 0$
and, $A_4 = T_4/4$ …………………... (7)
and, $T_4 = S_4 \text{ x } C + G$ …………………… (8)

For Year 5 (Assume t = 5):

If t = 5, then $R_5 = N_t P_{t-4} + N_{t-4} P_{t-3} + N_{t-3} P_{t-2} + N_{t-2} P_{t-1} + N_{t-1} P_t$ ….. (9)
and, $S_5 = N_t + N_{t-1} + N_{t-2} + N_{t-3} + N_{t-4}$ ..…................ (10)
and, such that $N_{t-4} = 0$, and $N_{t-3} = 0$; and $N_{t-4} P_{t-3} + N_{t-3} P_{t-2} = 0$
and, $A_5 = T_5/5$ …………………... (11)
and, $T_5 = S_5 \text{ x } C + G$ …………………… (12)

For Year 6 (Assume t = 6):

If t = 6, then $R_6 = N_t P_{t-5} + N_{t-5} + N_{t-4} P_{t-2} + N_{t-3} P_{t-3} + N_{t-2} P_{t-4} + N_{t-3} + N_{t-1} P_t$ .. (13)
and, $S_6 = N_t + N_{t-1} + N_{t-2} + N_{t-3} + N_{t-4} + N_{t-5}$ .... (14)
and, such that $N_{t-5} = 0$, and $N_{t-4} = 0$, and $N_{t-3} = 0$; and $N_{t-4} P_{t-3} + N_{t-3} P_{t-2} = 0$
and, $A_6 = T_6/6$ …………………... (15)
and, $T_6 = S_6 \text{ x } C + G$ …………………… (16)

Table 2. Cost Optimization Algorithm

Years (i)	Strategies for Expected number of Failure (N_i)	Least Cost Effect
A_i		
N=3 (Year 3):	$R_3 = N_3P_1 + N_1P_2 + N_2P_3$: 400 x 0.2 + 0 +0	= 80
	$S_3 = N_3 + N_2 + N_1$: 80 + 0 + 0	**= 80**
	$T_3 = S_3 \text{ x } C + G$: 80 x 5000 + 100,000	= 500,000
	$A_3 = T_3/3$	= 166.68
N=4 (Year 4):	$R_4 = N_4P_1 + N_1P_2 + N_2P_3 + N_3P_4$: 400 x 0.4 + 0 + 0	= 160
	$S_4 = N_4 + N_3 + N_2 + N_1$: 160 + 80 + 0 + 0	= 240
	$T_4 = S_4 \text{ x } C + G$: 240 x 5000 + 100,000	= 1,300.000

$A_4 = T_4/4$: 1,300.000 = 325, 000

N=5 (Year 5): $R5 = N_5P_1 + N_1P_2 + N_2P_3 + N_3P_4 + N_4P_5$: 400 x 0.3 + 0 +0 = 120

$S_5 = N_5 + N_4 + N_3 + N_2 + N_1$: 120 + 160 + 80 = 360

$T_5 = S_5 \times C + G$: 360 x 5000 + 100,000 = 2,180.000

$A_5 = T_5/5$: 2,180.000/5 = 380.000

N=6 (Year 6): $R_6 = N_6P_1 + N_1P_5 + N_2P_4 + N_3P_3 + N_4P_2 + N_5P_1$: 400 x 0.1 + 0 + 0 + 80 x 0.2 + 0 + 0 = 56

$S_6 = N_6 + N_5 + N_4 + N_3 + N_2 + N_1$: 56 + 120 + 160 + 80 + 0 + 0 = 416

$T_6 = S_6 \times C + G$: 416 x 5000 + 100,000 = 2,180.000

$A_6 = T_6/6$: 2,180,000/6 = 363.34

From the computed cost optimization algorithm in Table 2, the computed average costs were compared to determine the most effective year (time horizon) or least cost effect as shown in the average cost column with their respective finite horizons for replacement policy decisions. As observed from the table, the average cost increased, and after some years it started declining as the computer usage age increased, which was in collaboration with the work of Osama (2022) and Nepal et al. (2020). Specifically, the average cost of maintenance increased progressively from the third year (N = 3) through the fifth year (N = 5) but declined in the sixth year (N = 6). Hence, strategy three provided the best fit for the organization. It is so because strategy three integrates the accomplishment of all objectives stated in the study into a more stable state for the organization, which was found to be in conformity with the findings of Prabhuswamy et al. (2019).

To accomplish the objective, a careful observation of the strategy analyzed in Table 2 clearly shows that strategy three suggests that the optimal efficiency period for the use of a computer is at year three (N = 3), as well as its replacement year at the end of three years. This is because it has the lowest annual average cost of maintenance at N166.68k.

Recommendations

Organizations have choices regarding how to maintain their production equipment. They could choose to have no maintenance plan and operate in a purely reactive mode. Hence, based on the reviewed literature of the study, the paper further recommended the following:

1. Equipment managers should ensure that replacement equipment is adequately planned and budgeted for in order to prevent cash freezes when replacement decisions are made.
2. Inspection, verification, and proper inventory of equipment should be carried out regularly or at intervals as deem necessary in order to prevent sudden failure or breakdown of equipment in an organization.

3. A preventive maintenance schedule should be developed in order to avoid the sudden breakdown of operational equipment.
4. Equipment is a major asset for the productive activities of an organization; hence, a proactive decision for maintenance at a minimal cost is key for any organization in business.

Conclusions

The paper portrayed a method for computing equipment replacement decisions for group items that fail suddenly. The method assumed that equipment may be obsolete as a result of new technology or would have outlived its operational efficiency, resulting in an increase in operational cost due to frequent repair. A clearly defined and simple computational algorithm was developed to determine the cost optimization strategy for equipment replacement within a finite horizon and how an organization would actualize its specific objectives in managing equipment maintenance. Further study could be carried out on the subject by applying the dynamic programming (DP) approach.

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