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Review

A review and analysis of plant maintenance and replacement strategies of manufacturing firms in Nigeria

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Maintenance is important to the success and continuity of firms, particularly in the changing society as ours. The effectiveness and the survival of organizations are largely enhanced by the ability of management to ensure that there is functional equipment, lands and building, infrastructure and fixtures. In the manufacturing setup, there is wear and tear of machines and equipment in periods of usage that require sufficient maintenance to enhance their useful life. This ensures reliability of the machines and equipments in the production plants as to uninterrupted production runs. Most manufacturing firms have lost their effectiveness and productivity, because of poor equipment maintenance. Poor attitude towards equipment maintenance hamper firm's operation. This study examined the principles of preventive and breakdown maintenance aimed at addressing the issues of negligence and lack of equipment maintenance. Also, the study focused more on maintenance and replacement problem solving, and the main difficulties are reported along with probable solutions.

Key words: Maintenance, preventive maintenance, breakdown maintenance, reliability and replacement.

INTRODUCTION

Mangers of organizations are particularly interested in the smooth functioning of their assets especially, in manufacturing firms, where machines and equipments are used in the workstations in the conversation of inputs to product outputs. The regular use of these machines and equipments results in wear and tear, diminishing the value of the asset. Thus, regular maintenance of the assets will improve their functionality and enhance the efficiency of the production process. These efforts commonly include an examination of the maintenance function (Gustav and Hanna, 2012). Furthermore, the installation and layout of machines and equipments in a plant or factory and even the human resources are to bekept productive and reliable by having a maintenance performed by way of repair, rest, lubrication, and inspection. There are wears and tears of the components of the machine, by course of regular usage and even in a state of inertia as idle parts can rust, fixate and worn out.

LITERATURE REVIEW

Abdul-Moshen (2008) is of the opinion that maintenance means to hold, keep, sustain or preserve facilities to an acceptable standard. Also, maintenance is a combination of technical and administrative activities to keep a machine or equipment in its functional state. Machines or equipment with poor maintenance will result in dysfunction that might likely result to production of defective products which affect the quality of the product in a production process. It involves reliability of the machines and equipments to perform to a standard level of quality assurance (Shohet, 2009). Again, poor maintenance of production facilities can result in poor end-product quality and customer dissatisfaction, lost production runs, cost inefficiencies, and sometimes, unavailability of the facility for future use (Lavy, Garcia and Dixit, 2010).

Unfortunately, most organization's facilities in Nigeria, for example the refineries, lack good maintenance due to relatively high cost of maintenance, and this results in frequent breakdown and stoppages (Usman et al., 2012). Hence, there is usually unchecked rapid deterioration of the facilities and consequent loss of functional value and maximizing the useful life of the facilities.

Maintenance is one of the major activities which account for up to 40% of total costs, in some Nigeria organizations (Eti et al., 2006). Thus, maintenance plays a significant role that in most manufacturing firms there is a maintenance department which includes both building components and equipment (Alberto and Giulio, 2012). In the traditional accounting, maintenance is regarded as an expense that can easily be included to overall business costs, particularly in the short term (Tsang, 2002). To reduce maintenance cost in the short run, preventive maintenance involving prompt inspection and service of potential areas of failure will minimize cost of maintenance. This is contrary to allowing equipment or machine to fail before repairing it where repair and replacement cost will increase maintenance cost at the long run (Campbell and Jardine, 2001). According to Chika (2008), no single support technique and system can adequately give required solutions for both natural and artificial defects on structures. Olanrewaju et al. (2011) assert that there is need for shift from maintenance management principles to value-based initiatives.

Maintenance is the activities done to preserve the initial condition of an equipment or asset while atoning for the normal wear and tear. Bagshaw and George (2015) observed that "facility maintenance is the effort in connection with different technical and administrative action to keep a physical asset, or restore it to a condition where it can perform a require function". The function of maintenance is to ensure the reliability of machines or equipments in the course of its use. The concept of reliability has been defined by Meredith (1992) as "the

chance that a product or service will perform as intended for a stated period under specific operating conditions." The concept here is in groups of services but can very well be applied to machines and their components. More so, Hinchcliffe and Smith (2004) defined reliability as the dependence on the acceptable level of performance of the functioning of an equipment or machine within its useful life under normal operating conditions.

In the flow production system, there is continuous production run, requiring constant operations of the machines and equipments necessitating periodic inspection and servicing.

Failure, to ensure regular and periodic preventive maintenance will result in loss of operation due to failures of the machines or equipments highlighted the aspects of availability and reliability of the systems' safety (Birolini, 2010). The machines are designed for a particular functional use and the reliability of the machine is assured as quality control measures in the design of the asset to minimize machine failures.

When active and efficient maintenance principles are applied, it reduces the failure rate of operational assets to its minimum resulting in increase in the amount of time the asset or machine will be available for use. Also, this will reduce overall operational cost of the firm. Hence the maintenance plays a significant role in the overall profitability of the firm.

The machines are designed to perform certain functions and it is thus expected to do it within a given period of use. Hence, maintenance is to ensure that the expectation in the functionality of the machine of plant or equipment does not fail. In emphasizing the need for maintenance, Banjoko (2009) stated "it is therefore for business organizations to devise optimal maintenance policy which would ensure that operational disruptions due to failure or breakdown of machines and equipment are minimized".

Objectives of maintenance

According to Banjoko (2009), the objectives of maintenance are:

1. To maximize the amount of time the machine, tools, equipment, building etc will be available for use and for the purpose for which they are required.
2. To enhance toe operational reliability of the machine, tools and equipment.
3. To minimize overall operational cost of production through reduction of scraps and wastages that may be due to the malfunctioning of the machines.
4. To preserve the value of the assets by reducing the rate by which they deteriorate.

These objectives reveal the "infant mortality" and "wear and tear" period of an equipment or machine.

Benefits of maintenance

Slack et al. (1995) had identified the following benefits of maintenance.

1. Enhanced safety.
2. Increased reliability, that is, less disruption of normal activities of operations, results in increased production outputs.
3. Higher product quality.
4. Lower operating cost.
5. Longer life span through regular care, cleaning and lubrication of facilities.
6. Well maintained facilities will earn higher scrap values.

Maintenance strategies

Slack et al (1995) classified the maintenance activities into three approaches. These are:

1. Run to Breakdown (RTB) which is typical to breakdown maintenance where maintenance work is performed only after a breakdown has occurred. Examples are televisions, telephones in a hotel's guest room.
2. Preventive maintenance which is a procedure of eliminating or reducing the likelihood of failure of an asset or machine through inspection (checking potential areas of failure); and servicing (cleaning, lubricating, replacing) the facilities at preplanned intervals. Example, the engine of an aircraft are checked, cleaned and calibrated by regular, routine check after a number of flight hours.
3. Condition Based Maintenance (CBM). This is in the class of preventive maintenance, allowing maintenance of the facility only when the opportunity is created to do so. The prompting factors that call for maintenance action are the measured values (condition data indicating a developing failure) which indicate that the asset or machine will require maintenance action (Holmberg et al., 2010).

This leads to higher probability of preventing failures. As long as the failure is a gradual process with a detectable deterioration, the condition can be monitored; CBM can be a useful tool in ensuring smooth operations (Gopalakrishnan and Banerji, 2004).

However, a mixed maintenance strategy is advised to be used. The run-to-breakdown strategic option will be preferable where repair of machines or equipments are simple and easier, and where preventive maintenance carried out in stopping or disrupting normal production runs is very costly.

Also, in situations where failure of the machines do not have prevalent random occurrence of failure or breakdown, preventive maintenance of such machines or equipments can be carried under a predetermined timeframe.

The conditioned-based maintenance strategy can be adopted where turnaround maintenance of the plant or facility require very high cost estimate and again where disrupting production runs will not be permitted as in continuous production, for example, the refinery plant. Plant maintenance not only involve repair or replacement of faulty parts when they fail, called corrective maintenance or breakdown maintenance but also to prevent the breakdown of such equipments or machines, even to prevent their poor performance.

Basically therefore, there are mainly two types of maintenance policies- the preventive maintenance policy and the breakdown maintenance policy. In the two maintenance polices, both preventive and breakdown, maintenance involves cost, and the problem of which policy to adopt is influenced by cost minimization.

Preventive maintenance

Preventive maintenance involves identifying potential areas of failure as to avoid breakdown which might be costlier. This is followed through by inspection, service and replacement of parts before they fail. Banjoko (2009) stated that preventive maintenance "involves the regular or periodic check and servicing of the machines, tools and other facilities used in the production process so as to delay or prevent the breakdown or the total failure of the facilities." Some managers argue that why anticipate failure when it had not occurred and spend money that can be routed to other areas of need. On the other hand, not anticipating failure and preventing it, is to be ready to have a breakdown perhaps earlier than expected. Sometimes a breakdown of a component will result in further damage of other parallel sometimes costlier components.

Furthermore, the problem with in undertaking a preventive maintenance is to have a stand-by facility, which might increase the cost of asset. Again, stopping the machines for routine maintenance will cut down on its operating time, bearing in mind that the operation mode and plant-specific variables have a direct impact on the normal operating life of machine (Mobley, 2004). While preventive maintenance might not be the optimum maintenance strategic option, it does have several advantages over that of the breakdown maintenance strategy. Undertaking preventive maintenance of machines and equipments will ensure that the functional state of the machine or equipment is maximized as in the design specification.

Preventive (routine) maintenance therefore requires regular, consistent check by inspection and the inspection following a question - format "When to inspect? Where to inspect? and How to inspect?" Each these inspection analyses are to ensure that the equipment designed and built remains, "trouble - free" and that the production system is said to have "good

maintainability". The inspection procedure i~ followed by servicing. This most times requires stand-by facility in order not to disrupt the production process. Sometimes, servicing involves routines such as cleaning, lubrication and other necessary actions to reduce tear and wear.

Preventive maintenance should be carried out in work centers, and it is essentially important in continuous or flow production systems where no slack time is given for maintenance jobs. Preventive maintenance can be carried out therefore based on:

1. Time based, that is, periodic regular inspection and service.
2. Capacity or output based, that is, regular maintenance of machines parts, carried out after a pre-determined production output capacity.
3. Opportunity based. This occurs when there is no stand-by facility and where the equipment or machine is daily required such that the single facility cannot be halted for routine maintenance work. However, in periods of low production (downtime) change, in plant layout necessitating a general stoppage of work then the opportunity is created for routine maintenance.

In evaluating the Just-in- Time (JIT) philosophy, Adam and Ebert (1992) stated that "a distinctive feature of JIT environments is the constant attention to scheduled daily preventive maintenance of equipment". They went further to state that, "preventive maintenance runs counter to the traditional philosophy that machinery depreciates to a value of zero over a function of years".

In JIT production, the production process can be halted and machines lubricated, parts replaced where necessary. Meredith (1992) indicated that high reliability and good maintainability are important in the implementation of JIT system.
Some of the benefit of preventive maintenance includes:

1. It helps to curtailed pre-determined maintenance
2. It provide longer maintenance intervals
3. It helps to trim corrective maintenance and fewer unplanned breakdowns

Breakdown maintenance

When there is actual failure of the machine or equipment that have been in use until they fail to operate, then the breakdown maintenance strategy is the option to adopt. Breakdown maintenance involves the repair or replacement of faulty parts; often it occurs as an emergency in nature and requires a cost premium (Monks, 1996). Breakdown or corrective maintenance is a procedure to correct the faulty machine or equipment. Breakdown of machine will disrupt the production process especially in product layout where a breakdown of one machine will halt the production process causing a stoppage of the plant. The corrective maintenance takes

time, and with some specialized equipments, there is need for an expatriate or service personnel from the foreign manufacturing firm. Also, other associated breakdown costs are:

1. Loss of production output which can cause delay in product delivery dates.
2. Paying idle factory staff coupled with overtime costs that are sometimes doubled compared to regular pay to make up for the loss in output during the period of breakdown.
3. Also, in order not to disappoint customer orders, such orders are subcontracted out. Subcontract costs can be high, but more important is the stockout cost created by such idle capacity due to breakdown.

Meredith (1992) stated Murphy's Law that, "what can go wrong will go wrong. And it will go wrong in exactly the worst possible way, at the worst possible time, and in the worst possible place." Therefore, goes the saying prevention is better than cure.

However, firms are unwilling to undertake preventive maintenance where there are low budgetary allocations for such routine maintenance. For example due to lack of funds, routine turn-around maintenance (TAM) could not be carried out in the refineries resulting in breakdown of machines that could not easily be repaired or replaced because of the higher costs involved. Other government establishments in Nigeria, such as the Nigerian Fertilizer Company (NAFCON) at Onne in Rivers State; Ajaokuta Steel at Kogi State; Alaja Steel company at Delta State are all replicates of poor maintenance culture resulting in complete breakdown of such plants.

Total productive maintenance

Total productive maintenance (TPM) is the maintenance that is carried out by all employees through small group activities (Slack et al., 1995). The concept of total production maintenance started in Japan. Nakajima (1998) stated the goals of TPM as:

1. Improve equipment effectiveness.
2. Achieve autonomous maintenance, that is, to allow the operators using the machines or equipment to be responsible and knowledgeable in undertaking some level of maintenance tasks.
3. Plan maintenance that is, having a schedule programme on maintenance task.
4. Train all staff in relevant maintenance skills. Training will ensure that both maintenance and operating staff have all the skills to do their tasks.
5. Achieve early equipment management. This is geared towards 'maintenance prevention. Maintenance prevention involves identifying the course of failure and the 'maintainability' of equipment.

Table 1. Quadrant on Total Productive Maintenance.

Maintenance staff	Operating staff
Roles to develop: Preventive actions; Breakdown services	**To take on:** Ownership of facilities
Responsibilities train operators: Devise maintenance Practice; Problem solving; Assesses operating practice	**Correct operation:** Routine preventive Maintenance ; Routine condition based maintenance

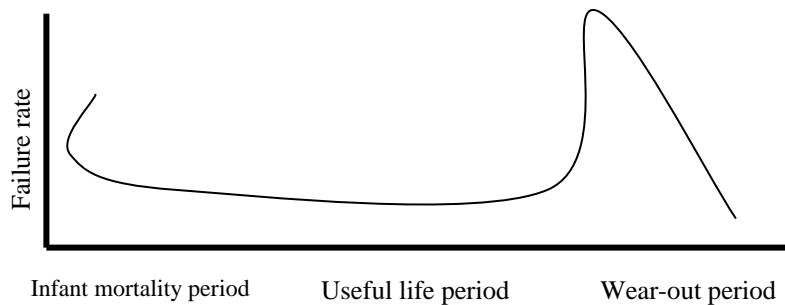**Source:** Operations management Slack et al. (1995).

Figure 1. Typical system failure rate distribution (Source: The management of operations: A conceptual emphasis, Meredith (1992)).

Slack et al (1995) developed a 2x2 matrix model of the roles and responsibilities of operating staff and maintenance staff in TPM (Table 1).

Reliability of a machine over the usage period

In a typical failure rate distribution as shown below, there are three systems' failure rate distributions, infant mortality period, useful life period and wear-out period in determining the degree of reliability of the machine or equipment.

From Figure 1, reliability is the chance that a machine or equipment can last this long of the useful life of the machine or equipment. The reliability of the machine or equipment is time dependent, and if the mortality rate and wear-out failures are relatively insignificant, then the items that fail during the useful life can be estimated to determine reliability.

According to Meredith (1992), if the time taken before failure, T is very short, then there is high reliability; that is, the probability that the machine will last through its useful life is high. However, if T is very long, then the machine's reliability is very low. Reliability for time $T = e^{-T/MTBF}$ where, e is exponential distribution and MTBF is the mean time between failures. Statistically, it was found out that the failures that occur within the useful life of the machine are relatively random and the time between

failures follows the negative exponential distribution. Meredith (1992) Moving beyond the useful life to the wear-out period, we can appreciate that assuming that most of the failures occur during the wear-out period, the distribution of failures follows approximately the normal distribution.

In determining the reliability of equipment used in Rivers Vegetable Oil Company (RIVOC), Port Harcourt; four random samples of that equipment was taken, and tested: data presented showed that one failed at 120 hours, one at 900 hours, one at 1380 hours and the last one at 2400 hours respectively.

The average or mean time before failure:

$$(MTBF) = \frac{120 + 900 + 1380 + 2400}{4}$$

= 1200 hrs.

The probability of failure, P(f) = 1 – R; where R is reliability

$$\text{Reliability} = e^{-\frac{T}{MTBF}}$$

n = cumulative time = 3000 hours
T = number of samples = 4

MTBF = mean time to failure = 1200 hours

Therefore, R = $e^{-\frac{3000\,(4)}{1200}}$

e^{-10}

But P(f) = 1 - e^{-10}

Therefore P(f) = 0.999

The probability of failure is higher, which show that the proper maintenance policy is not been carry out or implemented in this organization.

The replacement problem

When a breakdown occurs, there is either a repair or replacement and essentially, there are certain com-ponents or parts like the fan belt that need replacement. Also, in other institutions, the high buildup of maintenance cost can warrant a replacement especially in long life assets (machines or plant). Meredith (1992) stated that the replacement problem is an economic issue as either in terms of:

1., The optimum life, that is, the situations where the most economic future time to replace current asset with another identical one. Or,
2. The value of a "challenger". Here due to technological innovation, a new machine was developed and available for more effective performance of task.

It is typical that, as the asset deteriorates over its life, it results in higher operating costs and loss of resale value. As the rate of usage of the machine increases; the operating cost increases due to reduced efficiency, wear and increased maintenance cost. Also, with the higher life span with deterioration, the salvage value of the asset decreases. It is necessary to determine the annual capital loss in the value of the asset for each year, and the annual operating cost.

The cumulative cost values for the annual capital loss and the annual maintenance cost are summed up to give the total cost for each respective year in the life of the asset. The optimum life cycle is that year where the average of the total cost element is minimized. Initially, the average cost decrease but begins to increase and at that point the machine should be replaced.

The optimum life problem exists for operating equipment with losses in value of the asset with age and use. As in the case of the "challenger" a new machine can be in the market, resulting in the "premature" replacement of the old asset. This seldom occurs in event of replacement of machines to newer more efficient ones. The reason given by most Nigerian manufacturing firms is their inability to assess foreign exchange and the high cost of operations from self-power supply. The cost analysis creates a situation where the decision has to be either to accept the loss in the resale of the old asset or

in purchasing the new asset termed the "challenger".

In applying the present value (pv) concept, the approach is to compare the costs and revenues of the old machine against that of the new machine so as to have an optimize solution of net present value (NPV).

Group versus individual replacement

In contrast to the replacement policy in items that deteriorate, there is one replacement decision analysis in replacing items that fail suddenly. Examples of such items are fan belt, safety valves, electrical bulb, etc. The replacement decision analysis is done in two categorizations. Individual replacement of items as failure occurs; or Group replacement of all the items that fail at the end of a given period coupled with items that was replaced previously but has now failed.

Items that failed suddenly

This involves items that fail suddenly without a priori notice but with cost consequences of failure and/ or installation costs. It is therefore necessary to estimate the various costs involved and choose the least cost. The costs calculations are:

1. Purchase price of the item to be required.
2. Labour cost.
3. Consequential cost of failure.

While (1) and (2) are quantitative inputs into the decision model; (3) is a qualitative input that can be used to obtain improved decision in having an optimal replacement policy. In items that fail suddenly, two cost components are involved:

Individual replacement policy

Step 1: Determine expected life of the item using the probability distribution of failure from historical data.

$E(x) = \sum Xi\ Pi$

where Xi = length of time item had been in use
Pi = probability of item failing in time x

Step 2: Determine average replacement per time period.

$Ra = \dfrac{N}{E(x)}$

where Ra = average replacement,
N = number of items that need replacement.
Step 3: Determine total cost of individual replacement = R_a x c.

where c = unit cost of the item.

Group replacement policy

This involves individual replacement on failure followed by mass replacement after every interval as to locate the alternative that results in the least average replacement cost in each of the calculated group replacements.

Step 1: Determine the given replacement per time period:

R_1 = first group replacement in time period
$R_1 = NP_1$ (replacement in first period 1, with probability of failure P_1)
$R_2 = NP_2 + R_1P_1$ (replacement in period 2)
$R_2 = NP_3 + R_1P_2 + R_2P_1$ (replacement in period 3)
$R_n = NP_n + R_1P_{n-1} + R_2P_{n-2} + ... + R_{n-1}P_1$ (replacement in n period, of items that were replaced previously but have now failed).
Note, as R increases, P decreases,

Step 2: Determine sum of group replacements (Si)

$S_1 = R_1$ (for the first group replacement)
$S_2 = R_1 + R_2$
For group replacement at end of time t^n.
$Sn = R_1 + R_2 + R_3 + ... + Rn$

Step 3: Determine total replacement cost (Tc) for each replacement option

Step 4: Determine Average replacement cost (AC) for each replacement option

$AC = \dfrac{TC}{n}$

Decision criterion

The replacement cost in individual replacement policy and the average replacement cost for each option under group replacement (with intervening individual replacement) are compared, and the option with the least cost accepted as the optimal strategy.

Example 1: Example on replacement policy of items that fail suddenly

Nigeria Engineering Works (NEW) has a factory with 500 machines each with two fan belts, wants to apply an appropriate replacement policy for the fan belts that are likely to fail suddenly. The following information is provided for the likely number of failures for a given five month.

Month: 1; 2; 3; 4; 5
Probability of failing: 0.10; 0.15; 0.25; 0.30; 0.20

Assuming the unit cost for the fan belt is ₦45 and the group replacement cost is N12000. The company is considering the alternative of replacing the fan belts as they fail; or replacing all the fan belts that fail in a given month together with all items that have previously failed. Advise management on the best strategy.

Solution to the problem on items that fail suddenly

Number of fan belts installed (N) = 1000
Cost of individual replacement   = ₦45.00 per fan belt
Mass replacement cost = ₦12000
Month: 1; 2; 3; 4; 5
Probability of failing: 0.10; 0.14; 0.25; 0.30; 0.20

1. Individual replacement policy:

Expected life $E(x) = 1(0.1) + 2(0.5) + 3(0.25) + 4(0.3) + 5(0.2)$
= 3.35 months
Average replacement $(Ra) = \dfrac{N}{E(x)} = \dfrac{1000}{3.35}$

= 299 per month
Cost of individual replacement   = Ra x C
= 299 x ₦45
= ₦13455 per month

2. Group replacement at end of first month:
Replacement in first month
$R_1 \quad = NP_1$
$\quad\quad = 1000 \times 0.10$
$\quad\quad = 100$
Sum of replacement as at $t_1 = S_1$
$\quad\quad S_1 \quad = R_1 = 100$

Total cost   = $(S_1 \times C) + G$
= (100 x 45) + 12000
= 4,500 + 12000
= ₦16500
Average cost = ₦16500 per month

3. Group replacement at end of second month:

$R_2 = NP_2 + R_1 P_1$
    = 1000 x 0.15 + 100 x 0.10
    = 160
Sum of replacement as at $t_2 \quad = \quad S_2$
$\quad\quad S_2 = R_1 + R2$
$\quad\quad\quad = 100 + 160$
$\quad\quad\quad = 260$
Total cost = $(S_2 \times C) + G$
        = (260 x 45) + 12000

= 11700 + 12000
= ₦23700

Average cost = ₦23700
$\overline{\qquad}$
2 =   ₦11850 per month

4. Group replacement at end of third month Replacement in third month:

$R_3 = NP_3 + R_1 P_2 + R_2 P_1$
  = (1000 x 0.25) + (100 x 0.15) + (160 x 0.10)
  = 281

Sum of replacement as at $t_3 = S_3$
$S_3 = R_1 + R_2 + R_3$
  = 100 + 160 + 281
  = 541
Total cost = $(S_3 \times C)$ + G
      = 541 x 45.0 + 1200
      = 24.345 + 12000
      = ₦36.345
Average cost ₦ 36345
$\overline{\qquad}$
   3 = ₦12115 per month

5. Group replacement at end of fourth month
   Replacement in fourth month
 $R_4 = NP_4 + R_1 P_3 + R_2 P_2 + R_3 P_1$
 = (1000 x 0.3) + (100 x 0.25) + (160 x 0.15)
+ (281 X 0.1)
= 377
Sum of replacement as at $t_4 = S_4$
 $S_4 = R_1 + R_2 + R_3 + R_4$
= 100 + 160 + 281 + 377
= 918
Total cost = $(S_4 \times C)$ + G
      = (981 x 45.0) + 12000
      = 41310 + 12000
      =   ₦ 53510
N53310
$\overline{\qquad}$
Average cost = 4
= ₦13328 per month

6. Group replacement at end of fifth month

Replacement in fifth month

$R_5 = NP_5 + R_1 P_4 + R_2 P_3 + R_3 P_2 + R_4 P_1$
  =   1000 x 0.2 + 100 x 0.3 + 160 x 0.25
      + 281 x 0.15 + 377 x 0.l
  =   350
Sum of replacement as at $t_5 = S_5$
$S_5 = R_1 + R_2 + R_3 + R_4 + R_5$
= 100 + 160 + 281 + 377 + 350 = 1268
Total cost   = $(S_5 \times C)$ + G
= (1268 x 45.0) + 12000
= 57060 + 12000
= N69060
$\overline{\qquad}$
    5

= ₦13812 per month

Average replacement cost is minimized at option (iii) mass or group replacement at end of second month.

Source: From the Author

Items that deteriorate

Some equipment can be kept operating with satisfactory performance for a long time. However, the annual maintenance cost will increase, while annual resale value of the asset decreases. It therefore becomes necessary that in determining to replace such assets proper cost analysis are made to determine the most replacement time, ignoring inflationary rate, and other factors that might influence the replacement decision. Categories of cost include:

1. Annual capital loss (difference between market value the beginning of the year and at the end of the year.)
2. Annual maintenance costs.

The two costs are cumulated over the years of use and are added together to obtain the cumulative total cost, and then the average cost annually. The minimum average annual cost shows the optimum replacement time option. This is because at that point (year) average total maintenance cost including annual capital loss of the asset and the annual maintenance or operating cost is minimized.

Example 2: Example on replacement policy of items that deteriorate

The management of a manufacturing company wishes to decide when to replace a certain machine with initial outlay of ₦200,000. The scrap value remains constant at ₦1,800. Maintenance costs have been reliably estimated as follows:

Year: 1; 2; 3; 4; 5; 6; 7;8; 9; 10; 11; 12
Maint.cost (₦)   200; 400; 700; 1100; 1600; 2200; 2800; 3400; 4100; 4900; 5800; 6800

Solution to the problem on items that deteriorate

In the aforementioned problem, the criterion for replace-ment is the minimization of the average annual cost over the life of the equipment. Since the resale value of the asset over the years remains constant, then the annual capital loss will be zero after the first year of use. The cumulative annual capital loss is therefore the same value over the useful life. Cumulative capital loss constant.

Table 2. Solution on items that deteriorate.

Years in usage	Cumulative capital loss	Annual maintenance cost	Cumulative maintenance cost	Total cost	Average annual cost
1	₦18.200	₦200	₦200	₦18.200	₦18.200
2	"	400	600	18.800	9.400
3	"	700	1300	19.500	6.500
4	"	1100	2400	20.600	5.150
5	"	1600	4000	22.200	4.440
6	"	2200	6800	25.000	4.167
7	"	2800	9600	21.800	3.971
8	"	3400	13000	31.200	3.900
9	"	4100	17100	35.300	3.922
10	"	4900	22000	40.200	4.020
11	"	5800	27000	46.000	4.182
12	"	6800	34000	52.800	4.400

Source: From the author.

= ₦20.000 - ₦1.800
= ₦18.200

The result to the problem solution is presented in Table 2. The decision is to replace the equipment after 8 years of use. However, better decisions will result in the consideration of time value of money, the book value of the asset and capital need for effecting the replacement.

CONCLUSION

One of the driving forces behind maintenance in manufacturing firms is the continuous improvement in technological development. The issues here that concern maintenance most are the concept of process of innovation which has to do with the development of new technologies. This is not seen to be encouraging in technology adoption of manufacturing firms especially small and medium firms (SMEs) in Nigeria with obsolete manufacturing processes. Small and medium manufacturing firms may lack the capacity to improve productivity through acquiring new technologies.

Nigeria SMEs is extremely important and contribute significantly to the economic growth particularly to the nation's gross domestic product (GDP). SMEs are important source of capacity building and the diversification of the entire economy. Thus, maintenance strategists can ill-afford to ignore the technological environment since technological function define the business of organizations. Therefore, it can then be deduced that firms that practice modern technology adoption in the production system are more likely to innovate and improve on their product competitiveness. Furthermore, constraints to full industrial maintenance management include limited source of allocated funds to acquire modern machines that have efficient processes,

high cost of financing bank loans and high tarrifs and levies on imported spare parts of manufacturing. Also, price fluctuations in developing countries like Nigeria have serious effect on manufacturing firms. In the current recession experienced in the Nigerian economy with high exchange rate has appeared to affect the prices of materials used in maintenance. The need for effective maintenance policy is dependent on impending or actual failure of the machine or equipment. Therefore, undertaking maintenance programme is to ensure continuous functioning of the machine or equipment. The useful life of most machines or equipment requires periodic maintenance in order not to disrupt production runs.

Having identified and discussed the various maintenance strategies and replacement policies, a mixed maintenance strategy is advised where it is applicable in enhancing the performance of the facility. Also, production and operations managers should adopt the optimum replacement policy of machines and equipment to have at least cost of maintenance and maximize production efficiency.

Conflicts of Interest

The author has not declared any conflict of interests.

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