Optimization Of Maintenance Reliability Programme For Transport Corporation Fleet

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ABSTRACT
This paper presents the development of reliability based maintenance programmes for Transport Corporation fleet. Several Transport Companies were visited to interview transport corporation owners and operators, studied service/maintenance manuals, gathered information from locations maintenance records and personnel. The researcher's personal experience as a workshop/maintenance manager in a motor industry for years was also employed in formulating the maintenance programme. Selection of functionally significant Items (FSI) to be maintained was carried out using experience, manufacturer's maintenance/parts manuals and items maintenance history records. Various types of reliability based maintenance work-orders/work-packs were then developed for selected and frequently occurring maintenance jobs in transport companies. Reliability based replacement intervals for FSI were suggested, as well as maintenance schedule and economic utilization strategy for transport corporation fleet.

Keywords: Maintenance, Vehicle Fleets, Work-order, Checklist, Replacement

• INTRODUCTION

In today's competitive market, high productivity and low production costs are crucial values for manufacturing and transportation companies, Unexpected machine, vehicle or process breakdowns could severely limit their effectiveness and result in costly downtime. Two main types of maintenance policies are usually considered in the maintenance literatures, reactive/corrective maintenance and preventive maintenance. Details in the following references (Wang 2002, Dekker 1996, Pham & Wang 1996, Pierskala & Voelker 1976, Kijima et al, 1998, Kijima 1989, Valdex & Feldman 1989, Cassady & Leutonoghu 2005, Yang et al., 2006, Eti et al., 2006, Tsang 1995, Tsang 2002). Every other type is an extension of the above mentioned two categories.

One pervasive cost that drags down productivity improvements, hence process optimizations, is unplanned equipment and manufacturing process down time. Equipment degrades with age and usage and eventually fails.

This impacts business performance negatively in several ways – reduced equipment availability, lower output quality, higher operating costs, increased customer dissatisfaction etc. The degradation can be controlled through preventive maintenance actions while corrective maintenance actions restore failed equipment to its working state. It has also been discovered that transport companies spent a lot of their profit on unnecessary maintenance activities. This paper intends to consider various reliability based maintenance programmes with a view to developing same for use by Transport Corporation. These are

1) Reliability based maintenance inventory
2) Reliability based Preventive Maintenance
3) Reliability based corrective maintenance
4) Reliability based replacement maintenance
5) Reliability based maintenance schedule
6) Economic utilization strategy for Transport Corporation fleet

- **TERMINOLOGY DEFINITION**

1) **Workorder/Workpack:** This is a document that contains everything about the job – craftman, man hour needed to execute the job, expected date of job completion, procedure, checklist, safety kits to be used, materials needed, tools needed. Etc.
2) **Checklists** – This document mention all items to be examined or checked in a workorder. It is an integral parts of a workorder or work pack.
3) **Maintenance:** This is an act of ensuring that equipment continues to perform its intended function properly.
4) **Replacement:** This is an act of restoring failed equipment to its functional state
5) **Vehicle Fleet:** A large number of vehicles usually utilized for commercial transportation purposes.

- **Development of Reliability Based Maintenance Inventory Programme**

In developing reliability based maintenance inventory programme for fleet company, ABC analysis approach comes to mind.

Inventory of an industrial organization like fleet company generally consists of thousands of items with varying prices, usage, rate and lead time. Here ABC analysis would be used to segment fleet spare parts, in to.

A – Class: These are non-moving and expensive parts

B – Class: Slow moving and less expensive spare parts

C – Class fast moving and lesser expensive.

'A' class items hardly constitute more than 5-10 percent of the total items but account for 70-75 percent of the money spent on inventory cost.

'B' Class items are generally 10-15 percent of total items and represent 10-15 of of the total expenditure on inventory materials.

'C' Class items are about 70-80 percent in number and constitutes only 5-10 percent total expenditure on materials

ABC analysis is not one time exercises and items are to be reviewed and re-categorized periodically.

Feature and Policy Guidelines for ABC Analysis is shown below:

	A CLASS (HIGH VALUE)	B CLASS MADE AT VALUE	C CLASS LOW VALUVE
1	Tight control on stock level	Moderate control	Less control
2	Low safety stock	Medium safety stock	Large safety stock
3	Ordered frequently	Less frequently	Bulk ordering
4	Individual posting in stores	Individual posting	Collective posting
5	Weekly control report	Monthly control reports	Quarterly control reports
6	Continuous efforts to reduce lead time	Moderate efforts	Minimum effort
7	Procured from multiple sources	Two or more reliable sources	Two reliable sources for each item

Procedure for making ABC Analysis:

1) Calculate the total inventory value for each item held in inventory value for each item held in inventory by multiplying the number of units used in a year by its unit price
2) Tabulate these items in descending order of their values placing first the items having the highest total value and so on.
3) Prepare a table showing item number unit cost, annual unit consumed and naira value of unit used.
4) Compute the running total item by item for the items and also for naira value of consumption.
5) Compute the cumulative percentage for the item count and cumulative annual usage value
6) Classify the items as per the norms for ABC items.

The cumulative percentage are represented graphically as shown in fig. 2.1

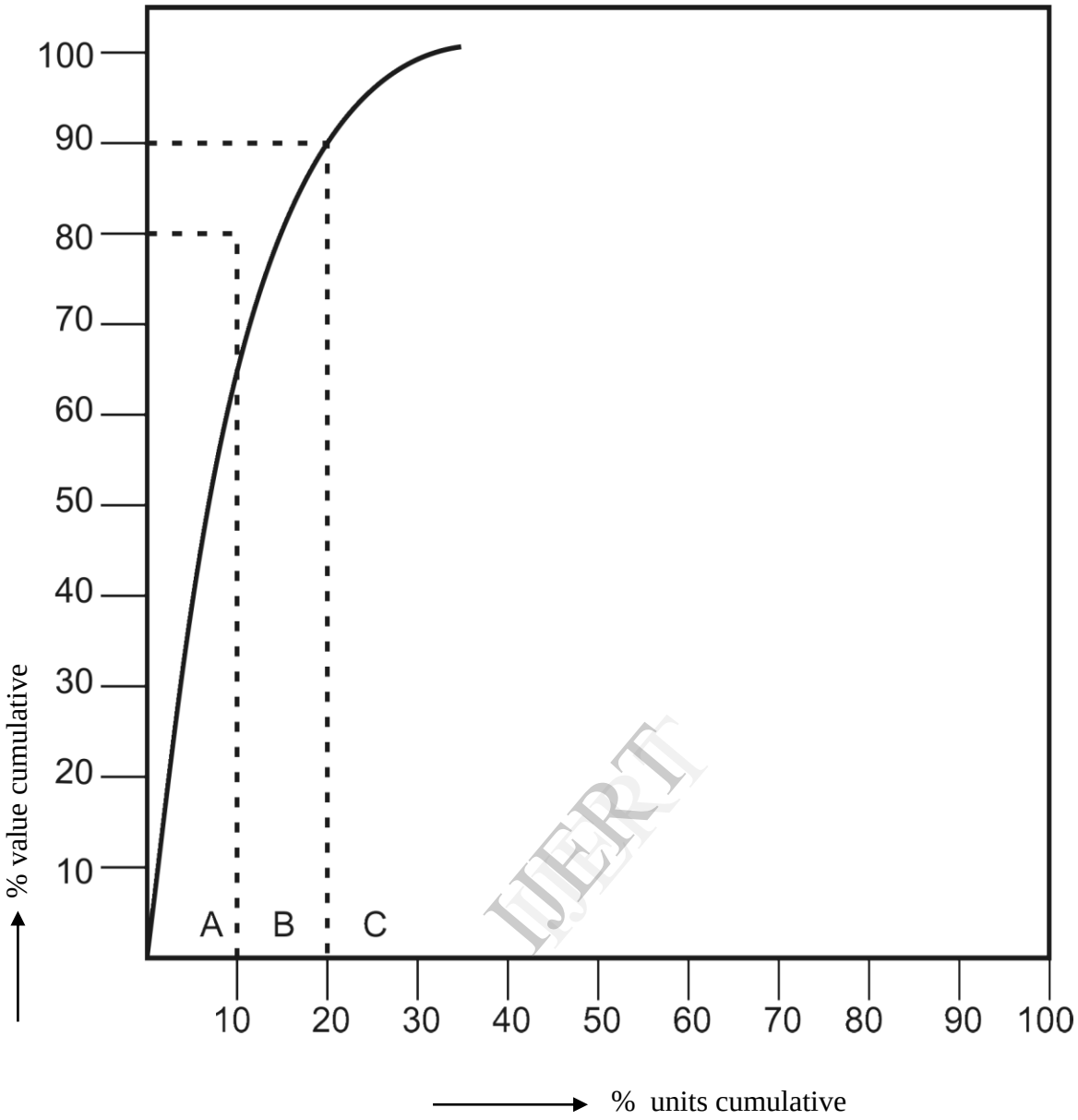

Fig. 2.1 ABC Analysis

Establishment of Minimum and Maximum Stock Level Procedures:

The method used is known as fixed order quantity system and it is also called perpetual inventory system or Q-systems. In this system, the order quantity is fixed and ordering time varies according to the fluctuation in demand. The characteristics of this system are.

- Re-order quantity is fixed and normally it equals economic order quantity (EOQ).
- Depending upon the demand, the time interval of ordering varies.
- Replenishment action is initiated when stock level falls to re-order level (ROL).
- Safety stock is maintained to account for increase in demand during lead time.

Parameters to Operate the System

1) Re-Order Level (ROL). This equals the sum of safety stock and lead time consumption

ROL = M + (L x C)

Where M = is the minimum or safety stock

L = Lead time (daily/weeks/months)

C = Consumption rate (Per day/per week/per months)

2) Re-order quantity (Q). This normally equals Economic Order Quantity (EOQ).

3) Maximum Stock level (M)

It equals the safety stock + Order Quantity

M = m + Q

Where Q0 is order quantity

m = Safety Stock or minimum stock

M = Maximum stock

- **Development of Reliability Based Preventive Maintenance:**

a) Identifications of FSIs. The following system items are selected as FSIs using experience, manufacturers' maintenance/parts manuals, usage and environmental specifics-

Engine, Cooling system, Gear box, Clutch, Air conditioning system, Electrical system, Braking system, Suspension system, Transmission system, Tyres, Starting system, Hydraulic system – clutch, Hydraulic system – brake, Steering system.

These FSIs list could be expanded from time to time depending on conditions and necessities to ensure better and improved service delivery

b) Intervals/Frequencies: Establishing applicable and effective PM task intervals is very important for the PM programme to succeed. This is based on experience, performance manual, usage and environmental specifics. The interval selection may be calendar based or speedometer reading based. For commercial transport vehicles, speedometer reading methods is preferable for effective PM programme. Maintenance intervals selected on the basis of long time experience (not necessarily an inferior alternative to mathematical models).

To this day, this is the approach most frequently used. (Aborehaid et al., 1999). Safety and cost considerations are also addressed in establishing PM intervals.

c) Skill/Craft Selection: This should be carefully, selected based on training, experience and the systems/items involved for PM.

d) Activities/Tasks: The approach used for identifying applicable effective PM tasks is as important as selecting FSIs, reason being that it is the tasks/activities that would provide a logic path for addressing each FSI functional failure, prevention and mitigation. The tasks/activities and related intervals will form the initial scheduled PM programme. Activity is a detailed breakdown of task. Again experience, manufacturer's maintenance manual are used as well as environmental requirement. The experience of this researcher as a workshop manager for years in a multi-national maintenance company is also utilized here.

e) Spares/Tools/Consumables: For any PM to succeed and reduced downtime ensured, spare requirement must be determined and availability ensured before any economically viable and reliable PM programme can strife. No PM programme will succeed without optimum availability of tools and consumables. They should be available in reliable quality and quantity.

f) Safety: Safety Considerations in any task performance must be seriously viewed if successful cost effective PM programme is to be achieved. This is because any safety violation can result in hazardous accident while the PM is conducted and even fatality (dead). Therefore, all PM tasks must identify potential hazards and reasonably controlled or mitigated if not eliminated.

g) Procedure: Step by step method of carrying out each activity/task must be developed. This will ensure that correct performance of each activity/task is done. Procedure also help in future repetitive jobs which are easily act as reference and adopted for future use of the same or similar type of job.

h) Checklist: Checklist acts as a reminder to a technician that all he needed to do have been accomplished in a particular task or work.

i) Testing/return to service: Testing involves comparing the result of the task to minimum accepted performance standards. Example, in the case of a motor vehicle undergoing a minor or major service it will require the technician to go through again and again the checklist and afterward the testing officer is call upon to

put the vehicle on road testing to further access the performance of the vehicle. Return to service involves cleaning and tidying up of work site. It also involves maintenance warning sign like "Vehicle on maintenance", "Do not start" etc, taken away and eventual handing over to operation to be put to service.

j) Report: For every completed task or work order a report is generated to be kept in the history data base. This is to be used for the purpose of developing corrective maintenance or replacement maintenance actions.

k) Programme feedback: Report generated in each of the task would be used by maintenance manager and upper management to take actions concerning the equipment.

Example of these decisions are involving external expert in maintenance of the equipment, need for major overall or rebuild or total replacement of the equipment with a new one

l) Duration/Labour Cost: Duration of task and consequently labour cost should be determined for each task using experience and work study approach. This is necessary to ensure labour cost is within the accepted norm in the industry for optimum economic advantage and return on investment to be achieved.

- **Development of Reliability Based-Corrective Maintenance**

Irrespective of the amount of PM conducted on an equipment/asset, corrective maintenance programme would still have to be done. This will come as a result of accident, negligence, metallurgical defect or wear due to age. In all these causes of corrective maintenance, only wear due to age can be controlled and planned for to prevent catastrophy and extremely high cost of maintenance in this case a well managed PM programme would provide report/feedback when this corrective maintenance should be carried out. Nevertheless, from experience and manufacturers maintenance manual, the following corrective maintenance are known to occur in motor vehicle under service conditions.

1) Tyre puncture,Brake pad/lining wear
2) Top cylinder gasket failure
3) Crank/shaft and oil seal wear/failure
4) Brake master cylinder hydraulic seal leakage
5) Fan belt wear
6) Suspension bushing failure
7) Starter bushing/bearing failure
8) Alternator bushing/bearing failure
9) Clutch hydraulic seal leakage
10) Air conditioning gas leakage.
11) Propeller shaft middle/end bearing failure
12) Steering rack/pinion failure
13) Clutch release bearing/disc/plate failure
14) Battery failure
15) Engine valve cover seal leakage/failure
16) Bulb failures
17) Wiper system failure
18) Gear box/oil seal failure
19) Rear axle/oil seal failure
20) Engine Failure

These lists are in-exhaustive but the corrective maintenance action should be carried out based on experience as they occur. In planning for corrective maintenance most of the issues discussed in section 2.3. (Reliability based PM) apply – tools, spare, labour cost, procedures, safety measures, duration etc.

- **Development of Reliability Based Economic replacement Programme**

Reliability based economic replacement programme is aim at the determination of best economically replacement point for the life of an equipment. The interest in maintenance optimization had been brought about by the high cost of industrial equipment such as automobile. A well known model is the age replacement model.

The age replacement strategy involves replacement upon failure or upon reaching a predetermined age, which ever occur first.

The pioneering work is summarized in (McCall 1965) and (Barlow and Proschan 1965). According to (Dekk 1996) and the age replacement model is one of the maintenance models that has been mostly applied.

As a basis for optimizing maintenance, some authors implemented the age replacement model with discounted cost by using discrete time renewal theory, the expected cost over an unbounded horizon can be written as:

$$\text{Lim } E\,[K(n,\partial)] = \frac{\sum = \partial c_i\, P_i}{1 - \sum_{i=1}^{\infty} \partial_i\, P_i} \qquad (1)$$

The maintenance of a systems can often be modeled as a discrete renewal process whereby the renewals are the maintenance actions that brings a component back into its original condition or as good as new state.

A similar result as in (1) can be obtained for continuous time renewal processes

Under an age replacement policy, a replacement is carried out at age K (preventive replacement) or at failure (corrective replacement) which ever occurs first, where K = 1, 2, 3. A preventive replacement entails a cost of Cp where as a corrective replacement entails a cost Cr, where $O < Cp \leq Cr$

According to equation (2), the expected discounted cost of age replacement over an unbounded horizon is

$$\text{Lim } E\,[K(n,\partial)] = \frac{\sum_{i=1}^{k} = \partial^i q_i) C_f + (1 - \sum_{i=1}^{k} q_i) C_p}{1 - [(\sum_{i=1}^{k} \partial^i q_i) + \partial^k (1 - \sum_{i=1}^{k} q_i)]} \qquad (2)$$

Where K is the age replacement interval. The optimal age replacement interval K* is an interval for which the expected discounted cost over an unbounded horizon is minimal. The expected discounted cost can also be calculated over a bounded horizon using equation (3)

$$E\,[K(n,\partial)] = \sum_{i=1}^{n} = {}^{i}q_i\{C_i + E[k\,(n-i,\partial)]\} \qquad (3)$$

$$n = 1, 2, 3, \ldots \; K\,[O,\partial] = 0$$

In situations with a bounded time horizon larger than 50 years, the cost over an unbounded horizon, equation (2) may serve as a good approximation.

3.0 Application Of The Reliability Based Maintenance Programme For Transport Corporation Fleet

For maintenance reliability programme to be effective in any organization, maintenance execution needs to be wholistically approached. For this to be achieved, materials, labour, safety, procedures, etc have to be considered in all maintenance tasks. This approach is summed up in a work order or "work pack", as usually referred to in industrial set ups. All jobs must have a work order or work pack

- **Reliability Maintenance Inventory Programme based on ABC Analysis for Transport Corporation maintenance spare parts and materials.**

Most of the spare parts and materials used in Transport Corporation vehicles, maintenance are listed in the table 1 below. The figures are based on Pareto analysis approach, various years of experience on maintenance of motor vehicle, and also on personal interview with Transport Corporation parts and materials store personnel. Transport Corporation being a profit making organization cannot afford to spend her resources on stocking unnecessary spare parts and materials, hence a careful compilation of this list with the hope that maximum profit

and also increased maintenance reliability programme of the Transport Corporation in the area of inventory management of the maintenance spare parts and materials would be achieved.

This list is based on new and genuine spare parts and material and not "2nd Hand" or "fairly used" spare parts and materials. The tabulation also includes minimum stock and maximum stock level for each of the spare parts, with their approximate cost per unit.

Generally, Transport Corporation is utilizing a lot of 'fairly used' spare parts and materials which make planning and predicting of MTBF of these parts to be very difficult or near impossible at the current company policy of using "fairly used" parts.

TABLE 1: ABC TABULATION TABLE

PARTS NAME	A	B	C	MIN. STOCK	MAX. STOCK LEVEL	COST PER UNIT
Engine	√			3	6	450,000
Gear box	√			3	5	350,000
Clutch plate				20	40	8000
Clutch disc				20	40	15,000
Tyres				40	100	15000
Fuses			√	100	250	50
Bulbs			√	200	350	30
Fuel filter			√	200	450	150
Oil filter			√	200	450	250
Air filter			√	40	60	6000
Brake pad			√	100	100	750
Brake lining			√	150	300	150
Spark plugs			√	450	750	250
Fan belt			√	100	250	200
Driver shift	√			5	10	30,000
Brake fluid			√	15	3000	300
Battery	√			20	40	12,000
Brake disc				200	40	10,000
Power steering pump	√			3	5	35,000
Ignition key		√		10	20	10,500
Head lamp		√		10	20	9,500
Engine seat			√	70	15	1500
Upper ball joint			√	70	150	1,500
Lower ball joint			√	70	15	1,500
Upper clutch kit			√	100	250	550
Lower clutch kit			√	100	200	1,500
Crankshaft oil seal			√	100	200	250
Exchange Gas kit			√	100	200	250
Throttle cable			√	100	200	450
Altenator	√			3	5	25,000
Suspension busing			√	250	400	250
Oil pump		√		20	30	12,500
Fuel pump		√		40	60	4,500
Fan blade		√		20	50	1,500
Brake wheel cycle		√		20	35	4,500
Power steering belt			√	10	20	750
Engine Turning Chain			√	10	20	2,500
Coalent hoses			√	10	30	350

Hydraulic hoses			√	10	30	250
Steering rack		√		50	10	6,500
Propeller shaft	√			5	10	15,000
Axle	√			3	5	120,000
Front wheel bearing		√		25	50	3000
Pear wheel bearing		√		25	50	2,500
Lubricating oil (4.5litre)			√	300	600	2000
Carburetor	√			5	10	45000
Wheel nuts			√	150	250	150
A/C compressor	√			1	5	35,000
A/C condenser		√		5	10	6,500
Radiator	√			5	10	7,500
A/c low pressure hose		√		10	20	2,500
A/C dryer		√		10	15	1500
Radiator Cover			√	20	30	150
Head lamb bulb			√	150	300	250
Brake waster cylinder		√		5	15	9,500
Brake calipers	√			5	10	15,000
Piston	√			20	50	20,000
Piston rings		√		150	250	2,500
Connecting rod	√			30	50	15,000
Main Engine bearing			√	80	120	3,500
Con rod bearing			√	80	100	2,500
Engine valves		√		80	120	3000
Pump rods			√	80	120	1,500
Top cylinder gasket			√	150	250	350

N/B: The list could be expanded to include those not listed based on usage.

- **Corrective Work Order (Work Pack) for Engine Over haul**

Work Description: Engine Overhaul
Craftman: Mechanics
Duration: 40hrs (4 days)
Procedures: 1) Removal of Engine from base
2) Dis assembly of engine
3) Washing of dismantled parts
4) Inspection/Measurement of Parts
5) Selection of reused parts
6) Resembling of Engine
7) Reinstallation of Engine on the base
8) Re coupling of Engine to the base
9) Fill up radiator water for start up
10) Start up and Test Vehicle for Engine Performance
Materials: 1) Washing Fluid (Petrol) (2) Washing Cloth (3) Wire brush
4) Scraper (5) Measuring tools – micrometer, dial gauge
6) Washing pan
Tools: Standard mechanic tools box

Basic Spare Parts for a 4 Cylinder Engine

1) Crank shaft bearing (main bearing), (2) Connecting rods bearing, (3) Top cylinder gasket, (4) Overhauling gasket, (5) 4 Piston Rings Sets, (6) 4 Cylinder sleeve *, (7) 4 Pistons *, (8) 1 Crankshaft *, (9) 4 connecting rods *, (10) 4 set of push rods *, (11) 4 set of tappets *, (12) Oil pump, (13) Water pump, (14) 4 Spark plugs, (15) Fuel filters, (16) Oil filters, (17) Contact set, (18) Engine oil,
* replaced if bad.

Labour Cost: 40 x 300 = ₦12,000
Materials Cost: About ₦10,000
Spare parts cost: ₦30,000 to ₦150,000
Note: More than 60% of complete Engine Cost on spare part, engine should not be overhauled.

Safety Kits:
Hand gloves, Coverall, Eye goggles, Safety shoes, Safety Hat

Note on Safety: While working on the vehicle either for removal or re-installation of engine. The vehicle should be efficiently wedged, to prevent it from rolling.

- **Corrective Maintenance Work Order on Braking System**

Description: Relining of Brake, replacement of brake pad, rekitting of Brake Wheel cylinders and brake master cylinder

Craftman: Two Mechanics
Duration: 5 hrs
Procedure:
1) Jack up vehicle and remove types
2) Deinstall brake lining, pad, wheel cylinders and brake master cylinder
3) Examine components for possible reuse
4) Reline brake lining
5) Rekit brake wheel cylinders
6) Rekit brake master cylinders (change out brake wheel cylinder and brake master cylinder after two rekits
7) Re-install brake lining, brake pads, brake wheel cylinders, brake master cylinders
8) Refill brake fluid
9) Start up Engine and bleed out air from brake system
10) Test vehicle for brake effectiveness

Materials:
1) Water for washing brake components
2) Washing Containment
3) Sand paper

Tools: Standard mechanics tool box
Spare parts: Brake pad, Brake lining, Brake wheel cylinders kit, Brake wheel cylinder kit, Brake Master cylinder kit, Brake Fluid

Labour Cost: N4,800
Material Cost: About N500
Spare Part Cost: About N7000 – N15000
Safety kit: Hand glove, Safety shoes, Safety goggles, Coverall, Safety hat

- **Preventive Maintenance Workorder based on Every 5000km for vehicle**

Work description: 5000km preventive maintenance for vehicle

Craftman: Mechanic

Checklist

- Change oil
- Change oil filter
- Change fuel filter
- Inspect air filter
    - Inspect valve cover
    - Inspect gear box for oil leakage
    - Inspect brake system for leak, adjustment
    - Inspect brake pad and lining
    - Inspect radiator for leak

No. of hours: 2hrs

Cost labour – ₦1,500

Cost material/parts – ₦7,500

Procedure for engine lubrication service:

- Loosen oil sump drain plug
- Drain oil completely
- Re-install oil sump drain plug
- Refill new oil to gauge
- Replace oil filter
- Replace fuel filter
- Road test vehicle for performance and reliability

Materials: oil containment , Cleaning cloth, Lubrication oil,

Spare part: Fuel filter, Oil filter

Tools: Standard mechanic tools box

3.3.2 Preventive Maintenance Work order based on every 10,000km for vehicle

Work order Description: 10,000km preventive maintenance for vehicle

Craftman: Mechanic and electrician

Checklist: Change oil
Change oil filter
Change fuel filter

- Inspect crankcase ventilation
- Inspect vacuum pump oil hose
- Inspect brake pedal/parking brake
- Inspect brake lining/drums
- Inspect brake pad/dices
- Inspect clutch fluid
- Inspect proper steaming fluid
- Inspect steering wheel and linkage
- Inspect steering gearbox oil
- Inspect ball joints/dust covers
- Inspect front/rear suspension
- Inspect all lights, horn wipers/washers – electrician
- Inspect fuel pump
- Inspect spark plugs
- Handle all activities listed under 5000km pm

- Road test vehicle for performance and reliability

Duration: 4hrs
Cost of labour: 42,500
Cost of materials/part: ₦7,500
Materials: Oil containment, Cleaning cloth, Lubrication oil

Spare parts: Fuel filter, Oil filter
Tools: Standard mechanic tools box, Standard Electrician Tools box
Safety Kit: Coverall, Safety shoes, Safety glasses, Safety hat, Hand gloves

- **Preventive Maintenance Work pack based on 20,000km for vehicle**

Workorder Description: 20,000km preventive maintenance for vehicle
Craftman: Mechanic and Electrician
Safety kits: Cover all, Safety shoes, (Safety glasses, Safety hat, hand gloves

Duration: 6hrs
Check list
Replace drive belt
Procedure for drive belt replacement:

- Loosen belt tension
- Slip off belt from pulleys
- Install new belt
- Adjust the belt to take up tension

- Inspect Engine coolant
- Inspect exhaust pipe/mounting
- Replace spark plugs
- Procedure for spark plugs replacement
- Take out old spark plugs
- Install new spark plug after setting the spark plug gap to recommended gap (see manufacturing service manual)
- Replace air cleaner
- Inspect fuel tank cap, fuel lines/connection
- Replace brake fluid
- Tighten propeller shaft bolts
- Inspect air condition refrigerant
- Handle all activities listed under 10,000km
- Road test drive vehicle for performance and reliability

Materials: Oil containment, Cleaning Cloth, Lubricating oil, Brake Fluid

SPARE PART
Spark Plug, An filter, Fuel Filter, Oil filter, Drive belt

Tools: Standard mechanic/electrician tools boxes, Cost of Labour N5,500,
Cost of material/part: N13500

N/B

1) Conduct for every multiple of 5000
   5000km preventive maintenance activities
2) Conduct for every multiple of 10,000
   10000km preventive maintenance activities
3) Conduct for every multiple of 20,000
   20,000km preventive maintenance activities

- **Reliability Based Economic replacement programme on Transport Corporation Vehicle Spare Parts.**

These estimations are based on experience, maintenance manual, personal interview with maintenance personal and literatures review on replacement theories.

TABLE 2: REPLACEMENT INTERVALS

Spare parts	MTBF	Replacement Internal
Brake pad	1 year	0.9 years
Brake lining	1½ years	1.25 years
Gear box	15 years	14 years
Brake matter	5½ years	5 years
Crankshaft	10 years	9.5 years
Piston	Piston 5 years	4.5 years
Clutch path	2 years	1.75years
Clutch disc	2 years	1.75 years
Clutch release bearing	2 years	1.75 years
Rear axle	10 years	9.5 years
Head light	4 years	3.75 years
Crankshaft bearing	5 years	4.75year
Front wheel bearing	4 years	3.75 years
Rear wheel bearing	4 years	3.75 years
Suspension bushing	3 years	2.75 years
Air conditioning low pressure	3 years	2.75years
Air conditioning high pressure	3 years	2.75 years
Battery	3 years	2.75 years
Engine	5 years	4.75years
Tyres	3 years	2.75 years
Fan belt	½ year	0.45 year

Note:

The summary of the above tabulations in table 2 is that the replacement interval of any spare parts should be lower than the MTBF by about 3 to 6 months duration to avoid emergency breakdown or failure.

Also for above MBTF and replacement intervals to be achieved, effective reliability based PM must be maintained.

- **Reliability Based maintenance schedule for Transport Corporation Fleet**

Transport Corporation fleet are consist of long distance vehicles i.e. those going up to 1000km, medium distance vehicle, that is those within 500km and Short distance vehicle that is those within 200km. These three categories of vehicles are to be grouped as priority A, B and C, C being the short distance vehicles.

Those in priority A should first be scheduled while those in category C should be scheduled last. This method of scheduling is practiced in many industries where equipment with priority A is first scheduled for PM.

If Transport Corporation fleet have about 450 vehicles, about 150 are for long distance, 200 for medium distance and about 100 for short distance.

If 3 monthly schedule cycle is maintained, the following schedule could be adopted for effective PM schedule as shown below in table 3.

TABLE 3 monthly schedule cycle for Transport Corporation Fleet

Weeks	Priority A No. of Vehicle	Priority B No. of Vehicle	Priority C No. of Vehicle
Week 1	38		
Week 2	37		
Week 3	38		
Week 4	37		
Week 5		40	
Week 6		40	
Week 7		40	
Week 8		40	
Week 9		40	
Week 10			34
Week 11			33
Week 12			33

The schedule would enable maintenance programme to be effectively planned and executed. By following these schedule strictly, within 3 months, PM would have been conducted on all the vehicles. And if any corrective maintenance is identified, during the course of these PM. It is scheduled as corrective maintenance and procedure for corrective maintenance followed in executing them.

- **Economic Utilization Strategy for Transport Corporation Fleet**

If for instance Transport Corporation is located in Uyo, Nigeria and fleet covers almost all state in Nigeria. For economic utilization of this fleet, the following strategy should be applied to the vehicle. For long distance travel where break down would be very expensive, failure of the vehicle should be eliminated as much as possible. To achieve this goal, vehicle under 2 years of age should only be used for this purpose.

In medium distance travel that is within South South and Southeast of Nigeria vehicles under 4 years should be used.

Between 4 years and 5 years of vehicle age, the vehicles should be restricted to local runs whereby on breakdown, the cost of recovery of the vehicle would be minimized.

On no account should vehicle of 5 years and above of age should be available in the fleet. If this happens, most of the revenue from such fleet would be plugged back into the maintenance of such vehicles, thereby making nonsense of the optimization of the maintenance reliability programme for Transport Corporation fleet which is aim at increasing productivity.

- **Conclusion**

Upon interaction with all the department of Transport Corporation, it is concluded that reliability based maintenance programme had not been practiced in the company, which if adopted will increase reliability and hence increased profitability and productivity.

No organized inventory management programme for the spare parts is in place. A greater percentage of "fairly used" spare parts than new ones are being utilized in the company. This practice makes it difficult if not impossible for good spare part inventory planning. There is no standard maintenance workshop and most of the maintenance activities are done in the open environment.

Despite all aforementioned impediments, it is further concluded that Transport Corporation is doing well as a transport company and can do better if all her maintenance resources are well articulated and managed.

Maintenance Reliability programmes have been developed for Transport Corporation through work orders or "work pack" for Reliability based preventive maintenance and Reliability based corrective maintenance, Reliability-based inventory programme using ABC Analysis, Reliability-based replacement programme for spare parts, Reliability based maintenance schedule and lastly Reliability-based economic utilization strategy for the fleet for Transport Corporation fleet.

It is the belief of this researcher that if these Reliability based programmes are applied in Transport Corporation, the company will perform far better than what it is now in term of profitability, reliability, productivity and service delivery to her customers.

- **Recommendations**

The following recommendations are hereby offered:

a) All maintenance activities should be accompanied with work order or "work pack" developed by maintenance leads and supervisors and utilized by technicians.
b) New genuine spare part should be used for changed out activities rather than "fairly used" one to enhance reliability of the fleet.
c) Standard workshop should be provided for maintenance work.
d) Scheduled PM programe should be followed for all the fleet.
e) Maintenance personal should be trained on modern technique of vehicle maintenance.
f) Safety procedures should be followed in all maintenance activities. The safety slogan "do not do it if it's not safe" should be strictly adhered to.
g) All efforts should be geared towards implementing reliability centred – maintenance in all maintenance activity in the company, by so doing optimization of maintenance reliability programme for Transport Corporation fleet would be achieved.
h) Optimum quantity of spare parts and materials stock based on years of experience in industry should be pursued.

- **Further Research Areas**

It is the belief of this researcher that since there has not been any consolidated maintenance reliability prorammes developed and utilized for Transport Corporation and possibly other transport companies, it is hereby suggested that indepth study of these reliability based maintenance programmes be under taken with a view to offering better service delivery through these reliability based maintenance programmes. This could be in terms of optimum maintenance labour cost using work study approach, etc.

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