

**" OPERATIONS MANAGEMENT TECHNIQUES IN MAINTENANCE
MANAGEMENT
- A CASE STUDY OF KENYA RAILWAYS WORKSHOP "**

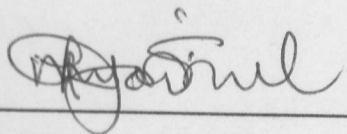
**BY
LAZARUS M. MULWA**

**A MANAGEMENT RESEARCH PROJECT SUBMITTED IN PARTIAL
FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF BUSINESS AND ADMINISTRATION, FACULTY OF
COMMERCE, UNIVERSITY OF NAIROBI**

AUGUST, 2000

This management research project is my original work and has not been presented for a degree in any other university.

signed



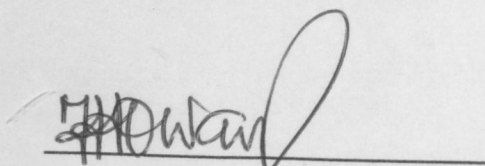
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This management research project has been submitted for examination with my approval as the university supervisor.

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Date

20/11/2020

Dedication

Dedication to my wife Felistus Nduku, my daughter Charity Mumo and to my parents Mr. and Mrs. Elijah Mulwa.

to my supervisor Mr. Tom Kengere lecturer, Department of Management Science for his open reactions and guidance from the inception of the project to the final report. His concern towards my education life during this period motivated me to work tirelessly.

I greatly feel indebted to my sponsor the University of Nairobi for paying my fees towards this worthy and life transforming course. Also appreciated in this category is Kenya Railways for allowing me to conduct my research in the organization.

My special regards go to my wife Felistus Nduku and daughter Charity Mumo. They continued to support me even when academic commitments stole me from my role as a husband and a father.

Lastly, may God the father reward everyone who was involved in this research project directly or indirectly.

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ABSTRACT

In this era of globalization, cut throat competition and liberalization, the only organization which is going to survive is that organization which is geared towards continual improvement in its customer-service delivery systems or goods. The organization must know its customers and the competition. Operations management is one of the key areas in which continual improvements in serving the customer can be achieved. Operations management focuses on the methodological ways of value addition.

This study was set to achieve three objectives ; firstly, it was aimed at finding out whether the duration allowed between two successive preventive maintenance dates was adequate. It was found out that the duration (four years) for one category of wagons was adequate, but the duration (six years) for the other category of wagons was too long and needed to be shortened. It is very necessary that preventive maintenance duration be reviewed from time to time because durability of components may change with time.

Secondly, the study set out to unfold whether operations management techniques were applied in workshop operations. The study established that scheduling was applied but manual in approach and rigid. It also established that materials requirement plan was applied but was traditional in approach and also manual. These approaches were used to control time taken during maintenance, financial control of maintenance, spare parts inventory control and planning maintenance. These techniques could be applied and yield better results if computerized.

Lastly the study extracted factors which could hinder the application of operation

management techniques in workshops operations. The following factors were found to be important starting with the most important if such techniques had to be applied successfully in workshops operations;

- Top management should support and motivate employees.
- Technology used in the work environment should be conducive .
- Staff should be empowered to apply the techniques .
- The organization should be committed to the goal of continuous improvement.
- The causes of breakdowns should be clearly identified.
- Maintenance time should be well managed.
- Bills of materials should be prepared in advance of scheduling.
- Operations management techniques to be applied should be known and understood by the employees.
- Facilities layout should allow easy movement of work in progress across work centers.
- Inventory control models in inventory management should be avoided and materials requirement plan used instead.
- Causes of backlog should be identified and addressed appropriately.

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CHAPTER ONE:

INTRODUCTION

1.1 OPERATIONS MANAGEMENT

1.1.1 OPERATIONS MANAGEMENT DEFINED

All organizations have operations; banks and public accounting firms operate out of offices, hospital operations are in admissions, examining rooms and surgery. Manufacturing companies conduct operations in a factory and transport companies conduct operations in running their fleet and maintaining them.

Operations Management first focuses on methodological ways of value addition. Secondly it's emphasis is on management which is an interactive cycle involving planning, implementing and monitoring for continuing improvement.

Regarding the management of operations in any organization, the following is critical;

- 1) Operations should be performed geared towards improving customer service.
- 2) Approach to operations management should be normative- emphasizing what should be based on a guiding philosophy of continual improvement.
- 3) Operations management principles with proven applicability exist to guide the management of operations.
- 4) Operations managers are key human resource and a revision of our thinking about their role is essential.

1.1.2 PRINCIPLES OF OPERATIONS MANAGEMENT

As the era of globalization and liberalization dawned on organizations, leading companies began to adopt surprisingly similar new practices in operations management.

The new practices were aimed at serving the customer better so as to achieve a competitive hedge in the global front. These competitive strategies or principles serve as a foundation for any organization.

As put forward by Schonberger (1991), the following are the principles of Operations Management:

1. Get to know the customer and the competition.
2. Cut: work in process (Waiting lines), throughput times, flow distances and space.
3. Cut set up and changeover times.
4. Produce and deliver at the customer's usage rate.
5. Cut the number of suppliers to a few good ones.
6. Cut the number of components in a product or service.
7. Make it easy to make or provide goods or services without error the first time.
8. Convert multi path flows to single - channel lanes.
9. Arrange the workplace to eliminate search time.
10. Cross-train for mastery of multiple skills.
11. Record and retain output volume, quality and problem data at the workplace.
12. Ensure that line people first get first crack at problem solving before experts.
13. Maintain and improve present equipment and human work before thinking about new equipment.
14. Look for simple, cheap, and movable equipment.
15. Automate incrementally when process variability can not otherwise be reduced.

16. Seek to have plural rather than singular work stations, machines, cells and flow lines for each product, service or customer.
17. Become dedicated to continual rapid improvement.

The above seventeen principles and especially the first principle "Get to know the customer and the competition", govern the formation of operations strategy which should ensure that company strengths match customer requirements.

1.1.3 TYPES OF OPERATIONS

There are basically three types of operations.

- i. Continuous or repetitive used in refineries; mining and egg hatcheries.
- ii. Job- used in machine shops.
- iii. Project- for example retooling an assembly line.

It therefore follows that the operations management tools and procedures employed by a work center or an organization largely depend on the types of operations it carries out.

Kenya Railways is involved in job and repetitive type of operations in its workshop. It therefore implies that the management of its operations should be job and also process based. Its operations strategy should be based on knowing what the customers wants in the area of wagons and coaches maintenance and the challenges posed by the competitors in the same area. Its grand operations objective should be to improve wagons and coaches availability as well as reliability.

1.2 BACKGROUND OF KENYA RAILWAYS

Kenya Railways is one of the leading organizations in offering transportation services in Kenya. The organization specializes in long haulage of both goods and passengers. However, its core business lies in the transportation of goods.

To be able to transport goods and passengers the organization uses wagons and coaches. The organization has over 6000 coaches and wagons. Coaches are used for carrying passengers while wagons are used for carrying goods.

Both wagons and coaches need to be maintained if the organization has to be in business. To be able to do this, the organization has its main workshop in Nairobi (Central Workshop) which handles the major maintenance activities . It also coordinates all the minor maintenance activities done by its other workshops . These are basically situated in Mombasa, Nakuru, Kisumu and Eldoret. The organization does two types of maintenance.

Preventive maintenance;

This is normally planned maintenance which is done at specific intervals before the equipment breaks down.

Curative maintenance;

This type of maintenance is usually unplanned and is carried out due to equipment failure.

1.2.1 THE PRESENT SYSTEM OF MAINTENANCE

Kenya Railways has an Advanced Cargo Information System (Railtracker) which tracks the whereabouts of all its wagons and coaches in both local and foreign networks (for example Uganda and Tanzania networks). The system is also able to reveal whether the wagon/coach is loaded or empty and also whether it is in normal operating condition or awaiting maintenance. However the system is unable to schedule the wagons/coaches through the workshop for maintenance.

Vehicles (coaches and wagons) are given preventive maintenance at fixed intervals in time.

The interval varies with vehicle type but for most coaches it is two years and for wagons four years and six years depending on the type of wagon as defined by bearings.

In April/May a budget is prepared for the following financial year's maintenance programme in workshops which normally starts on 1st July of every calendar year. The number of preventive maintenance services to be carried out is based on the number of vehicles due taking into account any peaks due to provisions for accident repair work.

From a basic cost per unit, for the various types of work, a total budget figure is calculated using the total number of vehicles expected to be maintained in a financial year.

The projected annual figures may stand or be adjusted at year end.

Examination of internal maintenance records revealed that the maintenance of coaches is more consistent than that of wagons probably because;

The operation of coaches in traffic is more easily controlled and their locations more readily known than for wagons.

Some attempt is made to programme specific coaches at specific times for maintenance ; although this has not prevented there being a backlog at every year-end.

The incidence of casual and accident repair in workshops is variable but can be predictable since historical data available can be used to forecast such in the future.

Hereafter the system is concerned with preventive and curative maintenance of vehicles.

Obtaining goods vehicles for maintenance

Carriage and Wagon (CXR) staff affix a 'workshops' label to a wagon if they notice that it is due for next preventive service painted on it .

Traffic staff are informed that the vehicle is to be sent to workshops and should make arrangements to transport the wagon to Nairobi Central Workshop.

Due to the labeling of vehicles being carried out in a hit and miss fashion and also the lack of coordination of CXR effort in this direction, throughout the system the flow of vehicles to the workshops is irregular. The result is that some vehicles end up being in operation when they are due for preventive maintenance. This has resulted in a lot of wagons breaking down and hence a pile up of wagons which need curative maintenance.

This has led to a greater concentration on curative maintenance which is more costly as opposed to preventive maintenance.

There is also a chance that the wagons input for preventive maintenance many also be labeled for workshops when they are not yet due. It therefore appears that costly attention may be being given to vehicles not yet requiring it. This is because, on preventive maintenance some parts are automatically changed regardless of condition and this increases expenditure on spare parts. This may be done at the expense of large numbers of vehicles which are acutely overdue for preventive service or have broken down and hence not available to carry traffic and earn revenue for the organization.

Vehicles which have designated faults or had been involved in accidents are identified for maintenance using planned inspection which reveal when maintenance is prudent and not identified for maintenance on due date. Although a variation of a month or two in the due date of the vehicles received is unavoidable and indeed not critical in an operating cycle of every three years, it is the significant proportion of vehicles shopped at times lying outside this acceptable period which causes alarm.

Maintenance records reveal that some of the wagons received in a given month were overdue for preventive service.

Obtaining Coaches for Maintenance

The method of identifying coaches varies slightly from that for wagons in that a programme of specific vehicles is drawn up each month for each week in the month. The 'mix' of vehicles is chosen carefully especially with regard to cabooses (rest coaches for drivers) and restaurant cars which are in very short supply.

Traffic Department is informed of the programme so that relief vehicles can be provided in places of those coaches and cabooses which have be selected to go to workshop. These vehicles together with brake vans are labeled for workshops by CXR staff only at Nairobi.

Even though a more direct approach is made in shopping coaches, the actual performance figures show a similar trend, although to a lesser extent, to those for wagons. The variation for coaches is smaller than for wagons although the operating cycle is only two years for most coaches compared with three years for most wagons. The backlog of preventive maintenance servicing of coaches is estimated at about 15% of the coaching fleet.

1.3 THE RESEARCH PROBLEM

Over the years, there has been a large number of vehicles lying in the Nairobi yard of Kenya Railways awaiting to be taken to the workshop for maintenance. However many of these vehicles have been lying unattended for a very long time.

The huge backlog of the vehicles awaiting maintenance then prompted the researcher to ask himself , *"is the productivity of the Central workshops in Nairobi to the required level?"*

An investigation into the grounded theory, then showed that the workshop was maintaining a relatively small number of vehicles and some of the vehicles then have to continue being in use even though their date of preventive maintenance was long overdue.

The researcher using grounded theory also established to a great extent that one of the factors leading to low productivity at the workshop could be;

"Unclear logistics on the maintenance issues in terms of policies and priorities".

Holding other factors constant, the researcher hence sought to consider whether operations management techniques such as scheduling, materials requirement plan and queuing theory were applied in maintenance management. Towards this end, the researcher will be concerned with preventive and curative maintenance of wagons and coaches and workshop equipment's which are used in the maintenance programme.

1.5 OBJECTIVES OF THE STUDY

Hypothesis

1. H_o : Current preventive maintenance duration is adequate.
 H_a : Current preventive maintenance duration is higher than optimal duration.
2. H_o : Operations management techniques are applied to a great extent in workshop operations.
 H_a : Operations management techniques are applied to a very small extent in workshop operations.
3. H_o : There are no organizational factors prohibiting application of operations management techniques in workshop operations.

H_a : There are organizational factors prohibiting the use of operations management techniques in workshop operations.

1.4 IMPORTANCE OF THE STUDY

The study is expected to be of help to the following:

1. It will help Kenya Railways in improving its wagon availability and hence earn more revenue to be in better position to compete with road haulers.
2. It will help Kenya Railways in optimally using workshop resources.
3. It is expected that it will help in reduction of accident cases occasioned by wagon or coaches faults.
4. Other organizations like Kenya Bus Services and road haulers will be able to borrow a leaf from this case study and hence be in a position to apply in their workshop operations with minor alterations.

1.5 OBJECTIVES OF THE STUDY

The study sets out to achieve three broad objectives as mentioned below:

- (a) Determine whether the current preventive maintenance duration is optimal.
- (b) Establish the extent of application of operations management techniques in Kenya Railways workshop operations.
- (c) Find out the organizational factors which may hinder the application of operations management techniques in workshop operations.

Clearly many units can be picked up for maintenance. However, the current system is limited in that;

- (i) The attempt to schedule a specific number of units for workshops each day is done manually and remains rigid after it's prepared.
- (ii) There is no attempt to inform automatically, CXR depots of vehicles passing through or at stations in their areas for labeling to workshops.
- (iii) A bill of materials for the units to be maintained in a given day is not availed to the stores personnel in advance to avoid delays in locating spare parts.

CHAPTER TWO: LITERATURE REVIEW

2.1 HISTORY OF KENYA RAILWAYS

The history of Kenya Railways dates as far back as 1896 when the first line was laid in Mombasa. The construction of the railway line was done by Imperial British East Africa Company and it was initially known as Uganda Railways. It took five years for the line to reach Kisumu the then fort Florence. Hill F. M. (1961), laments that the mere length (572 miles) conveys no idea of the difficulties which had to be overcome in realization of the permanent way. Later the line was extended to Kampala in Uganda.

Kenya Railways employee handbook (1989), points out that the management of Kenya Railways has changed over the years. Initially it was managed as (UR) Uganda Railways, in 1926 its name changed to Kenya Uganda Railways (KUR). On 20th December, 1927, the control and management of the Railways and Ports was taken over by the British High Commission and its name changed to Kenya Uganda Railways and Harbours (KURH). In 1948, KURH joined Tanganyika Railways and Ports Services to form East African Railways and Harbours (EAR&H). After the independence of the East African countries, the British High Commission which was in charge of the railways was replaced by East African Common Services Organization which later changed to East Africa Community which gave birth to East African Railways Corporation (EAR) in 1969.

The breaking up of the East Africa Community in 1976, led to the formation of Kenya Railways Corporation (KRC) in 1977 through an act of parliament . KRC inherited a network of railway line of over 2650 kilometres within the republic of Kenya boundaries.

2.2 PRODUCTIVITY AND COMPETITIVENESS

2.2.1 PRODUCTIVITY DEFINED

Chase/Aquilano (1989) defines productivity as a ratio of outputs to inputs. If this ratio is as large as possible for a given situation, it will indicate that one is getting more than he has put in. The units used in productivity measurement for output may be for example shillings generated, goods produced or customers' served. Measurements for inputs may include shillings invested, machine hours used or labour hours used. Increase in productivity can be gauged by answering the following questions; has the action taken increased throughout? Has it decreased inventory? Has it decreased operational expenses? This leads us to a new definition.

Productivity is all the actions that bring a company closer to its goals (Chase/Aquilano, 1989).

Productivity in services

A service firm can only remain competitive if a continual productivity and quality are part of its corporate culture and strategy. According to Schonberger (1991), a firm should continually evaluate its service delivery system to see to it that it is not overtaken by competition. For an organization to remain competitive in the global front, wages can only be increased if a firm registers increased productivity. Kenya Railways may be able to maintain more vehicles at the same cost or less so as to keep maintenance costs low and compete effectively while at the same time compensating employees well to raise their morale.

2.2.2 COMPETITIVENESS DEFINED

A firm is said to be competitive if its goods or the services it offers at the marketplace match the features, quality and price expectations of the customer. If a firm can remain competitive, it can be assured of remaining a going concern while at the same time paying dividends to its owners. At a national and international level, the definition for competitiveness becomes a little more complex ; according to Chase/Aquilano (1989), in 1985 the presidents council on Industrial competitiveness offered the following definition.

Competitiveness for a nation is the degree to which it can, under free and fair market conditions, produce goods and services that meet the test of international markets while simultaneously maintaining and expanding the real incomes of its citizens.

What are the solutions to achieving competitiveness ?

For a firm to be more competitive it should lay emphasis on the following:

- (a) Research and development should be the major focus to lead to both product and process innovations as opposed to placing more emphasis on short-term financial payoffs . Kenya Railways rarely, if at all does research on workshop operations.
- (b) Corporate strategies should include responses to global competition. This in turn calls for a more focus in people and equipment to improve manufacturing or service capability. Railways may not be doing well in staff recruitment, training and compensation. Also maintenance technology may be obsolete. The success of the firm in a technologically turbulent environment depends first on matching the firm's strategy to the environmental turbulence, Ansoff I. (1990).
- (c) Information flow within the organization should be adequate and the organization should recognize mutuality of interests with other companies and suppliers.

- (d) Human resource should be a resource to be nurtured but should not be viewed as just a cost to be avoided.
- (e) Basics in managing production operations should be made a base line. The organization should build in quality at the design stage, place more emphasis on process innovations rather than focussing sole attention on product innovations.

Porter E. (1980), puts forward that one of the major areas of competitor strengths and weaknesses is operations. To be able to have an hedge over competitors, technological sophistication of facilities and equipment is essential. Facilities and equipment should be designed to accommodate flexibility and skills in capacity addition and quality control should be emphasized with respect to operations. Kenya Railways must therefore become better at managing its productive capabilities in all dimensions, in strategy and in the five P's of operations: people, plants, parts, processes and planning and control systems.

The focus of this paper is in applying operations management techniques to improve productivity through both preventive maintenance and curative maintenance of wagons. The focus then will be in planning and control of the maintenance systems used.

•2.3 MAINTENANCE POLICIES

2.3.1 THE REASON FOR MAINTENANCE WORK

Oliver Wendell Holmes wrote the following in one of his poems, 'The Wonderful One-Horse Shay', Kelly A. (1991);

*'For the wheels were just as strong as the thills
And the floor was just as strong as the sills,
And the whipple-tree neither less nor more,
And yet as a whole it is past a doubt,
In another hour it will be worn out!'*

The implication was that the vehicle was designed for zero maintenance, since each of the constituent parts had a life of exactly hundred years. The complexity and expense of modern plant even if possible to be designed for zero maintenance, would be uneconomic. Many of the constituent components will have been designed for technological and economic reasons with a useful life greater than the longest operating cycle but less than that of the plant itself.

Within the context of maintenance, failure is defined as "an inability to produce work in Naylor J. (1996), writes that for many organizations, the cost of maintenance is a significant fraction of total costs. Control needs to be exercised to ensure that the department adds value to the business through delivering productive and reliable assets. Being a service operation in its own right, maintenance function can itself be seen as a cost - effective supplier of capital productivity.

Lockyer K. et al (1991) , notes that maintenance of plant and equipment in good working order is essential to achieve specified levels of quality and reliability, and efficient working. The best equipment will not work satisfactorily unless it is cared for and the cost of a breakdown in the system can be very high not only in financial terms but also in poor staff morale and bad relations with customers. The workforce and the materials must also be 'maintained' through training, motivation, health care and even entertainment for the people while the materials should be properly handled and stored.

The objectives of maintenance are to;

- (i) Enable product quality and customer satisfaction to be achieved through correctly adjusted, serviced and operated equipment.
- (ii) Maximize the useful life of the equipment.

- (iii) Keep equipment safe and prevent the development of safety hazards.
- (iv) Minimize the total production costs directly attributable to equipment service and repair.
- (v) Minimize the frequency and severity of interruptions to operating processes.
- (vi) Maximize production capacity from the given equipment resources.

Within the context of maintenance, failure is defined as , "an inability to produce work in the appropriate manner rather than an inability to produce work", Lockyer K. et al (1991). Thus a piece of plant which deteriorates and consequently produces work of too low a quality or at too high a cost is said to fail. Work carried out before failure is said to be overhaul or preventive maintenance work, while that carried out after failure is emergency, breakdown or recovery work. As indicated in the figure below maintenance has to be balanced within the continuum of preventive maintenance and breakdown maintenance so as to keep the costs of maintenance at the lowest level.

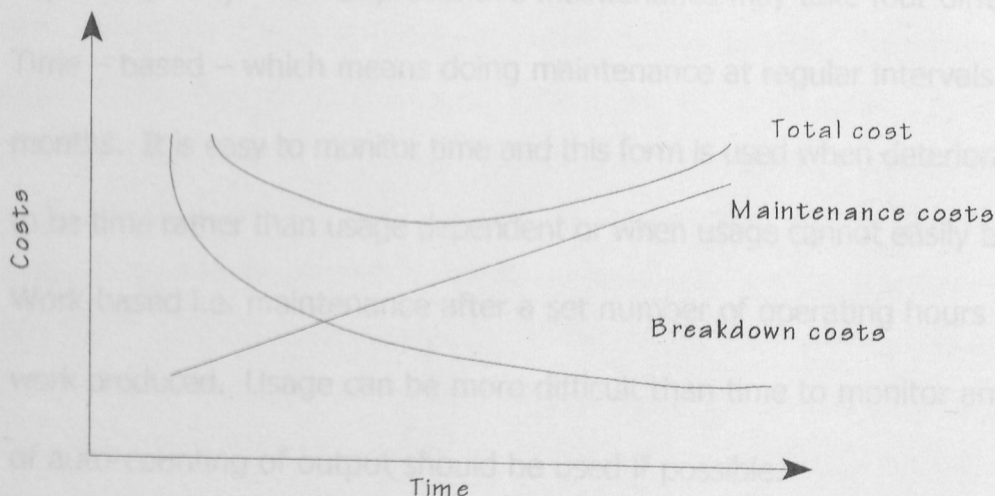


Figure 2.1 Derivation of total cost of maintenance policy (Note – total cost is the sum of the two)

It has been pointed out by Chase and Aquilano that the maintenance system exists within and as a part of the operating system as a whole. Inevitably the needs of the sub-system may appear to conflict with the needs of the system itself. For example frequent overhauls may reduce costs by avoiding expensive breakdowns or replacements. Unfortunately, the more frequently the overhaul, the lower the availability of the plant so that direct production costs will increase. It therefore implies that maintenance system used should not lead to sub-optimality.

There are broadly two types of maintenance policy:

- (1) Repair or replacement due to equipment breakdown
- (2) Preventive maintenance

This first type is an emergency – based policy in which the plant or equipment is operated until it fails and then it is maintained.

Preventive maintenance is founded on statistical analysis of an asset and its component parts, Naylor J. (1996). Formal preventive maintenance may take four different forms;

- (a) Time – based – which means doing maintenance at regular intervals e.g. every 2 months. It is easy to monitor time and this form is used when deterioration is likely to be time rather than usage dependent or when usage cannot easily be measured.
- (b) Work-based i.e. maintenance after a set number of operating hours or volume of work produced. Usage can be more difficult than time to monitor and some form of auto-counting of output should be used if possible.
- (c) Opportunity – based, where repair or replacement takes place when the equipment or system is available e.g. during a holiday closure. This is suitable for equipment which has intermittently heavy use.
- (d) Condition – based, which often relies on planned inspection to reveal when maintenance is prudent e.g. replace a brake pad when it has worn to 2 mm thickness.

These various types of policies often operate together, overlap or coincide.

The need for data in maintenance

Choice between the various policies needs to be made on objective grounds if possible and this underlies the need for good data collection and analysis concerning failure, causes of failure, staff performance and material usage.

2.3.2 ASPECTS OF MODERN MAINTENANCE

Fitzsimmons A. J and Fitzsimmons J. M. (1998), argues that technology is increasingly more complex with electronics, robotics and computer control now influencing every walk of life.

These have clearly led to many changes in maintenance activities. Unlike manufacturing services are characterized by much greater variety of activities. The lack of standardization is a major reason for the slow progress in automating services. Increased flexibility in automation capabilities is permitting at least parts of some service operations to be automated, notes Dilworth J. (1992). Special and continuous training programmes are required to provide the necessary knowledge, understanding and skills to service the increasingly specialized equipment and to keep up with the developments in the field. Specialist organizations have developed to provide maintenance services on a sub-contract basis, and transport vehicles, computers, office equipment and medical support systems are often serviced by outside companies. The specialized technical knowledge and skills are frequently more economical to acquire on a call-in fee basis than an in-house team.

The advances in technology have enabled the development of systems which reduce the cost of maintenance while improving operational performance. These are usually computer-based devices which enable the detection of faults before severe difficulties and even damage occur. This approach has been called predictive maintenance and can usefully be coupled to a preventive maintenance policy. Computers can be used in the actual maintenance for;

- (a) Planning maintenance
- (b) Financial control of maintenance
- (c) Spare part inventory control
- (d) Reliability and failure data collection and analysis
- (e) Operational research models applied to maintenance e.g. queuing theory and simulation.

Modern maintenance management is far more than repairing and servicing equipment. The perspectives of maintenance must be broadened to the long-range performance aspects of the complete customer service system.

Failure of any component in that system can cause total disaster and the viability of the whole organization is dependent on effective maintenance policies and operations.

These aspects of modern maintenance define the playing ground for any organization which is involved in maintenance activities. If Railways has to lead other service organizations in Kenya it is very important that its maintenance operations should be carried out within the limits defined by the modern aspects in maintenance.

Various operations management techniques have been applied in maintenance using the new computer technology. These techniques include the following:-

- (a) Scheduling
- (b) Materials requirement plan (MRP)
- (c) Resource Assignment Techniques (e.g. Queuing theory)

2.3.3 SCHEDULING

Scheduling involves the timing of operations to achieve the efficient movement of units through a system, Heizer J. and Render B. (1996).

Scheduling approaches

(a) Forward Scheduling

Starts the schedule as soon as the requirements are known. Used in a variety of organizations such as hospitals, clinics and machine tool manufacturers. The schedule is usually designed to produce a schedule that can be accomplished even if it means not meeting the due date. In many cases it causes a buildup of work-in-process inventory.

(b) Backward scheduling

Begins with the due date. Steps in the job are then scheduled one at a time in reverse order. By subtracting the lead time for each item, the start time is obtained. However the resources to accomplish the schedule may not exist. Used in manufacturing as well as service environments such as catering a banquet or scheduling surgery. In practice, a combination of forward and backward scheduling is often used to find a reasonable trade-off between what can be achieved and customer due dates.

Railways can use a combination of forward and backward scheduling. Forward scheduling will be used for vehicles which are not limited in supply while backward scheduling will be used for vehicles which have limited supply and hence should be out of workshops as demanded by customers.

Scheduling Criteria

Scheduling sets out to achieve the following:-

1. Minimize completion time
2. Maximize utilization - determining the percentage of time the facility is utilized.
3. Minimize work-in-progress (WIP) inventory. The fewer the number of jobs in the system the lower the inventory.
4. Minimize customer waiting time - evaluated by determining the average number of late days.

Good scheduling approaches should be simple, clear, easily understood, easy to carry out, flexible and realistic. Therefore the objective of scheduling is to optimize the use of resources so that the production objectives are met.

To run a facility in a balanced and efficient manner, the manager needs a production planning and control system. This system should:

1. Schedule incoming orders without violating capacity constraints of individual work centres.
2. Check the availability of tools and materials before releasing an order to a department.
3. Establish due dates for each job and check progress against needs, dates and order lead times.
4. Check work in progress as jobs move out through the shop.
5. Provide feedback on plant and production activities.
6. Provide work efficiency statistics and monitor operator times for payroll and labour distribution analysis.

Sequencing Jobs in work centres.

Scheduling provides a basis for assigning jobs to work centres. Loading is a capacity control technique that highlights overloads and under loads. Sequencing specifies the order in which jobs should be done at each Centre.

Priority Rules in dispatching jobs.

They provide guidelines for the sequence in which jobs should be worked. They are applicable for process - focused facilities such as clinics, print shops and manufacturing job shops. Rules try to minimize completion time, number of jobs in the system, and job lateness while maximizing facility utilization.

Rules:

1. FCFS - First come first served.
2. SPT - Shortest processing time.
3. EPD - Earliest due date.
4. LPT - Longest processing time.
5. Critical ratio (CR)

A critical ratio is:

An index number computed by dividing the time remaining until due date by the work time remaining . It is dynamic and easily updated and tends to perform better on the average job lateness criterion. It gives priority to jobs that must be done to keep work on schedule.

If:

CR = 1.0 means job is on schedule.

CR < 1.0 means job is falling behind schedule.

CR > 1.0 means job has some slack.

$$\text{CR} = \frac{\text{time remaining}}{\text{Work days remaining}} = \frac{\text{Due date} - \text{today's date}}{\text{Work (lead) time remaining}}$$

CR rule can help in most production scheduling systems to do the following:

1. Determine the status of a specific job.
2. Establish relative priority among jobs on a common basis.
3. Relate both stock and make-to-order jobs on a common basis.
4. Adjust priorities (and revise schedules) automatically for changes in both demand and job progress.
5. Dynamically, track job progress and location.

Limitations of Ruled-based systems:

Traditional ruled-based systems have a number of limitations. Among those are:

1. Scheduling is dynamic, therefore rules need to be revised to adjust to changes in process, equipment, product mix and so forth.
2. Rules do not look upstream or downstream; rule resources and bottleneck resources in other departments may not be recognized.
3. Rules do not look beyond due dates.

Bottleneck work centres.

They are critical areas of attention in developing schedules because they set the pace at which work moves, notes Everett E. A. and Ronald J. E. (1980). They limit the output of production. They have less capacity than the prior or following work centres. They are common occurrence because even well-designed systems are seldom balanced for very long. Changing products, product mixes and volumes often create multiple and shifting bottlenecks. Consequently, bottleneck work centres occur in virtually all production processes from hospitals and restaurants to factories.

Approaches used to address bottlenecks;

- ◆ Increasing capacity of the bottleneck.
- ◆ Rerouting work.
- ◆ Changing lot size
- ◆ Changing work sequence
- ◆ Accepting idleness at other workstations.

Advances in scheduling and sequencing.

Two recent advances are proving very beneficial to operations scheduling. They are:

1. Expert systems
2. Finite scheduling

Expert Systems

An expert system is a computer program that makes decisions and solves problems much as a human expert would handle them. The idea in scheduling is to use the knowledge and skills of a person who is an expert at sequencing and scheduling. The firm can then derive the benefits of the expert when he is away by making use of the expertise stored in the system he has developed. A scheduling program should work by searching solutions to satisfy the scheduling constraints. When it can not find a feasible solution, it relaxes the constraints based on their relative importance.

Finite scheduling

It overcomes the disadvantages of rule-based systems by providing the schedules with graphical interactive computing. The system is characterized by the ability of the schedule to make changes based on up-to-the-minute information. These schedules are often displayed in Gantt chart form. The scheduler has the flexibility to handle any situation including order, labour or machine changes.

Finite scheduling allows delivery needs to be balanced against efficiency based on today's conditions and today's orders not according to some predefined rule.

Many of the current finite scheduling computer programs offer resource constraint features a multitude of rules of the ability of the scheduler to work interactively with the scheduling systems to create a realistic schedule.

These systems may also combine an expert system and simulation techniques allowing the scheduler to assign costs to various options. Finite scheduling helps the scheduler but leaves it up to the scheduler to determine what constitutes a "good" schedule.

Achieving world-class standards in scheduling

Because customers expect deliveries on schedule world-class firms perform scheduling correctly. Fitzsimmons A. J. and Fitzsimmons J. M. (1998), argues that scheduling plays a very large role in employee morale, plant utilization and winning orders. Consequently, world-class firms are moving toward scheduling systems that use a combination of both computers and people. Increasingly, this means using systems that include dispatching rules, expert systems, simulation and finite scheduling systems. Computer - generated schedules adjusted by humans, are proving to yield exceptionally good scheduling.

Naylor J. (1996), puts forward three patterns of service delivery - isolated service, self service and personal service. Isolated service takes away from the customer. Kenya Railways in its maintenance workshop uses isolated service delivery pattern because vehicles are not maintained by the department which uses them. Scheduling therefore can be jobbing in the case of breakdown maintenance and repetitive processing in the case of preventive maintenance.

2.3.4 MATERIALS REQUIREMENT PLANNING (MRP)

If the delivery schedule for the end - products is known, then the size and timing of the requirement of the various lower-level work-in-process items and raw materials can be planned exactly by simple arithmetical calculations such planning is known as MRP, Chary S. N. (1995).

In order to make MRP computations, one needs to know;

- (a) The product structure showing how the end-products made up of certain assemblies down to the components, a bill of materials being derived there from.
- (b) The lead times to produce/procure the different items at the various levels from components to the end-product;
- (c) The demand or the delivery schedule of the end-products
- (d) The current on hand stock of the various items as also the scheduled receipts of the items being planned.

MRP is thus a calculation of the requirements of the dependent demand items i.e. items whose demand is dependent upon the demand for their respective higher level items and a reconciliation of these requirements with the production capacity available.

Computing the MRP for releasing a production/procurement order involves the following steps;

- (a) To determine the time the higher level items are required and in what quantity.
- (b) To determine the time when and in what quantity the next lower level item is required.
- (c) To obtain the real or net requirement, the 'on hand' and scheduled to receive quantities of the item are deducted from the gross requirement.

If there is a sufficient quantity on hand or scheduled to be received then there is no need to order for a further quantity. Only when the (on hand plus scheduled receipts less gross requirement) during any period shows a negative quantity would there be a need to order for the additional quantity or a lot-size quantity one lead time earlier. Order release are planned automatically.

- (d) The above MRP order releases are checked for viability vis-a-vis the production capacity. If there is dissonance the master production schedule is modified and the MRP exercise is carried out all over again.

Schonberger (1991), argues that the main advantage of MRP system is that it avoids unnecessary stock items and produces/procures them only when required and in the quantities required. Classical inventory systems use 'averaging' techniques making use of the average annual and usage figures. Such statistical averaging techniques suffer from a predicable drawback; in some periods, there is more of the stock when less (or nothing) may be needed and in others there is less when more is needed. The uniform average rate is an unrealistic concept when in fact for most dependent demand items their demand is "bunched" or lumpy.

MRP treats the discrete distribution of demand as discrete and not continuous. In the classical production - inventory systems, averaging is a part of the system. In such cases the economics in materials are sought to be attained externally and indirectly through Economic Order Quantities (EOQ) or Optimal Period of Review which try to balance the order costs with carrying costs for the materials.

Dilworth J. B. (1992), observes that MRP obviates this need and treats the problem of costs due to materials directly by producing/procuring the materials in the quantity and at the time these are required. There is no extrinsic trigger for placing an order such as an order quantity or a review period. Instead, the order is placed only when the item is genuinely required for production (with, of course, the lead time to procure being kept into consideration).

Flexibility is the key to many production efficiency problems;

The amount and type of flexibility needed in an MRP system is not too difficult to obtain in a majority of cases. However, in some cases the flexibility can come with either the increased capacity or improved technology both of which may involve capital expenditure. Strictly in an MRP production system, it is not necessary to carry safety stocks because the materials can be planned to arrive at the precise quantities required at that time, whereas in the classical inventory systems one of the important reasons for keeping a safety stock is to cover the variations in the usage of the item. This is so because the usage is seen as an average rate to which an insurance against a higher usage rate is required in the form of extra stock called a safety stock.

But even in an MRP, unless the supplies arrive precisely according to the lead time, it may be necessary to order the component item with a little 'safety time' added to the lead time. Sometimes the persons responsible for scheduling production are not sure that the supplier (or supplying internal production shop) would deliver the ordered quantities in full and/or with all items of the acceptable quality.

In such cases it becomes necessary to hold some safety stocks even in an MRP system - therefore good quality supplies internal quality management production, quantity control and purchase quantity control are essential to an MRP system. Otherwise there is a danger of its degenerating into a less efficient system.

Implementing Preventive Maintenance system

If an MRP is to be a system which plans as per the requirements it should be a dynamic and interactive system. Dynamism requires flexibility and quality (not only of materials but also of information) which are the keys to the success of an MRP.

due to improper use of poor components or fitting implies maintenance system implementation should include

2.3.5 QUEUING THEORY IN RESOURCE ASSIGNMENT

Though capacity planning and resource scheduling can be treated under an assumption of adequate "get ready" time - that is enough time to develop a plan for resources after demand becomes known, this is not always the case. the demand may remain unknown until very late in the planning cycle and this uncertainty may translate into idle service centres or long waiting lines. Awaiting line may be simple, involving only one server (or channel) and one stage of service. It may also be one server and multistage waiting line. Finally a waiting line may be multichannel, single stage or multichannel, multistage. It therefore follows that four types of queuing analysis are essential because there are mathematical formulas for each type of queue, Kothari C. (1992).

Queuing formulas do not imitate awaiting-line; rather they make simplifying assumptions easy so that summary waiting line data can be easily solved. Simulation - imitating awaiting line by use of members can be used effectively to entice decision making in real situations.

important part of a preventive maintenance system such records can also provide information about the family of equipment as well as supplies

Kenya Railways may find queuing applications quite necessary in its multichannel, multistage waiting lines used in its work centres.

Data files to use in the system include the following:

2.4 CONCEPTUAL FRAMEWORK

Implementing Preventive Maintenance system

Preventive maintenance implies that we can determine when a system needs service or will need repair. Failure occurs at different rates during the life of a product. This failure rate may follow different statistical distributions. Infant mortality - due to improper use or poor components or fitting implies maintenance system implementation should include training and personnel selection.

Maintenance schedules

Once the product, machine or process "settles in", a study can be made of the MTBF (Mean time between failure) distribution. When the distributions have a small standard deviation then this implies a candidate for preventive maintenance even if the maintenance is expensive. It should be determined when preventive maintenance is economical. Typically, the more expensive the maintenance, the narrower must be the MTBF distribution. Additionally, if the process is no more expensive to repair when it breaks down than the cost of preventive maintenance, perhaps it should be left to breakdown and then do the repair, Lockyer K. et al (1989).

Computerized system will then be able to produce reports like the ones listed above after

With good reporting techniques, firms can maintain records of individual processes machines or equipment. Such records can provide a profile of both the kinds of maintenance required and the timing of maintenance needed. Maintaining equipment history is an important part of a preventive maintenance system such records can also provide information - about the family of equipment as well as suppliers.

To be able to serve the customer timely, efficiently and effectively, a maintenance system needs to be managed electronically (Should be computer based) .

Data files to use in the system include the following;

1. Equipment file with parts list.
2. Repair history file for vehicles maintained.
3. Inventory of spare parts used in maintenance.
4. Personnel data with skills and wages/salaries.

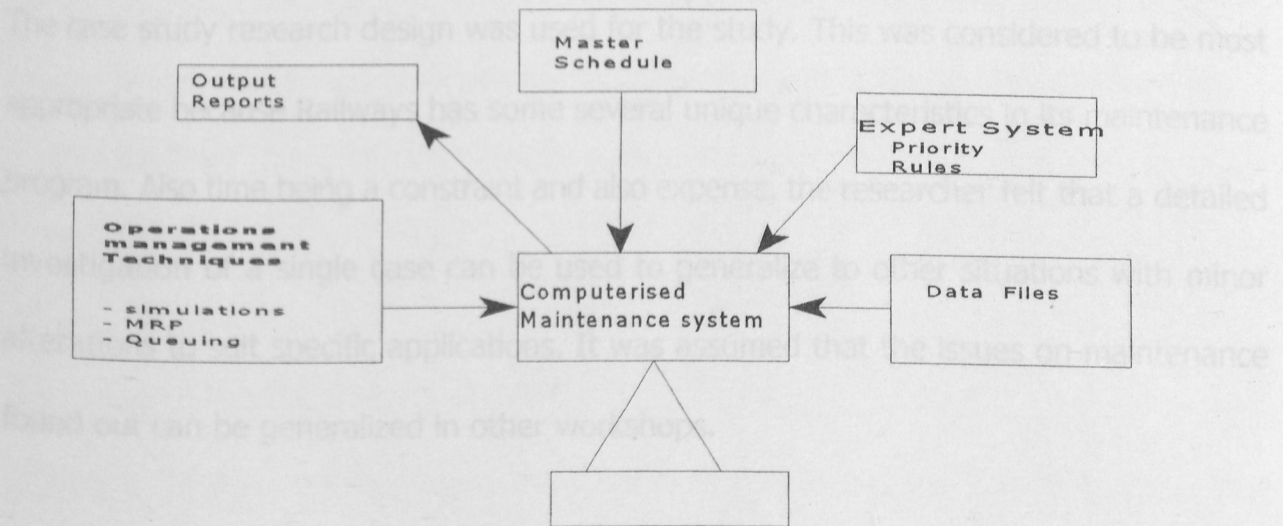
Output reports to be produced by the system include the following;

1. Equipment parts list.
2. Inventory and purchasing reports.
3. Maintenance schedules.
4. Scheduled down time.
5. Cost analysis - Actual versus standard costs.

Heizer J. and Render B. (1996), notes that expert systems and decision support systems use artificial intelligence to handle repetitive jobs and also unique jobs respectively. Kenya Railways will have to develop these systems using knowledge base and also model base of the various techniques to be employed in the maintenance system. The knowledge base forms the rules governing the flow of work into the various work centres. The computerized system will then be able to produce reports like the ones listed above after interrogating the database containing the various input files.

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 RESEARCH DESIGN



3.2 POPULATION

The study was conducted at Kenya Railways. The study focussed on how the output of the workshops can be improved through the applications of operations management techniques. It aimed at collecting information regarding current failure rates of wagons and at collecting information on the extent operations management techniques in use. Information was also collected pertaining to the organisational factors which could hinder the application of operations techniques which the researcher felt that they were important if the productivity of the workshop was to increase.

The population of interest was the employees who work in the workshop. These employees consisted of supervisory staff (top and middle management staff) and non-supervisory staff. The management and non-management staff were interviewed separately grouped into management and non-management. Information was collected from supervisory staff only because it was assumed that only such group would be able to fully comprehend what was being tested.

CHAPTER THREE:

RESEARCH METHODOLOGY

3.1 RESEARCH DESIGN

The case study research design was used for the study. This was considered to be most appropriate because Railways has some several unique characteristics in its maintenance program. Also time being a constraint and also expense, the researcher felt that a detailed investigation of a single case can be used to generalize to other situations with minor alterations to suit specific applications. It was assumed that the issues on maintenance found out can be generalized in other workshops.

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The population of interest was the employees who work in the workshop. These employees consisted of supervisory staff (top and middle management staff) organizationally grouped into management and unionisable. Information was collected from supervisory staff only because it was assumed that only such group could be able to fully comprehend what was being tested.

3.3 SAMPLING

Every employee working at the workshop was not administered a data collection instrument. This was because of time and cost constraints. However a simple random sample was drawn ensuring representation of each group of supervisory staff according to its proportion. To ensure randomness, computer random numbers were used to select the sample.

3.4 DATA COLLECTION METHOD

Primary data was collected using questionnaires and interviews from both groups of respondents. The questionnaire was personally administered to the respondents by the researcher. The researcher was going to a selected respondent then explained the purpose of the visit. The respondent was then left with the questionnaire after making arrangements on the most appropriate time to collect the filled questionnaire and also to hold the interviews.

The questionnaire was divided into two parts. A sample questionnaire is attached at the back as Appendix A. Part A of the questionnaire captured information on employee work experience, types of maintenance done, awareness of operations management techniques and extent of applications of operations management techniques in workshop operations. Part B of the questionnaire collected information regarding the organizational factors which may have hindered the application of operations management techniques in Kenya Railways workshop activities. In particular, the following dimensions were investigated;

- ◆ Top management support
- ◆ Employee empowerment
- ◆ Technology used

◆ Materials management

The questions in part B employed a five scale Likert type ranging from "strongly disagree" to "strongly agree".

Secondary data was also used in the study. Official records were examined pertaining to the movement of the wagons into the workshop for maintenance and the length of their performance before failure. This information was used to develop the bath-tub model which helped in testing whether the duration allowed between two successive preventive maintenance dates was optimal. The information collected appears in appendix B. The history maintenance files were randomly selected and in particular, the following details extracted;

- ◆ Last preventive maintenance date
- ◆ Date the wagon was examined and found in need of either preventive or curative service
- ◆ Date the wagon was actually taken to the first work centre in the workshop
- ◆ Date the wagon was released from the workshop after the service

3.5 DATA ANALYSIS METHOD

Primary data collected was analysed using descriptive statistics and also factor analysis. In particular proportions, frequencies and percentages were used to gauge the applications of the operations management techniques while factor analysis was used to determine which factors had to be considered if operations management techniques were to be applied.

3.5.1 FACTOR ANALYSIS OVERVIEW

Factor analysis deals with the analysis of interdependence. A large number of variables is reduced to a small number of factors according to what the variables have in common (inter-correlation). Churchill (1983), argues that factor analysis is applied in data reduction, scaling, transformation and structure identification. Factor analysis follows three steps to generate a solution;

1. Identification of a set of correlations between all combinations of the variables of interest.
2. Extraction of a set of initial factors from the correlation matrix developed in step one.
3. 'Rotation' of the initial factors to find an initial solution.

The factors identified as important are listed in order of importance starting from the most important in terms of its contribution in explaining the observed variation in the issue of interest in this case 'factors which could hinder the application of management techniques in workshop operations'.

Lastly, secondary data was analysed by fitting the bath-tub model. Normal distribution was further used to test the first hypothesis set to be tested in the research.

CHAPTER FOUR: DATA ANALYSIS AND FINDINGS

4.1 ANALYSIS AND FINDINGS

A total of 40 questionnaires were given to the sampled respondents, out of which only 30 were received back . Out of the 30 received 3 of them were excluded from the analysis because they were not complete. This left 27 questionnaires valid for data analysis. Part A of the questionnaire is summarized and presented in terms of proportions and frequencies. Part B of the questionnaire was analysed presented using factor analysis.

4.1.1 ANALYSIS OF RESPONSES ON APPLICATION OF OPERATIONS MANAGEMENT TECHNIQUES.

The results of part A are summarized and presented in the table below:

Table 4.1 Work experience.

Experience	Frequency	Percentage
Less than 5 years	12	44
Between 5 to 10 years	9	33
Between 10 to 15 years	2	7
Over 15 years	4	15
Total	27	99

Table 4.1 shows that 44% of the respondents had served in their present job positions for less than five years. This is followed by 33% which is the proportion of respondents who had served for more than five but less than 10 years. In other words, 56% of the respondents had a work experience in their present job positions for more than five years.

This shows that most of the respondents had adequate time to gain the required experience in their present roles.

Table 4.2 What makes a vehicle be labelled “ For workshops”

	Frequency	Percentage
Preventive service	3	11
Preventive, breakdown and accident service	14	52
Preventive and breakdown Service	4	15
Preventive and accident service	4	15
Breakdown and accident service	2	7
Total	27	100

The main reason which makes vehicles be labelled for workshops is to undergo preventive breakdown and accident service. This represents 52% of the total respondents. Only 11% of the respondents indicated that vehicles to go to workshops because of preventive maintenance service. This indicates that the common shopping reason used by the wagons/coaches inspectors was breakdown and accident. To avoid a lot of break-downs and accidents occurring, preventive maintenance should be the key to shopping vehicles for maintenance. Also this keeps maintenance costs low and provides a smooth input to works.

Table 4.4 Arrival of vehicles at the workshop.

	Frequency	Percentage
Overdue	17	63
Under due	1	4
Expected time	9	33
Total	27	100

Table 4.3 Method used to establish type of maintenance to be done on a vehicle.

	Preventive		Breakdown		Replacement	
	F	%	F	%	F	%
Chart printed	15	56	0	0	3	11
Inspection	4	15	6	22	5	19
Failure	0	0	17	63	3	11
Life span	0	0	0	0	1	4
Don't know/unsure	8	29	4	15	15	55
Total	27	100	27	100	27	100

On the method used to establish the type of maintenance needed by a vehicle, the highest proportion of 56% indicated that the chart printed on the body of the vehicle was used for preventive maintenance. 63% indicated that failure was used for break-down maintenance and 55% didn't know or were unsure of the method used for replacement maintenance. It should be mentioned at this juncture therefore that manual methods are applied. While break-down maintenance is okay when identified by failure and inspection method preventive and break-down maintenance need to be automated for increased accuracy, reliability and efficiency of the shopping system.

Table 4.4 Arrival of vehicles at the workshop.

	Frequency	Percentage
Overdue	17	63
Under due	1	4
Expected time	9	33
Total	27	100

About whether vehicles are identified to go to workshops for preventive maintenance on schedule, 63% indicated that identification was overdue 4% under due and 33% at the expected time. This reveals that the span for preventive maintenance was not really being followed. Through interviews, it was established that human error in reading the charts printed or shortage of fit vehicles made vehicles be left to continue being used when they were due for preventive maintenance.

Table 4.5 Whether operations management discipline is applicable in workshop Operations.

	Frequency	Percentage
Applicable	23	85
Not applicable	2	7.5
Don't know/unsure	2	7.5
Total	27	100

It is time that operations management techniques are applicable in workshop operations. 85% indicated that the techniques were quite applicable. The remaining 15% indicated either the techniques were not applicable or they were not sure. However, it is one thing for the techniques to be applicable and another thing to really apply them.

Table 4.6 Operations management techniques currently being applied.

	Frequency	Percentage
Scheduling only	3	11
MRP only	1	4
Queuing theory only	0	0
All the three techniques	4	15
None of the three	1	4
MRP and scheduling only	18	67
Total	27	100

It is true that operations management techniques were being applied in the workshop. This is indicated by 67% who choose to indicate that only MRP and scheduling were being applied; However, only 15% indicated that the three techniques: Scheduling, MRP and queuing were being applied. Though these techniques are applied, an observation of the workplace revealed that the plans developed for schedules were manual and MRP was also manual and traditional in approach hence MRP was not used to signal re-order points.

Table 4.7 Ranking of scheduling priority rules used.

Rank number	Priority rule	Frequency	Percentage
1	First-come first served	21	78
2	Shortest operation time	20	74
3	Earliest due date first	11	41
4	Critical ratio	8	30
5	Random order	7	26
6	last-come last served	5	19
7	Queue ratio	3	11
8	Shortest slack time first	2	7

Scheduling priority rules were ranked by the respondents. As it is presented in table 4.7. The first rule in rank was first-come first served ranked by 78% of the respondents. Two in rank was shortest operation time rule ranked by 74% of the respondents. The ranks for the other rules are as indicated in the table and also their corresponding proportions indicated . An observation of the application of these rules also indicated that they were manual human based in application.

Table 4.8 Ordering of wagon spare parts.

	Frequency	Percentage
Workshop staff	22	81
Supplies department	2	7
Don't know/unsure	3	12
Total	27	100

Table 4.8 presents sourcing of wagon spare parts. 81% indicated that workshop staff placed orders for wagon spare parts, 7% indicated supplies department and 12% did not know or were unsure of who places the orders. However on interviewing the respondents, they said that all orders have to pass through supplies department for approval and re-order points of the various parts were detected manually. It is not easy to maintain a smooth flow of parts using the conventional inventory control and manual inventory check systems.

Table 4.9 Use of computers and need for computerization

	Use of computers		Need for computerization	
	F	%	F	%
used	17	63	-	-
needed	-	-	24	89
not used	10	37	-	-
not needed	-	-	3	11
Total	27	100	27	100

An examination of the above table 4.9 reveals that 63% indicated that computers were used in workshop operations while 37% indicated they were not used. 89% supported computerization while 11% did not support it.

Observation of the workplace showed that only one personal computer was being used for data capture and generation of minor reports on the output of the workshop. This does not really amount to the required use of computers in workshop activities. Reasons advanced for the need of computerization include the following:

- ◆ Spare parts cataloguing
- ◆ Monitor purchase and use of spare parts
- ◆ Placement material orders
- ◆ Monitor operations expenditure
- ◆ Staff data and staff utilization
- ◆ Schedule vehicles for maintenance
- ◆ Show movement of vehicles along work centres
- ◆ Keep history of the vehicles
- ◆ Perform costing of maintenance activities
- ◆ Keep record of supplies
- ◆ Application of computer aided design

Table 4.10 Extent of application of operations management techniques

	Less Important	Important	Neutral	More Important	Most Important	Total
Control of time	4%	4%	11%	11%	70%	100%
Financial control of maintenance	4%	0%	15%	20%	63%	100%
spare part inventory control	7%	4%	26%	11%	52%	100%
data collection and analysis	7%	7%	38%	15%	33%	100%
planning maintenance	4%	7%	22%	4%	63%	100%

On the extent to which operations management techniques were applied in workshops the following comes out from table 4.10;

- i Control of time duration during maintenance activities was most important as indicated by 70% of the respondents.
- ii Financial control of maintenance was most important as indicated by 63%.
- iii Spare parts inventory control was most important as indicated by 50%.
- iv Reliability and failure data collection and analysis was in between the two extremes as indicated by 38%.
- v Planning maintenance was most important as indicated by 63%.

Table 4.12 Correlation Matrix

However on interviewing the respondents, it came out clear that all the above activities were manually done. This means a lot of time is needed, human resources, plans can not be versatile and generation of reports on the above issue is a nightmare because of the amount of paperwork involved.

Table 4.11 Preventive maintenance duration

Enough time	Frequency	Percentage
Agree	9	33
Neutral	9	34
Disagree	9	33
Total	27	100

As indicated in table 4.11 the respondents were well spread among the three available choices. It therefore means that many of them were unable to tell whether the duration is enough or not. However this is a matter which is addressed by secondary data analysis under the bath-tab curves. However they put forward that wagons varied in preventive maintenance durations depending on the bearings used by the wagon.

Wagons with plain bearings took 4 years and wagons with roller bearings took 6 years.

4.1.2 FACTOR ANALYSIS

Factor analysis was performed on part B of the questionnaire to extract the components or factors which may hinder the application of operations management techniques.

SPSS statistical package for windows was used to analyse the data. The results of the factor analysis are as shown below.

Table 4.12 Correlation Matrix:

	Q1	Q2	Q3	Q4	Q5	Q6	Q7
Q1	1.00000						
Q2	-.13423	1.00000					
Q3	-.27488	.12347	1.00000				
Q4	-.32049	.19491	.22950	1.00000			
Q5	.12448	-.03202	-.43999	.07260	1.00000		
Q6	.11251	-.16224	-.08357	.13204	.13652	1.00000	
Q7	-.07238	.29763	.21317	.14089	-.00086	-.25801	1.00000
Q8	.17139	.03848	.27387	.06376	.07584	-.02165	.13964
Q9	.42954	-.47713	.10191	-.42016	.04621	-.05040	-.20615
Q10	-.26506	.01185	.33518	.23000	-.17519	-.22094	.36902
Q11	-.14246	-.04207	.44776	.30616	-.20371	-.22770	.22940
Q12	-.20950	.16960	-.07219	.25171	-.05806	-.05123	.00810
Q13	-.25511	.39057	.20180	.03010	-.37111	-.38149	.26366
Q14	-.01654	.04192	.18812	-.18202	-.27349	-.24720	.08540
Q15	-.20588	.52971	.05081	.42433	.11892	.03493	.07115
Q16	-.19774	.67353	.13923	.44211	-.01136	-.30889	.06888
Q17	-.32115	.12115	.35583	.13596	-.21955	-.22080	-.05174
Q18	-.41181	.14972	-.11276	.12893	.13599	.02284	-.08271
Q19	-.07803	.30991	-.03994	.36627	-.31383	-.06020	-.12264
Q20	-.13619	.66044	.26435	.41436	-.12756	.07425	.20101
Q21	.19701	.23410	.00516	.17237	-.13429	-.03007	.37338
Q22	-.02198	-.04754	.25569	.38508	-.38474	.24300	.06456
Q23	-.19798	.43114	-.09965	-.02574	.22885	.01036	-.11077
Q24	.21568	-.37473	-.25689	.03379	.13359	.19884	-.02770
Q25	-.13407	.10213	.41228	.12892	-.35782	-.20183	-.03963
Q26	.47806	-.45218	-.26262	-.18161	.05898	.07484	-.08911
Q27	.30624	-.22241	-.05932	-.14678	.39100	-.06091	-.33557
Q28	.40047	-.27670	-.39059	-.02657	.30899	.17444	-.20626

Q29	.06594	.43317	.13413	.59512	-.06569	-.09509	.04842
Q30	.08580	-.31796	.20772	.08714	-.05096	.19006	-.16071
Q31	.28220	.09920	-.26666	.04696	.15194	-.07794	.15052
Q32	-.11081	.08477	-.05476	.00994	-.15725	-.08402	.21088
Q33	.35224	.11760	-.06221	-.03316	.14667	.01334	.19708
Q34	-.00080	-.06573	-.21288	-.24820	-.19213	.01070	.15804
Q35	-.25843	-.00464	.14831	-.12309	-.29593	-.38193	.10878
Q36	-.42059	-.16618	.14151	-.07387	-.28531	.16314	.04851
Q37	.17977	.01242	.28082	-.35660	-.38052	-.37564	-.08010
Q38	-.09071	-.03033	.35199	-.05025	-.08082	-.16303	.18922
Q39	.31330	-.17369	-.20232	-.29485	.27815	-.30203	.10370
Q40	-.13710	-.37699	-.07418	.26404	.32259	.04444	-.22164

	Q8	Q9	Q10	Q11	Q12	Q13	Q14
Q8	1.00000						
Q9	.10715	1.00000					
Q10	-.30903	-.10298	1.00000				
Q11	-.24365	-.03322	.77951	1.00000			
Q12	-.37956	-.32238	.41140	.38557	1.00000		
Q13	-.32813	-.22567	.51056	.45809	.45664	1.00000	
Q14	-.17041	-.07679	.37276	.34442	.46029	.35291	1.00000
Q15	-.05165	-.43886	.36875	.23283	.36852	.41796	.05322
Q16	-.03359	-.24350	.27886	.29561	.40500	.47245	.05152
Q17	-.07183	.00251	.50907	.58957	.45661	.70616	.25902
Q18	-.09006	-.13117	-.03245	-.08311	.01654	.31582	-.22297
Q19	-.29775	-.43715	.30733	.39391	.70937	.47716	.20903
Q20	.00991	-.44194	.27545	.23872	.43023	.53313	.22478
Q21	-.33073	-.34053	.44094	.47920	.47222	.24123	.54246
Q22	.12053	-.17198	.28751	.21129	.38361	.05057	.33000
Q23	.02298	-.24846	-.16981	-.05854	.31219	-.01859	-.08285
Q24	.34682	-.05606	-.19409	-.20024	.02532	-.40268	.14112
Q25	-.30002	.10208	.53591	.65620	.50788	.51993	.27912
Q26	.15765	.14629	-.15423	-.20530	.10598	-.43390	.15418
Q27	.20120	.25538	-.35489	-.19741	-.18730	-.32690	.08296
Q28	.21222	.17435	-.14848	-.22316	-.04480	-.18715	-.03972
Q29	.00670	-.18555	-.03771	-.01378	.05410	.17700	-.30586
Q30	.07121	.15157	.34022	.44590	.45294	.09155	.15299
Q31	-.05260	-.34168	-.07406	-.16459	.19225	-.08721	.07403
Q32	-.23391	-.13753	.22288	.18134	-.03562	.34831	-.07087
Q33	.37318	-.19506	-.14436	-.34737	-.10249	-.22356	-.04321
Q34	-.15792	-.04387	-.20527	-.12694	.01566	.35124	-.10016
Q35	-.08388	.21085	.37392	.20290	.06269	.32786	-.09552
Q36	-.33652	.01476	.38515	.19032	-.04434	.23767	-.06021
Q37	-.10362	.23405	-.00739	.08728	-.11946	.36160	.29485
Q38	.12495	.14292	.24357	-.00989	-.12002	.29038	.09821
Q39	.16377	.46474	-.09390	-.05059	-.53291	-.21297	-.42761
Q40	-.03496	.08271	-.01504	-.03465	-.08275	-.35944	-.16578

	Q15	Q16	Q17	Q18	Q19	Q20	Q21
Q15	1.00000						
Q16	.63359	1.00000					
Q17	.48553	.39713	1.00000				
Q18	.37885	.14747	.51130	1.00000			
Q19	.33910	.42020	.46649	.07215	1.00000		
Q20	.77325	.59099	.38330	.12020	.37197	1.00000	
Q21	.20946	.10883	.06529	-.13117	.45068	.31137	1.00000
Q22	.12964	-.11194	.19583	-.05652	.50006	.26654	.43899
Q23	.29391	.27935	.16398	.26434	.20606	.23598	.00111
Q24	-.25546	-.36668	-.30275	-.25228	.06099	-.28788	.03494

	Q15	Q16	Q17	Q18	Q19	Q20	Q21
Q25	.16909	.37321	.61016	.06360	.47726	.30800	.36250
Q26	-.36214	-.39291	-.48733	-.65968	.01206	-.32670	.07856
Q27	-.19251	-.15379	-.13874	.01399	-.17376	-.31265	-.04111
Q28	.06766	.02124	-.10943	.01073	-.04276	-.17446	-.16920
Q29	.42133	.46303	.11967	.26374	.36818	.42429	.08599
Q30	.15401	.00230	.43574	-.19503	.27232	.21048	.07476
Q31	.10558	-.12773	-.32520	-.49725	.17690	.14280	.15696
Q32	.23933	.08237	.25337	.36383	-.01327	.09424	.08740
Q33	-.05629	-.18236	-.41137	-.32866	-.12493	.11079	.05502
Q34	-.30013	-.17154	.04644	.02181	.07872	-.12514	-.22395
Q35	.06410	.21022	.47936	.28256	.19443	-.15062	-.16212
Q36	.30464	-.08980	.38190	.46797	-.10436	.03548	-.05035
Q37	-.23491	.03588	.15664	-.06366	.07212	-.15664	.01241
Q38	.16283	.04017	.24206	.13859	-.14988	.07028	-.19814
Q39	-.29922	-.04863	-.25815	-.12510	-.42100	-.49075	-.34159
Q40	-.13163	-.16680	-.15938	.00273	-.17695	-.15623	-.24551

	Q22	Q23	Q24	Q25	Q26	Q27	Q28
Q22	1.00000						
Q23	-.05767	1.00000					
Q24	.43053	-.03711	1.00000				
Q25	.19858	.05752	-.52923	1.00000			
Q26	.28756	-.11938	.72311	-.27105	1.00000		
Q27	-.12332	-.19772	.25953	-.16084	.22145	1.00000	
Q28	.00558	-.07114	.65455	-.48735	.44661	.32082	1.00000
Q29	.20588	.02883	-.20344	.08124	-.24648	.03597	.03907
Q30	.23960	.07014	.06852	.48101	.22044	-.15813	.00505
Q31	.12399	-.04006	.25656	-.33554	.50828	-.01674	.04064
Q32	-.11695	.20576	-.27008	.12626	-.32335	-.56696	-.09670
Q33	.20432	-.04894	.28833	-.35342	.40212	.17117	.15070
Q34	-.22981	-.15333	.08146	-.18546	-.03312	-.28326	.04765
Q35	-.10342	-.05228	-.29528	.39573	-.28502	-.23600	-.15211
Q36	-.00564	-.07329	-.38026	.22422	-.43453	-.38834	-.22378

Q37	-.09795	-.17793	-.04449	.24578	.07243	.30398	.05139
Q38	.06333	-.26387	.00679	.07450	.01264	.17333	.14823
Q39	-.48591	-.03620	.10498	-.31579	.12167	.09321	.32276
Q40	-.07679	-.03555	.21823	-.26054	.07831	.12521	.24127

	Q29	Q30	Q31	Q32	Q33	Q34	Q35
Q29	1.00000						
Q30	-.25291	1.00000					
Q31	.13526	.01020	1.00000				
Q32	-.04594	.02174	-.13525	1.00000			
Q33	.19967	-.19860	.57124	-.24596	1.00000		

	Q29	Q30	Q31	Q32	Q33	Q34	Q35
Q34	-.22555	.01830	.13700	.27679	-.14714	1.00000	
Q35	.01939	.20623	-.33812	.21754	-.45003	.12719	1.00000
Q36	-.12412	.10341	-.37081	.49433	-.47299	.00082	.51331
Q37	-.02305	-.12777	-.11703	.17509	-.07004	.24343	.20639
Q38	.08444	-.01433	-.00405	.19186	.15998	.05193	.31546
Q39	-.16197	-.22961	-.10132	.17521	.00978	.13924	.10783
Q40	.14505	.11391	-.00327	-.28716	.05523	-.19877	-.10126

	Q36	Q37	Q38	Q39	Q40
Q36	1.00000				
Q37	-.04642	1.00000			
Q38	.29561	.58308	1.00000		
Q39	-.16175	.20157	.07180	1.00000	
Q40	-.14567	-.39780	-.23271	.03040	1.00000

Table 4.12 shows the correction matrix of the forty variables in part B. This forms the basis for generating factors and shows inter correlation among the various variables.

From the above table, it can be noted that the correlation between a variable and itself is 1000. Correlation is said to be strong if it is close to 1 or -1. The significance of any loading can be judged using either statistical or practical criteria. Statistical criteria mean that the loading is statistically significant at some specified alpha level typically 0.05. This means that for samples of less than 100, the loading would have to be greater than 0.30 or less than -0.03 to be considered statistically significant .

For example from the above table then we can say that variable 16 is fairly highly correlated with variable 15 as indicated by a correlation coefficient of 0.63359. A negative coefficient represents negative correlation.

Table 4.13 Initial out put of variable communality and Eigen values.

Variable	Communality	* Factor	Eigenvalue	Pct of Var	Cum Pct
	*				
Q1	1.00000 *	1	8.16671	20.4	20.4
Q2	1.00000 *	2	4.64109	11.6	32.0
Q3	1.00000 *	3	3.86643	9.7	41.7
Q4	1.00000 *	4	2.93364	7.3	49.0
Q5	1.00000 *	5	2.53494	6.3	55.4
Q6	1.00000 *	6	2.27519	5.7	61.0
Q7	1.00000 *	7	2.05875	5.1	66.2
Q8	1.00000 *	8	1.91755	4.8	71.0
Q9	1.00000 *	9	1.55183	3.9	74.9
Q10	1.00000 *	10	1.52988	3.8	78.7
Q11	1.00000 *	11	1.39531	3.5	82.2
Q12	1.00000 *	12	1.21931	3.0	85.2
Q13	1.00000 *	13	1.03042	2.6	87.8
Q14	1.00000 *	14	.85907	2.1	90.0
Q15	1.00000 *	15	.81169	2.0	92.0
Q16	1.00000 *	16	.73805	1.8	93.8
Q17	1.00000 *	17	.56427	1.4	95.2
Q18	1.00000 *	18	.46903	1.2	96.4
Q19	1.00000 *	19	.43073	1.1	97.5
Q20	1.00000 *	20	.37889	.9	98.4
Q21	1.00000 *	21	.23937	.6	99.0
Q22	1.00000 *	22	.20012	.5	99.5
Q23	1.00000 *	23	.11147	.3	99.8
Q24	1.00000 *	24	.07625	.2	100.0
Q25	1.00000 *	25	.00000	.0	100.0
Q26	1.00000 *	26	.00000	.0	100.0
Q27	1.00000 *	27	.00000	.0	100.0
Q28	1.00000 *	28	.00000	.0	100.0
Q29	1.00000 *	29	.00000	.0	100.0
Q30	1.00000 *	30	.00000	.0	100.0
Q31	1.00000 *	31	.00000	.0	100.0
Q32	1.00000 *	32	.00000	.0	100.0
Q33	1.00000 *	33	.00000	.0	100.0
Q34	1.00000 *	34	.00000	.0	100.0
Q35	1.00000 *	35	.00000	.0	100.0
Q36	1.00000 *	36	.00000	.0	100.0
Q37	1.00000 *	37	.00000	.0	100.0
Q38	1.00000 *	38	.00000	.0	100.0

Q39	1.00000	*	39	.00000	.0	100.0
Q40	1.00000	*	40	.00000	.0	100.0

In the above table, the communality expresses the proportion of the variance of the variables extracted by the factors . Communality estimates have been secured using initial principal components analysis. All variables have a good contribution to the factors as indicated by a communality of 1 or 100%.

A look at the Eigen values reveals that there are 13 main factors. These factors are indicated by Eigen values more than 1. Variation explained by these factors appears in the column of variation explained by the factors. The highest explanation is yielded by factor 1 which explains 20.4% of the variations and the lowest is by factor 13 which explains 2.6% of the variations. In total, these factors explain 87.8% of the variation in the responses being measured by part B of the questionnaire.

Table 4.14 Initial factor matrix

Factor Matrix:

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Q1	-.45434	.20697	.28036	.28592	.07573
Q2	.46965	.26392	-.52649	.50720	-.04814
Q3	.39473	-.13635	.22604	.11118	.50430
Q4	.36863	.44362	-.30810	-.23800	.31285
Q5	-.37599	.14869	-.40130	-.17192	.11920
Q6	-.20875	.20962	-.12912	-.51855	-.13524
Q7	.21593	.06512	.00314	.44661	-.15770
Q8	-.32519	.11245	-.10971	.17311	.50170
Q9	-.35343	-.50624	.35148	-.07113	.36586
Q10	.65782	-.00137	.37748	-.07770	.07784
Q11	.64193	-.00538	.42628	-.13909	.14573
Q12	.58340	.47521	.24377	-.20731	-.18327
Q13	.78427	-.13143	.10757	.33964	-.11913
Q14	.30948	.24455	.58818	.13688	-.06842
Q15	.62545	.28857	-.41503	-.01236	.15892
Q16	.61125	.14989	-.34543	.23223	.27497

Q17	.76667	-.21261	.12556	-.14564	.24891
Q18	.34624	-.35149	-.51589	-.20976	.07865
Q19	.59296	.45164	.16453	-.05747	-.09689
Q20	.65600	.44699	-.26771	.14670	.08323
Q21	.40550	.48555	.32804	.10057	-.21742
Q22	.25658	.53993	.37145	-.18410	.13083
Q23	.18765	.15656	-.40142	-.11899	-.15420
Q24	-.51181	.44599	.30378	-.11405	.03295
Q25	.72892	-.12767	.36905	-.10393	.15971
Q26	-.55918	.44871	.53908	.02281	-.05065
Q27	-.44226	.07514	.10651	.08250	.53416
Q28	-.41705	.18233	.03568	-.04081	.24270
Q29	.28192	.30759	-.44147	.20582	.40325
Q30	.26634	.11071	.46312	-.47141	.10966
Q31	-.19832	.60838	.06629	.31116	-.29215
Q32	.35748	-.37408	-.12552	.11165	-.39435
Q33	-.36663	.53263	-.04411	.41833	.09731
Q34	-.05288	-.26548	.09424	.21924	-.54839
Q35	.39994	-.56543	.13003	-.01614	.10310
Q36	.41875	-.54841	-.03122	-.31714	-.16580
Q37	.06987	-.34937	.43176	.58645	.15565
Q38	.13452	-.27132	.18278	.40910	.37690
Q39	-.45007	-.43098	-.04888	.28890	.09140
Q40	-.28070	.11208	-.13809	-.51246	.25824

Factor 6 Factor 7 Factor 8 Factor 9 Factor 10

Q1	.25479	-.09278	.09694	.21016	.12675
Q2	.00706	-.20214	-.07777	.14379	.09424
Q3	-.54668	-.05418	-.11580	.19270	.00655
Q4	-.20748	.17486	.15889	-.09582	-.36171
Q5	.30907	-.04827	.43278	-.15988	.33561
Q6	-.17891	.20743	-.31165	.15345	.23092
Q7	-.43097	.23248	.47032	-.05919	.06638
Q8	-.22326	.21832	-.04216	.48223	.13172
Q9	.12598	-.15141	.09316	.18210	.05773
Q10	-.13453	.15772	.48231	-.19702	.07135
Q11	-.04145	-.10839	.42434	-.03796	-.02625
Q12	.36128	-.05312	.00302	.01258	-.00573
Q13	.22374	.12479	-.04542	-.06014	-.06151
Q14	.05089	-.13350	-.12986	-.26211	.35321
Q15	.16840	.25305	.10089	.00194	.30374
Q16	.31787	-.15218	.17625	.13163	-.09197
Q17	.28421	.15672	-.07764	.10210	.06866
Q18	.24058	.26585	-.25326	-.26598	.12085
Q19	.36612	.00248	-.18555	.04576	-.37757
Q20	-.06962	.05569	-.06325	.19735	.20218
Q21	-.06161	-.17990	.13584	-.31598	.21275
Q22	-.25191	.31801	-.28744	-.00012	-.06197
Q23	.30431	-.15651	-.01502	.36732	.27107

Q24	.15721	.46592	-.03363	-.02845	-.04003
Q25	.04473	-.35912	-.02585	.13033	-.01791
Q26	.12938	.15404	.06967	.11534	-.03907
Q27	.30191	-.22390	-.22616	-.38030	.16955
Q28	.55201	.49643	.09898	-.06427	.05549
Q29	.02295	.05629	-.08613	-.12270	-.42657
Q30	.12683	.09358	.15121	.51151	.09549
Q31	.00178	.11867	.15243	.00979	-.12043
Q32	.03784	.37266	.17498	.08664	.14255
Q33	-.21979	.14666	.01784	.02467	.08605
Q34	.19406	.30176	-.11992	.19444	-.34205
Q35	.13118	.16011	.09505	.09221	-.25930
Q36	-.21291	.34989	-.06492	-.15858	.20646
Q37	.25164	.00456	-.31695	-.10075	-.03843
Q38	-.02532	.54272	-.12160	-.14475	.16838
Q39	.22232	.05425	.53584	.12592	-.08075
Q40	-.01683	-.00654	.28731	-.22830	-.30133

Q19	.05640	.13979	-.10826
Q20	.28889	-.21263	.19624
Q21	.24558	.33241	.00383
Q22	.07765	.29129	-.16576
Q23	Factor 11	Factor 12	Factor 13
Q24	.15887	.11380	.14541
Q1	.59743	.05145	.04905
Q2	-.05125	.09742	-.00594
Q3	-.13036	-.00265	.12899

Using principal component analysis the variables were grouped into their respective factors as follows:

Factor	Factor 11	Factor 12	Factor 13
Q4	.07753	.10847	.16115
Q5	-.08019	-.15267	.06951
Q6	.39608	-.02463	.24520
Q7	-.12382	.17458	.09770
Q8	-.27552	.21037	.05495
Q9	.25309	-.02116	-.00199
Q10	.00735	-.04895	-.07432
Q11	.04317	.13451	.20065
Q12	-.17616	-.10995	-.06600
Q13	-.05572	-.13472	.22427
Q14	-.28643	.01724	.12862
Q15	.13045	-.16573	-.06276
Q16	-.02853	.03308	.06999
Q17	-.12873	-.03213	.08173
Q18	-.03124	.18511	-.01689
Q19	.05640	.13979	-.10826
Q20	.08889	-.21263	.19624
Q21	.24558	.33241	.00383
Q22	.07265	.29129	-.15536
Q23	-.28137	.24684	-.30907
Q24	-.25887	.31200	.04641
Q25	.15748	-.02330	-.10705
Q26	-.01401	-.02885	-.23616
Q27	-.04765	-.04796	.06962
Q28	.08071	.11967	.16256
Q29	.36686	.00438	-.11529
Q30	.01561	-.26014	.04612
Q31	.01365	-.44351	-.18804
Q32	.22766	.19111	-.05802
Q33	.00757	-.19616	-.19798
Q34	-.10114	-.13571	.43169
Q35	-.09573	-.00160	-.39267
Q36	.18634	-.09212	-.21986
Q37	.03993	.03892	.02133
Q38	-.02649	-.28883	-.13862
Q39	.07661	.23205	-.01100
Q40	-.18668	-.19993	.04987

Using principal component analysis the variables were grouped into their respective factors as follows;

Factor	Variables involved
1	Q10, Q11, Q13, Q15, Q16, Q17, Q19, Q20, Q24, Q25, Q26
2	Q4, Q9, Q21, Q22, Q31, Q33, Q35, Q36
3	Q2, Q14, Q18, Q23
4	Q7, Q37, Q40
5	Q8, Q27, Q32, Q34
6	Q3, Q28
7	Q38
8	Q5, Q39
9	Q30
10	Q29
11	Q1, Q6
12 and 13	-----

The following then forms a list of the factors identified in the principle component analysis together with their themes;

Factor 1 ; *Top management support and employee motivation.*

- 10 Top management is responsible to request of additional resources whenever need arises
- 11 Top management is responsible to request of up to date technology for use in maintenance activities
- 12 Top management tours workshops from time to time to determine cause of bottlenecks
- 13 Top management support the decision of workshop staff concerning maintenance issues
- 15 There is team spirit in performing workshop functions
- 16 Workshop personnel are aware of their job description
- 17 Workshop staff receive training as needed
- 19 In case of maintenance difficulties, maintenance crew know exactly where to go for assistance
- 20 Immediate action is taken when problems come to the Supervisor's attention
- 24 There is need for creation of an operations management section to oversee workshop operations
- 25 Workshop personnel are not aware of operations management techniques which can lead to increased productivity
- 26 The level of breakdowns is higher than expected

Factor 2; Technology used in the work environment

- 4. The technology used in maintaining the vehicles is up to date
- 9. A lot of breakdowns are as a result of poor preventive maintenance programs
- 21. Top management has not seen the need for computerizing workshop activities
- 22. Communication has to follow the line of command
- 31. There is congestion in the workshop because of inadequate exit lines
- 33. There is too much paper work in the workshop which brings confusion
- 35. Vehicles are not scheduled for maintenance but are just maintained as they come
- 36. No priority rule is used to sequence jobs in the workshops

Factor 3; Staff empowerment

- 2. Every concerned personnel understand their role in maintenance activities
- 14. There is a detailed schedule for the maintenance of the vehicles
- 18. Workshop personnel are able to perform multiple functions
- 23. Subordinates receive instructions on how to do the job

Factor 4; Commitment to continuous improvement

- 7. Resources allocated for maintenance are adequate
- 37. Materials requirement plan is not used to determine reorder points
- 40. Continuous research on maintenance is necessary

Factor 5; Causes of breakdowns

- 8. Wagons are identified for maintenance by chance
- 27. Breakdowns are caused by low quality components
- 32. History of breakdowns of each specific vehicle is not followed up
- 34. Performance of workshop staff is not evaluated

Factor 6; Maintenance time

- 3. There is sufficient manpower to carry out maintenance activities
- 28. Supplies department takes a lot of time to give out required Spare Parts

Factor 7; Preparation of bills materials.

- 38. Bills of materials are not prepared in advance to allow supplies to get the necessary parts

Factor 8; Operations management techniques.

- 29. There is no detailed schedule on the maintenance activities being carried out
- 39. Queuing theory applications are not necessary in workshop activities

Factor 9; Facilities layout

- 30. The internal layout of the workshop prohibits flow of vehicles

Factor 10; Inventory control

- 29. Supplies department uses inventory control models to maintain inventories

Factor 11; causes backlog

- 1. There is a huge backlog of unrepaired vehicles in the yards
- 6. Support departments delay maintenance programs

Table 4.15 Final Statistics on contribution of factors to total variation

Variable	Communality *	Factor	Eigenvalue	Percentage Of variation	Cumulative % Variation
Q1	.92047 *	1	8.16671	20.4	20.4
Q2	.91566 *	2	4.64109	11.6	32.0
Q3	.87819 *	3	3.86643	9.7	41.7
Q4	.86477 *	4	2.93364	7.3	49.0
Q5	.82621 *	5	2.53494	6.3	55.4
Q6	.85802 *	6	2.27519	5.7	61.0
Q7	.79946 *	7	2.05875	5.1	66.2
Q8	.88447 *	8	1.91755	4.8	71.0
Q9	.79213 *	9	1.55183	3.9	74.9
Q10	.91479 *	10	1.52988	3.8	78.7
Q11	.89028 *	11	1.39531	3.5	82.2
Q12	.88319 *	12	1.21931	3.0	85.2
Q13	.92013 *	13	1.03042	2.6	87.8

4.3 SECONDARY DATA ANALYSIS

Secondary data was collected for the two types of wagons (plain bearings and roller bearings). Plain bearing wagons had a preventive maintenance service after four years of operation while roller bearings had six years. Secondary data extracted appears in appendix B. Bath-tub curves for the two types were plotted from the extracted data as follows;

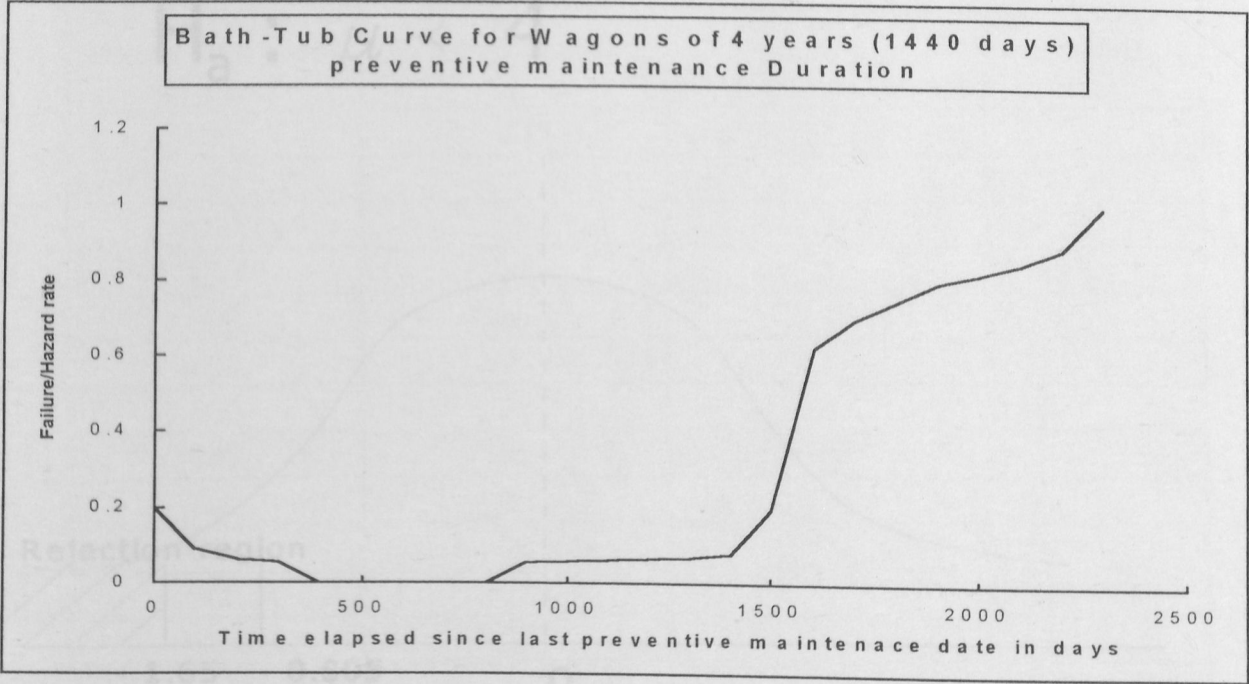
Using the above data, bath-tub curve was fitted to predict the most appropriate time of preventive maintenance. This is as shown in the chart below.

Table 4.31 wagons of four years duration

	Time elapsed since start of operations (in days)	Number still operating at time 't'	Number failing during the period between t and (t+1) $Q_t=(Q_t+1)$	Failure or hazard rate
1	0	30	6	0.200
2	100	24	1	0.042
3	200	23	3	0.050
4	300	20	1	0.053
5	400	19	1	0
6	500	18	0	0
7	600	18	0	0
8	700	18	0	0
9	800	18	0	0
10	900	18	1	0.056
11	1000	17	1	0.059
12	1100	16	1	0.0625
13	1200	15	0	0.000
14	1300	15	1	0.067
15	1400	14	4	0.0286
16	1500	10	2	0.200
17	1600	8	5	0.625
18	1700	3	1	0.333
19	1800	2	0	0
20	1900	2	1	0.500
21	2000	1	0	0
22	2100	1	0	0
23	2200	1	0	0
24	2300	1	1	1

Using the above data, bath-tub curve was fitted to predict the most appropriate time of preventive maintenance. This is as shown in the chart below.

chart 4.31



From the chart;

Failure rate is high at the start of operations after maintenance (infant stage) . This is normal. Curve remains low during the mature stage until it rises sharply after around 1375 days approximately 3.8 years. This is nearly the standard set which is 4 years but this has to still be tested further using normal distribution;

Mean life (for the population) = 4 years approximately 1440 days

Sample mean (appendix B) = 1375.23 days

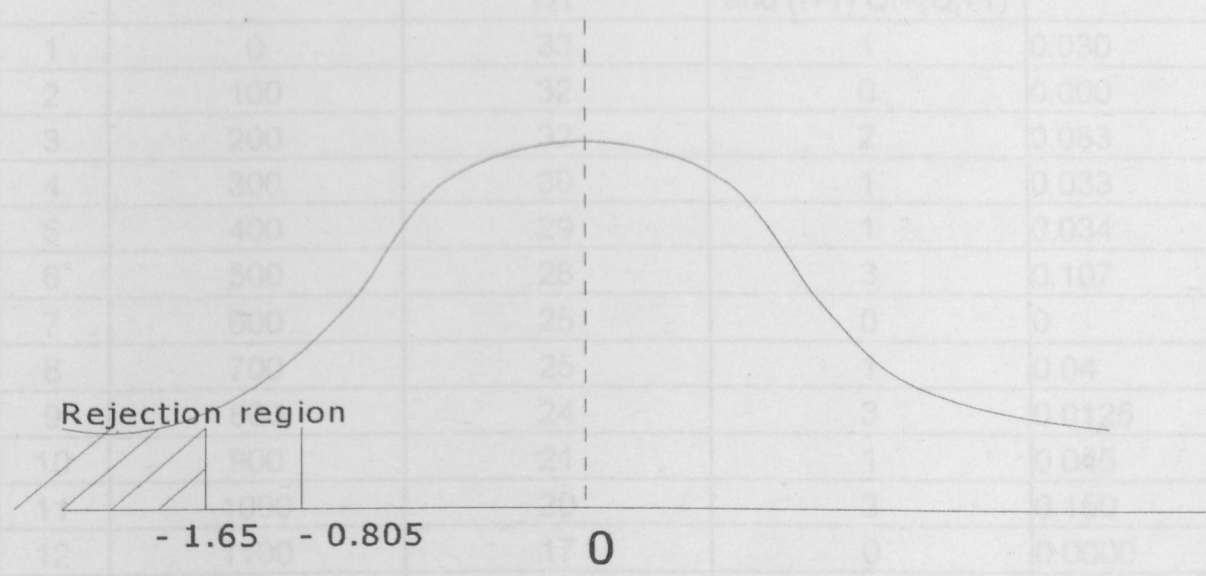
Sample standard deviation (σ) = 440.66 days

On standardizing the distribution the following resulted;

$$Z = \frac{(1375.23 - 1440)}{440.66/\sqrt{30}} = - 0.805$$

Hypothesis $H_o : \mu \geq 4$

$H_a : \mu < 4$



Z calculated = - 0.805 and At 5% confidence level Z table value = -1.65

At 5% level of significance, we fail to reject the null hypothesis and conclude that the mean duration is actually greater than four years (1440 days) indeed, the mean duration is far much higher than four years.

Table 4.32 wagons of six years duration

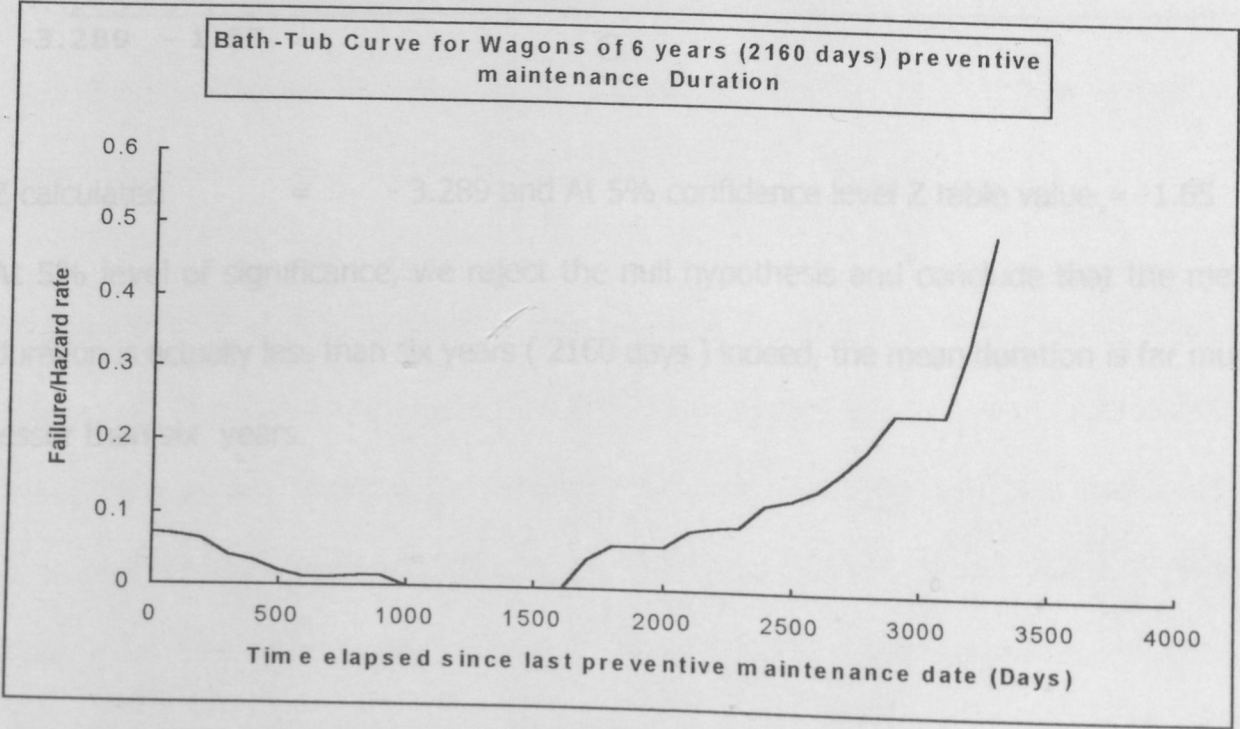
	Time elapsed since start of operations (in days)	Number still operating at time 't'	Number failing during the period between t and (t+1) $Q_t=(Q_t+1)$	Failure or hazard rate
		QT		
1	0	33	1	0.030
2	100	32	0	0.000
3	200	32	2	0.063
4	300	30	1	0.033
5	400	29	1	0.034
6	500	28	3	0.107
7	600	25	0	0
8	700	25	1	0.04
9	800	24	3	0.0125
10	900	21	1	0.045
11	1000	20	3	0.150
12	1100	17	0	0.0000
13	1200	17	1	0.0590
14	1300	16	0	0.0000
15	1400	16	0	0.0000
16	1500	16	0	0.0000
17	1600	16	1	0.0000
18	1700	15	2	0.0630
19	1800	13	1	0.1330
20	1900	12	0	0.0770
21	2000	12	1	0.0000
22	2100	11	0	0.0830
23	2200	11	1	0.0000
24	2300	10	3	0.0910
25	2400	7	0	0.3000
26	2500	7	1	0.0000
27	2600	6	1	0.1430
28	2700	5	1	0.1670
29	2800	4	1	0.2000
30	2900	4	0	0.2500
31	3000	3	1	0.0000
32	3100	3	0	0.2500
33	3200	2	1	0.0000
34	3300	2	0	0.5000
35	3400	1	1	
36	3500			

The above table was used to develop bath-tub curves for the wagons of six years duration. The bath-tub curve is as shown in chart 4.32 below;

From chart 4.32 it shows that the curve starts raising sharply after around 1600 days (4.4) years. This signals the start of the worn out stage and hence need for another preventive maintenance service. However, this appears to be far much below the standard set of four years. Normal distribution was used to test the accuracy of this prediction;

Mean life (for the population)	=	6 years approximately	2160 days
Sample mean (appendix B)	=	1672.75 days	

chart 4.32



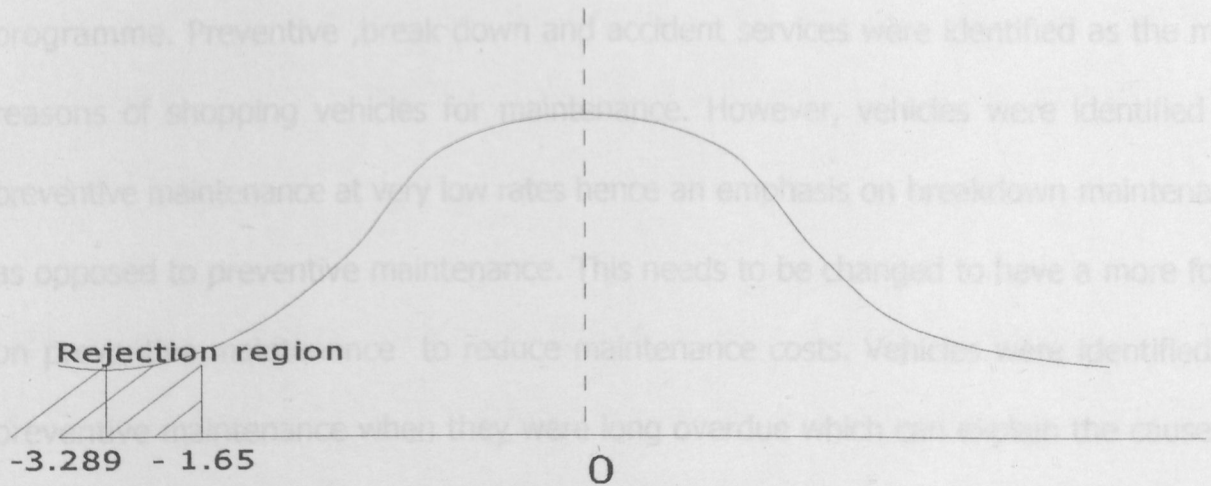
Sample standard deviation (σ) = 851.06 days

On standardizing the distribution the following resulted;

$$Z = \frac{(1672.75 - 2160)}{851.06/\sqrt{33}} = -3.289$$

Hypothesis $H_o : \mu \geq 6$

$H_a : \mu < 6$



Z calculated = -3.289 and At 5% confidence level Z table value = -1.65

At 5% level of significance, we reject the null hypothesis and conclude that the mean duration is actually less than six years (2160 days) indeed, the mean duration is far much lesser than six years.

CHAPTER FIVE: INTERPRETATIONS, CONCLUSIONS AND RECOMMENDATIONS

The respondents were found to have adequate experience of over five years in their present roles which is essential for implementation of an effective preventive maintenance programme. Preventive ,break down and accident services were identified as the main reasons of shopping vehicles for maintenance. However, vehicles were identified for preventive maintenance at very low rates hence an emphasis on breakdown maintenance as opposed to preventive maintenance. This needs to be changed to have a more focus on preventive maintenance to reduce maintenance costs. Vehicles were identified for preventive maintenance when they were long overdue which can explain the causes of frequent breakdowns and as a result, the present method of identifying vehicles for preventive maintenance should be automated.

Respondents felt that operations management as discipline is highly applicable in workshops. Materials requirement plan (MRP) was applied but this was purely traditional methods and also manual. Scheduling was done frowardly and also manually and schedules remained rigid once developed. First-come first-served and shortest operation time were the main priority rules used in scheduling. Computerized scheduling and decision support systems could be applied better in MRP, scheduling and prioritising jobs in workshop operations.

Ordering of wagon spare parts was done by workshop staff but re-order points were manual established and the order placed had to follow a line of command via supplies department for sanctioning. Supplies department used inventory control models to develop re-order points.

MRP is better applied in this aspect with orders being raised electronically and sanctioning being done also electronically.

Though respondents admitted that computers were used in workshop operations, the use was on a very small extent and the computer was only one. However, they really supported more computerization of workshop activities which is necessary for timely decision making.

Applications of operations management techniques was to a great extent mainly to do with the following; control of time of maintenance, financial control of maintenance, spare parts inventory control and planning maintenance. All these activities were manually done which made the application of the techniques difficult. Such issues would be better off handled by computerised systems which would also be used in reliability and failure data collection and analysis for improved activities monitoring. However, on the aspect of the duration allowed between two successive preventive maintenance dates, data collected as stated above can be of great use in tracking to detect when this duration changes as quality of spare part components also changes with time.

3.1 LIMITATIONS OF THE STUDY.

Results of factor analysis revealed that the most important factor that hinders application of operations management technique is top management support and employee motivation. Top management should provide the technology and resources (both financial and human skills) needed to apply the techniques.

3.2 SUGGESTIONS FOR FURTHER RESEARCH.

The second factor identified was technology used in work environment. If this techniques have to be applied for continual improvements and competitive advantage an organisation should keep up with the technology pace.

As evidenced by the remaining factors identified, staff should be empowered to do the job, the organisation should be committed to the goal of continual improvement and the real causes of breakdowns should be properly traced. Further, maintenance time should be properly managed (should not be wasted by unnecessary steps or procedures), bills of materials required in maintenance should be prepared in advance before scheduling the vehicles for maintenance and operations management techniques should be used in a great extent to achieve the specified maintenance targets and objectives.

Finally, flow of vehicles in work centres should be monitored to cut a lot of work in progress and materials requirement plan should be used instead of inventory control models to re-order maintenance inventories. Backlog should be avoided at all costs as this is a major contributor to loss of business and low staff morale.

On the duration allowed between two successive preventive maintenance dates the one for the four years was optimal (okay) but the one for six years needed to be revealed and made a bit lower . It is important that preventive maintenance be done exactly at the start of the worn-out stage of the bath-tub curve to avoid heavy breakdowns. However breakdowns can not be totally eliminated but preventive maintenance service should blend well with breakdown service so as to keep maintenance costs at the lowest level.

5.1 LIMITATIONS OF THE STUDY.

The study suffered from a few limitations. Among this, the researcher had to use a lot of time administering the data collection instrument because the concepts being tested had to be explained fully to several number of respondents . Also the study needed more time especially on the part of secondary data collection so as to collect bigger samples.

5.2 SUGGESTIONS FOR FURTHER RESEARCH.

This study focussed much attention on preventive maintenance which is actually done after fixed intervals of time or after specified usage of the equipment . However much can still be solved in the mentioned area using predictive maintenance which can be a good candidate for further study.

APPENDIX A

Muhwa L. Munyao
University of Nairobi
Faculty of Commerce
P.O. Box 30197
NAIROBI

Dear respondent,

I am a postgraduate student at the University of Nairobi. In partial fulfillment of the requirements of my degree course in Master of Business and Administration (MBA), I am conducting a study on operations management techniques in maintenance management - Case of Kenya Railways workshop.

I kindly request for your help in completing the questionnaire attached overleaf. Any comments made will be treated in confidence and will be used solely for academic purposes.

APPENDICES

Thanks in advance

Yours faithfully,

Muhwa L. M.

MR. KONGIET
SUPERVISOR

APPENDIX A

Mulwa L. Munyao
University of Nairobi
Faculty of Commerce
P.O. Box 30197
NAIROBI.

Dear respondent,

I am a postgraduate student at the University of Nairobi. In partial fulfilment of the requirements of my degree course in Master of Business and Administration (MBA), I am conducting a study on **operations management techniques in maintenance management - Case of Kenya Railways workshop.**

I kindly request for your help in completing the questionnaire attached overleaf. Any comments made will be treated in confidence and will be used entirely for academic purposes.

Thanks in advance.

Yours faithfully,

Mulwa L. M.

MR. KONGERE T.
SUPERVISOR.

QUESTIONNAIRE

PART A.

1. Please state which group you belong to as indicated below.

Management []

Unionisable []

2. Please state your designation

3. How long have you been doing the kind of work you are currently doing ?

Less than 5 years []

Between 5 to 10 years []

Between 10 to 15 years []

Over 15 years []

4. List in order of importance the assets which make Kenya Railways be able to discharge its services.

5. What makes a vehicle be labelled "For Workshops" ?

6. Who inspects vehicles to gauge whether they should be taken to Workshops for maintenance ?

7. After a vehicle is labelled "For Workshops", Is there information collected about the following?

Please tick as appropriate.

a) Time overdue []

b) Type of maintenance to be done []

c) State of the vehicle []

d) Reason for failure []

e) The spare parts needed []

8. On average how long does a vehicle stay in the yard before receiving attention at the workshop (use months please)

9. Please tick [✓] type or types of maintenance done at the workshops as indicated below.
- | | |
|-------------------------|-----|
| Preventive maintenance | [] |
| Breakdown maintenance | [] |
| Replacement maintenance | [] |
10. How is it established that a vehicle needs any of the following maintenance
- | | |
|-------------------------|-------|
| Preventive maintenance | _____ |
| Breakdown maintenance | _____ |
| Replacement maintenance | _____ |
11. On average vehicles for preventive maintenance arrive at the workshops when
- | | |
|----------------------|-----|
| They are overdue | [] |
| They are under due | [] |
| At the expected time | [] |
12. If the answer to number 11 is overdue please state by how many months else skip to question 13.
- _____ months
13. Is there an attempt made to schedule vehicles to the workshops for maintenance
- | | |
|-----|-----|
| Yes | [] |
| No | [] |
14. If the answer to question 13 is "Yes", state what type of scheduling is currently being practice else skip to question 15.
- _____
- _____
15. Is operations management as a discipline applicable in Kenya Railways Workshops operations?
- | | |
|-------------------|-----|
| Yes | [] |
| No | [] |
| Don't know/unsure | [] |
16. In the following list, tick [✓] the operations management techniques which are currently being applied in workshop operations
- | | |
|---------------------------------|-------|
| a) Scheduling | [] |
| b) Materials requirement plan | [] |
| c) Queuing theory | [] |
| d) All the above | [] |
| e) None of the above | [] |
| f) Only (a) and (b) | [] |
| g) Only (a) and (c) | [] |
| h) Only (b) and (c) | [] |
| i) Any other (please specify) | _____ |

17. In order to schedule vehicles for maintenance, what priority rule do you use ; You can tick as many as applies.
- | | |
|------------------------------|-----|
| a) First-come, first served | [] |
| b) Shortest operation time | [] |
| c) Earliest due date first | [] |
| d) Shortest slack time first | [] |
| e) Critical ratio | [] |
| f) queue ratio | [] |
| g) Last-come last served | [] |
| h) Random order | [] |
18. State the rationale if any of using the priority rule(s) you have ticked in 17 above.
- _____
- _____
- _____
19. Who signals the placement of an order for sourcing of wagon spare parts ?
- _____
20. Do you have computers used for workshop operations
- _____
21. Is there need of computerizing workshop activities ?
- Yes []
- No []
22. If the answer to question 21 is "yes", mention all the uses a computer will be put into for workshop operations else skip to question 23.
- a)
- b)
- c)
- d)
- e)
- f)
- g)
- h)
23. If your organization uses operations management techniques, to what extent do you use these techniques ? Else skip to question 24 . Please state the degree of importance in each case.
- | | Less important | | | Most important | | |
|--|----------------|---|---|----------------|---|--|
| i) Control of time | 1 | 2 | 3 | 4 | 5 | |
| ii) Financial control of maintenance | 1 | 2 | 3 | 4 | 5 | |
| iii) Spare part inventory control | 1 | 2 | 3 | 4 | 5 | |
| iv) Reliability and failure data collection and analysis | 1 | 2 | 3 | 4 | 5 | |
| v) Planning maintenance | 1 | 2 | 3 | 4 | 5 | |

24. The duration between two successive preventive maintenance dates is too long ?

Agree []

Neutral []

Disagree []

25. State the current duration set between two successive preventive maintenance dates (in months or years) - for wagons only.

a) Wagons with plain bearing []

b) Wagons with roller bearing []

		1	2	3	4
2	in maintenance activities				
3	There is sufficient manpower to carry out maintenance activities	1	2	3	4
4	The technology used in maintaining the vehicles is up to date	1	2	3	4
5	There is no detailed schedule on the maintenance activities being carried out	1	2	3	4
6	Support departments delay maintenance programs	1	2	3	4
7	Resources allocated for maintenance are adequate	1	2	3	4
8	Wagons are identified for maintenance by chance	1	2	3	4
9	A lot of breakdowns are as a result of poor preventive maintenance programs	1	2	3	4
10	Top management is responsible to request of additional resources whenever need arises	1	2	3	4
11	Top management is responsible to request of up to date technology for use in maintenance activities	1	2	3	4
12	Top management roots workshop from time to time to determine cause of bottlenecks	1	2	3	4
13	Top management support the growth of workshop staff concerning maintenance issues	1	2	3	4
14	There is a detailed schedule for the inspection of the vehicles	1	2	3	4
15	There is team spirit in performing workshop functions	1	2	3	4
16	Workshop personnel are aware of their job description	1	2	3	4
17	Workshop staff receive training as needed	1	2	3	4
18	Workshop personnel are able to perform multiple functions	1	2	3	4

SECTION B

Please circle the number that indicate the extent to which you agree or disagree with the following statements as they relate to workshop issues.

		Strongly Disagree			Strongly Agree	
1.	There is a huge backlog of unrepaired vehicles in the yards	1	2	3	4	5
2.	Every concerned personnel understand their role in maintenance activities	1	2	3	4	5
3.	There is sufficient manpower to carry out maintenance activities	1	2	3	4	5
4.	The technology used in maintaining the vehicles is up to date	1	2	3	4	5
5.	There is no detailed schedule on the maintenance activities being carried out	1	2	3	4	5
6.	Support departments delay maintenance programs	1	2	3	4	5
7.	Resources allocated for maintenance are adequate	1	2	3	4	5
8.	Wagons are identified for maintenance by chance	1	2	3	4	5
9.	A lot of breakdowns are as a result of poor preventive maintenance programs	1	2	3	4	5
10.	Top management is responsible to request of additional resources whenever need arises	1	2	3	4	5
11.	Top management is responsible to request of up to date technology for use in maintenance activities	1	2	3	4	5
12.	Top management tours workshops from time to time to determine cause of bottlenecks	1	2	3	4	5
13.	Top management support the decision of workshop staff concerning maintenance issues	1	2	3	4	5
14.	There is a detailed schedule for the maintenance of the vehicles	1	2	3	4	5
15.	There is team spirit in performing workshop functions	1	2	3	4	5
16.	Workshop personnel are aware of their job description	1	2	3	4	5
17.	Workshop staff receive training as needed	1	2	3	4	5
18.	Workshop personnel are able to perform multiple functions	1	2	3	4	5

19.	In case of maintenance difficulties, maintenance crew know exactly where to go for assistance	1	2	3	4	5
20.	Immediate action is taken when problems come to the Supervisor's attention	1	2	3	4	5
21.	Top management has not seen the need for computerizing workshop activities	1	2	3	4	5
22.	Communication has to follow the line of command	1	2	3	4	5
23.	Subordinates receive instructions on how to do the job	1	2	3	4	5
24.	There is need for creation of an operations management section to oversee workshop operations	1	2	3	4	5
25.	Workshop personnel are not aware of operations management techniques which can lead to increased productivity	1	2	3	4	5
26.	The level of breakdowns is higher than expected	1	2	3	4	5
27.	Breakdowns are caused by low quality components	1	2	3	4	5
28.	Supplies department takes a lot of time to give out required Spare Parts	1	2	3	4	5
29.	Supplies department uses inventory control models to maintain inventories	1	2	3	4	5
30.	The internal layout of the workshop prohibits flow of vehicles	1	2	3	4	5
31.	There is congestion in the workshop because of inadequate exit lines	1	2	3	4	5
32.	History of breakdowns of each specific vehicle is not followed up	1	2	3	4	5
33.	There is too much paper work in the workshop which brings confusion	1	2	3	4	5
34.	Performance of workshop staff is not evaluated	1	2	3	4	5
35.	Vehicles are not scheduled for maintenance but are just maintained as they come	1	2	3	4	5
36.	No priority rule is used to sequence jobs in the workshops	1	2	3	4	5
37.	Materials requirement plan is not used to determine reorder points	1	2	3	4	5
38.	Bills of materials are not prepared in advance to allow supplies to get the necessary parts	1	2	3	4	5

39. Queuing theory applications are not necessary in workshop activities 1 2 3 4 5

40. Continuous research on maintenance is necessary 1 2 3 4 5

WAGON CODE	LAST PM DATE	DATE EXAMINED	DATE IN WORKSHOP	DATE OUT WORKSHOP	OPERATION LIFE TIME	OVERDUE/ UNDERDUE	YARD DURATION	SERVICE DURATION
CSHB34008	13/03/91	17/09/97	05/11/99	16/12/99	1819	379	65	41
CSHB34011	12/08/94	31/08/99	05/11/99	16/12/99	1819	379	65	41
CLBL53001	18/09/94	30/12/99	25/06/00	05/08/00	1902	462	175	40
FMBC88137	01/03/98	11/04/99	26/04/00	01/08/00	400	1040	375	95
FWBC22395	19/11/95	05/05/00	17/05/00	20/05/00	1606	166	12	3
FWBC22390	23/11/95	25/11/99	12/05/00	23/05/00	1442	2	167	11
FWBC22376	01/12/95	27/03/97	17/05/00	26/05/00	476	-964	1130	9
FWBC22356	29/10/95	14/12/98	17/05/00	20/05/00	1125	-315	513	3
FWBC22355	29/10/95	27/09/99	06/04/00	11/04/00	1408	-32	189	5
FWBC22340	12/09/95	09/05/00	27/05/00	12/06/00	1677	237	18	16
FWBC22334	13/09/95	10/05/00	23/05/00	31/05/00	1677	237	13	8
FWBC22332	05/09/95	13/09/99	19/05/00	05/06/00	1446	6	248	16
FWBC22328	03/10/95	05/07/99	19/05/00	02/06/00	1352	-88	314	13
FWBC22324	11/09/98	30/01/99	17/05/00	18/05/00	139	-1301	467	1
FWBC22322	05/11/96	25/02/99	12/05/00	14/06/00	1190	-250	437	32
FWBC22317	11/10/95	23/12/99	23/05/00	28/05/00	1512	72	150	5
FWBC22307	27/09/95	07/01/99	17/05/00	28/05/00	1180	-260	492	9
FWBC22297	01/08/95	26/04/98	17/05/00	07/06/00	985	-455	741	20
FWBC22294	26/07/95	25/01/99	19/05/00	19/06/00	1259	-181	474	30
FWBC22293	15/08/95	13/02/00	19/04/00	22/04/00	1618	178	65	4
FWBC22284	30/07/95	25/06/99	02/05/00	13/05/00	1405	-35	307	11
FWBC22272	16/07/95	07/12/98	17/05/00	12/06/00	1221	-219	320	25
FWBC22265	25/06/95	26/07/99	19/05/00	23/05/00	1471	31	293	4
FWBC22262	17/06/95	26/05/99	26/04/00	02/05/00	1451	11	298	6
FWBC22261	15/06/95	23/10/99	17/05/00	21/05/00	1568	120	204	4
FWBC22255	14/05/95	06/01/00	19/05/00	05/06/00	1672	232	133	16
FWBC22243	01/06/95	29/04/99	27/05/00	16/06/00	1348	-92	388	19
FWBC22224	01/04/95	05/02/00	17/05/00	21/05/00	1244	304	102	4
FWBC22201	05/04/95	09/02/99	05/05/99	09/05/00	1383	-57	86	394
FWBC22128	15/03/96	12/03/99	23/05/00	29/05/00	1437	3	931	6
SUM					41237	-1943	9575	907
SAMPLE MEAN					1375.2333	-64.767	319.2	30.2333

APPENDIX B

WAGONS OF FOUR YEARS BETWEEN TWO SUCCESSIVE PREVENTIVE MAINTENANCE DATES (PLAIN BEARING WAGONS)

WAGON CODE	LAST PM DATE	DATE EXAMINED	DATE IN WORKSHOP	DATE OUT WORKSHOP	OPERATION LIFE TIME	OVERDUE/ UNDERDUE	YARD DURATION	SERVICE DURATION
CSHB34008	13/03/91	17/09/97	05/11/99	02/01/00	2344	904	768	57
CSHB34011	12/08/94	31/08/99	05/11/99	16/12/99	1819	379	65	41
CLBL53001	18/09/94	30/12/99	25/06/00	05/08/00	1902	462	175	40
FMBC88137	01/03/98	11/04/99	26/04/00	01/08/00	400	-1040	375	95
FWBC22395	19/11/95	05/05/00	17/05/00	20/05/00	1606	166	12	3
FWBC22390	23/11/95	25/11/99	12/05/00	23/05/00	1442	2	167	11
FWBC22376	01/12/95	27/03/97	17/05/00	26/05/00	476	-964	1130	9
FWBC22356	29/10/95	14/12/98	17/05/00	20/05/00	1125	-315	513	3
FWBC22355	29/10/95	27/09/99	06/04/00	11/04/00	1408	-32	189	5
FWBC22340	12/09/95	09/05/00	27/05/00	13/06/00	1677	237	18	16
FWBC22334	13/09/95	10/05/00	23/05/00	31/05/00	1677	237	13	8
FWBC22332	05/09/95	11/09/99	19/05/00	05/06/00	1446	6	248	16
FWBC22328	03/10/95	05/07/99	19/05/00	02/06/00	1352	-88	314	13
FWBC22324	11/09/98	30/01/99	17/05/00	18/05/00	139	-1301	467	1
FWBC22322	05/11/95	25/02/99	12/05/00	14/06/00	1190	-250	437	32
FWBC22317	11/10/95	23/12/99	23/05/00	28/05/00	1512	72	150	5
FWBC22307	27/09/95	07/01/99	19/05/00	28/05/00	1180	-260	492	9
FWBC22297	01/08/95	26/04/98	17/05/00	07/06/00	985	-455	741	20
FWBC22294	26/07/95	25/01/99	19/05/00	19/06/00	1259	-181	474	30
FWBC22293	15/08/95	13/02/00	18/04/00	22/04/00	1618	178	65	4
FWBC22284	30/07/95	25/06/99	02/05/00	13/05/00	1405	-35	307	11
FWBC22272	16/07/95	07/12/98	17/05/00	12/06/00	1221	-219	520	25
FWBC22265	25/06/95	26/07/99	19/05/00	23/05/00	1471	31	293	4
FWBC22262	17/06/95	28/06/99	26/04/00	02/05/00	1451	11	298	6
FWBC22261	15/06/95	23/10/99	17/05/00	21/05/00	1568	128	204	4
FWBC22255	14/05/95	06/01/00	19/05/00	05/06/00	1672	232	133	16
FWBC22243	01/08/95	29/04/99	27/05/00	16/06/00	1348	-92	388	19
FWBC22224	01/04/95	05/02/00	17/05/00	21/05/00	1744	304	102	4
FWBC22201	06/04/95	09/02/99	05/05/99	09/06/00	1383	-57	86	394
FWBC22426	15/03/95	12/03/99	23/05/00	29/05/00	1437	-3	431	6
SUM					41257	-1943	9575	907
SAMPLE MEAN					1375.2333	-64.767	319.2	30.2333

**WAGONS OF SIX YEARS BETWEEN TWO SUCCESSIVE PREVENTIVE MAINTENANCE
DATES
(ROLLER BEARINGS WAGONS)**

WAGON CODE	LAST PM DATE	DATE EXAMINED	DATE IN	DATE OUT	OPERATION LIFETIME	OVERDUE/ UNDER	YARD DURATION	SERVICE DURATION
CSHB36014	28/05/90	07/09/98	27/11/98	15/12/98	2979	819	80	18
CSHB36016	16/12/89	23/02/95	05/03/96	05/04/96	1867	-293	372	30
CSHB36017	29/05/95	19/08/98	02/10/98	10/10/98	1160	-1000	43	8
CSHB36020	18/12/89	01/07/97	20/08/98	04/09/98	2713	553	409	14
CSHB36021	26/06/89	29/03/98	07/09/98	20/09/98	3153	993	158	13
CSHB36024	18/01/89	07/08/95	11/10/95	12/11/95	2359	199	64	31
CSHB36026	02/12/93	17/04/95	10/07/95	11/08/95	495	-1665	83	31
CSHB36028	18/01/88	15/02/93	23/06/95	02/07/95	1827	-333	848	9
CSHB36029	28/01/92	02/06/98	08/02/99	03/12/99	2284	124	246	295
CSHB36030	13/06/97	17/04/98	18/05/98	21/06/98	304	-1856	31	33
CLBR54351	09/12/89	13/02/99	12/08/99	28/08/99	3304	1144	179	16
CLBR54353	11/06/90	29/03/95	08/05/95	14/05/95	1728	-432	39	6
CLBR54355	24/06/95	05/01/00	09/03/00	30/03/00	1631	-529	64	21
CLBR54360	10/02/94	23/08/96	12/11/96	02/12/96	913	-1247	79	20
CLBR54366	13/04/95	16/08/99	06/10/99	15/10/99	1563	-597	50	9
CLBR54368	13/10/94	08/03/00	04/05/00	15/05/00	1945	-215	56	11
CLBR54370	19/11/96	21/11/97	26/02/98	02/03/98	362	-1798	95	6
CLBR54373	16/11/89	11/06/96	04/11/96	05/12/96	2365	205	143	31
CLBR54374	17/04/89	19/10/95	14/12/95	20/12/95	2342	182	55	6
CLBR54376	05/11/96	07/02/98	07/05/98	09/05/98	452	-1708	90	2
CLBR54380	09/12/89	07/04/97	31/10/97	17/12/97	2638	478	204	47
CLBR54381	27/11/96	29/04/97	15/06/97	15/07/97	152	-2008	46	30
CLBR54382	01/12/89	13/11/95	22/04/96	02/05/96	2142	-18	159	10
CLBR54384	05/01/94	17/07/97	14/08/97	25/08/97	1272	-888	27	11
CLBR54389	18/08/89	12/09/96	23/12/96	21/01/97	2544	384	101	28
CLBR54387	17/04/96	30/07/99	30/09/99	04/10/99	1183	-977	60	4
FWBC22411	25/07/96	09/02/00	18/04/00	27/05/00	1274	-886	69	39
FWBC22403	04/02/96	12/01/00	09/04/00	15/04/00	1418	-742	87	6
FWBC22367	10/03/97	24/04/00	26/04/00	02/05/00	1124	-1036	2	6
FWBC22364	03/03/96	22/05/99	19/05/00	31/05/00	1159	-1001	357	12
FWBC22342	14/09/95	24/03/99	19/05/00	27/05/00	1270	-890	415	8
FWBC22312	31/08/95	16/02/00	07/06/00	08/06/00	1606	-554	111	1
SUM					53528	-15592	4822	812
AVERAGE					1673	-487.3	150.69	25.375

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