The Impact of Maintenance Systems on Water Supply: A case Study of a Utility Company

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Abstract

Approximately 50% of water pumped through distribution systems by the company under study is lost due to water-pipeline leakages and bursts resulting in high water pipeline downtime due to lack of a proper maintenance system. The purpose of the research was to develop a maintenance model to be used in the minimization of the water pipeline downtime. Assessment of the current maintenance system with a focus on mean time to repair (MTTR) and the amount of water lost were the objectives set. Exploratory research design was used in which data was collected using structured questionnaires, interviews and company records. The sample size for the research was small resulting in the consideration of the entire population. Data was analyzed using Microsoft excel and POM windows. The results showed 67% breakdown maintenance and 33% preventive maintenance systems were practiced in the department. 33% of the maintenance challenges faced in the department were due to lack of tools, 40% lack of spare parts, 7% lack of maintenance time and 20% lack of manpower. A maintenance model for value addition in water supply was therefore developed.

Keywords: *Maintenance, Value, Water Supply, Utility*

I. Introduction

According to [1], the purpose of municipal water delivery systems is to transport potable water from a water treatment facility to residential consumers and business industries. Water supply systems need to deliver adequate amounts of water to meet consumer consumption and at the same time be reliable and available to provide the needed water 24 hours, 365 days in a year. Although this is expected to be achieved, there are a number of challenges faced by water utility companies. One of the challenges faced is a lack of effective maintenance systems for the facility and the water utility equipments. According to [2], the challenges facing provision of water and sanitation services include the high levels of production cost, vandalism of infrastructure, run down water distribution pipes and overloaded sewage systems. Whereas water conservation is paramount, many of the water utility equipments and infrastructure has deteriorated due to untimely and lack of maintenance.

Reference [3] defined maintenance as a function charged with achieving the required asset capabilities within an economic or business context. While [4] argues that, maintenance has been defined as the engineering decisions and associated actions, necessary and sufficient for optimization of specified equipment capability. The capability in this definition is the ability to perform a specified level that may relate to capacity, rate, quality and responsiveness. Good maintenance assumes that maintenance objectives and strategies are not determined in isolation, but are in some way derived from factors such as company policy, manufacturing policy and other potentially conflicting demands and constraints in the company [5, 6, 7, 8]. According to some authors [9, 10, 11, 12] maintenance objectives are related to attainment of production target (through high availability) at required quality, and within the constraints of the system condition and safety. In the water utility companies, maintenance objectives are not determined in isolation of the company policy but the support given to such objectives is usually not adequate. Since the 1930's maintenance has evolved strongly from the so called first generation to the third generation maintenance. The new forms of maintenance are based on the ideas to positively affect plant availability, reliability, safety, quality, the environment and cost effectiveness. The third generation of maintenance does not only apply scheduled overhauls and corrective actions, but also looks at condition monitoring techniques and design improvements [13]. Determining the right maintenance system for the water pipeline systems is very cardinal as these facilities support mobility and is the primary mode of transportation of water from one point to the other. For this reason it is important that every pipeline system maintains its functionality with as little disruption as possible. To achieve this goal, regular maintenance, repair and rehabilitation operations must be carefully planned and executed at proper times.

Predictive maintenance programs measure equipment on a regular basis, track the measurements time, and take corrective action when measurements are about to go outside the equipment operating limits [14]. However, tracking the measurements requires new tools, training, and software to collect and analyze the data and predict repair cycles. Reference [15] argues that, if the asset (or similar assets) has been in existence for quite some time and if the owners have maintained good records of failures, it is possible that they know both the Failure Modes and the Failure Mechanisms present in the environment where the asset exists. On the other hand, if the asset is new to the operating environment where it is being used, it may be possible to identify only the Failure Mechanisms that are likely to affect the asset. Implementing predictive maintenance in the existing water utility company would not be a challenge as assets records exist.

According to [16], predictive maintenance differs from other forms of maintenance in that, it attempts to fix all problems by carefully and routinely monitoring the condition of the built asset and its fabrics before serious economic consequences such as unplanned failures. This type of maintenance system would therefore be very effective for the water utility company considering the number of maintenance challenges and associated costs resulting from the ineffective maintenance system used. Reference [17] also affirms that, condition monitoring offers the opportunity to discover defects weeks before a technician may find them and it provides advantages over performing maintenance at only manufacturer-recommended intervals (preventive maintenance).

Sufficient warning of an impending failure provides an opportunity to maximize resources downtime and materials. Therefore, using online condition monitoring techniques results in operations saving and reduced maintenance costs since pumps, wells, pipes and refineries can be monitored from a central location and maintenance personnel are only deployed when necessary [18].

This paper focuses on developing a predictive maintenance model for the water utility company that would result in the reduction of costs and number of customer complaints. The model is based on literature review [13, 16,18] and the information provided by the maintenance and operations department of the company under study.

II. Methodology

Exploratory research design was used as means of finding out what was happening at the company under study in order to determine insights for the new situation. Data was collected using designed questionnaires and structured interviews were conducted. Company records were also used to collect data. Formulas for determining the mean time between failure (MTBF) was used in order to determine the MTBF.

The research was conducted in the maintenance and operations departments which has a population of 20 employees.

A total of 19 employees were sampled out of 20 employees using a confidence level of 95% and confidence interval of 5%.

A. Structured Questionnaires

19 questionnaires were administered randomly to the employees in the maintenance and operations departments, three to the supervisors in the maintenance department, one to the divisional engineer in the maintenance department and 6 to the employees in the maintenance department and the rest were administered to the operations department of which 80% of them were returned in response. The questionnaires addressed the following issues, the type of maintenance system used in the company, challenges facing the maintenance department, the causes of leakages, level of equipment technology, frequency of equipment maintenance, number of employees in the maintenance and operations department, the level of employee training on new trends in maintenance and measures to reduce water pipeline breakdowns.

B. Structured Interviews

Interviews were conducted with the maintenance department and operations department. These offered first-hand information on the status quo of the plant maintenance and response rate to downtime. For management in depth interviews were conducted. These collaborated with the researchers to the cause and offered detailed information on pipeline downtime and provided records to backup information for the previous years. The interviews focused; on lead times on spare procurement, mean time to repair (MTTR), mean time between failure (MTBF), the costs as a result of water pipelines breakdowns, types of water losses and finally the systems which the management have put in place to minimize the challenges of water pipeline from the maintenance and operations point of view.

III. Results

The questionnaires and the structured interviews were designed in such a way to obtain information on the following; maintenance system used, challenges in the maintenance department, frequency of breakdowns, response time to repairs, maintenance planning, maintenance training, costs associated with poor maintenance systems.

A. Maintenance Approach

Fig 1 depicts the information regarding the type of the maintenance system at the utility company. 33% of the respondents indicated preventive system while 67% indicated breakdown maintenance. The results show that the majority of maintenance work on the water utility equipments is only performed when a breakdown occurs.

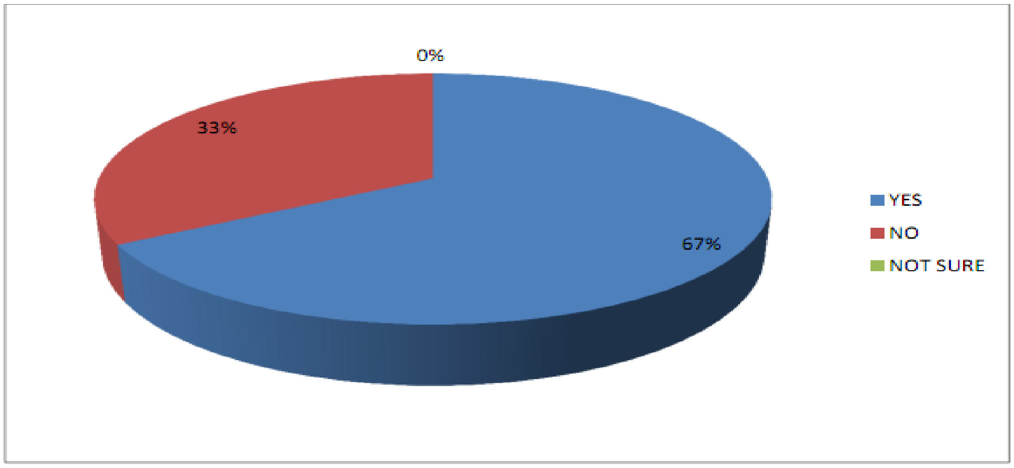

Fig 1: Maintenance Systems

B. Maintenance Challenges

Fig 2 depicts the major challenges the company is facing regarding the maintenance of water pipelines and equipments. 20% was attributed to lack of manpower, 33% to lack of tools, 7% to lack of time and 40% to lack of spares.

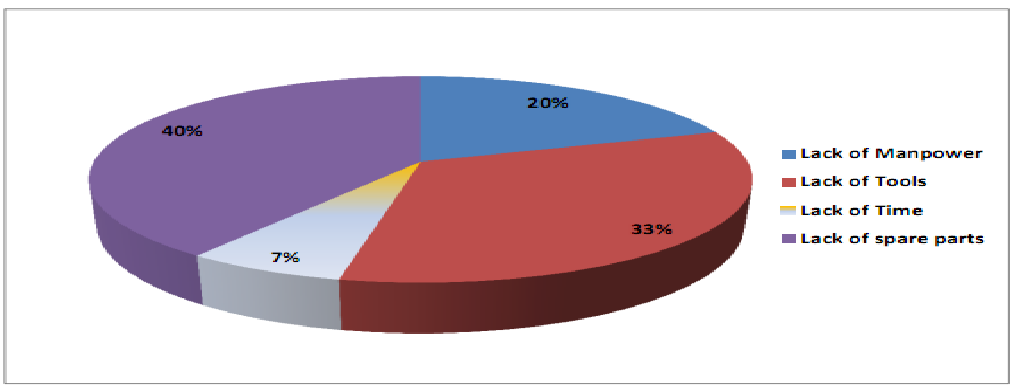

Fig 2: Maintenance Challenges

C. Frequency Distribution of Breakdown Causes

Fig 3 shows the frequency distribution of the causes of breakdowns in a period of 30 days. The figure indicates the major causes to the pipe bursts and leakages. Using the data obtained from the company records, 81 breakdowns were recorded in the month of January. Using this data, the researchers were able to determine the mean time between failure (MTBF),
MTBF = (24 hours * 28days/81breakdowns) = 8 hours/breakdown

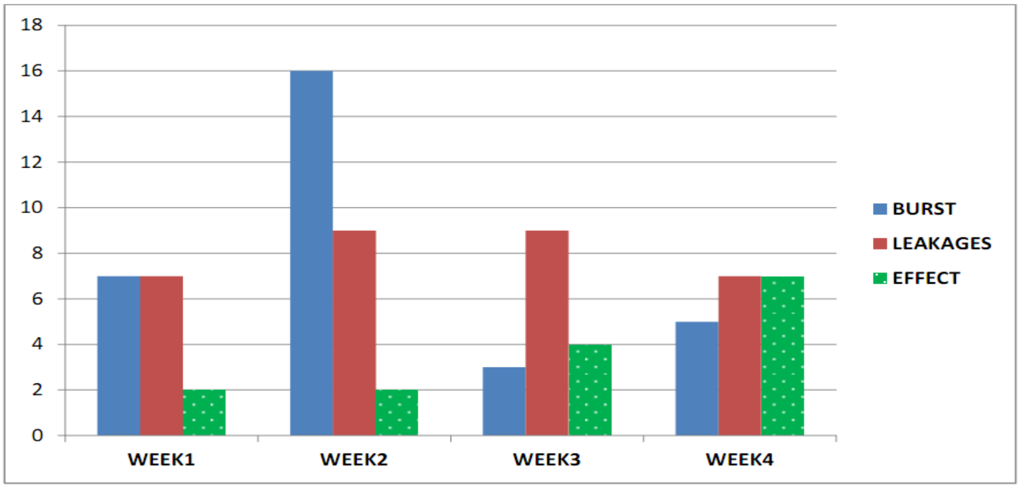

Fig 3: Frequency Distribution of Breakdown Causes

D. Level of Technology Improvement in Maintenance

Fig 4 depicts the results that were obtained after assessing the level of technology improvements in utility equipments and facilities for use in the distribution of water. The level of technology assessment was based on the number of years the equipments were purchased and type of techniques used to indicate the equipment are due for maintenance. 60 % indicated the equipments were very old while 20 % indicated old and the 20% indicated new. These percentages indicate and affirm that, level of improvement in equipments also contributes to breakdowns.

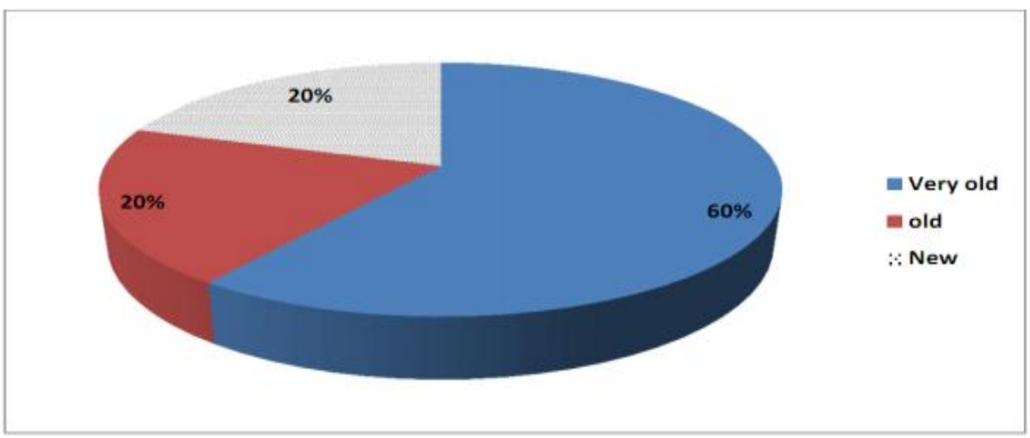

Fig 4: level of Advancement in Equipment Technology

E. Response Time to Repair

Fig 5 shows the response time to repair equipments reported to have broken down. This figure shows that customers notify the company about a water pipeline burst or leakage within a day but on average it takes them a month or 30 days to repair the pipe. The effect on this high MTTR is that, the company loses huge amounts of treated water, on average $741m^3$. This is not sustainable for the environment and the company.

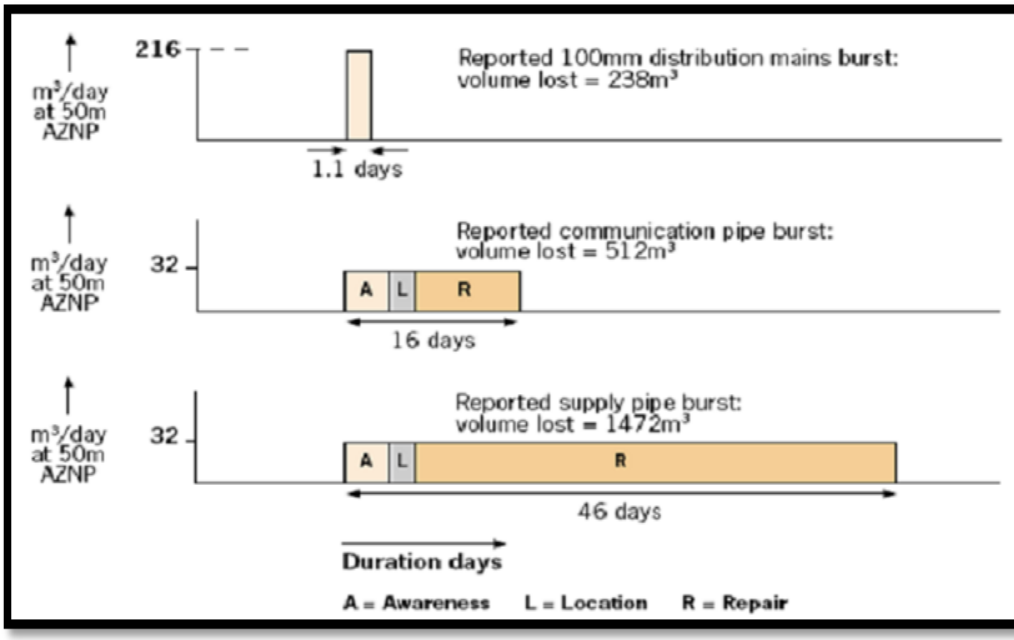

Fig 5: Response Time to Repair

F. *Water Losses*

Fig 6 shows the schematic of revenue water and non-revenue water. The company experiences two types of water losses, commercial and physical losses. These water losses are termed non-revenue water.

Commercial losses are as a result of administrative errors which include; meter management (e.g. stuck meters, meter invisibility), administrative lapses (information mismatches between what is in the system and what is on the ground), measurement errors (e.g. meter misreading), water theft or unauthorized consumption (illegal connections, meter by passes), unbilled unmetered consumption, water mismanagement at the utility's storage tanks (overflows).

Physical losses arise from asset management issues and include; dilapidated infrastructure (aged pumps and fittings, worn out pipes, etc), delayed leak repair response, unavailability of repair materials, vandalism, lack of offsite level controls and no leak locating programs.

Fig 6: Schematic of revenue water and non-revenue water

IV. Discussion

The company under study is running a breakdown maintenance system on water utility equipments. Breakdown maintenance is usually performed on general purpose equipments but in this case, 67% of the maintenance work performed is done after a breakdown. The company is also facing a number of maintenance challenges; lack of manpower, lack of tools and spare parts and lack of time. These challenges have affected water supply to many customers. The level of technology advancement in maintenance activities has contributed to the maintenance challenges the company is facing. Most of the maintenance work requires advanced machinery and equipment especially on issues of impeding failure. For this company, the kind of equipments and the maintenance system does not provide such information thus contributing to water losses and therefore affecting water supply.

A maintenance system has great impact on the supply of water to customers. Fig 6 shows the total water planned for distribution to customers. This amount of water has been subdivided into what is known as non revenue water. Non-revenue water is treated water yet the company accepts such water losses. It is water which can be supplied to customers and the company can make profits from it.

Focusing on the causes of water losses from both commercial and physical losses, maintenance is a key issue here. If the company had a proper and advanced maintenance system, meter mismanagement, dilapidated infrastructure, delayed leak repair response, unavailability of repair materials, lack of leak locating programs would be rectified. Fig 6 further shows that, the majority of the physical losses are due to poor maintenance system in place. It also shows that non revenue water losses account for a lot of money which the company can utilize in the purchase and installation of a predictive maintenance system for the company. Predictive maintenance system is ideal for water utility companies as it gives signals of impeding trouble before it actually occurs.

If the company had an advanced maintenance system, response to repair on pipe leakages and bursts would not result in 30 days of repair and the company losing 741 m^3 of water in a day. The frequency of breakdowns of MTBF of 8 hours is a clear indication that the facilities and equipments are poorly maintained and have aged. These are in need of a complete overhaul and on the part of employees; training will advance their skills to performing a better maintenance job.

A. Maintenance Model

The researchers developed a maintenance model (fig 7). The model was developed on the basis that the company invests in on-line predictive maintenance techniques for water pipes as they are the major causes of water losses. The developed model is built on the data collected from the maintenance and operations department and existing literature on different models that have been developed on predictive maintenance for water- pipelines. The model will be utilized on the day to day operations of the maintenance and operations department.

Requests for water-pipes maintenance will be received using the purchased on-line software for water-pipes and this software will be purchased together with the sensors suitable for dictating cracks on water-pipes. Once the signal for impeding failure has been received, maintenance planning for the task will start prior to work scheduling. The fact that predictive maintenance techniques give signals of impeding failure, it means the repair will be done before actual failure occurs. MTTR will be reduced while MTBF will increase.

However, tracking the measurements requires new tools, training, and software to collect, analyze the data and predict repair cycles [14]. Implementing the maintenance model, will require the training of employees and purchase of new tools. Since the pipes have been in existence for a long time, the maintenance department has records on equipment failures and therefore it will be possible for them to determine the failure modes and failure mechanisms present in the environment where the water pipes exist before failures.

Online predictive monitoring facilitates the creation of an asset register that hold comprehensive detail of each asset. Typical data to be stored would include asset number, department name, serial number, drawing number, purchasing price, location and unplanned maintenance history .This method is able to store proper record of time when leakage occurred for each period and maintenance periods. The model starts by receiving impeding failure from the equipment through the computer connected to the fault sensors on the water pipelines or the utility equipments. When the request is received, the maintenance personnel locate the water-pipeline shown on the computer and identify the type of task requiring maintenance work. The information on maintenance requirements is entered in the computer for the identified water pipe-line. Once data is entered in the computer, pending maintenance on the identified water-pipeline is checked and verified. Pending maintenance on the identified water pipe is not 100% accurate, the maintenance personnel will perform further diagnosis on the water pipe once assigned to the job. The maintenance personnel communicates with the personnel in charge of planning for the jobs with maintenance requests and after planning, the work is then scheduled for dates before failure occurs taking into consideration tools, spare parts, transport and maintenance personnel for the jobs to be performed. The scheduled jobs will also take into consideration priorities of the jobs in need of maintenance (day before failure occurs, lead times for spare parts). Once the task has been scheduled, the jobs are only ready for execution once the request for action is printed. The printed request for maintenance enables the maintenance personnel access to spare parts, tools, vehicles etc. The maintenance personnel records all the tasks performed on the job card and takes to the engineer to enter in the computer for completed task though the sensors would have stopped sending signals of impeding failure once the task is completed. The engineer verifies the completion of tasks on the jobs.

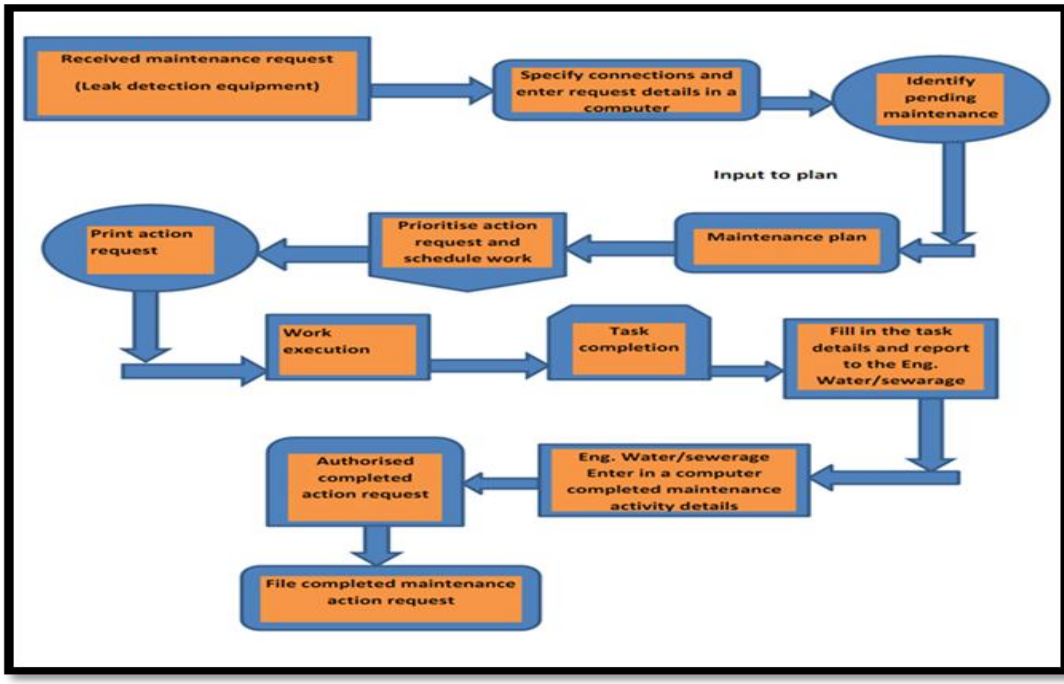

Fig 7: Maintenance Model

V. CONCLUSION

The maintenance system used in maintaining water pipelines is not sustainable for the company and the environment. The company loses huge amounts of water as a result of the breakdown maintenance system. The researchers have proposed a maintenance model that will employ on-line predictive maintenance in order to notify the maintenance department on impeding failure on their water pipelines. The researchers concluded that, the maintenance system impacted negatively on the company ability to supply water to customers.

The company should therefore consider investing in on-line predictive maintenance techniques to monitor cracks on the water pipelines before the actual burst or leakage occurs. Online predictive monitoring facilitates the creation of an asset register that hold comprehensive detail of each asset, typical data to be stored would include asset number, department name, serial number, drawing number, purchasing price, location and unplanned maintenance history .This method is able to store proper record of time when leakage occurred for each period and maintenance periods.

Acknowledgements

The researchers would like to thank all the maintenance personnel from the water utility company for assisting with information.

BIOGRAPHY

Bupe Getrude Mwanza is a part-time PhD student with the School of Engineering Management at the University of Johannesburg, South Africa. She is a holder of a BSc in Production Management from The Copperbelt University and MEng in Manufacturing Systems and Operations Management from the National University of Science and Technology. She has research interests in solid waste management, manufacturing technologies, maintenance management, cleaner production and operations management. She has taught Maintenance and Reliability Systems, Production and Operations Management, Integrated Production Systems and Manufacturing Technology. She has published and presented works on Maintenance Management and Solid Waste Management. Bupe has served as a Process Associate for Konkola Copper Mines in Zambia. She also served as a Lecturer at Harare Institute of Technology in Zimbabwe. She is currently employed as a Lecturer in the Department of Operations and Supply-Chain Management at The Copperbelt University in Zambia. She is a member of the Engineering Institute of Zambia (EIZ) and The Southern Africa Institute for Industrial Engineers (SAIIE).

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