Availability Performance Improvement by Using Autonomous Maintenance – The Case of a Developing Country, Zimbabwe

Kumbi Mugwindiri and Charles Mbohwa

Abstract: Autonomous Maintenance is an order winning paradigm shift maintenance philosophy which has operators that use machines personally conducting maintenance activities, including cleaning, oiling, retightening and inspection thereby raising production efficiency to its limit. Such activities prevent forced deterioration of equipment. This is because equipment can revert to systemic failure even after maintenance has been carried out if due regard to maintenance instructions is not adhered to. The savings accrued in routine operations and scheduling leads directly to large reductions in operations cost. This paper looks at how autonomous maintenance has a direct correlation with improving availability performance and hence profitability in the fertiliser industry in Zimbabwe.

Index terms: Autonomous Maintenance, Availability Performance, Overall Equipment Effectiveness (OEE), Preventive Maintenance (PM), and Profitability.

I. INTRODUCTION

This research assess and analyses the benefits of Autonomous Maintenance within the fertiliser manufacturing sector in a developing country – Zimbabwe, particularly the improvement of availability performance with the user of Autonomous Maintenance. It posits that maintenance profitability and a high Overall Equipment Effectiveness (OEE) within the fertiliser manufacturing sector in Zimbabwe are best achieved by the applications of Autonomous Maintenance. The objective of Autonomous Maintenance is to bring whatever is being maintained towards a state of free-failure operation. This, however, is not to be understood as implying "at whatever cost."

The main objectives of implementing Autonomous Maintenance:

1. Development of an implementation system of productive maintenance for the life of the equipment
2. Involvement of all maintenance departments that plan, design, use or maintain equipment in implementation of Autonomous Maintenance by considering all employees from engineering and production
3. Promoting Autonomous Maintenance through motivational management activities
4. To prove that crisis maintenance is at best, a cost-cutting strategy, whereas Autonomous Maintenance is a profitability strategy
5. Maximizing equipment effectiveness.

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II. AUTONOMOUS MAINTENANCE FUNDAMENTALS

Implementing Autonomous Maintenance is a dramatic organizational change that can affect organizational structures, work floor management system, employee responsibilities, performance incentive system, skill development, and the use of information technology [4], [22]. Usually difficulties faced in Autonomous Maintenance implementation include people showing strong resistance to change, people treat Autonomous Maintenance just as another programme of the month without any focus and also doubt its effectiveness, not having sufficient resources (people, money, and time) and assistance to back up Autonomous Maintenance, insufficient understanding of the methodology and philosophy by middle management [18]. Autonomous Maintenance is also not a quick fix approach, it involves a cultural change to the way things are done. Departmental barriers existing within the business unit can cause a major setback to Autonomous Maintenance implementation [19]. Lastly many people consider Autonomous Maintenance activities as additional work or even a threat to their job security [2].

TPM of which Autonomous Maintenance is one of the major characteristics, is a Japanese quality influenced concept developed in the 1970's by extending preventive maintenance to become more like productive maintenance [14]. TPM is a system (culture) that takes advantage of the abilities and skills of individuals in an organization in order to attain

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maintenance effectiveness [17]. It is not the big investments and changes which are secret to TPM, which have transformed the workplace at the Japanese firms, but the encouragement of production workers who fix many small defects and do minor changes [9]. When implemented fully, Autonomous Maintenance could dramatically improve productivity, quality and reduce costs. Autonomous Maintenance is an approach to eliminate/reduce losses in the plant (time & cost) and equipment management that involves all employees (officers, supervisors & operators) from production, maintenance and administration departments [18]. When Autonomous Maintenance is implemented together with Reliability Centred Maintenance, a comprehensive data base of maintenance requirements, skills required, and stocks that should be held is developed [22]. Within Autonomous Maintenance, operators are taught frontline maintenance skills such as online monitoring also known as Condition Based Maintenance (CBM). CBM is a management philosophy that posits repair or replacement decisions on the current or future condition of assets [15]; it recognizes that change in condition and/or performance of an asset is the main reason for executing maintenance [5]

Autonomous Maintenance is a relatively new practical application of TQM which aims to promote a culture, in which operators feel that they "own" their machines, learn much more about them, and in the process release skilled trades to concentrate on problem diagnostic and equipment improvement projects [22]. Autonomous Maintenance is an indispensable tool to meet customer demands on price, quality and lead times [10]. It has a positive and significant relationship with low cost (as measured by higher inventory turns), high levels of quality (as measured by higher levels of conformance to specifications), and strong delivery performance (as measured by higher percentage of on-time deliveries and by faster speeds of delivery) [8], [10]. All the above arguably have a direct correlation with overall effectiveness and profitability.

The implementation of Autonomous Maintenance takes a very structured approach [14].

This structured approach in Autonomous Maintenance implementation ensures that every activity is critically analyzed before being undertaken and this reduces the chances and probability of overlooking very important detail [15]. Within Autonomous Maintenance, improvement goals need to be closely integrated with the corporate objectives and should be considered separate to new capital intensive projects [8], [16]. Plans for improvement of product service, process quality, safety, environmental impact dependability and customer satisfaction are needed at all levels of any process. The performance measure for Autonomous Maintenance is Overall Equipment Effectiveness (OEE). Overall Equipment Effectiveness is an important performance measure metric for Equipment Effectiveness [17]. While Autonomous Maintenance requires increased commitments to training, resources and integration, there is also the promise to improve availability performance [19] as well as Maintenance performance indices and productivity [3]. One renders maintenance more effective by obtaining and implementing an Autonomous Maintenance plan [7]. The important issues in Autonomous Maintenance range from various optimization models, maintenance techniques, scheduling, and information systems [3].

As far as Autonomous Maintenance is concerned it is critical that there is a clear strategy [14] which is applicable to the obtaining maintenance dynamics. Within Autonomous Maintenance, one could choose the decision to implement Preventive Maintenance (PM) or a hybrid maintenance strategy which could be influenced by linking performance to productivity using an accurate measurement of productivity indices replete with evaluation of equipment performance based on:

- Condition
- Cost
- Failure Modes [22].

However in most applications it is usually found that PM is taken as the foundation stone for all maintenance strategies (hybrid or otherwise) requiring a paradigm shift- this improves the mindset and thus PM programs become more proactive [21]. Maintenance should be presented as a product to top management so that implementation and design of PM's are tailor made for that organisation and accounting justification should be made on all maintenance strategies whether they a based on monitoring as in CBM, or on reliability as in RCM [20]. It is equally important that workers be thoroughly motivated to innovate. Innovation is an outcome of an intentional and designed effort of the organization, and synthesizes the findings for enhancing creativity and innovation by developing three antecedents that positively influence innovation in organizations: (1) the garnered knowledge, (2) the presence of a knowledge-supporting culture, and (3) the accumulation of social capital [6].

III. IMPLEMENTING AUTONOMOUS MAINTENANCE

The purpose of Autonomous Maintenance is to minimize maintenance costs and downtime costs at a given quality of production whilst at the same time fulfilling the requirements of safety [16]. The current maintenance problems in Zimbabwe fertiliser manufacturing sector include:

1. Malfunctioning equipment
2. Process not meeting quality control standards
3. General deterioration of infrastructure
4. Frequent breakdown of equipment

These challenges result in the following consequences

- ➢ Failure to meet production targets
- ➢ Reduced plant availability
- ➢ Low overall equipment effectiveness
- ➢ Deterioration of process capability index
- ➢ Low plant utilization
- ➢ Loss of revenue [12].

With the current economic environment in Zimbabwe, buying new equipment or making drastic process changes is costly due to shortage of foreign currency. This of course could be abated by the use of multi-currency instead of heavily relying on a single currency. This calls for an optimal maintenance strategy that is cost effective. From historical data and records of companies, the consequences listed above can be addressed by utilizing Autonomous Maintenance. However its implementation can be labour intensive if carried out in full. Autonomous Maintenance has been identified as an important solution in having a committed maintenance workforce that is a sufficiently motivated workforce [6]. Some of the typical problems likely to face Autonomous Maintenance implementation are operator resistance and management inertia [14]. This has also necessitated the need for this project to analyse these likely problems in coming up with a possible smooth implementation of Autonomous Maintenance that can be accepted by all stakeholders.

The implementation of Autonomous Maintenance was considered for the fertiliser sector because it is a pivotal component in the agro based country's economy [12]. There are similarities in the implementation of Autonomous Maintenance for any plant and the method that will be considered is applicable to any plant with only minor variations needed [14].

Unlike predictive/preventive maintenance, Autonomous Maintenance is aimed at failure root causes, not just symptoms. Its central theme is to extend the life of mechanical machinery as opposed to:

- making repairs when often nothing is broken.
- pre-empting crisis failure maintenance in favour of scheduled failure maintenance [14].

Autonomous Maintenance prevents failures as the key to reducing the Maintenance, Repair and Operation (MRO) costs, and to increasing the return on assets. Within Autonomous Maintenance, the optimal reliability threshold is determined by minimizing the cumulative maintenance cost per unit time in the residual life of the system [21]. As such, regular Autonomous Maintenance helps keep machines running efficiently and eliminates potential breakdowns [22], [23].

An effective way of implementing Autonomous Maintenance is through the use of small group activities. These are actually achieved by using three main Task Groups.

1. A management task group 1.
2. An engineering task group 2.
3. A production task group 3.

The management task group will be responsible for:

- Formulating the Autonomous Maintenance policy and objectives
- Selling the Autonomous Maintenance philosophy to the whole plant personnel. The information should clearly describe the maintenance policy, Autonomous Maintenance concept and why it is going to be implemented in the factory
- Staff training
- Executives and the Managing Director should show enthusiasm in the implementation of the Autonomous Maintenance. Introductory seminars to remove resistance to change are necessary
- Formulation of master plan is imperative
- Kick off of Autonomous Maintenance programme, usually in the factory greens, and attended by sister companies, suppliers etc...

The other Task Groups, 2 and 3 are responsible for:

- Defining current problems in their areas
- Analysing the problem areas and bottleneck operations
- Identification of every condition potentially related to the problem.
- Evaluation of the equipment, materials and malfunctions
- Planning and investigating functions and malfunctions
- Improving plant availability for both task groups 2 and 3
- Implementation of autonomous maintenance for operators for task group 2
- Increasing plant utilisation for task group 2
- Autonomous maintenance can be achieved by using the five S's or 7 Nakajina steps of stage 8 in the 12 step Autonomous Maintenance implementation plan.
- 5S's stand for Seiri (Organisation), Seiton (Tidiness), Seiso (Cleaning) and Seiketsu (Discipline), Shitsuke (Training). The engineering task group shall also handle training and education.
- Preventive maintenance, reduction of breakdowns through continuous improvements, spare part consumption reduction, maintenance for quality and reliability.

IV. AUTONOMOUS MAINTENANCE AND PROFITABILITY

The generic cost of maintenance is usually given by:

- Plant unavailability
- Maintenance resources
- Plant life [11].

The following is an investigation into improvement of maintenance productivity over a three months period at a Fertiliser manufacturing company in Zimbabwe. The usual definition of Availability Performance applies i.e. actual running hours divided by planned available hours. Autonomous maintenance tasks were carried out such as lubrication, housekeeping Condition Based monitoring and trending. The result was a significant decrease in downtime which translated to a higher mean time before failure.

- the unscheduled downtime due to maintenance was 316 hours (T_{dm})
- the number of stops was 98 (N)

The factory has 2-eight hour shift production and it is estimated that 1 production hour per shift disappears due to change of product, tools, etc… With today's productivity, the plant produces 50000 products per year at a price of Z$1 5000.00.

The downtime due to maintenance was distributed as follows:

1. Failure diagnostics 10%
2. Technical information collection on machines, spare parts to be replaced, tools to be used, etc... 15%
3. Waiting for maintenance personnel 20%
4. Lack of spares 25%
5. Time of repairing 30%

The objective is to determine:

i. Mean Time To Failure (MTTF) =9.63hrs
ii. Mean Down Time (MDT) = 3.224hrs
iii. Mean Waiting Time (MWT) =2.257hrs
iv. Mean Time To Repair (MTTR) = 0.967 hrs
v. Present availability performance (AP) = 74.94%
vi. Effect of increasing the availability to 93% by using autonomous maintenance on the overall turnover/profit. This was achieved by improving on the percentage downtimes as listed above.

Effect of increase in availability performance (AP) by using simple proportion:

The number of products produced when AP is equal to 93% is given by

$$= \frac{93 \times 50\,000}{74.94}$$

$$= 62\,050$$

The turnover at:

1. 74.94% is 50 000 x 1500 = Z$75 million
2. 93% is 62 050 x 1500 = Z$93,075 million an increase of 24%.

World Class Manufacturing Autonomous Maintenance Key Performance Indices (KPIs)

1. Quality Rate >= 90%
2. Performance >=95%
3. Plant Availability >=90% and
4. OEE >=85% [23].

V. WAY FORWARD

Autonomous Maintenance presents a real and viable way by which the availability and hence the profitability of an organisation can be improved. Companies are encouraged to adopt Nakajima's seven steps of implementing autonomous maintenance, and this buttressed by top management support given below:

Table 1. Nakajima's 7 steps of Autonomous maintenance [14]:

Step	Name	Content or activities
1.	Initial clean up	All round clean up of dust and dirt, centering on the equipment. Implementation of lubrication and machine parts adjustment.
2.	Measures against sources of outbreaks	Prevent the causes of dust and dirt. Improve places that are difficult to clean, and reduce the time required for clean-up and lubrication
3.	Formulation of clean-up and lubrication standards	Formulate behavioral standards so that it is possible to steadily sustain clean-up, lubrication and machine parts adjustment in a short period.
4.	Overall check-up	Training to check up skills through checkup manuals; expose and restoration of minor equipment defects through overall check-ups
5.	Autonomous check-up	Formulation and implementation of autonomous check-up sheets
6.	Orderliness and tidiness	Standards for clean-up, check-ups and lubrication. Standards for physical distribution in the workplace Standardisation of tool management
7.	All-out autonomous management	Development of corporate policies and goals, and making improvement activities routine. Steadily record MTBF analysis, analyse these and carry out improvements

Failure to address these maintenance fundamentals results in loss of customers and overall poor profitability as exemplified in the Figure 1 below. The diagram lists causes which lead to primary relations which in turn have consequences at an operational level. By the time one reaches the business level the customer is gone or the business has closed all having stated from minimal autonomous maintenance.

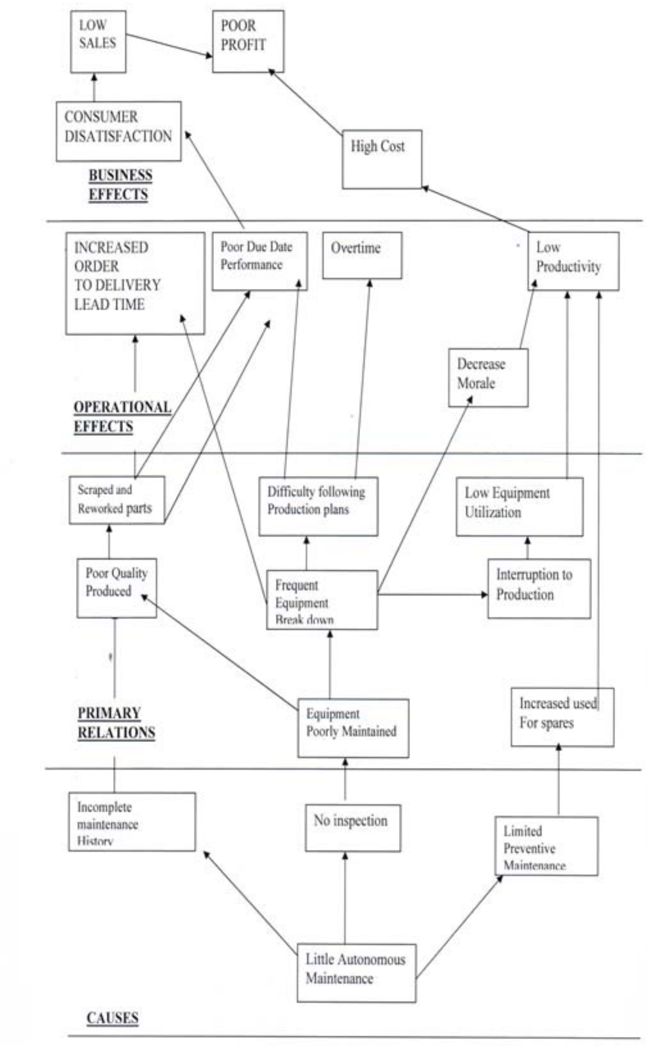

Fig. 1 Maintenance and company performance [1]

VI. CONCLUSION

It is important to note that the implementation groups are not mutually exclusive but have to interact. This is important especially on the implementation and reviewing of Autonomous Maintenance performance. The benefits achieved will form the basis of a Kaizen path (continuous improvement cycle).

The implementation of Autonomous Maintenance is usually done in tandem with an organisation structural change: the new proposed policy would have a deliberate bias towards Autonomous Maintenance to complete the Autonomous Maintenance implementation. The implementation of this policy is sure to improve performance efficiency and effectiveness. The centrality of Autonomous Maintenance and its overarching importance especially in increasing profitability, more than ever before in maintenance systems has clearly been brought out. From a learning standpoint, Autonomous Maintenance can provide benefits to organisations because:

1. Machines can run on, close to, the name plate capacity;
2. Breakdowns occur rarely;
3. Capital expenditure is reduced;
4. Products are produced to specification;
5. Cleanliness and pride improves the working environment.

This exercise was carried within one industry sector- the fertiliser industry, it would be interesting if implementation of autonomous maintenance's effect on availability and indeed profitability can also be studied across other industries.

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