Original Research Article

Total Productive Maintenance (TPM) as a business strategy in Manufacturing Small and Medium Enterprises in Nigeria

Abstract

The goal of this study is to provide insights into total productive maintenance implementation as a business strategy in a manufacturing SME in Nigeria that has had success in implementing it. A combination of a qualitative and quantitative investigation was used for this study, which comprises of literature review, questionnaire survey, comprehensive interviews, and direct observation. In order to achieve competitive advantage in the manufacturing sector, implementing TPM is an effective business strategy, thus this study reviewed Total Productive Maintenance (TPM) implementation as a business strategy in a manufacturing SME in Nigeria, and it was found that Total Productive Maintenance (TPM) not only improved overall equipment effectiveness (OEE) but also created a safe working environment enabling workers to achieve goals working as a team, thus increasing morale in the enterprise.

Keywords: Total Productive Maintenance (TPM), Manufacturing SMEs, Overall Equipment Effectiveness (OEE), Business Strategy, Competitive Advantage.

1.0 Introduction

To achieve competitive advantage in manufacturing sectors, Small and medium enterprises (hereinafter SMEs) are being forced to look inwards at various production functions and business processes. This is done to optimise manufacturing processes, eliminate equipment breakdowns and increase efficiency through economies of scale paying attention to quality and process improvements. According to Wang and Lee (2001), manufacturing systems often operate at less than full capacity potential equipment breakdown thus leading production wastes and losses. And as a result, productivity will be low, and the cost of producing goods and services will be high. To combat these losses, the concept of total productive maintenance (hereinafter TPM) is one of the several methodologies used to eliminate losses in a manufacturing process. This is further supported by Eti, et al. (2004). A study by Brah

and Chong (2004) further concluded that there is a positive correlation between implementing TPM and business performance thus necessitating the need for TPM to be an integrated effort of the entire manufacturing enterprise.

Total productive maintenance a methodology developed by the Japanese in 1971 is a philosophy based on productivity maintenance and innovative in approach ensuring that there is no equipment and production breakdown, optimizes equipment effectiveness, eliminates defects in a production system and promotes autonomous maintenance through the establishment of a thorough system of preventive maintenance for equipment life span. According to Singh, et al. (2013) the objective of every TPM implementation is to advance productivity and quality along with better employee self-esteem and job satisfaction, ensuring joint responsibility between supervisors, operators and maintenance workers, and not simply to keep machines running smoothly, but also to extend and optimize their performance overall.

Therefore TPM as a whole places emphasis on (Thomas, 2000):

- Maximizing overall equipment effectiveness.
- Establishing a planned system of Preventive Maintenance (PM) for the equipment's life span.
- Involving all employees from top management to shop floor workers.
- Empowering employees to initiate corrective activities.

TPM is successfully implemented through its unique eight pillar methodology as shown in figure one, paving the way for excellent planning, organising, monitoring and controlling manufacturing practices.

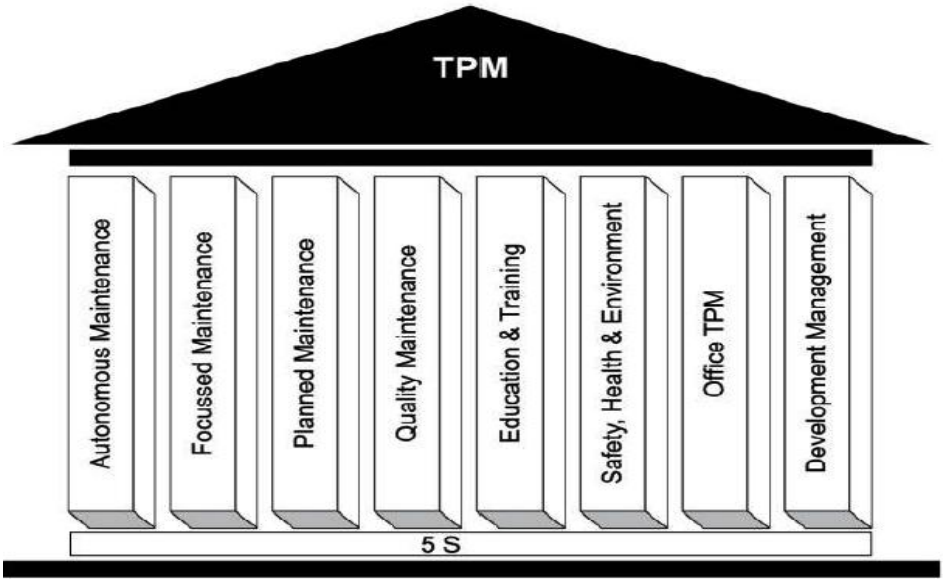

Figure 1: The eight pillars of Total Productive Maintenance (Ahuja I.P.S & Kumar, 2009)

Because it is the foundation on which TPM is built on, implementing TPM starts first with 5S. 5S according to (Amit Kumar Gupta & Garg, 2012) is a methodical process of housekeeping to achieve a peaceful environment in the workplace involving the employees with a commitment to implement and practice housekeeping sincerely. The philosophy starts with the cleaning and the arranging of the working environment and when implemented properly leads to a reduction of defective products, lead time, unhappy customers, disheartened workers, and dwindling returns.

Table 1 and 2 outlines the key activities for 5S and TPM implementation in a working environment

Japanese Term(English Term)	Characteristics
Seiri (Sort/Clear)	Sort out all unnecessary items from the Working environment and get rid of them
Seiton (Set in order/Configure)	Arrange all necessary items in good order so that they can be easily picked up for use
Seisio (Shine/Clean and check)	Clean the workplace completely to make it free from dust, dirt and untidiness
Seiketsu (Standardize/Conformity)	Maintain a high standard of housekeeping and workplace organisation
Shitsuke (Sustain/Custom and practice)	Train and motivate people to follow good housekeeping disciplines autonomously

Table 1: 5S activities

Pillars	Description
1. Autonomous maintenance	Targeted through towards developing operators that are able to take care of small maintenance tasks, thus freeing up the skilled maintenance people to spend time on more value-added activity and technical repairs.
2. Focused maintenance	Through which focused maintenance activities maximize the overall effectiveness of equipment and processes by the elimination of wastes/losses and continuous improvement.
3. Planned maintenance	Establishes and maintains optimal conditions through planned maintenance, achieved through daily, weekly and monthly assessments to monitor defects and implement improvement programmes.
4. Quality maintenance	Ensures customer satisfaction through zero defects by placing emphasis on eliminating non conformance cost.
5. Education & Training	Aims at upgrading the skills and morale of the operators and workers with the goal to create experts in the working environment.
6. Safety Health & Environment	Aims to create a safe working environment with the goal of achieving zero accidents etc.
7. Office TPM	Follows the first four pillars of TPM to improve productivity and efficiency of organizational activities through the automation of essential processes
8. Development Management	Aims to reduce overall the cost of maintenance in the working environment, reducing Mean Time to Repair (MTTR) and improving Mean Time Between Failure (MTBF)

Table 2: Description of the eight pillars of TPM

1.1 Small and Medium Enterprise (SME)

The term SME stands for small and medium enterprise; some countries have further extended the definition to be SMME, which stands for small, medium and micro enterprise (Monks P.G, 2010).

In Nigeria, the National Bureau of Statistics describes a small and medium enterprise as a separate and distinct entity including cooperative enterprises and non-governmental

organizations managed by one owner or more including its branches or subsidiaries. Table 3 illustrates this description

S/N	Size Category	Employment	Assets (=N= Million) (excl. land and buildings)
1	Micro enterprises	Less than 10	Less than 5
2	Small enterprises	10 to 49	5 to less than 50
3	Medium enterprises	50 to 199	50 to less than 500

Table 3: Definition of SMEs in Nigeria

Manufacturing SMEs play an essential function in global economies by creating employment and thus reducing poverty. This is further supported by the economic report by the Small and medium Enterprises development Agency of Nigeria (SMEDAN) and National Bureau of Statistics (NBS) for 2014, stating SMEs contribution to Gross Domestic Product in Nigeria in nominal terms stood at 55.55%, as seen in table 4

ACTIVITY	SECTOR	MICRO	SMALL	MEDIUM
Agriculture	86.53	6.53	3.95	97.01
Mining and quarrying	0.28	0.39	3.60	4.27
Manufacturing	**14.28**	**21.27**	**19.98**	**55.53**
Water supply, sewage, Waste management And Remediation	25.44	6.63	2.51	34.57
Construction	0.52	2.02	7.68	10.22
Trade	36.34	14.39	8.68	59.41
Accommodation And Food Services	4.23	27.98	13.68	45.90
Transportation and Storage	50.73	5.60	12.03	68.36
Information and Communication	0.00	2.38	9.57	11.95
Arts, Entertainment And Recreation	47.35	28.20	22.26	97.82
Finance and Insurance	1.05	1.39	3.69	6.13
Real Estate	31.00	13.25	11.29	55.55
Profession, Scientific and	13.25	2.08	5.28	20.61

Technical Services				
Administrative & Support Services	8.55	15.20	65.76	89.51
Education	2.09	14.69	24.48	41.26
Human health and Social Services	18.24	20.06	20.96	59.25
Other Services	80.76	17.01	2.23	100.00

Table 4: SMEs Contribution to National GDP, 2014 (Smedan, 2014)

According to Eti, et al. (2004), many industries in Nigeria function effectively for less than 50%. Part of the issues is usually caused by excessive downtime, supply failures for input resources, and low spare-capacity to cope with sudden high demands. Manufacturing SME's in Nigeria are not exempted from this issue and unfortunately, the idea of implementing TPM to effectively combat excessive downtime has not been adopted by a meaningful number of manufacturing SMEs. TPM as a tool for process improvement is a tool used to enhance productivity and efficiency, but Achanga, et al. (2006) reports that Manufacturing SMEs are not certain about the cost of implementing such tool hence have no idea about the tangible benefits obtainable. This puts Manufacturing SMEs in Nigeria in a precarious situation as they must be reactive to the current economic situation in order to stay in business and make profits.

On the other hand, most manufacturing SMEs in Nigeria lack access to adequate data necessary for decision making hence leading to disastrous decisions being taken by the owner/manager or the production manager Tom, et al. (2016). Thus this study aims to provide insights into total productive maintenance implementation as a business strategy in a manufacturing SME that has had success implementing it.

2.0 Materials and Methods

An empirical study was carried out in order to analyse and evaluate the effectiveness of implementing TPM in such manufacturing enterprises.

The study obtained historical maintenance records for 7 months prior to the implementation of TPM and carried out on the spot observation for a total of 4200 hours of machine time after TPM implementation this was done. Direct observation was carried out on the machine via method study in other find out the current efficiency, compare with the obtained data and to analyze the area associated with the problem which causes the low OEE.

It was conducted in an enterprise manufacturing foam mattress and began implementing TPM in 2013 as a result of the need to reduce downtime losses and production costs, and reactive maintenance cost that accounted for 23% of its manufacturing cost. This methodology was implemented in stages outlines as follows (See Table 5):

Stage 1 Introductory stage: in which the owner/manager and the production manager indicated the need to implement TPM. TPM targets and objectives were also identified (table 5).

Stage 2 Preparatory stage: Staff Training and the preparation of TPM implementation plan

Stage 3 Execution stage: Execution of TPM to improve efficiency, using the eight pillars of TPM.

Table 5: TPM Targets and Objectives (Manufacturing SME)

TPM Targets and Objectives (Manufacturing SME)	
Internal Targets	**External Targets**
Reduction in downtime losses and production cost	Increase in quality output
Eliminate reactive maintenance	Meeting customer demands Just-in-time
Target Goal	
To achieve zero downtime losses through preventive maintenance	
Target Objectives	
1. Reduce equipment and power failure	
2. Eliminate or reduce waiting time for instructions and materials	
3. Maximise effective utilization of resources	
4. Development staffs skill through skills acquisition and training	
5. Improve competitiveness, quality, performance and cost.	
6. Increase the reaction time to customer needs Just-in-time	

3.0 Results

Overall equipment effectiveness (OEE) takes into account, the availability rate, quality rate and performance rate and is represented as:

$$\text{OEE} = \text{Availability x Performance Rate x Quality Rate} \quad (1)$$

Where availability accounts for losses as a result of equipment failure, setup and adjustment and is calculated as the ratio of operating time to loading time and is calculated as follows:

$$\text{Availability} = \frac{\text{Plannedruntime} - \text{Planneddowntime}}{\text{Plannedruntime}} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

And performance rate accounting for losses due to idle time and minor stoppages and is calculated as ratio of net operating time to operating time and is calculated as follows:

$$\text{Performance rate} = \frac{\text{Total Actual amount of product}}{\text{Target amount of product}} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Quality rate factors in the defects in process and reduced yield and is defined as ratio of valuable operating time to net operating time and is calculated as follows:

$$\text{Quality rate} = \frac{\text{Processed Quantity} - \text{defective quantity}}{\text{Processed quantity}} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

In summary, the generally accepted world-class goals for each factor used to compare to the overall equipment effectiveness (OEE) of a firm is shown in Table 6.

Table 6: World class goals for OEE (Kailas, 2009)

OEE Factor	**WORLD CLASS RATE (%)**
Availability	>90.0%
Performance Rate	>95%
Quality Rate	>99%
OEE	85%

The manufacturing process for the production of a foam mattress in company A was observed and can be broken down into the following process below in figure one

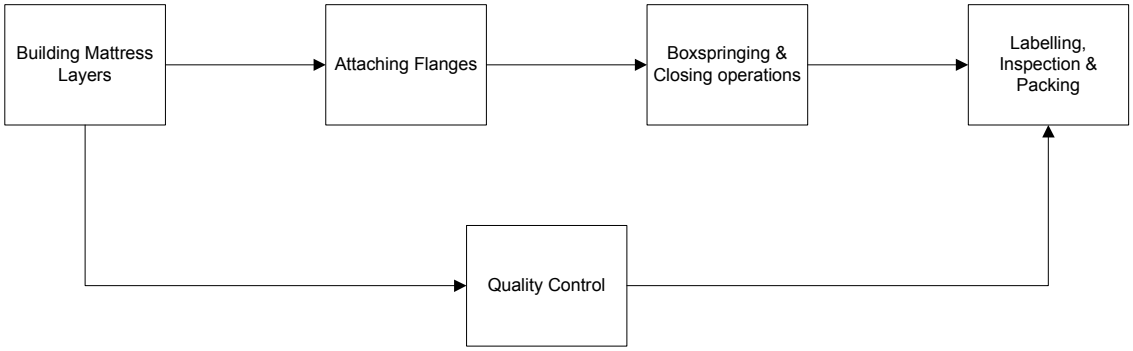

Figure 1: Manufacturing process foam mattress

Table 7: Summary of OEE measurements before TPM Implementation

No of Observations	Availability (%)	Performance (%)	Quality (%)	OEE (%)
1	76.9	91.7	95.5	67.3
2	77.0	92.0	96.8	68.5
3	77.5	92.2	95.0	67.8
4	77.4	91.8	95.1	67.5
5	76.9	91.6	94.9	66.8
6	75.9	92.0	96.3	67.2
7	77.0	92.0	96.2	68.1

From the table three, it was observed that the availability figures were found to be comparatively lower than the world average standard for availability (see fig 2). In order to identify the causes behind these findings, detailed downtime analysis was carried out.

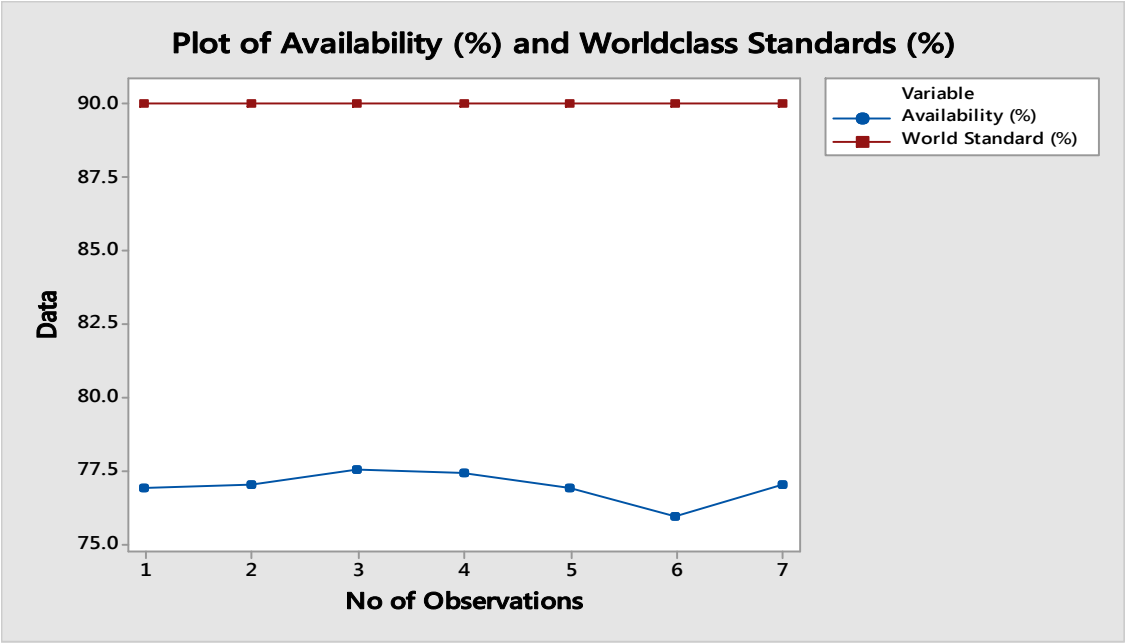

Fig 2: Measured availability in comparison with world standards

From data collected during the interviews and direct observation of the manufacturing process, factors causing the downtime losses before TPM implementation were identified and a Pareto analysis of the downtime losses showed that equipment breakdown was the major cause. Pareto analysis helps in identifying the factors that are majorly responsible for production system failure (see Table 7 and Figure 3).

Table 7: Downtime losses

Downtime factor	Downtime factor(Mins)	Percentage	Cumulative Percentage
Equipment failure	**300**	**46.15**	**46.15**
Power Failure	150	23.07	69.22
Scheduled Maintenance	100	15.38	84.6
Waiting for materials and instructions	40	6.15	90.75
Job meetings and training	40	6.15	96.9

Others	20	3.07	100

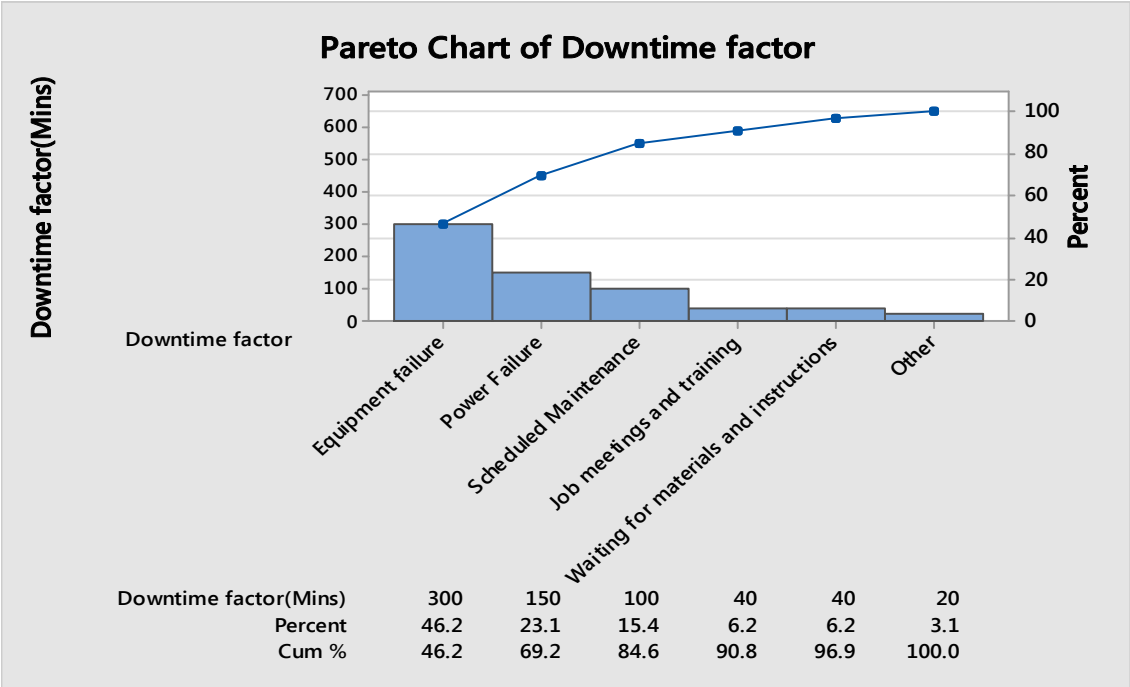

Figure 3: Downtime analysis Pareto chart

4.0 Discussion

With the major cause of downtime indentified, and by implementing TPM, a systematic form of planned preventive maintenance was put in place that establishes and maintains optimal conditions through routine maintenance of equipments thus ensuring that downtime losses was reduced.

Table 8: TPM effectiveness analysis and benchmarks

S/No	Category	Before TPM Implementation	After TPM Implementation
1	Total Time	4200	4200
2	Downtime	650	600
3	Planned Runtime	3550	3550
4	Runtime losses	820	570
5	Operating time	2730	2980
6	Total Units produced	200	233
7	Production rate(Units/min)	0.80	0.80

8	Target Unit	218	238
9	Defected units	9	3
10	Availability (A)	76.9%	83.9%
11	Performance rate (P)	91.7%	97.8%
12	Quality rate (Q)	95.5%	98.7%
13	QEE	67.41%	80.98%

From table eight, it can be seen that after TPM was implemented, overall equipment effectiveness (OEE) improved tremendously as seen in figure 4, thus proving to be very effective business strategy for improving competitive advantage and customer satisfaction for the end user.

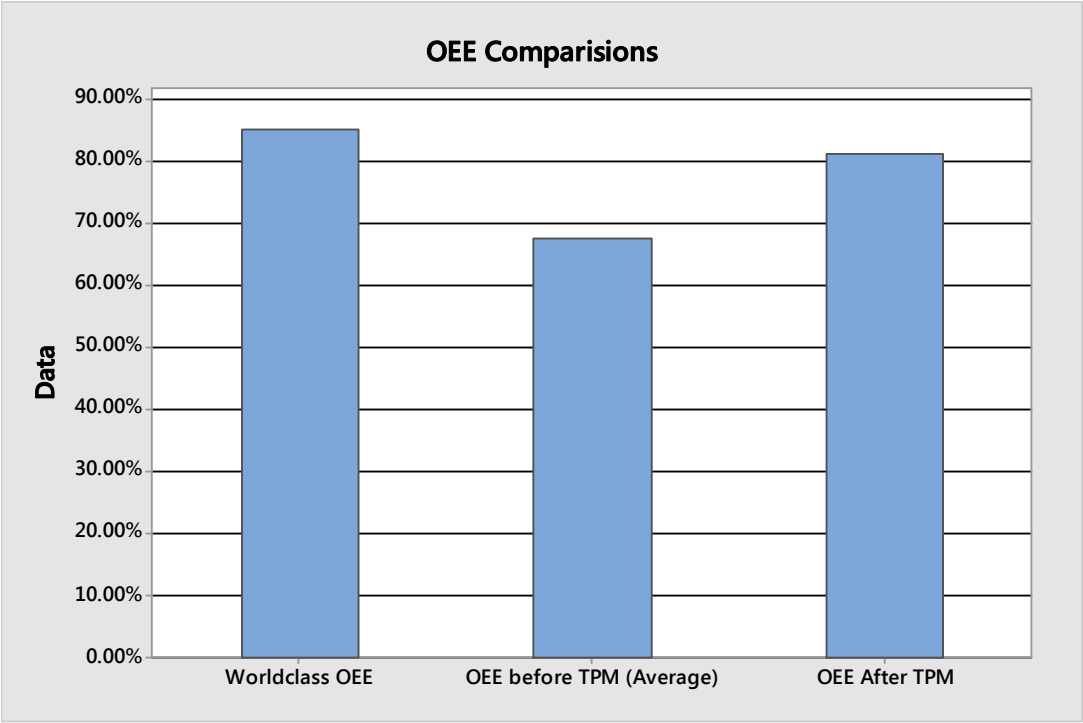

Figure 4: OEE Comparisons

Implementing TPM at the manufacturing enterprise also enable the enterprise to reduce the need for reactive maintenance hence achieving reduced manufacturing cost, reduced customer complaints and improved its product sales. This is very important as it is necessary for manufacturing firms to achieve full productive capacity. Indirectly, implementing TPM created a safe working environment enabling workers to achieve goals working as a team, thus increasing morale in the enterprise.

It was also observed from the survey that implementing TPM wasn't easy initially due to the need to training staffs to acquire TPM skills thereby increasing manpower cost and the

amount of time required in doing so, thus requiring long-term planning. This is further supported by Marcelo Rodrigues and Hatakeyama (2006) and Bamber, et al. (1999), In which they stated that in order to combat these factors that contribute to the failure of TPM implementation in manufacturing SMEs, it is necessary to maintain the synergy and willingness of the staffs and the owner/manager involved in order to make TPM implementation continuous and successful.

5.0 Conclusion

In order to achieve competitive advantage in the manufacturing sector, implementing TPM is the key. It has been proven to be efficient and effective in improving performance efficiency and quality thus improving revenue from product sales.

Therefore the following can be adopted from this study:

- Implementing TPM can enable a manufacturing SME to reduce production losses and achieve competitive advantage.
- An appropriate TPM implementation plan has to be in place considering the manufacturing SME's values, beliefs and mission.

The study also found that TPM not only improves overall equipment effectiveness (OEE) but also created a safe working environment enabling workers to achieve goals working as a team, thus increasing morale in the enterprise, hence making it a tool to improve workers productivity.

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