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World Class Manufacturing status Assessment for a Margarine Producing Company in Zimbabwe

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Abstract- The world has become global in the way goods and services are produced and marketed. The stiff global competition faced by these companies necessitates a need to embark on radical strategies in the form of World Class manufacturing philosophies to survive, make profit and remain competitive. While companies in developing countries strive to adopt these World Class Manufacturing (WCM) philosophies into their production process, there is often lack of a measure on their progress towards world class manufacturing status besides the improvement in productivity. This paper's focus is on how companies can assess their progress in terms of achieving a world class manufacturing status. The research starts with an assessment of the world class status of the company that has adopted best manufacturing practices. A Current State Radar Chart (CSRC) is drawn to see the company's position on the radar. Researches methods (questionnaires, interviews, company audit) are used to identify wastes according to WCM. WCM techniques were used to minimise wastes. A Future State Radar Chart (FSRC) is drawn to assess the improvements made. The company was operating its margarine production process at 35% of a world class process. The major waste identified was the downtime. Downtime contributed to 74% of the total available time leaving production only 26% of the available time. WCM techniques realised a reduction in downtime by 30% and increased the available time for production to 56%. These changes achieved a 56% of a world class process on the FRC drawn.

Index Terms—Lean manufacturing, Margarine Production, World Class Manufacturing.

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I. INTRODUCTION

World Class Manufacturing is a status that many organisations strive to attain. This will help any such organization gain global competitiveness. It however becomes difficult for many organizations due to waste in their operations. Waste in product manufacture is costly to companies and thus requires minimisation if not elimination [1]. If wastes are not minimised or eliminated, a company may risk missing the major strategic goal of profit making. Companies fail to operate profitably due to inefficiencies of their production processes.

The law of conservation of mass states that the amount of raw materials that we put in a production process should be equal to the output [2]. The gap between the inputs and outputs will determine the company's ability to achieve satisfactory profitability. Some companies would not bother reduce this gap but rather simply increase prices of their products. Days for such operations are numbered due to the globalization phenomenon. Companies must strive to reduce the gap between their inputs and outputs. World Class Manufacturing (WCM) tools such as Lean manufacturing and Six Sigma among others help to reduce this gap. Their thrust is to eliminate or reduce waste in processes.

This paper is an assessment of a margarine producing company to establish its WCM status after having implemented some improvement philosophies such as Lean Six Sigma [1]. The aim is to establish the level of the company's competitiveness against major principles of WCM. The researchers used radar charts to indicate the leanness of the process and the potential areas of improvement.

II. RELATED LITERATURE

A. *MARGARINE PRODUCTION*

Margarine is a blend of around 80% hydrogenated vegetable oil or animal fat, and 20% water mixed with emulsifiers, salt, flavourings, colour, and preservatives [3]. In many countries proportions are controlled by legislation. The production process of margarine varies according to ingredients used and product formula. The company has 22.5 working hours per day and operates on a full calendar month. There are 5 production lines for margarine at DX industries. Therefore the available time for production is 3375 hours on average per month. Of the 3375hours available the bulk is consumed by downtime with actual production taking place in 875hours a month on average. The flow-line for margarine production at the case study company is shown in Fig. 1 [4].

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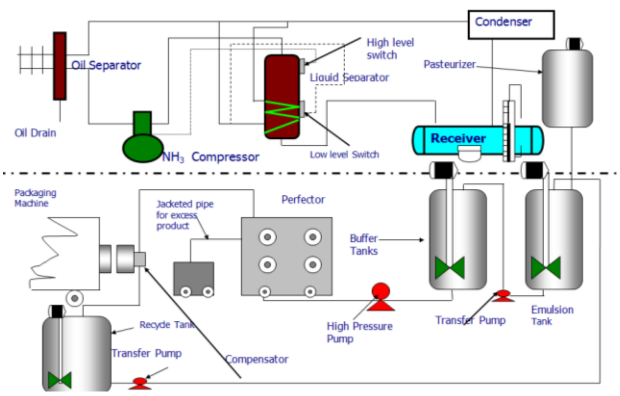

Figure 1: Margarine production process at a Company X in Zimbabwe [4]

The vegetable oil used in the manufacture of margarine is modified to harden it. There are three ways to modify oils and these are hydrogenation, rearrangement or fractionation. The hardened oil is then blended with ingredients such as vitamins, colours, flavours and emulsifiers. At the same time a mixture of water, brine and powdered ingredients is created. These two ingredient mixtures are blended together at temperatures around 50 - 60ºC while being slightly mixed. This mixture or emulsion needs to be pasteurised at temperatures around 70 to 86ºC. Pasteurisation can be defined as the partial sterilization of food, at a temperature that destroys harmful micro-organisms, without major changes in the chemistry of the food [5]. Figure 2 shows the graph of pasteurisation at the case study company.

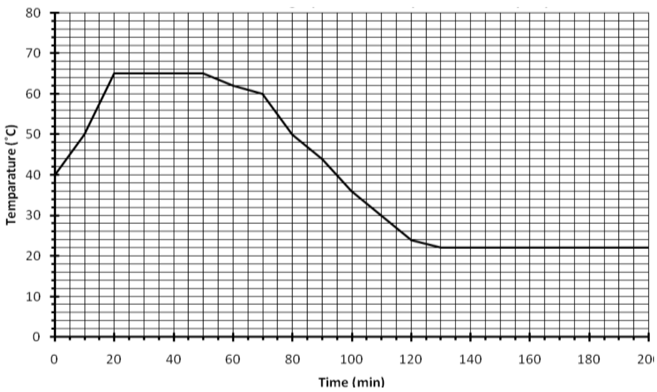

Figure 2: Pasteurisation Graph for water phase DX industries

The next process is chilling and crystallisation where the mixture is now chilled to solidify it. During the chilling process, the product is worked in a cylindrical chamber with a series of pins, which kneads the spread at a fixed speed. After the chilling process, the product can be packed. The packed product must exhibit a firmer texture than a filled product and if this texture is not optimal the product will be diverted to the re-melting system, melted and added to the buffer tank for reprocessing. The margarine is then stored, transported to distribution where it needs to be stored at temperatures between 2 and 5ºC [6].

B. WORLD CLASS MANUFACTURING

The key to the success in implementing WCM is hinged on the organisation's ability to focus on the following activities: reduced lead time, speed time to market, cutting of operations costs, exceeding customer expectations, manage the global enterprise, streamline outsourcing processes and improvement of business performance visibility [7]. The drive by companies to adopt WCM comes naturally from both inside the organisation and outside. The strongest driver from outside is the increase in the level of competition in the global markets. It is also driven by consumer's dynamic tastes for the products which are never ending. Technological changes drive organisations to change their processes, communication and strategy. Internal drivers are the need to change in the organisational strategies and the need to save the costs [8]. The desired goal for implementing WCM is to improve business growth and attain global competitiveness [9].

It was identified that WCM is a management system that focuses on reducing or eliminating losses. The model is based on ten pillars which are methodologies structured to solve different kinds of losses in an organisation. The implementation of world class can be achieved by opening each of the pillars of world class manufacturing strategy which are [10; 7]:

- Health & safety: the goal is to have zero accidents.
- Cost deployment (CD): is done to identify major losses and actions are taken to solve them.
- Focused improvement (FI): application of problem solving methods to manufacturing problems.
- Autonomous Maintenance (AM): It requires machine operators and maintenance team to able to detect problems and to engage shop floor people in keeping the machines working.
- Professional Maintenance(PM): maintenance technician should focus on making the machine reliable and to eliminate any root causes of machine problems
- People Deployment (PD): to ensure that employees have the skills that are needed to perform their duties currently and in the future.
- Early equipment management (EEM): planning and preparing equipment investments, guaranteeing an efficient start up, safe and reliable operation, easy to maintain and run machine.
- Product quality(PQ): making the system stable and improving the processes so that the product produced is of consistent quality
- Customer service (CS): WCM companies aspire to be suppliers of choice by delivering first class service to customers.
- Environmental and corporate social responsibility (ECSR): products are produced in safe way to the environment and community

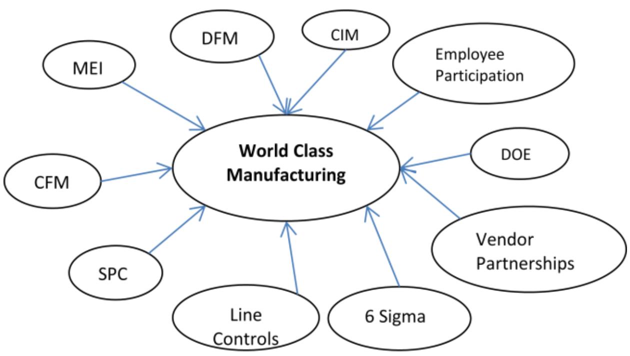

Fig. 1. A conceptual frame work of world class manufacturing strategy [11]

IBM developed a conceptual framework of how their products are designed and manufactured globally [11]. This can be adopted as assessment framework for companies that have adopted world class manufacturing.

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The core idea of lean manufacturing is to maximise customer value while minimising wastes. In lean manufacturing wastes are any activities that do not add value to the product or service [12]. The most identified sources of wastes are overproduction, waiting, transportation, over-processing, inventory, defects and motion. Most scholars focus on the seven wastes mentioned above, but an eighth one has been discovered in the form of under -utilising resources [13]. The waste of under-utilising resources also includes not using human resources to the best of their unique abilities. A ninth waste has also been discovered in the form of knowledge disconnection, which can be defined as lack of correct information where it is needed.

Fig. 3 shows the wastes classification in terms of lean manufacturing [13]. Lean Manufacturing is the extensive analysis of processes with the aim of waste-free production system through identifying Non-Value Adding activities and subsequently reducing them [13]. The founding principles of lean manufacturing are the 5s and value stream mapping. The Association for Manufacturing Excellence (AME) developed a lean assessment tool in form of a radar chart to enable companies to identify ways of becoming lean [14].

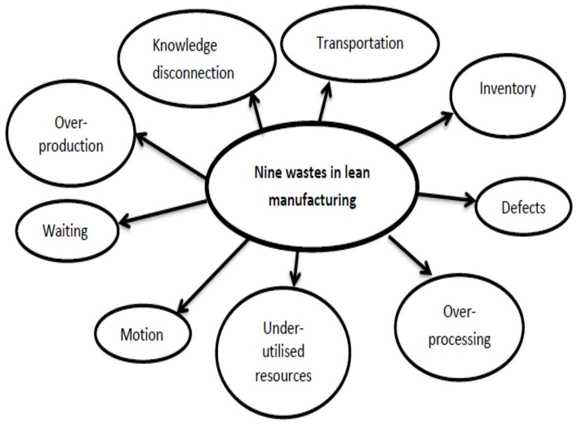

Figure 3: Nine wastes in lean manufacturing [15]

The first step is to recognise what does and does not create value from the customer's perspective [16]. Any material, process or feature which is not required for creating value from the customer's perspective is waste and should be eliminated. Table 1 shows the different approaches of lean manufacturing and traditional manufacturing [17].

Table1:Key implications of lean manufacturing [17]

	Traditional batch production	**Lean manufacturing**
Orientation	Supply driven	Customer driven
Planning	Orders are pushed through factory based on production plan/forecast.	Orders are pulled through factory based on customer or downstream.
Batch size	Large	Small
Quality inspection	Checking of samples by quality control inspectors.	In-line inspections by workers.
Inventory	Buffer of work-in-progress between each production stage.	Little or no work-in-progress between each production stage.
Hand off of work-in-progress	Materials after each stage accumulate into work-in-progress storage areas before being retrieved by next production stage.	Materials handed off directly from one production stage to the next.
Production cycle time	Total production cycle takes significantly longer than actual time spent processing the materials.	Total production cycle shortens to approach time spent on processing materials.

C. 5S IN LEAN MANUFACTURING

Most companies implementing lean manufacturing frequently select Five S as a method to start their lean manufacturing program. Five S is a manageable process that is relatively easy for people to understand [18]. The S stands for Sort; Set in order; Sweep; Standardisation; and Sustain. At times a sixth S for Safety is considered. With cleanliness in the work area, problems can easily be identified. That is why it is so crucial for the team to be empowered to improve and maintain their workplace [19]. When employees take pride in their work and workplace it can lead to greater job satisfaction and higher productivity.

Margarine Production requires high hygiene such that DX industries perform scheduled wash-downs twice a week. The process of cleaning takes almost 8 hours per line. Efficient cleaning and disinfection equipment has been developed. The cleaning system is known as Clean-in-Place (CIP) system [20]. CIP is a part of the modern margarine production facility that prevents bacteria growth and assures sanitary equipment conditions [20]. CIP involves recirculation of the liquids through the assembled food processing equipment in a continuous circuit with a rinse and detergent solutions at proper concentrations, temperature, pressure and time. This process takes between 20 to 30 minutes and removes organic matter.

D. VALUE STREAM MAPPING (VSM)

Value Stream Mapping (VSM) is a lean manufacturing technique used to analyse and design the flow of materials and information required to bring a product or service to a consumer. It is a set of methods to visually display the flow of materials and information through the production process. The objective is to identify value-adding activities and non-value-adding activities [16]. Value Stream Mapping is often used in process cycle-time improvement projects since it demonstrates exactly how a process operates with detailed timing of step-by-step activities. It is also used for process analysis and improvement by identifying and eliminating time spent on non-value-added activities. Previous studies have shown process cycle improvements of upto 86% for the margarine plant [1]. Research at the Lean Enterprise Research Centre (LERC) in the United Kingdom indicated that for a typical processing company the ratios of activities could be broken down as shown in Table 2 [19].

Table 2: Typical ratio of activities in a processing company [19]

Activity	% contribution
Value added activity	5%
Non value added activity	65%
Necessary non value added activity	35%
TOTAL ACTIVITIES	100%

This is a clear indication that up to 60% non-value adding activities at any manufacturing company can potentially be reduced greatly.

III. METHODOLOGY

The WCM status assessment was done using a combination of the Lean Assessment tool developed by the Association for Manufacturing Excellence (AME) and radar charting. The company's current position on the world class radar chart in terms of leanness was established. The assessment was done before any changes to the margarine production process and after employing WCM techniques [14]. The AME lean assessment tool has a series of questions that carry scores from 1 to 10, 10 indicates a world class position regarding the question and a 1 is the least score. Questionnaires, interviews and company audit were done to allocate the scores for the radar.

IV. RESULTS

A. *Current State Radar Map*

Fig. 4 below is the Current State Radar Chart (CSRC) of the margarine producing company. It shows the company's benchmark position on the world class radar in terms of lean manufacturing. The company has already applied lean six sigma techniques for sustainable production [1].

There are 29-points on the radar chart with each point carrying a maximum score of 10. Summation of all the points for DX industries indicates that the company is only at 35% of a world class lean status. Therefore DX industries have to gain 65% points to be called a world class company in terms of lean manufacturing.

DX industries has however gained some ground on the general lean thinking in the following areas; search for Non-value adding activities; six sigma; root cause analysis as discussed by reference [1]. The company managed to improve productivity by reducing the non-value adding activities from 61% to 6% of the total production cycle [1].

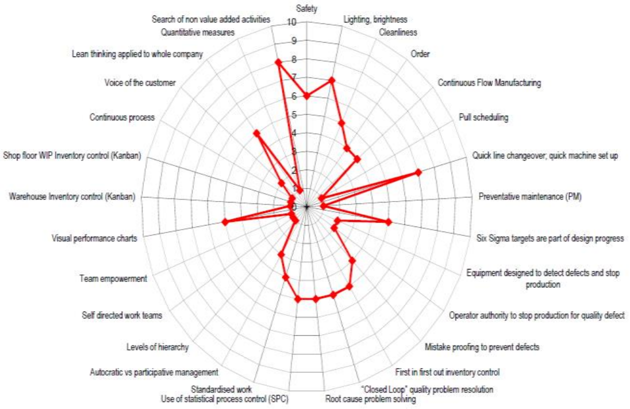

Figure 4: Current State Radar Chart (CSRC) using a 29 point lean assessment tool

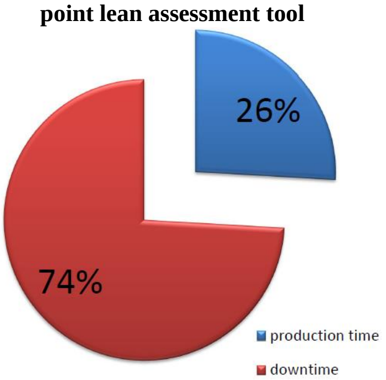

Figure 5: Production time-downtime ratio

Fig. 5 above shows production- downtime ratio before implementation of WCM techniques [1]. Wastes are contributing to 74% of the available time and only 24 % is being utilised for production.

The researchers detected seven wastes (motion, overproduction, inventory, waiting time, knowledge disconnection, defects, and transportation) that constituted 74% of available time at DX industries as shown in Table 3.

Table 3: Waste Categorisation at DX Industries

TYPE OF WASTES	AVERAGE DOWNTIME (HOURS)	% CONTRIBUTION
Waiting	1211.30	48.5%
Inventory (stock-outs)	711.80	28.5%
Defects	289.70	11.6%
Overproduction	169.80	6.8%
Transportation	87.40	3.5%
Knowledge disconnection	17.50	0.7%
Motion	10.0	0.4%
Total	**2497.50**	**100.0%**

Fig. 6 below shows a Pareto Analysis of the waste in production. It shows that waiting and inventory wastes contributed 80% of the total production down time.

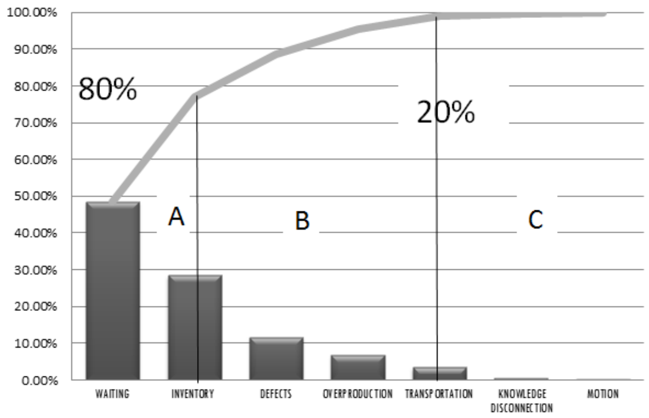

Figure 6: Pareto analyses of percentage contributions of the wastes

Table 4: Average individual waiting time wastes

WAITING TIME WASTE	HOURS	WAITING TIME WASTE	HOURS
Scheduled wash down	390.3	Machine jam	9.4
HP pump breakdown	92.9	Wrapper mark off position	9.1
Machine test run	61.5	HP pump tripped	8.6
Waiting for emulsion	54.68	Comp breakdown	6.5
Set \start up	54.38	Machine grippers and rollers breakdown	6.4
Machine cups and chain pushers defective	52.3	Fat transfer pipeline blocked	5.75
General cleaning	42.3	Feed churn leaking	5.5
Perfector breakdown	40.1	Wrapper change	4.74
Chemetator shaft breakdown	36.8	Waiting for test results	4.5

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new product trial	32.7	Product change	4.32
No water treatment chemical	30.5	Heating\Cooling emulsion	4.31
water pipe leaking	28.3	Equipment swabs	4.16
New Machine setup	22.5	Resting tube bolt worn out	4.0
HP pump connected to another line	21.2	Shoe breakdown	4.0
No ready milk solution	19.07	Machine drum defective	3.5
Cleaning tubs	18.75	Compressor cut out	3
Chemetator motor breakdown	15.7	Inch button not working	2.7
No vacuum	14.5	Ammonia leaking	2.55
Inter-worker breakdown	14.5	Draining water	2.14
Machine blade defective	13.2	Adjusting nitrogen gas	1.76
Mixer breakdown	11.0	Wrapper fold	1.72
Water sand filter breakdown	11.0	Nitrogen gauge valve leaking	1.5
Compressor loading	10.97	Wire cutter broken	1.3
Switchboard failure	10.3	Defective wrapping system	0.3
Perfector not starting	10.05	Machine Lubrication	0.25

Fig. 7 below shows the Pareto analysis for the waiting time waste, to determine the most contributing waste to waiting time.

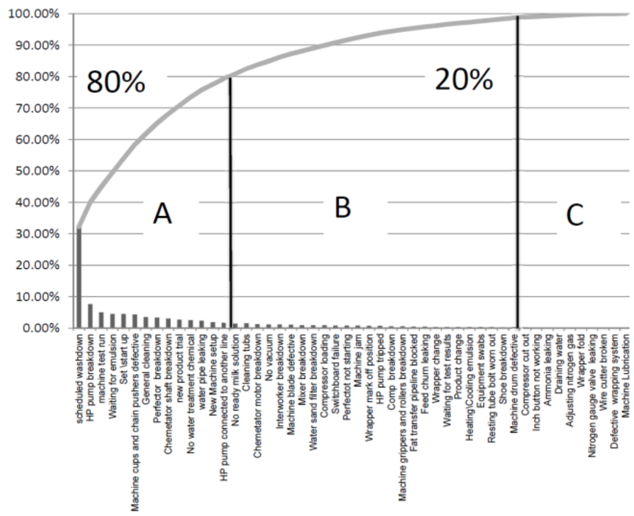

Figure 7: Pareto analysis for waiting time

From the Pareto Chart Figure 7, the most contributing waiting time is due to scheduled wash-downs. Manual cleaning reduces the plant availability by 390.3 hours a month. A single cleaning schedule takes 8 hours per line. An improvement will mean that the downtime due to scheduled cleaning will be reduced from 390.3 hours to 56.7 hours per month. An increase in plant availability of 10% will be realised.

The other physical components that are in category A should have high priority since they contribute to the 80% of the downtime.

Inventory wastes contributing to downtime in figure 4 are due to stock-outs. The identified recurring stock-outs are shown in table 5 and the corresponding Pareto chart is shown in figure 8.

Table 5: Inventory wastes contribution

Inventory wastes (stock-outs)	Hours	% contribution
No packaging reels	412.30	56.9%
No Blend	125.36	17.3%
No steam	115.94	16.0%
No water	66.66	9.2%
No electricity	2.90	0.4%
No pressure	1.44	0.2%
Total	**724.60**	**100%**

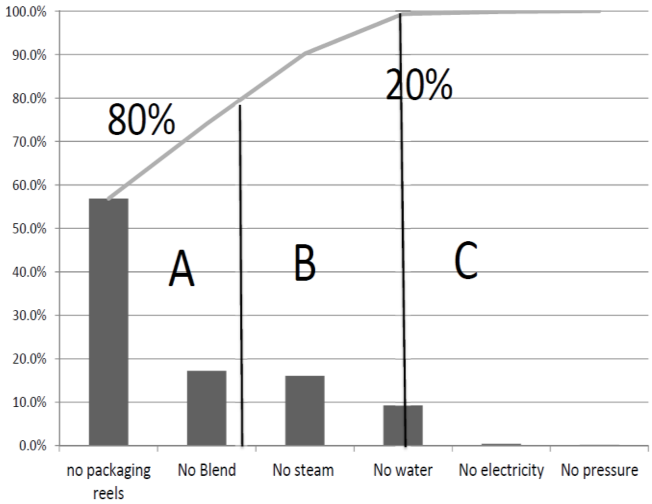

Figure 8: Pareto analysis for inventory (stock-outs) waste

Figure 8 shows the inputs to the margarine production process that contribute to downtime in their absence. Packaging reels contribute to 56.9% of the inventory downtime and is classified under category A in the Pareto chart. A proper material requirements planning was done and eliminated these problems by 75%. This translates to an increase in plant availability by 16% or 543.45 hours.

B. Future State Radar Map

A Future State Radar Map was developed from suggested improvements from the initial assessment. The results are shown in Fig. 9 below.

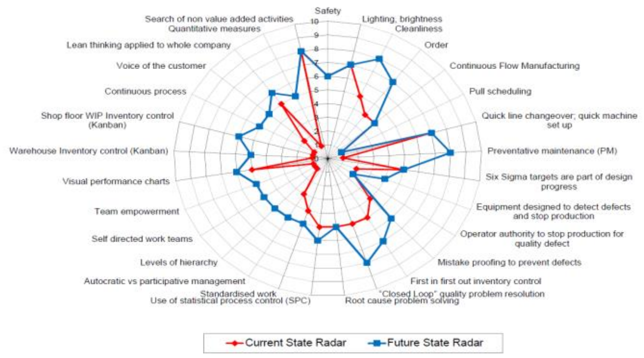

Figure 9: Current State Radar Chart (CSRC) and Future State Radar Chart (FSRC) comparison using a 29 point lean assessment tool

The Radar Chart in Fig. 9 shows that DX industries gained some points by embarking on preventive maintenance and material requirements planning. The overall gain for the company is 60 points to 162 points.

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The 60 points gained translates to 21 % gain to world class lean status.

The Future State Radar Map indicates that the company is at 56% of a world class lean company. Previously the company was at 35% of a world class lean company. It should be noted that the company is not yet a world class lean company. There are opportunities for improvement to gain 128 points that translates to 44%.

Downtime was reduced by 30% and this means an increase in plant availability by 1012.5 hours. A comparison of the Current State and Future State Production – Downtime Ratios is shown in Fig. 10 and Fig.11.

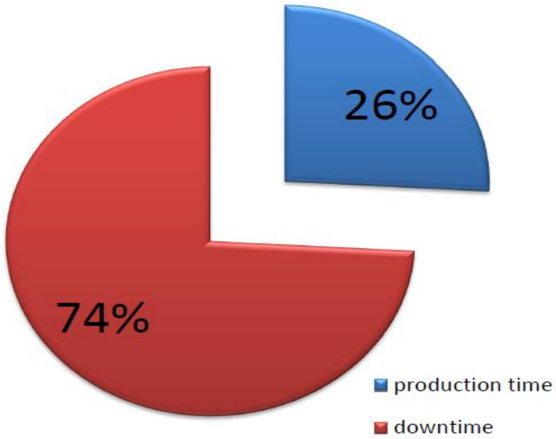

Figure10: Current state production time-downtime ratio

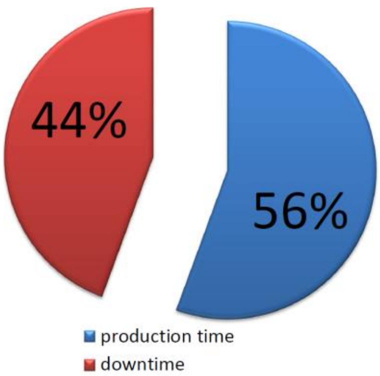

Figure 11: Future state production time-downtime ratio

Plant availability was improved from 26% of the available time to 56% of the total available time by cleaning wastes as defined by lean manufacturing.

V. CONCLUSION

An World Class Manufacturing status assessment for DX Industries was done. This was on the basis that the organization had implemented some WCM techniques such as Lean Six Sigma to improve their world class status. Radar charts were developed to compare the Current State to the Future State against best practices. The organization was operating at 35% world class status. It was established that DX Industries did not achieve world class status but moved 56% of world class status.

Lean techniques were used to identify wastes on the margarine process. Plant availability was the major waste identified as the plant was operating at 26% of the total available hours. The wastes were reduced using lean principles and the company's available time for production improved by 30% to 56%.

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