International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-1 Issue-5, October 2012

Lean Six Sigma Application for Sustainable Production: A Case Study for Margarine Production in Zimbabwe

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Abstract: ***Lean Six Sigma is an integration of two World Class Manufacturing improvement philosophies(Lean Manufacturing and Six Sigma) that help organizations improve their performance and competitiveness. The principles are applied to margarine manufacturing. The Value Stream Mapping tool is used to map the processes and the Six Sigma's Define, Measure, Analyze, Improve and Control (DMAIC) methodology applied to attain improvements. The Current State Map (CSM) is drawn and using the DMAIC methodology, the Future State Map (FSM) is drawn. The production line ultimately achieves improvements in cycle times and in Value Added time ratio from 39% to 94%. There are envisaged improvements of up to 86% on cycle times for individual processes.***

Keywords: Lean Six Sigma, Process Variance, Margarine Production, World Class Manufacturing

I. Introduction

Waste in product manufacture is costly to the company and thus requires minimization if not elimination. Lean Six-Sigma strategies can help achieve the minimization of waste while improving productivity and profitability. Waste is defined as any activity which does not add value to the end product with respect to the customer's perspective [1]. It includes anything other than the minimum amount of equipment, materials, parts, space and time [2]. The thrust is to reduce costs incurred during the manufacturing process by ensuring that products are produced in the required amounts. This then reduces warehouse utilities, labor, time and storage. Many attempts to reduce waste have been done but with differing results of success.

This paper is a Case Study of a company that implemented improvement initiatives based on Lean Six-Sigma principles. Process-Variance is studied using the Six Sigma principle that is integrated with the lean manufacturing philosophy. The aim was to attain process improvement in margarine manufacture. It was achieved by identifying and eliminating waste in processes and concurrently determining process variation which paved way for continuous improvement. The Lean Six-Sigma approach was utilized as it seeks to optimize flow by using empirical methods to decide what matters, rather than uncritically accepting pre-existing ideas [3].
Manufacturing environments vary from company to company and this necessitates differences in their purpose, design and control. As such, there is no single set of management procedures that can be universally adopted to govern them [4]. Certain lean techniques are more compatible with certain facility layouts than others. It is thus a major limitation and hence thorough research and simulation is required. However, lean production provides us with a starting point for viewing a company's operating practices with the final goal of seeking operational improvement.

Revised Manuscript Received on 30 October 2012
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II. Related Literature

Six Sigma (LSS) is a World Class Manufacturing technique that integrates Lean Manufacturing principles and Six Sigma philosophy into a single approach to solving problems in industrial activities [5]. It is about relentless, sustained improvement that takes the implementers through analysis, metrics and improvement projects. The integration of the two philosophies thus produces a situation where, "*Lean causes products to move through processes faster, and Six Sigma improves Quality"*. There is however a major overlap of both philosophies on Quality [6].

Lean is thought of as a cost-reduction measure [7; 8], which is aimed at the elimination of waste in every area of production and beyond [9]. Lean Manufacturing is the extensive analysis of processes with the aim of waste-free production system through identifying Non-Value Adding activities and subsequently eliminating them.

Six Sigma is a philosophical though scientific tool for cost reduction through reducing variability in processes [10]. Reference [11] notes that the evolution of six sigma over time came up with a philosophy that helps in designing, improving and monitoring business processes. The target for all these improvements would be to move towards "zero defects" as depicted by the 3.4 Defects Per Million Opportunities (DPMO). While there is this statistical dimension, other authors depict Six Sigma as a fad [10] and all the efforts mentioned here lead to Continuous Improvement efforts [12].

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Six Sigma is thus thought to be a Vision, Philosophy, Symbol, Metric, a Goal and/or a Methodology [10]. Reference [10] studied the evolution of Lean Six Sigma in order to establish its originality. He compared it with the older concepts of Just in Time (JIT) and Total Quality Management (TQM). He concludes that Lean Six Sigma concepts have mainly replaced but not necessarily added to the concepts of JIT and TQM. Reference [13] argues that improvement approaches are steps along the way in business evolution. *"Each approach builds on previous approaches adopting the effective aspects while removing or improving on the identified limitations".*

Reference [14] also studied the evolution of Lean Six Sigma and notes that the approaches to improvement complement each other. They conclude that the "*business improvement philosophy of lean thinking and the more scientific improvement paradigm of six sigma have experienced success in a wide ranging spectrum of industries".* Key business processes may be disjointed but using an improvement initiative such as the Lean Six Sigma ensures that a holistic approach is followed [13].

An opportunity for using Lean Six Sigma principles for organizations in Zimbabwe was identified and the approach developed [15]. Ever since then, the Zimbabwean manufacturing sector has declined due to economic challenges that prevented successful implementation of improvement strategies. The Value Stream Mapping tool was successfully applied to improve operations for a Bread Manufacturing plant in Zimbabwe [16].

III. METHODOLOGY

The Value Stream Mapping (VSM) tool was used on a margarine production line to develop the Current State Map (CSM). The CSM was analysed using the Six Sigma's Define, Measure, Analyse, Improve and Control (DMAIC) Improvement methodology [5]. The Future State Map (FSM) was developed after incorporating improvement derived from application of Lean Manufacturing principles. It is important to note that during application of lean principles, many have fallen into the trap of thinking that mapping the value stream is lean [14]. VSM will be used together with other The Six Sigma DMAIC process to avoid falling into the same trap.

A. *Six Sigma's DMAIC*

1) *Define*

DX Industries is one of the companies in Zimbabwe that is faced with productivity problems that hinder attainment of targeted Key Performance Indicators. Figure 1 below shows the trend of productivity measures for one production line during the periods 2008-2009.

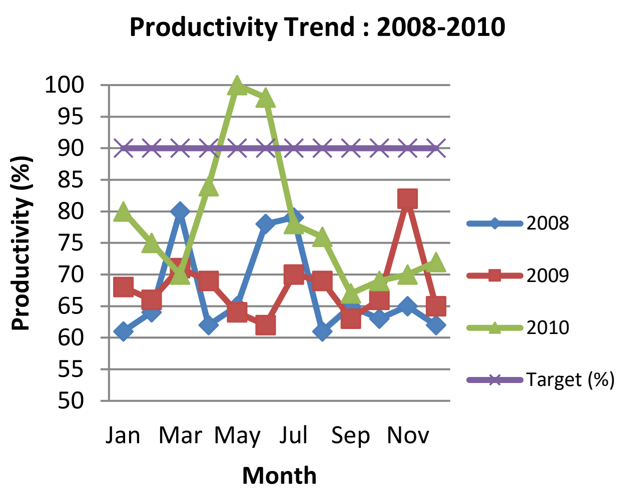

Figure 1: Monthly Productivity for Year 2008-2010

The trend shows variations in productivity which are well below the target value of 90% for all the months and years. The other peculiar problem is that of high defect rate. Quality parameters being measured showed significant variations and inconsistencies.

2) *Measure*

Key Performance Parameters were measured and using the VSM tool, the CSM in Figure 2 below was developed. It shows all the processes in margarine making and their associated cycle times.

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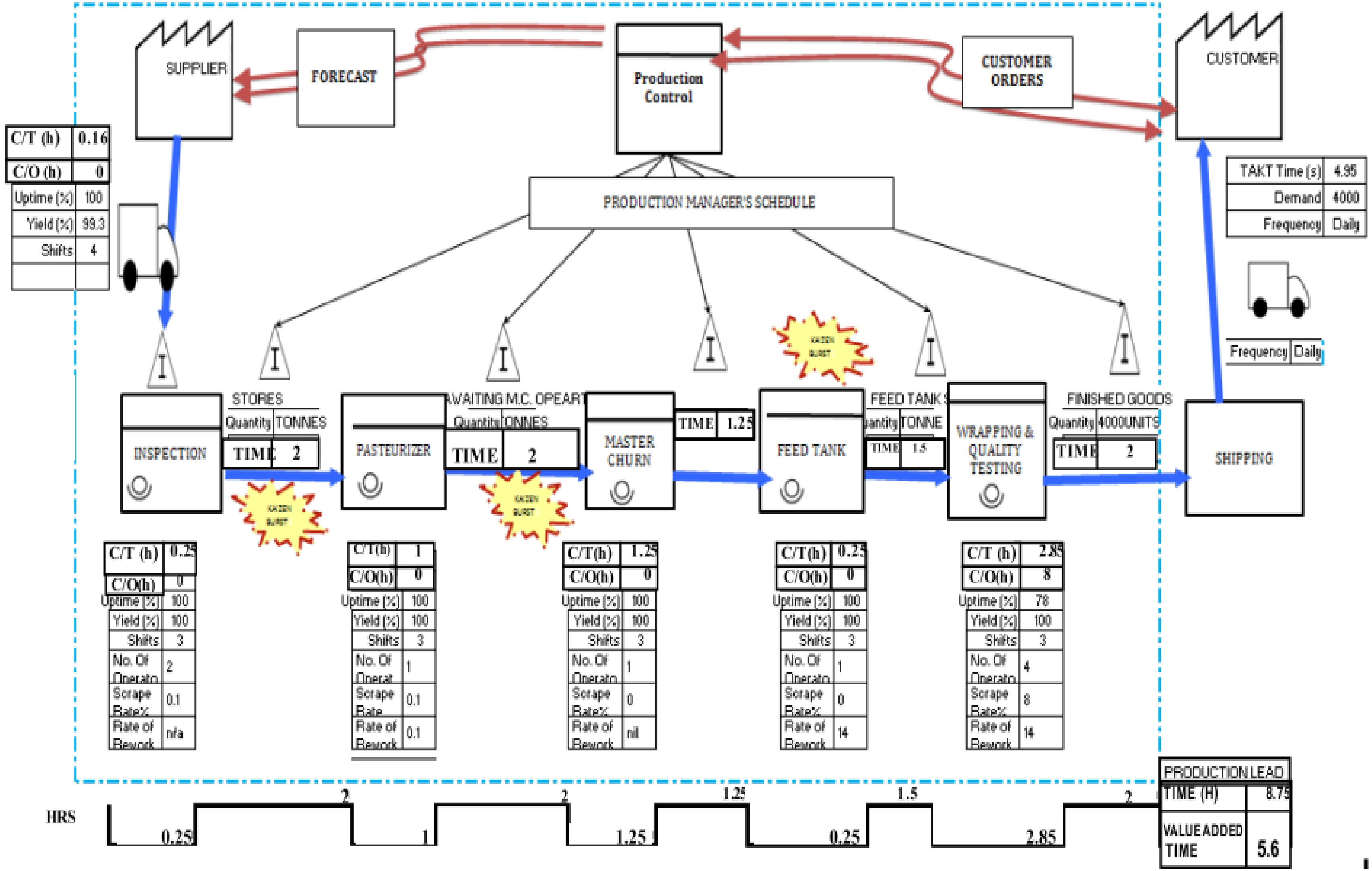

Figure 2: Current State Map (CSM) of the Margarine Production Line

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The Current State Map (CSM) shown in Figure 2 depicts that Value Added Time is about 40% of the Total Lead time. The Non-Value Added time becomes the focus of lean manufacturing strategies and their elimination would result in improvement shown in the Future State Map.

3) Analyze

The CSM was evaluated using Lean thinking on the various Parameters. The focus was on waste streams with emphasis on the seven wastes. Data and Processes were analysed and the Root Cause Analysis tool was used to get to the bottom of the causes of underperformance. The Pareto Principle was also used to determine the significant causes of the most waste streams. These were then analysed using the Fish Borne Diagrams for waste elimination.

a) *CSM data analysis*

Cycle times from the CSM were categorized into Value Added and Non-Value Added times. The recorded times are shown in Table 1 below. The Value Added time ratio was calculated for the CSM.

Table 1. Activity Classification for Processes

	Process Time (Hours)			
Process	**VA**	**NVA**	**NNVA**	**COMMENT**
Pasteurizer	**1**	**1.75**		NVA Time Is Due To Delays(1 hr Fill Time) And 0.75h Storage
Master Churn	**1**	**1**	**0.25**	Storage And Delays Due To WIP In The Feed Tanks
Feed Tank	**0.25**	**1.5**		Delay Due To Machine Stoppages And Breakdowns
Wrapping Machine And Manual Packaging	**2.35**	**0.5**		Delay Due To Machine Stoppages
Shrinking and Transportation			**0.5**	

Key: VA – Value Adding Time; **NVA-** Non-Value Adding; **NNVA –** Necessary Non-Value Adding Time

$$\%NVA = \frac{Total\ NVA}{Total\ Time}$$

$$\%NVA = \frac{8.75}{14.35}$$

$$= 60.9\%$$

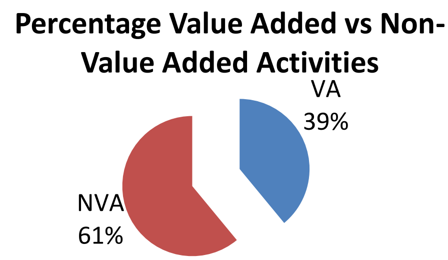

Figure 3: Analysis of Percentage Value Added Time Ratio

The Pie Chart in Figure 3 shows that more time is spent doing Non-Value Adding activities. These are the focus for elimination.

b) *Pareto Analysis*

The Pareto Analysis was applied on the NVA activities to identify the most critical processes. These were then further analyzed to identify the root cause of the inefficiency. The Pareto analysis is used to establish the critical few manufacturing process that have significant impacts. The results will be based on the fact that 20% of the highest cumulative percentage of time causes 80% of the problems or shortcomings of the production process. The cumulative table of processing time results is shown in Table 2 below.

Table 2: Pareto Analysis for NVA Activities

	NVA time (Hrs)	Cumulative %	% NVA per process
PASTEURISER	**1.85**	38.10	38.10
FEED TANK	**1.50**	66.67	28.57
MASTER CHURN	**1.25**	90.48	23.81
WRAPPING MACHINE	**0.50**	100.00	9.52

Results in Table 2 were developed into a Pareto Chart shown in Figure 4 below.

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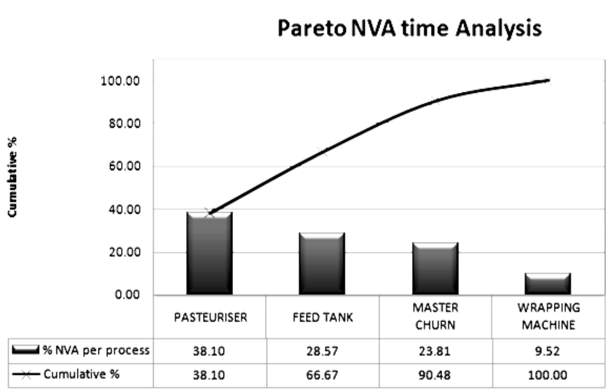

Figure 4: Pareto Analysis of NVA Times

The Pareto chart shows that the Pasteurizer has the greatest cumulative percentage of NVA activities at 38%. The second worst NVA activity time is recorded on the Feed Tank. This shows that the Pasteurizer and Feed tank contributes most of the NVA activities and are thus the initial focus areas for improvement.

c) *Root Cause Analysis (RCA)*

The Root Cause Analysis (RCA) was used to get to the “root cause” of increased NVA activity times. Addressing the root cause of the problem would ensure that it is completely resolved and recurrence would not happen. The approach was led by asking three basic questions. What is the problem?, Why did it happen (the causes)? and What should be done to prevent it? These where asked on the problems identified at the Pasteurizer and the Feed Tank.

(1) Pasteurizer

The main potential causes of high cycle time in the pasteurization process are grouped into Cause and Effect diagram shown below in Figure 5

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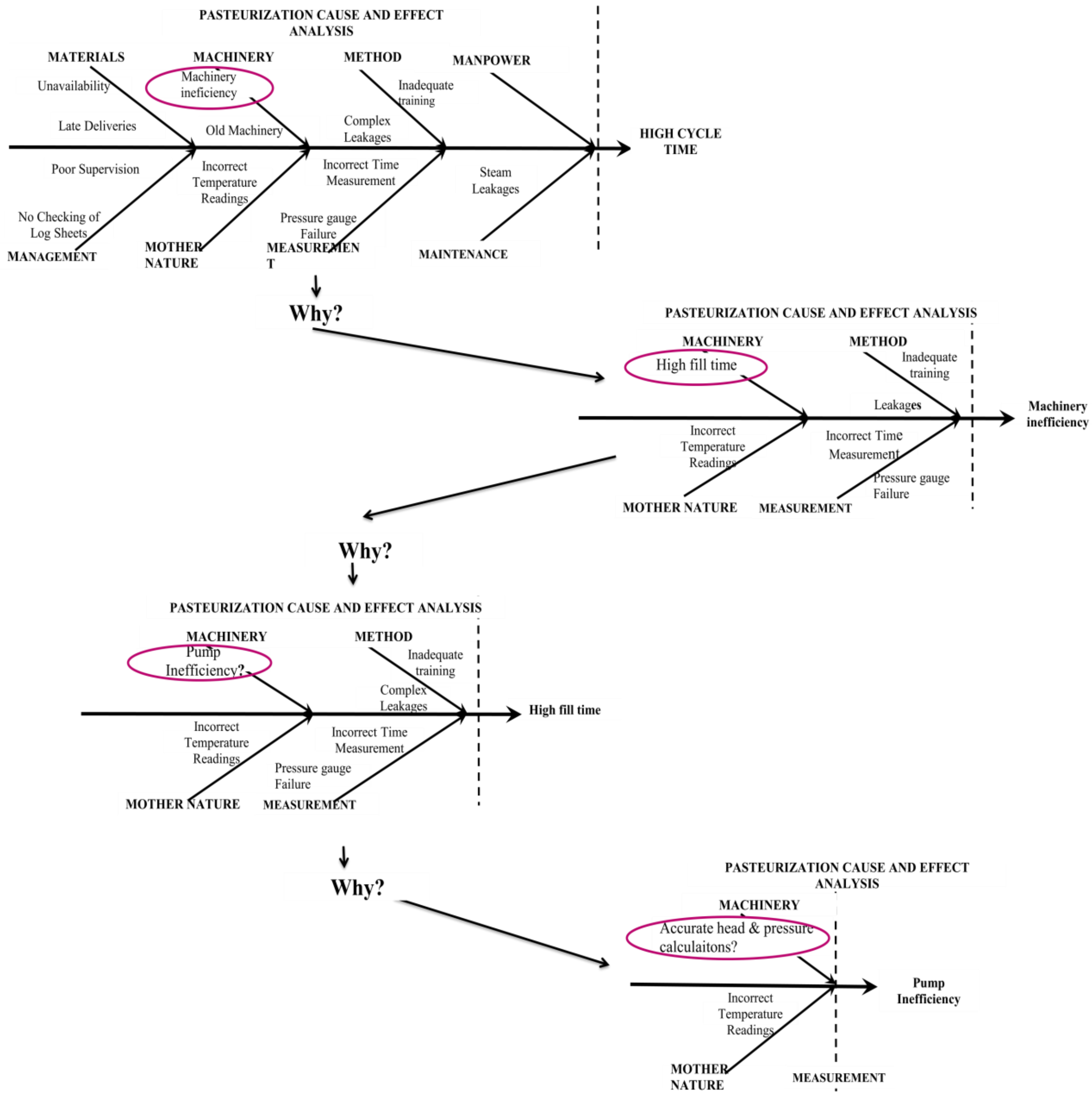

Figure 5 : Pasteurizer Cause and Effect diagram

(2) Feed Tank and Master Churn

The intermediate processes of the Feed Tank and the Master Churn comprises of many delays due to waiting time and inventory buildup. This was established to be the root cause and hence had an impact on productivity.

4) Improve

The Improve phase improves the current state by proposing a better process design. A FSM was developed to incorporate improvement suggestions after elimination of all waste. This is work done on the NVA activities. In order to achieve improvements, various lean manufacturing techniques are employed to restructure the process. The focus is on eliminating non-value-added activities from within the process by reducing lead times and excessive inventory. A set of solutions is generated to improve the poor performance and the optimum is selected. After each implementation, the process performance is recalculated until the objective is met.
The main focus is on:

- Non-Value Added (NVA) process steps on the CSM
- Distance between people, materials and equipment
- Changeover, setup and adjustment time
- Defects, scrap and rework.

a) *Takt Time analysis.*

Production Planning and Scheduling is critical in meeting customer demand. However, large orders are rough-scheduled on the production units on a weekly basis. This also then includes the planning for raw materials purchasing basing on storage capacity. On average, demand for 500g margarine is 100tonnes per month. The plant runs on a 24 hour basis except for major shutdowns and runs a 3 shift operation. The morning shift and afternoon shift are 5.5 hours long (breaks excluded) and the night shift runs on an 11 hour shift, summing up to a total of 22hours/day. The Takt time is an important parameter in the Value stream map and is determined as follows:

$$T = \frac{Ta}{Td} = \frac{22hrs * 360\sec}{16000units} = \frac{79200}{16000} = 4.95s / unit$$

Therefore for the standard 2tonne batch (400units), the Takt time is calculated by:

$$Batch.\Pr ocessng.Time, T == 4.95s / unit * 4000units$$
$$= 19800\sec = 5.5hours$$

b) *Developing one-piece flow*

The development of the FSM starts with the identification of the analyzed target areas. These include:

a) Large inventories
b) Huge difference between production lead time and VA time, which is only 39%
c) Each process is currently producing to its own schedule.

The basic philosophy is increase in inventory results in increased lead-time due to waste of waiting. Reduction of inventory and attaining on-time completion will automatically generate quality improvements. The pump was identified as the only bottleneck to be dealt with using the root cause analysis. The other wastes identified are storage wastes which could be resolved by production scheduling. The Kanban system can be employed to create one piece flow and using the Takt time. The aim would be to reduce the huge difference between production lead time and Value Added time, which is currently at 39%.

c) *Design Optimization: Pump Improvement*

The pump in use was the 2900rpm 50-32-160 centrifugal pump which was identified as the root cause of delays at the Pasteurizer as shown in the Pareto chart (Figure 4).

d) *Solution brainstorming*

Solution brainstorming is a form of Design Optimization. The possible solutions to the pump inefficiency were brainstormed and are:

- Change the pump altogether
- Add pipe constrictions to increase pressure
- Close all other water inlets when filing the pasteurizer tanks

The brainstorming Solution Matrix was employed to decide on the best optimum solution, whereby counter measures are identified. A Cost/Benefit Analysis was undertaken and the result is confirmed.

5) Future State Map (FSM)

The FSM was then developed based on the design optimization and process refinement which is discussed in the above sections. Figure 5 below shows the Future State Map.

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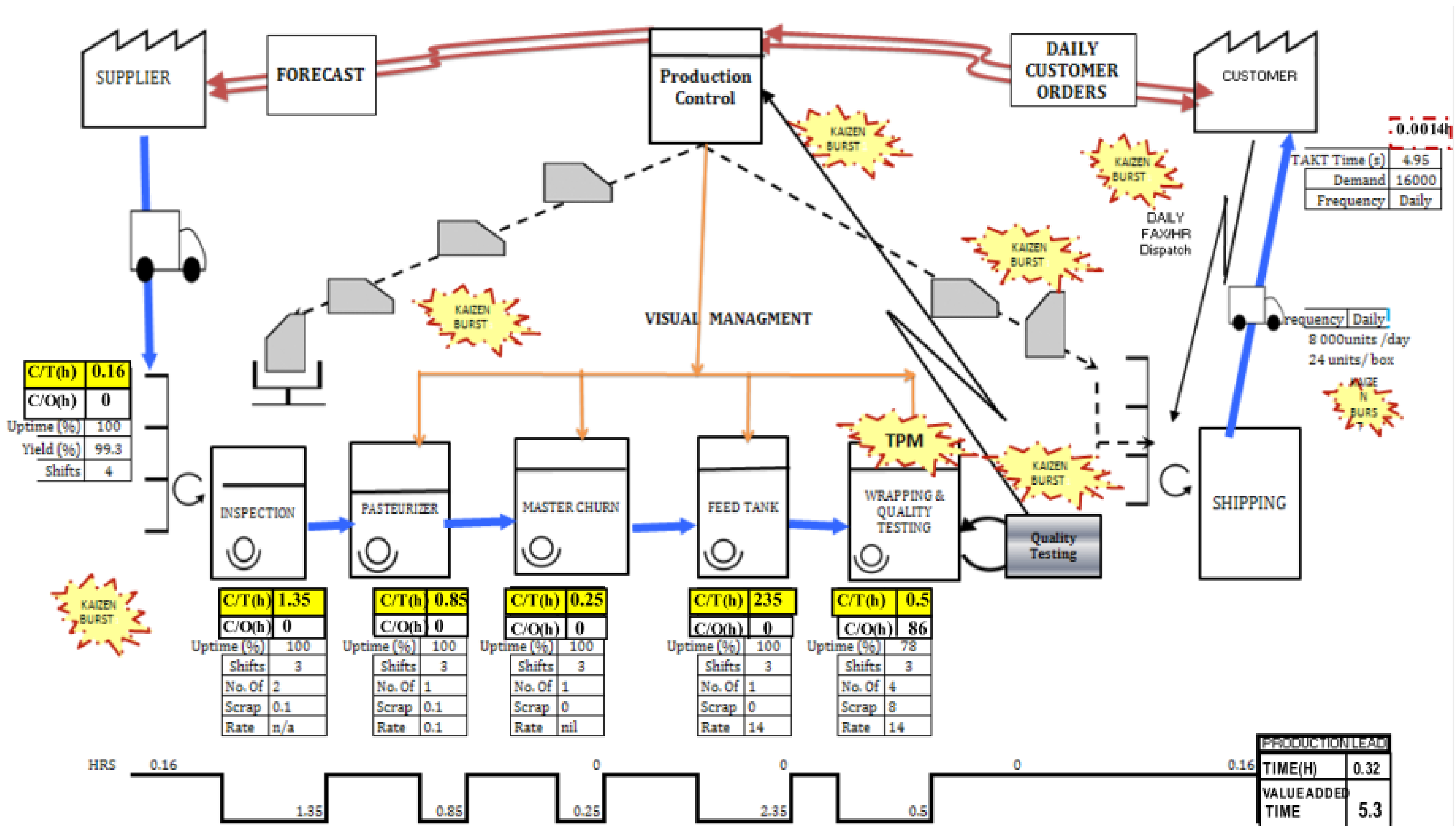

Figure 5: Future State Map (FSM) of the Margarine Production Line.

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6) Control

The future-state (improved) is controlled by monitoring process variables and behavior and setting controls to maintain six-sigma and lean performance. Several lean techniques can be used to control the improved production environment and maintain the lean performance. Examples include using visual controls and displays, documenting and standardizing work procedures, and deploying a Kaizen (continuous improvement) plan. This will be complementary to the various six-sigma tools that are applied at the control stage of DMAIC, such as statistical process control, failure mode and effect analysis, and error-proofing plans. The focus here is on enforcing means to sustain the LSS process gains.

IV. RESULTS ANALYSIS

The production lead time for the FSM is 5.62hrs with 5.3 hrs of Value Added Time. This then gives the percentage Value Added ratio of 95%. The comparison of the results analysis between Value Added Times of the CSM and FSM are shown below in Figures 5 and 6.

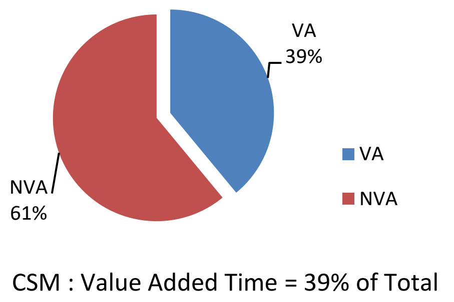

Figure 5 : Current State Map VA Ratio

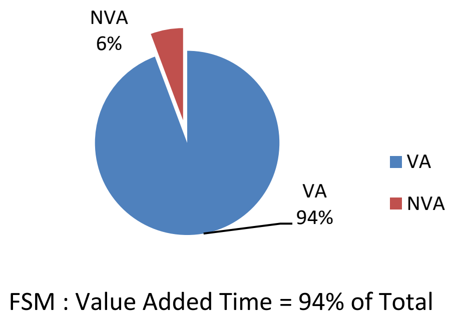

Figure 6 : Future State Map VA Ratio

The FSM was developed using the proposed improvements developed in the above sections. The processing times have been scheduled to create a pull-system and a TPM schedule has been developed for the equipment. The FSM processing times are shown below in Table 5 and Figure 7 and compared with the current processing times for design validation.

Table 3: Comparison of CSM and FSM cycle times

	Pasteurizer	Master Churn	Feed Tank	Wrapping & Packaging Machine	Packaging and Transportation
CSM Cycle Times (Hours)	2.75	2.1	1.75	2.85	0 . 5
FSM Cycle Times (Hours)	1.35	0.85	0.25	2.35	0.5
%Improvement	51%	60%	86%	18%	0%

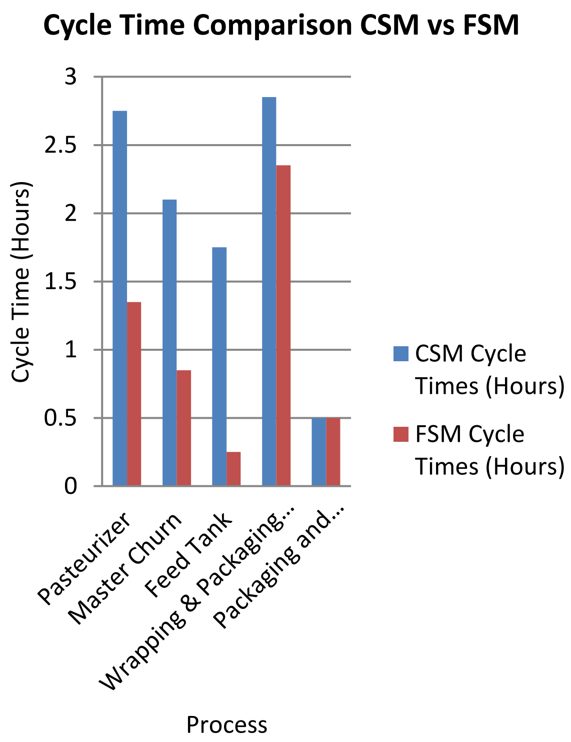

Figure 7 : Cycle Time comparison of the CSM and the FSM.

V. CONCLUSION

The Lean Six Sigma approach was used in identifying and effecting process improvements in margarine manufacturing. Lean Six Sigma is a tool that encompasses two powerful tools for attaining World Class Manufacturing status.

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These are the Lean Manufacturing philosophy and the Six Sigma principle. The DMAIC approach of Six Sigma was used together with Kaizen Blitz that are characteristic of the Lean Manufacturing philosophy. The VSM tool was used to draw the CSM of the margarine making line. The Value added ration on the CSM was 39% and was improved to 94% using the Lean Six Sigma approach. Waste reduction measures were employed mainly using the Total Productive Maintenance approach and effecting a pull system. The results obtained are shown in the FSM and they indicate improvements in cycle times of up to 86%. Any such improvements directly translate to waste reduction and hence cost reduction. While Lean Six Sigma are company-wide initiatives, their constituent components can be used to achieve improvements in processes and efficiency.

REFERENCES

1. Ohno, T. (1988). *Toyota Production System; Beyond large scale production*, Productivity Press, Portland, Oregon.
2. Russell, R.S. and Taylor, B.W., 2000, Operations Management, Prentice Hall, Englewood Cliffs, NJ.Achanga, P., 2006, "Critical success factors for lean implementation within SMEs", Journal of Manufacturing Technology Management, Vol. 17 No.4, pp 460-71.
3. Shah, R. and Ward, P.T., 2007, Defining and developing measures of lean production, Journal of Operations Management 25 pp 785 – 805.
4. Hayes, R.H., Pisano, G.P., Upton, D.M and Wheelwright, S.C., 2005, Operations, Strategy and Technology: Pursuing the Competitive Edge, Wiley
5. Carreira, B and Trudell, B., 2006, Lean Six Sigma That Works: A Powerful Action for Dramatically Improving Quality, Increasing Speed and Reducing Waste, Amacom, New York.
6. Shah, R., Chandrasekaran, A and Linderman, K., 2008, In pursuit of implementation patterns: the context of Lean and Six Sigma, International Journal of Production Research, Vol 46, Issue 23, Special Issue: Effective Decision Support for Lean and Six Sigma Methodologies , pages 6679-6699.
7. Pettersen, J., (2009),"Defining lean production: some conceptual and practical issues", The TQM Journal, Vol. 21 Iss: 2 pp. 127 – 142.
8. Bicheno, J., 2004, The New Lean Toolbox towards Fast and Flexible Flow, PICSIE Books, Buckingham.
9. Phillips, T., 2000, "Building the lean machine", Advanced Manufacturing, January, pp 21-6.
10. Dag Näslund, (2008),"Lean, six sigma and lean sigma: fads or real process improvement methods?", Business Process Management Journal, Vol. 14 Iss: 3 pp. 269 – 287.
11. Arnheiter, E. and Maleyeff, J., 2005, "The integration of lean management and six sigma", The TQM Magazine, Vol.17, no.1, pp5-18.
12. Hammer, M., 2002, "Process Management and the future of Six Sigma", Sloan Management Review, Vol 43, No.2, pp26-32.
13. Snee, R.D., (2010),"Lean Six Sigma - getting better all the time", International Journal of Lean Six Sigma, Vol. 1 Iss: 1 pp. 9 – 29.
14. Pepper, M.P.J. and Spedding, T.A., (2010),"The evolution of lean Six Sigma", International Journal of Quality & Reliability Management, Vol. 27 Iss: 2 pp. 138 – 155
15. Chikumba, S. and Goriwondo, W.M., 2006, Integrating Lean Management and Six Sigma Methodology as a Tool for Re-industrialization, ZIE, ECZ Engineers Without Borders Conference, Victoria Falls.
16. Goriwondo, W.M., Mhlanga S. and Marecha, A. (2011), Use Of the Value Stream Mapping Tool For Waste Reduction In Manufacturing. Case Study for Bread Manufacturing in Zimbabwe. Proceedings of the 2nd International Conference on Industrial Engineering and Operations Management

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