Dynamic Value Stream Mapping in the Realm of Green Manufacturing

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Abstract

Value stream mapping is a lean tool which is used in lean manufacturing to find the flow of information and material, as a product it makes way through value stream. These envision tool helps to understand processes by using of stream lined work process. In these paper value stream maps of a process by using simulation is developed. By creating dynamic value stream maps makes it possible to analyze and optimize more complex systems than traditional VSM. Simulation can be used with value stream mapping to give it power and flexibility in order to dynamically change the state of the system. The study is conducted in milk processing plant, in particular a company who manufacture dairy based products. The aim is to identify extent of waste and how these can be reduced and/or eliminated from the value stream and consequently promoting Green Manufacturing. The benefits are visualized with the help of simulation which can reap long term yield for the manufacturers.
Keywords- Lean Manufacturing, VSM, Simulation, Dynamic Value Stream Mapping, Green Manufacturing

I. INTRODUCTION

Lean manufacturing involves never ending efforts to eliminate or reduce 'muda' (Japanese for waste or any activity that consumes resources without adding value) in design, manufacturing, distribution and customer service processes. Value Stream Mapping is a procedure used in lean manufacturing where the process of disseminating materials and information is streamlined to bring a product or service to the customer by creating the most efficient system possible.

Paul [1] in his paper suggested that Green technology is the application of one or more of environmental science, green chemistry, environmental monitoring and electronic devices to monitor, model and conserve the natural environment and resources, and to curb the negative impacts of human involvement. The term is also used to describe sustainable energy generation technologies such as photovoltaic, wind turbines, bioreactors, bio filtration, bioremediation, desalination etc. The scope of green operations spans from product development to management of the entire product life cycle involving such environmental practices as eco-design, clean production, recycling, and reuse with a focus on minimizing the expenses associated with manufacturing, distribution, use, and disposal of products as interpreted bu Lai and Wong. [2].

Womack and Jones [3] define the value stream map as follows: raw materials along with knowledge and information enter the system upstream (the suppliers); and, products or services of value flow out from the system downstream (the customers).Rother et al. [4] explained that a value stream is comprised of all the actions (both value added (VA) and non-value added (NVA)) that are required to bring a product or a group of products from raw materials to the arms of the customer. Value stream needs to flow in a way that serves the customer with overall shortest possible lead time, lowest cost, highest quality and most dependable delivery. A new scheme of classifying operations into three generic categories as non-value adding (NVA), necessary but non-value adding and value adding is suggested. This scheme proved to be more generic and was extended to different areas in his work done by Monden [5].

It was shown by Jones et al. [6] that unnecessary inventory, defects, inappropriate processing and transportation were the most serious wastes in the system, further suggested to adopt five of the VSM tools: process activity mapping, supply chain response matrix, quality filter mapping, demand amplification mapping, and decision point analysis. Narasimhan et al. [7] introduced a new approach known as the "simulation-aided Value Stream Mapping" (saVSM), and illustrated a case study, showcasing the successful application of saVSM approach, at a global engine manufacturer's test Environment. A simulation tool was used in saVSM is used for quick and efficient data analysis and for facilitating continuous VSM updating. Melvin et al. [6] pointed that VSM can be applied to the food and drink industry to identify areas of waste and how these can be reduced and/or eliminated from the value stream. Ana Julia Dal Forno et al. [10] investigated the main difficulties and limitations encountered during the construction of current state maps, analysis of the associated causes, and pointed out guidelines to facilitate the use of VSM to map processes. To do so, a search and evaluation of papers in journals, conferences, theses, and dissertations was conducted, and the articles were categorized according to the field of application (factory floor, supply chain, product development and services) and approach (theoretical or practical). VSM is currently used to identify wastes in processes and make

improvements. There are increasing opportunities in the realm of remanufacturing and Eco design that can also allow using VSM for identifying environmental wastes arising from inadequate process flow.

II. METHODOLOGY

The section describes the methodological approaches adopted for this research. This includes the value stream mapping of the dairy plant, interviews with key respondents to further enhance the information captured from the shop floor. Value stream mapping was carried out whilst walking around the factory floor and talking to key individuals in each area. The study is conducted in a dairy plant which processes milk which varies from 30,000 litres to 63,000 litres based on the daily demand. Company's activities include chilling, pasteurizing, homogenization, cream separation and packing the processed milk and transporting the packets to the cold storage in pallets. The data collection started with the incoming tankers and subsequent raw milk collection through each of the individual processes identifying the linkages between the states of production and establishing the flow of information and material resources. Data such as process cycle times (CT) and number of workers were also recorded to add to the current state map so an overview of how the company currently operates could be viewed. In order to convert the data obtained into a current state map icons were drawn representing each of the process steps and flow of materials using the simulation software.

A. Process description
Pictorial representation of the process is shown in the Fig.1 that involved the following activities.
− On arrival to the site, raw milk is firstly tested for fat, acidity, solid not fat (snf) & clot on boiling (cob).
− Before the milk is pumped into large insulated storage silos, it is passed through a chiller (7,500 litres/hour) to attain a temperature of 4-6 deg Celsius.
− Then as required milk is pasteurized by pasteurizing unit (10,000 litres/hour), portion of milk is sent for homogenization and remaining is sent to the cream separator, portion of the extracted cream is also sent to the homogenizer for homogenization. Though the homogenizer's processing rate is 5,000 litres/hour the portion of the cream sent to the homogenizer in such a way that the processing rate from the homogenizer is enhanced to 10,000 litres/hour. The milk from the cream separator and homogenizer is then passed again through pasteurizer for chilling.
− After the above processes milk is stored in HMC tanks (T1, T2 & T3 respectively each of capacity 10,000 litres) and ready to be filled. The remaining processed milk is sent to tanks S1 & S2 of capacities 20,000 & 30,000 litres respectively).
− Processed milk is taken to filling units from the HMC tanks where 500ml of milk packets are filled. When the HMC tanks are empty they will be filled with the milk from the tanks S1 & S2.
− Twenty packets are collected in tray. When ten such trays are ready, they are taken to the cold storage unit and stored at a temperature 0f 6 deg Celsius.
− During one shift five packing lines will be working simultaneously. The raw milks are collected in vertical tanks S3 and S4 of capacities 50,000 & 60,000 litres respectively.
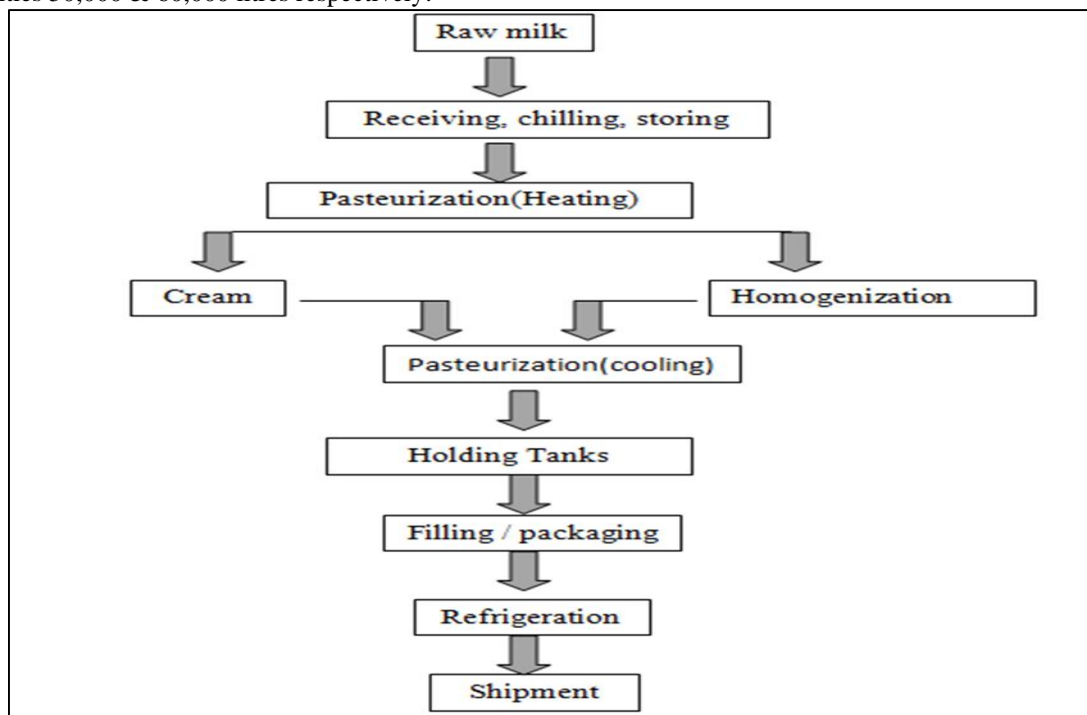

Fig. 1: Milk processing procedure

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B. Simulation of tankers arrival

Tankers start arriving 7 hours after plant starts at 8 am. Arrival of tankers ends at 8pm.The number of tankers arriving to the plant varied between seven and ten and triangular distribution was selected. Size of the tankers varied between varied between 5,000 litres and 15,000 litres. Total quantity arrived for the day was fitted with uniform integer distribution using Stat::Fit of ExtendSim software from the data collected for thirty days which varied between 32,600 and 63,177 litres. Time between tanker arrivals varied between minimum of 0.5 hours to maximum of 3 hours and was fitted with triangular distribution. If the tanker quantity for the last tanker is less than 5,000 litres, it is added to the previous tanker for the flow diagram to be complete. Thus the model for the arrival of tankers is developed with the help of the flowchart shown in fig.2.
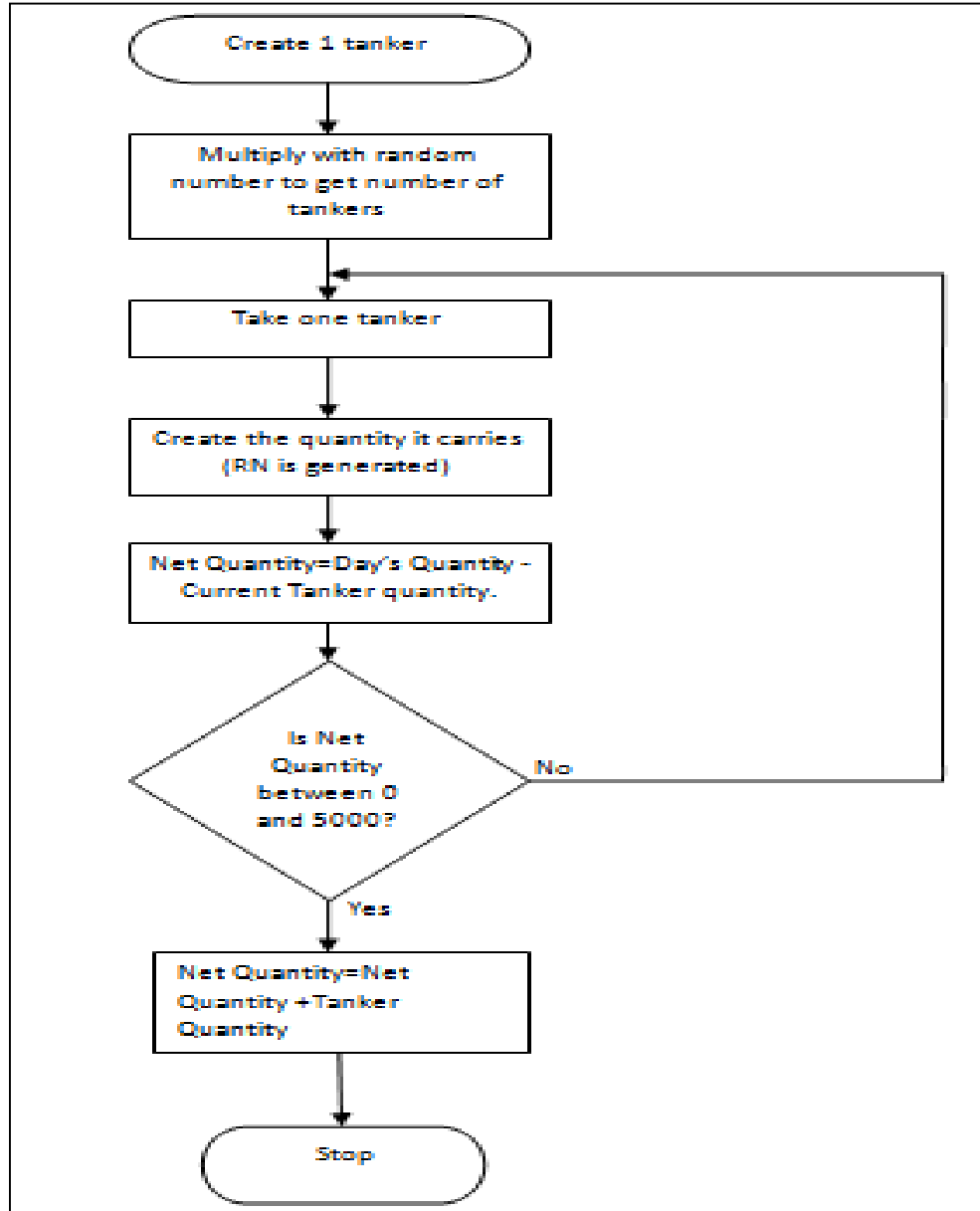

Fig. 2: Flowchart for arrival of tankers

C. Time schedule

Pasteurization starts at 8.00 AM. The first shift filling starts at 9.00 AM to 1.00 PM. Lunch break is from 1.00PM to 2.00PM (Packing resumes at 2.00PM).Tea break at 5.00PM to 5.10 PM (Packing resumes at 5.10PM and proceeds till processed milk is finished).Second shift starts at 3.00 PM and five workers are involved. Filling time is not fixed initially, filling continues till processed milk is finished. Workers work in 8 hour shift. The remaining time other than packing and processing of milk will be used for cleaning & maintenance works.

D. Building the current state model

The current state VSM simulation model developed using ExtendSim software is shown in the figure. It tries to replicate all the process that take place in the plant. This is done by identifying the templates of different processes from the software library.
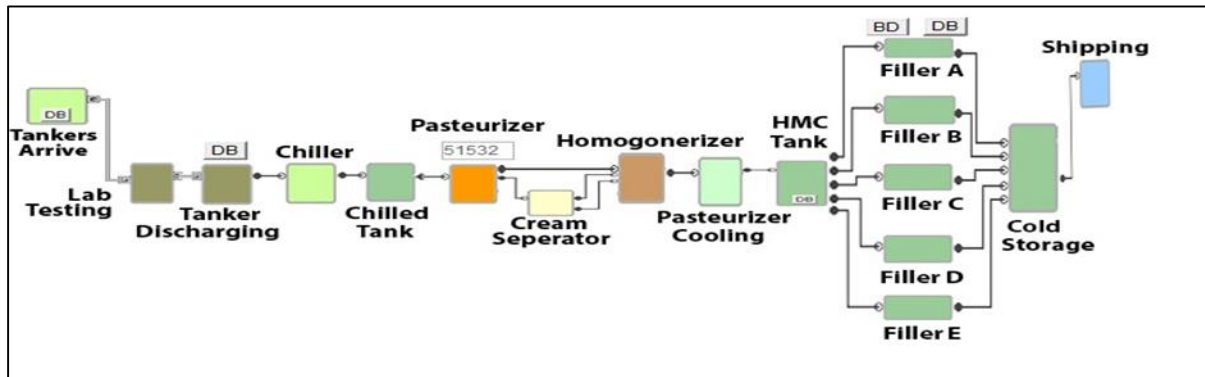
Fig. 3: Model built using ExtendSim simulation software

E. Data analysis

The data was collected for thirty days from the plant to simulate the process included the number of tankers arrived each day, tanker quantity, pasteurized quantity, demand on each day, number of damaged packets, power consumption, electricity tariff. The data as and when required was fitted with appropriate distribution using Stat::Fit of ExtendSim software to build the current state model. A suitable database was created for recording the parameters obtained for detailed evaluation. The data collection started with the daily demand identifying the linkages between the states of production and establishing the flow of information and material resources.

Table 1:   Connected Load of Equipment's

Sl No	Equipment	Connected load (KW)
1	Tanker pump	2.58
2	Chiller	2.24
3	Pasteurizer	11.56
4	Cream separator	7.46
5	Homogenizer	37.3
6	Filler 1	4.5
7	Filler 2	4.5
8	Filler 3	4.5
9	Filler 4	4.5
10	Filler 5	4.5
11	Compressor	44.68

The power consumption of various equipment's is shown in the table. There are two refrigerant compressors each of connected load of 22.34KW, which worked during the chilling, pasteurization and homogenization process. For the remaining time only one compressor is needed for cold storage refrigeration purposes.

The electricity tariffs are depicted in the table.

Table 2: Tariff of Electricity

	Category	Time	Demand Charge	Energy charge/unit
1	Normal	6.00 AM - 6.00 PM	Rs 300/-	Rs 5.2/-
2	Peak	6.00 PM - 10.00 PM	Rs 300/-	Rs 7.8/-
3	Off peak	10.00 PM - 6.00 AM	Rs 300/-	Rs 3.9/-

The time between failures (TBF) and time to repair (TTR) is noted and corresponding distributions are fitted for each filling line. The data was obtained by directly observing the break down and repairs of filling lines.

III. RESULTS AND DISCUSSIONS

A. Simulation results – Current State

The current model is executed for thirty days and ten runs were conducted and following observations were made. The validation and verification is conducted for various demand pattern and production control policy options as shown.

Table 3: .Demand as fitted to Data and Orders as Per Received

Description	Mean Value	Std. Deviation
Delivery (Litres per month)	1406331.27	33704.24
Customer short supply/month (Litres)	14.69	7.74

Partial stock outs per month (Litres)	0.40	0.21
Relevant electrical cost per 100 Litres	13.63	0.24
Total Breakdown	1645.90	4.46

Table 4: Demand as Fitted to Data and Standard Quantity Pasteurized (50,000 Litres)

Description	Mean Value	Std. Deviation
Delivery (Litres per month)	1398270.58	24725.54
Customer short supply/month (Litres)	1.88	2.82
Partial stock outs per month(Litres)	0.07	0.11
Relevant electrical cost per 100 Litres	13.47	0.25
Total Breakdown	1645.67	4.66

B. Building a future state model

Some modifications are proposed working with the current state model after identification of areas of improvement. From the various demand pattern and production control policy options it is found that when standard quantity is pasteurized and demand pattern as fitted to data gave the best results in terms of processing cost ,customer short supply and partial stock outs per month.

At present plant has scheduled lunch break from 1pm-2pm, if avoided for continuous production has the following advantages:

a) Every restarting process is accompanied with the draining of milk in the pipe line thus reprocessing of 200 litres of milk can be avoided. This leads to energy savings.

b) When filling lines are started after a break, it takes time to regularize the weight of the filled pouches which results in defective packets. This leads to an increase in the consumption of plastic films used for packing which needs recycling for it to be used again. The elimination of breaks helps to overcome these problems.

c) Filling during the peak time can be reduced which can lead to savings in electricity charges.

The table shows the simulated results of the various demand patterns and production control policy options after the shift rescheduling.

Table 5: Demand as Fitted to Data and Orders as Per Received

Description	Mean Value	Std. Deviation
Delivery (Litres per month)	1397857.83	23347.97
Customer short supply/month (Litres)	57.70	30.41
Partial stock outs per month	0.48	0.25
Relevant electrical cost per 100 litres	13.52	0.22
Total Breakdown	2175.20	6.11

Table 6: Demand as Fitted To Data and Standard Quantity Pasteurized (50,000 Litres)

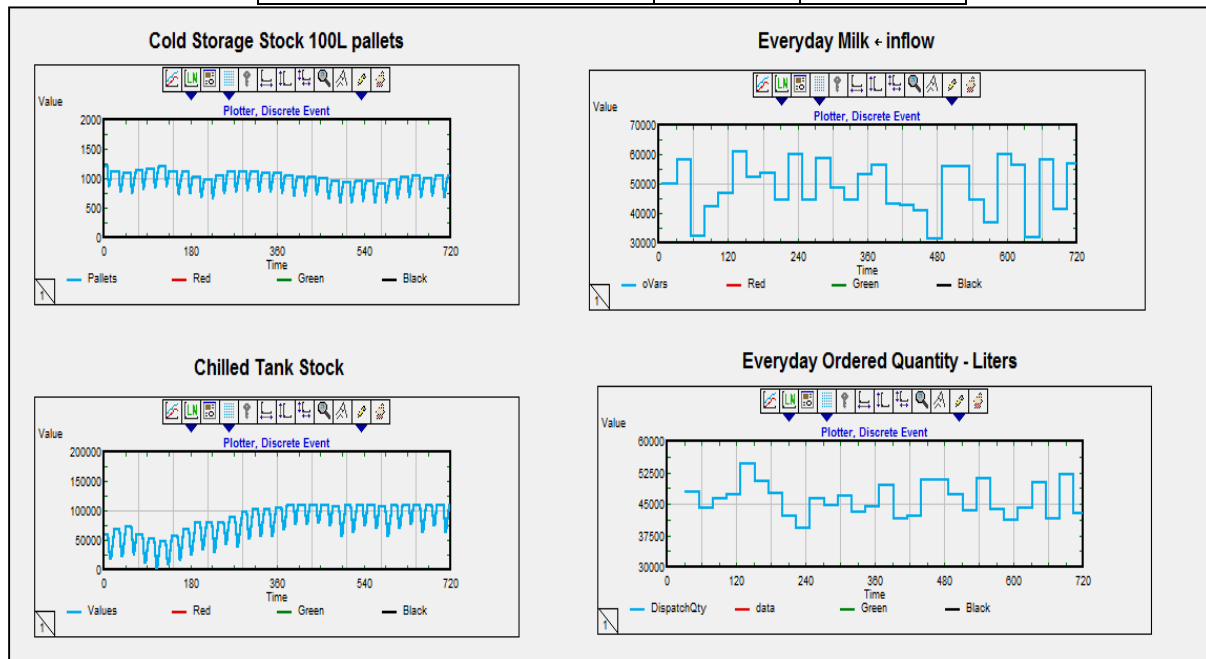| Description	Mean Value	Std. Deviation
Delivery (Litres per month)	1398608.08	24636.08
Customer short supply/month(Litres)	0.00	0.00
Partial stock outs per month	0.00	0.00
Relevant electrical cost per 100 Litres	13.29	0.20
Total Breakdown	2175.00	6.44

Fig. 4: Operation Monitors for the future state model (using ExtendSim software)

IV. CONCLUSIONS

The study focuses on obtaining the optimum parameter level departing from the traditional practices available and subsequently analyzing the benefits. In this work an improved suggestion plan is developed with the help of VSM and simulation. The developed model helps us to envisage more than the single process level and also provides a blueprint for implementation. The benefits can receive significant savings for manufacturers. It is now very easy to represent the state of a system under different circumstances to allow for better decision making. Thus the combination has provided both strength and power to both the tools. The reduction in the electricity costs to Rs.13.29/- per hundred litres leads to better energy conservation, less depletion of fossil fuels The change in the shift timing results in water conservation, reduced film consumption, increased quality of packed products and is depicted by running the future state. The promotion of Green Manufacturing results in lowering the raw material costs gain in production efficiency and improved corporate credibility among the peers.

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