Multicriteria Modeling and Analysis of Manufacturing Activities in an Industry

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Abstract— In the recent years, in order to sustain in the competitive markets manufacturing firms started focusing on delivering the product to the customer in the lowest possible costs, with the highest possible quality in order to hold its market share. It became a tougher job for the firm to manage both these requirements fulfilled without decreasing the profit. This sometimes may destroy its own existence. The only way one can achieve these feet is by reducing the waste to as minimum as possible. Thus the concepts of TQM and Lean Manufacturing came into picture. Operating a manufacturing firm over these principles is not so easy until efficient tools are used in indentifying the wastage of resources in the firm. Manufacturing systems provide one of the most important applications of simulation. Simulation is more a tool than a solution for this problem. Simulation when used along with some statistical tools give reliable results/insight of a manufacturing firm whose performance is a function of many stochastic factors. Thus necessary changes can be implemented in an organization for its profitable existence and increased customer delight.

Key words: Manufacturing Firms, TQM, Lean Manufacturing, Simulation

I. INTRODUCTION

To eliminate waste, it is important to understand exactly what waste is and where it occurs. While products differ significantly between factories, the typical wastes found in manufacturing environments are quite similar. For each kind of waste, there is a strategy to reduce or eliminate its effect on a company, thereby improving overall performance and quality. Implementing change can be a difficult task for any organization, big or small. Its furthermore risky for an organization to implement the changes which they were not sure would reduce the waste and improve its performance. Thus they use model of the real world system over which the proposed changes can be implemented.

A simulation is the imitation of the operation of a real-world process or system over time. Whether done by hand or on a computer, simulation involves the generation of an artificial history of a system, and the observation of that artificial history to draw inferences concerning the operating characteristics of the real system.

The behavior of a system as it evolves over time is studied by developing a simulation model. This model usually takes the form of a set of assumptions concerning the operation of the system. These assumptions are expressed in mathematical, logical and symbolic relationships between the entities or objects of interest, of the system. Once developed and validated, a model can be used to investigate a wide variety of "what if" questions about the real world-system. Potential changes to the system can first be simulated in order to predict their impact on system performance. Simulation can also be used to study systems in design stage, before such systems are built. Thus, simulation modeling can be used both as an analysis tool for predicting the effect of changes to existing systems and as a design tool to predict the performance of new systems under varying sets of circumstances.

In some instances, a model can be developed which is simple enough to be solved by mathematical methods. Such solutions may be found by the use of differential calculus, probability theory, algebraic methods or other mathematical techniques. The solution usually consists of one or more numerical parameters which are called measures of performance of the system. However, many real world systems are so complex that models of these systems are virtually impossible to solve mathematically. In these instances numerical computer based simulation can be used imitate the behavior of the system over time. From the simulation data are collected as if a real system were being observed. This simulation generated data is used to estimate the measures of performance of the system.

II. LITERATURE SURVEY

Literature survey related to simulation in manufacturing is briefly detailed hear:

Lima et al. (2008) work presents a method, based on simulation, to help the selection of the bottleneck detection method to be applied to a given situation. Productivity being the main objective of any firm,the sensitivity analysis has been done on the simulation model .process improvement ,decreasing the setup time ,increasing the batch size even all the three simultaneously. The proposed method was successfully applied to a real bottling process.

Law and Kelton (2000) made a detailed explanation regarding the simulation modeling and analysis. It consists of the modeling of complex systems. This work made a serious look into building of Valid and credible models. Modeling of manufacturing facilities comprises of some variables like resources, material handling control logic, workstation logic, buffers, orders/process plans, reports, etc are introduced by him.

Miller and Pegden (2000) reported the overview of simulation to manufacturing design and scheduling. A review of the modeling considerations in both application areas is provided. Finally, a number of example applications had been presented to illustrate the concepts.

David Krahl (2001) demonstrated the extend Simulation software environment which has exposed the features and advantages of this package to its fullest.

Barnes (1988) investigated the data collection techniques in a shop floor which is very helpful in increasing the reliability of the collected data that is to be used in simulation modeling.

Moris et al (2008) examined simplification and aggregation strategies are incorporated in a modeling, simulation and analysis tool, with the aim of supporting decision making in conceptual phase. The results from the test cases were very promising, both in terms of output equivalence and system behavior. This gave the advantage of being able to make more thorough test on system behavior and not only focus on outputs like throughput, lead time and WIP levels.

Mason et al (2008) developed a full factory simulator as a daily decision support tool. A key requirement to support daily and weekly decision-making is good validation results of the simulation against actual factory performance which has been reported.

Tjahjono et al, (2008) reported the effects of inadequate experimentation which may lead to poor decision making and can be detrimental particularly when financial investment is involved. He proposes a practical approach to simulation experimentation in the context of simulation study of an engine assembly line.

III. METHODOLOGY

The objective of the project has been defined as follows.

A. Objective, Approach and Facility

The objective of this project basically focuses on eliminating/minimizing the wastage of resources and its effect on the performance of a typical manufacturing firm. Thus the objective has framed as follows:

1) To study and analyze the production line.
2) To identify and collect all necessary relevant data of the production processes.
3) To build a valid simulation model of the existing production line.
4) To use the model to find ways to increase the production capacity and enhance the production rate.

Discrete System Simulation has been chosen in fulfilling the objective because, the inherent capabilities of DSS in representing a system as a model, for which a closed form mathematical solution can not be applied economically due to stochastic nature.

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Results at the end of the first step gives the performance measures such a throughput, utilization of resources etc., This stage ends up with a virtual factory simulation model which behaves as a real system would do when working under different loads. The model thus obtained is ready for experimentation.

The final being after experimentation on the model with lean principles which gives conclusions such as a set of operating policies, resource requirements, modifications to be implemented at varying demand conditions for a profitable and improved production.

B. Proposed Methodology for the Study

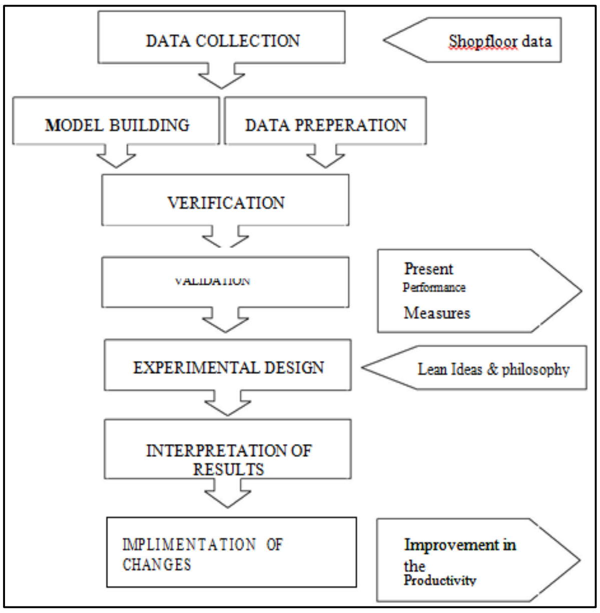

Fig. 1: Proposed Methodology

IV. RESULTS & ANALYSIS

A. *Bottleneck Analysis:*

The bottlenecks in a production system are detected by the parameters such as utilization, Max. Or avg. waiting time and waiting length of the component in front of a machine for being processing. All these parameters are studied from the simulation model and are tabulate below. In every system there is one machine that is the largest, i.e. the primary bottleneck. However, often there are also a number of other machines that constrain the system, although to a lesser extend as the primary bottleneck which are secondary bottlenecks. The improvement of the system will naturally focus on the primary bottleneck, but in some cases it may also be cost-effective to improve the secondary bottlenecks. It may even be possible to save some money by reducing the speed of the non-bottlenecks. Therefore it is not only important to find out which machines are primary bottlenecks but also the secondary bottlenecks and non-bottlenecks. Thus the results for all the machines are indicated instead of naming the first few. These numerical indicators for each machine will denote the probability that a machine be a bottleneck in the descending order.

Number of parts in the queue waiting for the processing to be done, determines the bottleneck in one way. This method looks for the machine where the parts have to join the queue with the longest length, and defines the bottleneck according to the queue length. Average queue length at which the parts are joining the queue can also be considered for the matter of fact.

The other way is to look for the average or the maximum waiting time the part spends in the queue. Both this parameters are tabulated below. Surprisingly no agreement between the results is observed in order to draw some specific conclusions from the above two methods.

The reason for these ambiguous results is found out to be the fact that the method of queue length is applicable only for the linear systems containing only one type of part not the assembly line (as in our case a core builder). There might be occasions where a machine with a few parts being processed slowly constrain the system more than a machine with a lot of parts being processed quickly. Therefore the results obtained from the queue length. Method is to be ignored.

Thus we explored into other methods of finding the bottle necks and ended up our search with parameter “utilization”. This method of analysis gave as some promising results. The utilization method measures the percentage of time a machine is ACTIVE, and then defines the machine with the largest active percentage as the bottleneck.

An action performing on a machine can be classified Active or Inactive as follows:

- Processing Active
- Setup Active
- Breakdown Inactive
- Repair Active
- Starving Inactive
- Blocking Inactive

As in our case ‘Blocking’ makes no sense as an infinite queue is attached in front of each machine as buffer. Breakdown and repair are not considered because of the lack of historical data. Utilization of the machine is calculated on the basis of Processing time, Setup time and Starving. For that matter, utilization of the machine is considered with setup time as Active once and then inactive whose effects are analysed in detail in the Sensitivity Analysis.

Machine	Machine code	Avg. Wait (sec)	Rank Avg. Wait	Rank Avg. Length	Avg. Length (no’s)
FIN MILL - CONDENSOR Fin Mill - 3 (18.5 X7.77mm, 25.9 X7.77, 25.9X9,	3102	2.92E+05	1	1	6223.4
42X8,56X7.7,72.6X7.35 Fin height)	3303	2.58E+05	2	4	4761.3
CORE BUILDER - 3	4302	1.30E+05	3	3	5348.3
SEMI AUTO -2 Fin Mill -2 (18.5 X7.77mm, 25.9 X7.77, 25.9X9,	4101	1.26E+05	4	2	5816.1
42X8,56X7.7,72.6X7.35 Fin height)	3302	98975	5	12	632.53
FIN MILL - EVAPORATOR	3201	64302	6	6	1358.7
IDAM RAD CORE BUILDER	4303	36598	7	13	610.16
MANUAL C/B - 2	4103	35601	8	5	1564.3
SEMI AUTO CORE BUILDER - 4	4304	33808	9	17	425.01
Fin Mill - 5 (25.9 X 7.7 mm & 5.6mm Fin height)	3305	31709	10	10	668.14
Fin Mill - 1 (18.5 mm With 7.77mm Fin height)	3301	29649	11	21	267.74
EVAP SUSRING	4104	29182	12	18	391.6
Matrix core Builder - 7	4307	28807	13	26	126.93
CORE BUILDER - 5MANUAL CORE					
BUILDER					
(SEYUN SYSTEM)	4305	27155	14	11	658.15
CORE BUILDER – 6 MANUAL CORE BUILDER	4306	26324	15	16	442.16

(SEYUN SYSTEM)					
Fin Mill - 4 (14 X 8mm Fin height)	3304	25807	16	27	49.434
FIN MILL - CONDENSOR	3101	21729	17	24	172.44
Heater Core Builder(SEYUN SYSTEM)	4404	21227	18	15	517.24
SEMI Auto Core Builder - 8 (from Condenser Line)	4402	17903	19	20	318.3
EVAP SUSRING	4202	17433	20	8	874.45
EVAP SUSRING	4201	17326	21	7	928.91
CORE BUILDER - 2 (NEW PA C/B)	4203	17127	22	25	132.18
TUBEMILL2	2602	16543	23	14	590.62
Heater Core BuilderSemi Auto	4403	16367	24	19	364.5
TUBEMILL1	2601	15369	25	9	758.42
300 T PRESS	1201	12144	26	22	259.21
400 T PRESS	1601	3103.6	27	23	200.4
150 T PRESS / Roll Forming Machine	1401	2220.9	28	28	46.797

Table 1: Comparison of the bottleneck analysis using Avg. Length and Avg. Wait method

Machine	Machine Code	Utilisation (Setuptime-Inactive)	Utilisation (SetupTime Active)
Fin Mill - 3 (18.5 X7.77mm, 25.9 X7.77 ,			
5.9X9,			
42X8,56X7.7,72.6X7.35 Fin height)	3303	0.68813	0.98312
FIN MILL - CONDENSOR	3102	0.6736	0.98171
SEMI AUTO -2	4101	0.80371	0.96626
CORE BUILDER - 3	4302	0.96399	0.96399
FIN MILL - EVAPORATOR	3201	0.43936	0.91291
Fin Mill - 5 (25.9 X 7.7 mm & 5.6mm Fin			
height)	3305	0.35539	0.84193
TUBEMILL1	2601	0.45943	0.78178
Fin Mill -2 (18.5 X7.77mm, 25.9 X7.77 ,			
25.9X9, 42X8,56X7.7,72.6X7.35 Fin (eight)	3302	0.57191	0.71749
Fin Mill - 1 (18.5 mm With 7.77mm Fin			
height)	3301	0.50895	0.71583
TUBEMILL2	2602	0.48109	0.71227
Heater Core Builder(SEYUN SYSTEM)	4404	0.69192	0.69192
EVAP SUSRING	4201	0.61532	0.61532
300 T PRESS	1201	0.55485	0.59316
EVAP SUSRING	4202	0.58842	0.58842
FIN MILL - CONDENSOR	3101	0.38729	0.57118
Heater Core BuilderSemi Auto	4403	0.46867	0.46867
IDAM RAD CORE BUILDER	4303	0.45776	0.45776
400 T PRESS	1601	0.22936	0.35524
SEMI Auto Core Builder - 8 (from			
Condenser Line)	4402	0.30467	0.30467
MANUAL C/B - 2	4103	0.23892	0.28325
CORE BUILDER - 5MANUAL CORE			
BUILDER			
	4305	0.26906	0.26906
SEMI AUTO CORE BUILDER - 4	4304	0.26224	0.26224
Fin Mill - 4 (14 X 8mm Fin height)	3304	0.15085	0.192991
EVAP SUSRING	4104	0.1213	0.141002
150 T PRESS / Roll Forming Machine	1401	0.088098	0.126408
Matrix core Builder - 7	4307	0.095101	0.095101
CORE BUILDER - 2	4203	0.094257	0.094257
CORE BUILDER - 6MANUAL			
CORE BUILDER(SEYUN SYSTEM)	4306	0.086904	0.086904

Table 2: Results of the bottle neck analysis using Utilisation method

B. Sensitivity Analysis:

Being able to track the bottlenecks by the bottleneck analysis, its turn to find the way in which the bottle necks are attacked. Productivity (Through put) being the main objective of any firm, the sensitivity analysis has been done on the the simulation model. This has given an insight details about the system, where the sensitivity of the system to various parameters such as Process time, Setup time and batch size are analysed

A Set of four experiments has been done for a simulation run of 1 month period for the following cases and the effect of these parameters on the through put is found out as a percentage increase in production.

- Process Improvement of 10%
- Decrease the Setup time by 10%
- Increase Batch Size by 10%
- All the three simultaneously

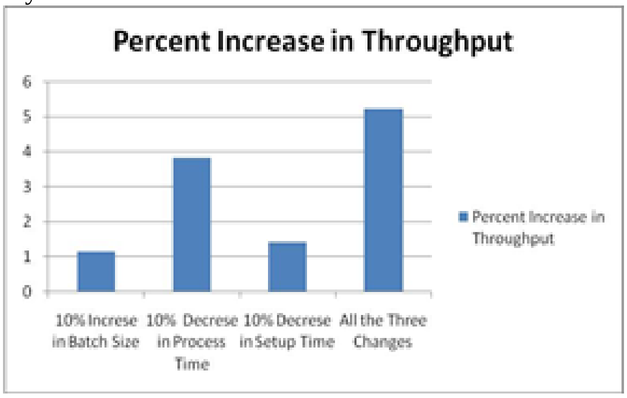

Fig. 2: Bar Chart showing the sensitivity of the system to different parameters 55

C. Conclusions:

Following are the conclusions drawn from the above analysis conducted on the simulation model for a run of 1 month.
Conclusions from the bottle neck Analysis:

- Six(6) of the total Eight(8) Fin Mills in the facility are among the top Ten(10) in terms of utilization which will be a major challenge for the production which questions the capacity of the facility in long term.
- The above statement is also in partial agreement with the results obtained in Average waiting time method with Five(5) Fin Mills out of the top Ten(10) .
- Little Relief in the rankings of the Fin Mills is observed when utilization does not include setup time as active. Thus concluding that a huge amount of productive time is lost in setup of tool or coil changing
- The Secondary Bottlenecks being the Core Builders, Which can be tackled easily by taking steps in order to distribute the load evenly among the various Core Builders which are spread along the list from top to the least.
- Further every single core builder is only responsible for a single type of product or a few as compared to Fin Mills which effects the whole category (Say Radiators OR Condensers) of products

1) Conclusions from Sensitivity Analysis:

- The system is found to be more reactive to the process time comparative to the batch size and the set up time.
- Though productivity can be increased to very little extent with improvement in the batch size and setup time.
- The other interesting fact that have found is the increase in the productivity when all the three factors are applied (around 5% in the chart) is less than the summation of the sensitivity of the other three factors which comes around 6 % (1%+4%+1%). This behavior is due to the lack of demand beyond this point.
- Therefore increase in the performance of the facility beyond this may be useful only in decreasing the response time of the facility but not the productivity.
- Further the parameter with high sensitivity (say process time) is to be focused for improving for that of bottleneck machines given in the bottleneck analysis section compared to the less sensitive parameters.

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