ANALYSIS

27(98), January 1, 2015

ISSN 2278–5469 EISSN 2278–5450

Discovery

Influence of Defect Rate Analysis on Production Planning: A System Dynamics Perspective

Giridhar Kamath B[1], Aruna Prabhu[2]

1. Manipal Institute of Technology, Manipal, India; Email: giridhar.kamath@manipal.edu
2. Manipal Institute of Technology, Manipal, India; Email: aruna.prabhu@manipal.edu

Publication History

Received: 07 November 2014

Accepted: 16 December 2014

Published: 1 January 2015

Citation

Giridhar Kamath B, Aruna Prabhu. Influence of Defect Rate Analysis on Production Planning: A System Dynamics Perspective. *Discovery*, 2015, 27(98), 48-53

ABSTRACT

Effective production planning has always been a threat to manufacturing plants. In this extremely competitive era, manufacturing firms are facing stiff competition in the market based on price, quality and reliability. Any factor that can be of some competitive advantage to the firm is well appreciated. A lot of research is done to enhance the effectiveness, efficiency, and productivity of the firms. Optimum inventory levels, well planned production rates, minimum delays and reduced breakdowns, can help in capacity utilization. In-process inspection carried out to identify the process deviations affecting the quality of the product, and the finished product inspections shows a firm's commitment to quality standards. In these stages lot of products are accepted, rejected and repaired making it very difficult for the production department to plan the production activities. In this paper an attempt has been made to look in to the various reasons that causes the defects mainly focusing on men, machine, material and methods, and based on the interpretations a system dynamics model is developed to observe the rate of defects. This paper describes the way to plan the future production based on the presumed deviations which varies the rate of defects.

Index Terms— Quality, defects, rejection, rework, acceptance, production, system dynamics

1. INTRODUCTION

Planning is the heart of all operations and can act as a tool which can provide substantial leverage over the competitors. India being a country with 65% population below 35 years of age is exceedingly focusing on manufacturing the various consumer goods in India

itself rather than importing from other countries. With lot of emphasis by the government for manufacturing consumer goods in India, it becomes essential for the manufacturing firms to carry out a lot of introspection and spot the reasons for quality defects, work on it, reduce it or eliminate it. It has become a common trend for manufacturing firms to go for various certifications of quality. Even though the various quality certifications don't guarantee better quality, it definitely encourages the manufacturing firms to focus on the basics and deliver high quality goods to the customer at a competitive price. Goods can be competitively priced based on various factors. One of these factors would be reduced rejection while manufacturing. This paper focuses on the importance of reduced defect rates that can play a vital role in producing more from minimum inputs there by saving time, energy and expenses for the manufacturing firms. The underlying idea is that by reducing the in process defects, the planned production can be achieved to a great extent. This paper address the aforesaid issues based on System Dynamics modelling. Based on factors that influence defect rates, a simulation is carried out and the graphs are studied to understand the various scenarios and an attempt has been made to draw conclusions from the same that can be of help to the manufacturing firms.

2. LITERATURE REVIEW

In simplest terms productivity is defined as output by input where the emphasis is on increased output with minimal inputs. Productivity always brings with it quality in to discussion. In simple terms quality is defined as confirmation to standards or fitness for use. These are the most famous and widely accepted quality definitions often used by researchers. Quality always focuses on minimizing or eliminating defects. Concepts like six sigma highlights the importance people pay to overcome defects and minimize rejection or scrap. Minimal defects and rejection always help in cost reduction which is the prime focus of any manufacturing firm. Reliability plays a pivotal role that eventually reflects on the manufacturing performance [1].

The performance of a manufacturing firm lies on different factors [2]. Based on the type of analysis, the measure of firm performance varies. Researchers have proposed many factors that could help in measuring the performance of a manufacturing firm [3]. Two of these factors were quality and productivity. Literatures also have stressed on quality and productivity as performance indicators [4]. Focusing on manufacturing sector, many have stressed on importance of quality in the current era [5].

Quality comes with a cost and one has to make sure that the quality costs are always in control. Dale and Plunkett describe Cost of Quality (COQ) as the costs that include not only design implementation, and operation and maintenance of a quality management system but also the costs involved in continuous improvement and the costs of product and service failures [6]. Costs could be quantitative measure of various costs such as costs added for new machines along with material handling equipment or overtime [2]. This clearly has drawn attention of people to the costs of defects that can add up to millions in mass production.

Prevention costs are those investments done to eliminate the cause of defects whereas the appraisal costs are incurred in detection of defects either during the process or during the end process inspection [7]. The failure costs deal with the costs incurred in correcting a non-conformity before or after the product reaches the customer [8]. Manufacturing firms in India face a great challenge from frequent down times and low obtainability of plants [9].

Keeping in mind the quality issues and the need for Total Productive Maintenance (TPM), researchers have developed many models with TPM as the focus. One such model [10] is as shown in Fig. 1.

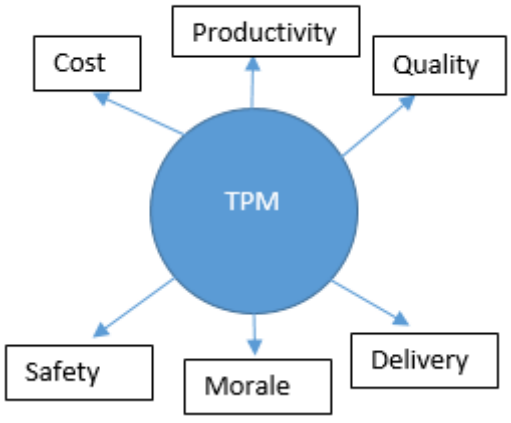

Figure 1 Elements of TPM

Researchers have successfully concluded that TPM helps in achieving high levels of quality and ensures strong delivery performance [11]. Talking about performance, [12] many papers have also emphasized the importance of quality and cost. Firms focusing on Total

productive maintenance [10] give importance to increased productivity, highest quality, minimal cost, high emphasis on safety, timely delivery of high quality products, and of course high morale of the employees. The different performance indicators of quality and their units of measurement are as shown in the table 1 [13]. This paper takes in to considerations these four indicators namely, line rejection, process defect, scrap and rework, and defect rate [13].

Table 1 Tpm element- quality: performance indicators

	Performance indicator	Units of measurement
Quality	Line rejection	Percentage increase/decrease
	Process defect	Percentage
	Scrap and rework	Numbers
	Defect rate	Percentage

3. METHODOLOGY

The methodology used in this research is System Dynamics (SD) methodology. It originated in the 1950s and has five steps that helps in conducting research in any field of science and technology. The five basic steps [14] are firstly, the problem identification or the boundary selection process. In this stage the problem is studied systematically and the boundary of the research is defined. In the next step dynamic hypothesis is framed and analyzed. Here a causal loop is developed with problem and the boundary in mind. This makes way for the stock and flow diagram where the parameters are equated using mathematical formulas. Successful simulation of the model helps in problem solving based on the results obtained. In this research based on the surveyed literatures, a causal and effect diagram has been developed which is then converted in to the stock and flow diagram. The simulations are carried out and the final graphs are analyzed. The whole manufacturing system is seen as a whole rather than just focusing on the defect rate. This broader vision helps in identifying parameters that could possibly have an influence on causing the defects.

4. MODEL DEVELOPMENT

Keeping in mind the manufacturing scenario and the various factors that affect the quality of the product, a fish bone diagram or a cause and effect diagram has been developed as shown in Fig.2. With defects as the dependent variable, men, machine, methods and material have been considered as the independent variables. Men, machine, methods and materials may in turn be considered as dependent variables and the various factors influencing its impact can be studied. The main advantage of the fish bone diagram is that it clearly demonstrates the relationship between the outcome and the various factors influencing the same. Fish bone diagram can lead to the root cause analysis and several problems can be solved by taking the corrective actions thereby.

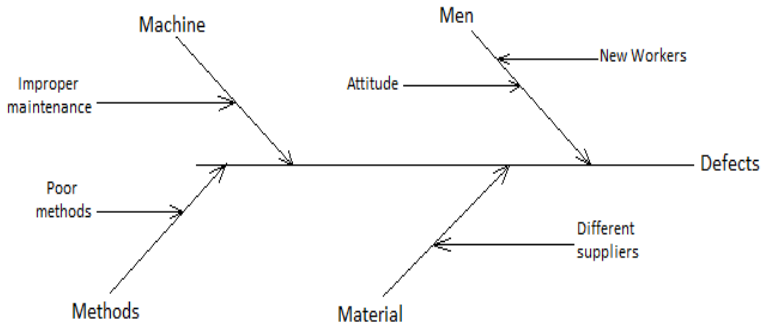

Figure 2 Cause and effect diagram

The various factors that are considered in this paper are discussed below.

Root Cause Analysis: Root cause analysis is carried out to identify the sources which create the defects. Sources may be normally generated from Men, Machine, Material, Methods, Mother Nature, or Money.

Men: As demand varies over a certain period of time organizations increase the rate of production by increasing the man power. So newly employed technicians may not able to perform as per the predefined standards which could possibly increase the in-

process deviations. Hence these deviations increase the defects in the products.

Machine: The machine can perform well and can consistently produce good quality products only when it's in a good condition. Defective machine also may damage both quality of the product as well as safety of worker. Routine maintenance activities should be followed in order to avoid these uncertainties.

Material: The suppliers of any manufacturing organization may be different and the products produced from different supplies will have different quality characteristics. An organization cannot be depending on only a single supplier due to the demand and supply variations. These raw material variations will have impact on quality which leads to creation of new defects. This needs to be corrected during the processing which effects the production.

Methods: Any production process or methods are adopted based on the various tests carried out during the prototype production. Procedures used for prototype modelling are validated and implemented based on the results. These methods require process improvements which may improve the quality of the product.

Mother Nature: Environmental conditions also affect the quality of the product. Temperature and humidity variation during the production activities gives rise to defects in the products.

Money: Manufacturing organizations may collaborate with the poor quality suppliers to take credit benefits due to the financial constraints. Industries may not be able to pay workers' salaries which may reflect on their reduced performance levels thereby affecting the quality of product.

So in root-cause analysis sources are found and fixed, and preventive actions are taken in order to avoid the recurrence of the defect.

Based on the root cause analysis, an attempt has been made in this paper to generate a System Dynamics model shown in Fig.3. In this model inventory is taken as a stock which depends on the production rate and the clearance rate.

The defect rate is controlled by the various root causes. As errors vary, the defect rate also varies. The defective parts can be grouped in to accepted stock, rework stock and rejected stock based on the severity of defects. Severity of defects is judged based on the error contribution which has structural impact on the product. For example material error and process error affects the structural integrity of products, so these errors contribution will have more severity which leads to rejection. So all these factors are considered and the model is simulated varying the error rates gradually. This model can be used for planning the production when there are different types of errors challenging the production system.

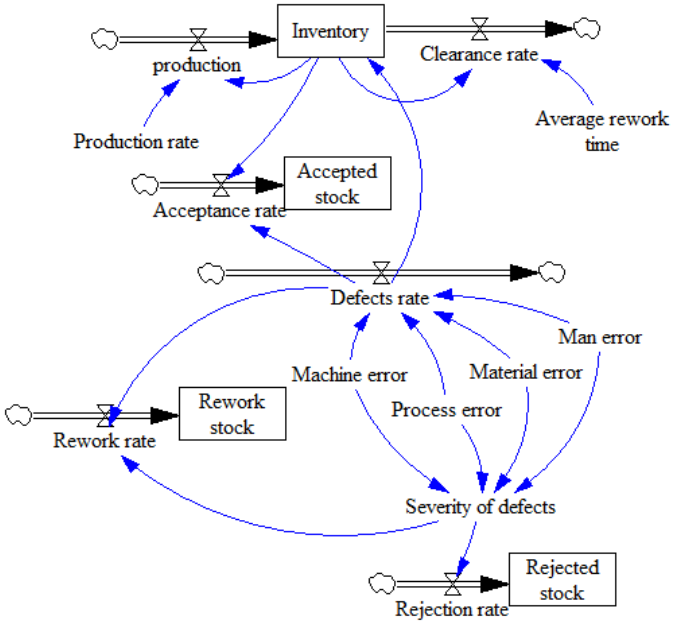

Figure 3 Stock and Flow diagram

5. ANALYSIS

This study was conducted on composite manufacturing industry. Process deviations was one of the prime reasons for defects. Interview was conducted with technicians and engineers to find out the actual cause of the problem. It was found that only 60% of

the products were accepted, 30% went for rework and 10% were rejected. The rate of defects were varying from time to time. These variations cause problems in planning the right production. Analysis of the last year data showed that summer season caused variations which could directly be credited to the humidity factor which is considered as a method error in this case. It was observed that with new recruits in the process, men error rate was slightly higher where as poor maintenance of the machines increased the machine error rate. Improper storage and handling of materials during the process also affected the quality of the product. Accepted stock, rework stock and rejected stock are the outputs whereas, various defects were considered as the input parameters in the model. So simulation was done based on the contribution of various percentages of errors described in different scenarios. The rate of errors were varied gradually and the outputs are as shown in the graphs.

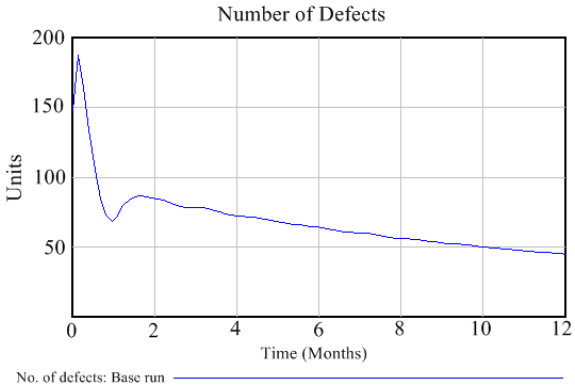

Figure 4 Number of defects

The model developed was simulated and the rate of production was studied when subjected to various defects like men, material, machine and process defects. As shown in Fig. 4, the simulation was carried for 12 months. The model was simulated based on the rate of defects and its causes in the past. The graphs obtained can help us in forecasting the production rate for the upcoming year. As shown in Fig. 4, initially, the rate of defects is high due to the high error rate. After the causes are identified and rectified, the defect rate comes down and stabilizes over a period of time.

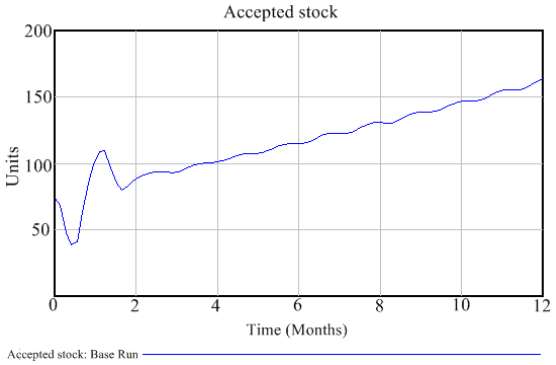

Figure 5 Accepted stock

The defect rate increase impacts the accepted stock and the inventory level. When the defect rate was high, the accepted stock was less. Hence it is very clear that the defect rate control is a must and focus on quality is very important to control the product cost and increase the sales. As shown in Fig. 5, when the root cause is identified and corrective measures are taken, the accepted stock rate can be increased. The defect rates when carefully studied helps in planning the production rate so that the demand can be met optimally keeping inventory levels in control. The accepted rate going down is because of the number of defects at high. As the number of defects are taken care of by focus on corrective measures, the accepted stock increases. High accepted stock plays a key role in controlling the inventory levels too. With the rate of acceptance increase, the rework and the scrap ratio comes down which means the cost of quality is not exceeding the preset limits. The cost of quality when in control can help the firm with competitive advantage that can provide a high leverage in the industry under consideration.

Fluctuations in different error rates, causes fluctuations in the inventory levels as shown in Fig.6. Also the inventory levels depends on the shipping rate. Shipping rate depends on the orders received and the quality of the product. The products sent for

rework may either be accepted or scrapped which further has its toll on the inventory levels. High inventories, increased scrap rate, delayed shipments and substandard quality can have negative impact on the costing of the product and may hamper the firm performance to a great extent. The model discussed in this paper can be extended by adding many other variables like demand, supply, and other cost parameters and can be simulated for different situations. The findings discussed in this section can help firms to maintain their production rate at optimum level and also focus on the root causes that cause certain defects and help the firms maintain a high quality timely product delivery thereby staying ahead of the competitors.

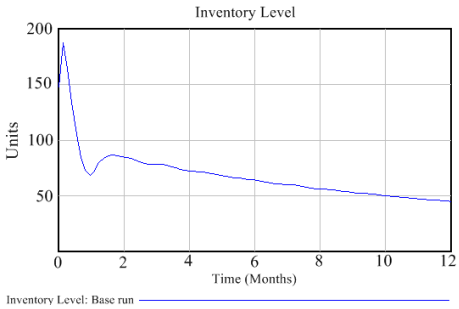

Figure 6 Inventory level

6. CONCLUSION

The System Dynamics model developed in this paper can be used as tool for planning the production when there are different sources affecting the quality of the products. Manufacturing of standard quality products is a tough ask because of the random causes which cannot be identified and they are also independent of time. Some of the errors due to known sources can be controlled. But in mass production it is difficult to monitor these activities which lead to complexity in decision making. So this model helps to understand the quantity of the products to be produced when different causes are quantified for a given period. The model discussed in this paper concentrates on fixing minimum errors but this can be extended for varieties of errors that a production system faces. Many other parameters that seem to influence the inventory levels, production rates, productivity, effectiveness of the system, efficiency of the employees can be added to the existing model in this paper and variations in defect rates and accepted stock can be studied.

REFERENCE

1. K. Rezaie, M. Dehghanbaghi, and V. Ebrahimpour, “Performance evaluation of manufacturing systems based on dependability management indicators-case study: chemical industry”, International Journal of Advanced Manufacturing Technology, Vol. 43 No. 5, 2009, pp. 608-619.
2. Garbie, "Performance analysis and measurement of reconfigurable manufacturing systems", Journal of Manufacturing Technology Management, Vol. 25 No.7, 2014, pp. 934 – 957.
3. W. Zhong, V. M. Speredelozzi, A. Bratzel, S. Yang, S. Chick, and S. Hu, “Performance analysis of machining systems with different configurations”, Proceedings 2000 Japan-USA Flexible Automation Conference, MI, July, 2000, pp. 783-790.
4. V. M. Speredelozzi, and S. J. Hu., “Selecting manufacturing system configuration based on performance using AHP”, technical paper, Society of Manufacturing Engineers, Dearborn, MI, 2002.
5. M. Colledani and T. Tolio, “Impact of quality control on production system performance”, CIRP, Vol. 55 No. 1, 2006, pp. 453-456.
6. B. G. Dale, and J.J Plunkett, Quality Costing, 2nd edition, Chapman and Hall, London, 1995.
7. P. Love and I. Zahir, “Influence of Project Type and Procurement Method on Rework Costs in Building Construction Projects” Journal of Construction Engineering and Management, 2002.
8. J. Robison, “Integrate quality cost concepts into team problem solving efforts”, Quality Progress, March, 1997.
9. R. Sharma and V. Trikha, “TPM implementation in piston manufacturing industry for OEE”, Current Trends in Engineering Research, Vol. 1 No. 1, 2011, pp. 122-129.
10. B. Johansson and C. Nord, “TPM – one way to increased competitiveness: examples from a medium sized company”, (in Swedish), 1996.
11. K.E. McKone, G.S Roger, and O.C Kristy,. “Total productive maintenance: a contextual view”, Journal of Operations Management, Vol. 17 No. 2, 1999, pp. 123-144.
12. M.R Abdi, and A.W. Labib, “Performance evaluation via holonic architecture and the analytic network process”, International Journal of Production Research, Vol. 49 No. 5, 2011, pp. 1319-1355.
13. J Kumar, V Kumar, S Agnihotri, “Impact of TPM implementation on Indian manufacturing industry", International Journal of Productivity and Performance Management, Vol. 63 No.1, 2014, pp. 44-56.
14. J. Sterman, Business dynamics: systems thinking and modeling for a complex world. USA: The McGraw-Hill Companies, Inc., 2000.