Risk Mitigation in manufacturing process through development of 4M Model

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Abstract

This study deals with the formulation and implementation of a risk mitigation frame work for identifying the critical nodes of failure, in the manufacturing process at an auto major, and development of an IT system to track and control these changes. Faced by an increasing level of complaints in the products from customers, the company decided to conduct a study of the root causes of the major problems reported by the customers. One of the main cause of the problem was due to unapproved 4 M (Man, Machine, Material, Method) changes at the company's plant and the suppliers. The company decided to develop an IT system to track and identify the changes made on the company's shop floor and it's suppliers, and to check if the changes had the requisite approvals from the process owners.

Rather than designing a system to only track 4 M change approvals, the company decided to initiate the implementation of a customer facing risk mitigation framework, through the IT system. To identify the critical nodes of failure in the process, an FMEA (Failure Mode and Effect Analysis) approach was used and RPN (Risk Priority Number) was be estimated for these nodes using field failure data over a period of time. Tracking of changes using an IT based 4 M framework , helped in checking the unapproved changes and thus reducing the variability in the manufacturing process. Traceability of these changes also improved, both internally and with suppliers.

Key words: risk mitigation, 4 M framework, traceability of changes, FMEA, RPN

1.   Introduction

Good product quality is crucial for the image of any manufacturer. Thus when products are manufactured, there is an attempt to see that there is no defect in the product. If the customer finds a defect, there is a loss of 'customer goodwill' through word of mouth and also through 'warranty claims'. However stricter norms are in the pipeline, with the 'Society of Indian Automobile Manufacturers' now initiating the 'vehicle recall policy', where if a defect is found in any component, the manufacturer will have to recall all vehicles with the defective component. This has two immediate implications on the manufacturing shop floor. First there has to be a traceability built at the component level, so that the batch of components being assembled into the product, are identified. This would enable the company to 'recall' a batch of vehicles with defective components. Next the

company has to have a risk mitigation plan, so that the potential liability or risk of a 'major recall' can be mitigated and managed.

Building on these requirements, the automobile company under study, which already had a global database in terms of customer discovered 'defects' and warranty claims, wanted to build a an IT system which would allow traceability, risk mitigation, and reduced quality defects which came to the customer's notice.

The paper is laid out as follows: First literature related to risk management framework is reviewed. Next the methodology for the paper is discussed. The next section relates to results and is broken up in three parts. First the analysis of the defects and warranty data is done to identify the frequency and

severity of occurrence of the defects. Next the data is used to generate a scale for assessing the Risk Priority Number (RPN) of the defect. Then defects with the highest priority are taken up for root cause analysis and action for mitigation or removal of the defect. The approach and initial pilot was finally audited by a senior management team in the organization, and when the benefits from the pilot were established, the project was approved for full scale implementation.

2.0   Literature Review:

2.1   Risk and Risk Management:

Risk and risk management have become the dominant features of the lexicon of today's management. The definition of risk has been changed and broadened ascribing this to increasing unsystematic risks. Common features in the various paradigms relating to risk typically incorporate the issues of unpredictability, decision-making and potential loss. For example, Sitkin and Pablo (1992) define risk as 'the extent to which there is un-certainty about whether potentially significant and/or disappointing outcomes of decisions will be realized.' MacCrimon and Wehrung (1986) identified three components of risk: the magnitude of loss, the chance of loss and the potential exposure to loss. March and Shapira (1967) suggest that the reason that risks are taken or not depends on the variation in perception of such losses. Zsidisin et al (2004, p 397) provide a useful operational definition that 'risk is perceived to exist when there is a relatively high likelihood that a detrimental event can occur and that event has a significant associated impact or cost[1].'

2.2   Risk Management process:

Risk management process consists of 4 steps which includes the following 1) Risk identification 2) Risk assessment 3) Risk prioritization 4) Risk Management

Risk Identification: Risk identification deals with the systematic and thorough compilation of all risks relevant for a supply chain. As many entities are involved in a supply chain, not only do the risks within the own company have to be identified. Incorporating the company's proximate and macroeconomic surroundings in the risk appraisal is essential. Environmental factors are made possible. Commonly, managers attempt to comprehensively identify risks from an individual company's

viewpoint. Due to the lack of supply chain simplicity and visibility, it is often too costly and difficult for managers to identify all risks, for instance those upstream at a tier 2 supplier. It is often not feasible for a company to be aware of all collateral suppliers (Jüttner, et al., 2003). Therefore, supply chain complexity paired with insufficient supply chain visibility and information sharing can lead to a far from complete risk profile. (Hallikas, et al., 2004).

2.3 Risk assessment :

In order to assess the likelihood (probability of occurrence) of the identified risks and their impact, Jüttner (2005) identifies nine rather informal, process-based tools. Among these methods are supply chain specific assessment practices, such as critical path analysis or supply chain mapping and traditional risk assessment techniques, such as brain storming, scenario planning or the Six Sigma method. Neureuther& Kenyon (2009) propose one possible formula to compute the overall risk index of a supply chain. Risk severity (i.e. impact) and the business level risks take effect on have established themselves as the primary qualitative criteria in assessing risk (Jüttner, et al., 2003).

Risk management framework:

It consists of the followings

1. Identification of risk drivers
2. Measurement of consequences
3. Assess alternative responses
4. Risk mitigation
5. Avoidance of risk
6. Monitor and review risks

2.4   Recall and Traceability:

Recall

A product recall is a request to return to the maker a batch or an entire production run of a product, usually due to the discovery of safety issues. The recall is an effort to limit liability for corporate negligence (which can cause costly legal penalties)

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[1]This section on Literature Survey severely curtailed. Interested readers may request a more detailed literature survey by sending an email to professor.skumar@gmail.com.

and to improve or avoid damage to company brand image through negative publicity.

Traceability

Product recall are costly and time consuming process. (Nelson, 2000) Without adequate traceability, many products will be recalled for repair or replacement. Product traceability is the process of maintaining records of all materials and parts from purchasing to finished goods where a unique number identify a part, batch, or a finished product.

3.0   Methodology:

The paper has used field data and analysis of this field data with respect to defects reported by customers and warranty claims. The detailed reports of the service center and the 'Automobile Company's Engineer' with respect to 'on the spot' root cause analysis for failure have been incorporated in the database. This data has then been used to create a working scale for 'risk priority number' (RPN) based evaluation of the defects.

To evaluate the 4M system, first the FMEA analysis of 5 most critical systems has been done by the automobile company's technical team. Next the 4 M

4.0   Discussion of Results

Results can be discussed in three distinct sections. In section 4.1 we discuss the results of the analysis of the customer and warranty data. In section 4.2 we discuss the parameters for classification of the items under frequency of occurrence, severity and detection. Then the various main defects are classified using the scales developed above. In this same section we also show how root cause analysis helps to find the main nodes and items where defect removal takes place. We also discuss the role of the 4 M framework and the IT based tracking / approval system in the process. In section 4.3 we discuss the results of the audit, set up by the senior management of the company, for assessing the results of the pilot project in this area.

4.1   Analysis of the defect / warranty database of last 5 years:

A detailed analysis of the defect database of the last 5 year showed the following trends:

Traceability provides the ability to identify and track a product or a component to its point of origin. .

4 M system: The 4 M framework is used to reduce variability of the shop floor through standardizing the work practices and resources used in manufacture of a component. The IT system has been developed and implemented in select locations in the company, to allow the monitoring of standard work practices, and each deviation from the standard is approved in this system, by a process owner.

system was implemented on a pilot basis, and the data was presented to an Audit Committee set up by the company. This committee consisted of four senior most executives associated with product quality. These executives evaluated the data for the pilot and re-assessed the RPN numbers of the nodes associated with the five critical components. The main parameters affected by the new data were 'frequency of occurrence' of the defect and the ability of the firm to 'detect' the defect.This Audit was used by the company to approve the IT based 4 M approval system and recommend a company -wide approval of the system.

1. The distribution of failures by warranty claims, was analyzed by component and the top 5 components with maximum occurrence of failure were :

    (i.) Compressor, (ii.) Fuel filter, (iii.) Hose, (iv.)   fuel lid, (v.)   roof lining

2. The initial inspection of failed component at the dealer workshop was done by the 'technician' undertaking the repair. The failed components were subsequently analyzed by a 'Company Engineer' and a probable cause was identified for failure. This report of the company engineer, formed the basis of the input to the warranty / defects database. The distribution of failures by the company was identified as below:

3. Thus the data showed that 70% of the failure were attributable to supplier and only 30% were attributable to the firm (the automobile manufacturer). 60% of the total defects were attributed to supplier process problems

and 10% to the supplier part design. Of the total defects the automobile manufacturer found that 30% of all defects originated in-house with 20% arising from the manufacturer's internal production process, and 10% could be attributed to a faulty design specifications of the component.

4. The automobile manufacturer had set up a 'center of excellence' for supplier quality. A study taken up by this center showed that of the supplier defects, 70% could be attributed to process non-adherence. In supplier process capability studies, only about 30% could be attributed to 'inadequate process' or 'process capability issues'. Studies of the company's internal processes showed a similar trend for process defects. Thus the company concluded that 'system non-adherence' was a major reason for the production of defective components.

Systems non-adherence was further investigated by the company as it was a major cause of defects. The distribution of reasons for system non adherence was further classified in following heads

1. Unapproved 4M changes

2. Poor Sub vendor control

3. Process defects during production ramp up

Company's study by the center of excellence' identified the following reasons for non-adherence –mainly due to unapproved 4 M changes, as given in Table 3. This lead to variations in the process, and hence variation in process output quality.

Table 1: The percentage distribution of Failure

Supplier process:	60%	System Non-adherence	70%
Supplier Design	10%		
Company In-house Process	20%	System Inadequacy	30%
Company Internal design specifications	10%		

Table 2: Results from a supplier process capability study

Process change	Unapproved sources	Untrained operator	Unapproved raw material	Die/Tool change without
15%	15%	10%	20%	40%

4.2 Scales for the occurrence, severity and detection, and FMEA

The scale for occurrence of a defect, severity and detection are drawn up here. The process as suggested by literature (Nelson, 2003; Teng and Michel, 2009; Ritchie and Brindley, 2007) was followed and the occurrence categories were created based on evidence of actual numbers from the data base. Similarly, the severity assessment, and detection assessment was the outcome of a team of experts put together by the management of the automobile manufacturer. As Finally the team for implementation of the project had the scales to conduct the FMEA of the five critical components based on field reports, internal tests and visit to the suppliers for data collection. The final FMEA report for the 5 most critical components is given in Table 4.

Table 4: FMEA of 5 critical components based on market(field) reports & process evaluation at company and at supplier

Component name	Problem reported	Defect % contribut-ion due to 4M	S	O	D
Compressor	A/C funct-ioning not ok	22	8	6	8
Fuel filter	Filter defective	18	9	6	8
Rubber hose	Fitment loose	17	6	5	7
Fuel lid	Closing not OK	12	8	8	8
Roof lining	Appearance not ok	13	7	8	8

As can be inferred from Table 4, a reasonable percentage of defects occur due to non-adherence to

4 M (Man, Machine, Material, Methods) norms in the company and at the supplier. Thus the need for a IT based system to approve any changes in process and take approval for any proposed process change from the process owner was initiated.

4.3 Implementation of 4 M system and benefits from Pilot:

The concept of process knowledge says that for any process there are certain inputs to any process which are converted into outputs. There are certain controllable variables which affect the process, and if these variables are controlled about a mean value, then the process output is fairly constant and the process is repeatable. Sometimes a new variable starts affecting the process and the output varies. This variable is then identified using experimentation, and the variable is brought under control.

The 4 M approach follows the same approach for managing the 4 M parameters related to a manufacturing process. As long the inputs in terms of materials, men, machines and methods are not changed, the process output should be fairly consistent, and so quality defects should not arise. Thus the 4 M systems once implemented, should

yield in a reduction in the output variability, and hence in the number of defective components produced.

The pilot was implemented for the critical 5 components identified. This led to a reduction in the occurrence of defects. Also since the changes in dies, tooling, operator, methods etc was being monitored, the chances of detection of a probable defect increased. This happened because in the new system, any proposed change involved a period of monitoring and correction, before the change was approved. Thus the probability of detection of the defect also improved, because of intensive monitoring when a change was allowed.

As can be seen in tables A1 (in Appendix), the RPN numbers after implementation of the pilot show a reduction in the Risk associated with each component and node. Thus the benefit of the 4 M tracking system was component level tracking and risk reduction for the component using 4 M tracking and monitoring process. This has significant impact on the traceability and recall capabilities of the company.

5.0 Conclusion and Future Work:

The paper discusses the development of a risk management framework which is embedded in a 4 M based IT system for approving changes in the 4 m inputs and work procedures on the manufacturing shop floor of an automobile manufacturer. The warranty and customer reported defect database was used to identify the critical 5 components. This 4 M system was implemented at these five locations on a pilot basis and significant improvements were observed in the frequency of occurrence of defects. Also 'detection' improved and so the overall RPN for these five critical components improved, as assessed

by the Audit Committee, which affects traceability and 'recall' capabilities of the firm which are critical given the 'recall policy' being implemented in India.Future work can be to observe the data for 4 M implementation across the company, and see the overall reduction in defects over a period of atleast three years. Also traceability of defects has improved, since all 4 M changes are now approved with a timeline. Thus traceability of defects should also improve, and this traceability and recall capability of the company should have significant impact in the future.

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APPENDIX 1

Table A1: Results of the 4M Audit Committee based on independent evaluation of 4 experts

4M CHANGE MANAGEMENT SYSTEM EFFECTIVENESS FORECASTING BASED ON EXPERT'S VIEW																				
Name of Component	Problem reported	Reason for failure	Impact :cost Multiple of X units *	Defect % contribution due to 4M	Risk Priority No before implementation of system			Risk Priority No After implementation of system												
								Expert-1			Expert-2			Expert-3			Expert-4		
					S	O	D	S	O	D	S	O	D	S	O	D	S	O	D
Compressor	AC functioning Not OK	1.No information sharing/approval during process change 2.Unapproved tool usage	2.5X	22%	8	6	8	8	4	6	8	4	7	8	4	6	8	4	5
Fuel Filter	Fuel filter defective	1.No information sharing/approval during process change 2.Unapproved change in Molding Temperature	2X	18%	9	6	8	9	5	7	9	5	7	9	4	7	9	4	7
Rubber Hose	Hose Fitment Loose	1.No information sharing/approval during process change 2.Use of unapproved rubber compound	X	17%	6	5	7	6	4	5	6	4	6	6	4	6	6	4	5
Fuel Lid	Fuel Lid closing is Not OK	1.No information sharing/approval during process change 2.Usage of Unapproved Mould tooling	0.5X	12%	8	8	8	8	6	6	8	7	7	8	6	7	8	6	6
Roof Lining	Apperance is not OK	1.No information sharing/approval during process change 2.Usage of Unapproved Fibre material	1.5 X	13%	7	8	8	7	6	6	7	7	7	7	6	7	7	6	6