FMEA - A Team-Based Decision-Making Approach To Quality Management

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Total Quality Management (TQM) is now widely accepted as a company-wide philosophy of quality control and management to achieve world-class performances (Fogarty, *et al*, 1989). The philosophy suggests that decision-makers should analyze *backwards* the desired state of quality and in the process, identify and understand the necessary resources and decisions that would be necessary to arrive at that state within the given time frame. The broader (and rather sweeping) concept of TQM encompasses more `local' philosophies such as Just-in-Time and Statistical Quality Control (SQC) such that wastage in any form (time, space, rework, failure, materials, labour, etc.) are eliminated. Failure Mode Effect Analysis (FMEA) is a powerful proactive technique developed to prevent product and process failures. It intensively studies the design and production processes and attempts to uncover weak points at the planning stage itself for timely elimination. Conceptually, a decision tree or cause-effect chain could be created by moving backwards and identifying all the possible reasons that could lead to failure. The idea is to ultimately trace the external symptom (event) to the root problem and arrive at a cost-effective controllable process point in the short term. In this paper, I propose to provide an overview of FMEA as a management tool and at the same time suggest improvements for better effectiveness. In a separate paper, I shall use this concept to develop a technique to detect organizational failures and suggest mechanisms for turnaround and rehabilitation of sick corporations.

FMEA (also known as the fish-bone or the Ishikawa technique after its originator) was first used by Japanese automobile manufacturers to plan their production systems on the shop floor (Pfeifer, *et al,* 1994). It is now gaining acceptance in other areas like logistics, quality control and even personnel management. FMEA in its traditional form

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is largely dependent on managerial judgment and uses minimal mathematics or computer time. Despite simplicity it is an elegant technique for ensuring process performance. Like many other management techniques originating from Japan, FMEA requires team-based thinking and a mutual belief in collective responsibility. The success of this method therefore rests largely upon the behavioural-motivational aspects of the people involved in the process.

Setting up cross-functional teams

The technique is common-sensical. All that need be done is to consider *all the possible modes of failure* for a system. Any system can be studied as an input-output combination of four major factors, viz. man, machine, materials and measurements. These can be further broken down into sub-systems, e.g. man (motivation, skills, numbers), machine (components, technology, design), materials (input-output logistics, raw materials), and measurements (instruments, human element, and standards). This process of discovery of failure modes is usually done through brainstorming sessions by several cross-functional groups. The modes are then successively broken down into first level causes, second level causes and so on. Generally, the team limits the cause-effect chain analysis to a few important failure modes identified through the Pareto technique. It is important to understand that a process-system is defined by the involved team, rather than by any top-management or `outside' agencies. This constraint ensures that the system-boundaries are flexible so that the team may define its working parameters itself. The reason for creating cross-functional teams is obvious. No individual system, no matter how much experienced and closely defined it is, can ever be one hundred percent self-sufficient with regard to knowing, understanding and fulfilling the needs of different functional areas on its own. The success of the technique depends upon the correct assessment of all the possible failure modes, and therefore the need for having relevant expertise on board for the different sub-systems cannot be overemphasized.

Defining flexible system boundaries

In a cause-effect chain, the most difficult task often is to identify the beginning and end. For a backward-linking chain, this process could be never-ending. For example, in case of a railway accident, a fact-finding committee may identify drunkenness of the signalman as the main cause of accident. However, one can push this further and ask, why was the signalman drunk? It could be due to a public snub by his superior for something he was not responsible. Then is his superior responsible for the accident? This cause-effect identification can be extended to infinite levels. The key task in FMEA therefore is to decide the point where the process of breaking down a failure mode must be stopped. This means that the team may have to analyze beyond the points where control can be presently exercised, to obviate the possibility of short-term solutions based on an incorrect understanding of the entire underlying structure. A sharper penetration may unveil more fundamental reasons. Consider the following real-life problem of a heat reactor failure. It was found that the reactor had failed because of overheating of the cooling water the temperature of which was regulated by a safety valve. The safety valve had failed because the periodic maintenance required for it was neglected. Mandatory maintenance was neglected because of unclear employee responsibility structures. Employee role accountability was poor because of low employee motivation which in turn was due to poor management-staff relations. In such a judgmental scenario, there cannot be hard rules. This is a fuzzy area requiring consensus, experience, and a holistic approach towards problems.

Failure mode - frequency - severity ratings

After all the failure cause-chain has been identified for a given mode, further brainstorming should be done for creating a hierarchy of failures based on their *cost* to the organization. Some of the failure states may simply be unacceptable and some may be *tolerable*. An aircraft engine failure would be unacceptable, whereas non-latching of a passenger's seat-belt may pass in the short-term.

Once the weightages to all the failure modes have been established, the team must embark upon a cost-benefit exercise for the control systems required at various levels of the cause-effect chain. Going back to the problem of heat reactor failure, the team may decide at the first level to redesign the safety valve such that it does not require any maintenance, or it may lay a set of safety valves based on different technologies so that failure of one valve can be checked by another. Or a special post may be created for verifying the maintenance code is adhered to by the concerned staff. At the second-level, it may be felt more worthwhile to talk to the demotivated employees and redress their problems. A systematic approach is to draw a columnized table (see Table 1). The first column lists each of the failure modes. The second column denotes a severity-weightage rating on a continuum scale of 1 to 10 (1 for `low significance' and 10 signifying `catastrophic'). The third column gives a frequency rating, which is another continuum scale from 1 to 10 (1 for `very rare' occurrence and 10 for `most frequent'). The fourth column contains a detection-rating on another 10-point scale (1 signifying `easily predictable' much before the actual failure occurs and 10 denoting a failure mode which is `impossible to detect' till after its occurrence). The scores in each row across the three rating columns are now multiplied to give a *danger-rating* to the failure mode (Table 1).

TABLE 1

Failure Mode (1)	Severity rating (2)	Frequency rating (3)	Detection chance (4)	Overall rating (5)

Ascending level of final scores would imply higher dangers. Any high score (above the pre-decided cut-off score) would signify a highly possible failure mode having grave and cascading negative consequences on the performance of the system. The reason for multiplying the scores (instead of say adding) across columns is to recognize the fact that *within an acceptable severity band,* a mode with medium scores on the three columns is more dangerous than one with some high and some low scores. For example, a rating of 5, 5, 5 (multiplied total 125) is conceptually far more dangerous than a rating of say, 1, 9, 5 (multiplied total 45).

While deciding the ratings, it would be useful to bear :

i) The ratings must be given in terms of the present context and not any futuristic event. This approach takes into account the efficacy of the present organizational control systems. However, the existing system of controls becomes irrelevant once the process of identifying and breaking down of failure modes commences.

ii) The ratings, strictly speaking, are not interval scaled. Therefore, no rating should be given before all the modes have been discussed thoroughly by the team members. The ratings are relative to each other, that is, the most severe must be given a value of 10 on severity and the least severe a value of 1. The rest of the modes are then appropriately scaled relative to these two ends of the continuum. To ensure compliance, the ratings should first be given column-wise, first for all the modes on severity, then for frequency, and finally for detection- rating. The raters should move row by row for the first column, and only after finishing the column, switch to the second column and so on. This caution is exercised to ensure correct relativity of the scores on each column.

After all the danger-ratings have been allotted, the modes can be sorted on a descending order. The team at this stage can decide on a cut-off point, in terms of which no action will be taken for the modes falling below the cut-off point. This cut-off score also becomes the target point to which all other modes having a higher value need to be brought down to.

An iterative process

Starting with the top most mode, all the final level causes are explored to check whether the existing controls can be improved or need to be revamped. Fresh controls are established if there are no existing controls for that cause. Once this is done, the values in columns 3 and 4 are rerated keeping the new controls in mind. This requires quantification of costs and benefits of proposed controls. The team should be able to quantify the relative performance improvement expected from a work station once the new controls have been put into effect (such as, fewer machine break-downs (frequency), the cost impact for each breakdown (severity), and the advance time available for detecting the breakdown. The iterative process of rating, sorting and reclassification of modes in terms of the cut-off point continues till all the modes reach the stage of being below the cut off level.

Setting the cut-off point

One key question remains: how is the seemingly all-important cut-off point decided. For this purpose, quantitative methods would be useful if past data on failures is available. For instance, factor analysis can detect the factors that seem to contribute most to failures. If past failure data is not available, the firm has to rely on experience and contextual familiarity to decide the cut-off point. Cooperation of key employees and departmental functions at this stage becomes essential. In any case, the management has to exercise judgment in deciding the *dangerousness* of the factor.

***Kaizen* -- the desire for continuous improvement**

The FMEA technique presupposes *kaizen* (continuous learning and improvement) approach towards quality management. Once all the weak points have been addressed to and brought below the maximum acceptable cut-off point, the next obvious step is to review the cut-off level. After the resetting of the cut-off point, an iterative process of rerating the cause-effect chain would reveal new fault lines and areas of process improvement requiring newer cost-effective control measures. At this point of time, the team or senior management may wish to bring in the dimension of future technological competitiveness as well.

Limitations of and preconditions for success of FMEA

1) FMEA can be time consuming and often important personnel from key operations have to be pulled out to form an effective cross-functional team.

2) FMEA, as might have been observed, is a labour-intensive process and therefore expensive. The conventional approaches therefore are sought to be replaced by more form-based and knowledge-based concepts.

3) Extensive data of the existing system is often necessary for a thorough analysis. Often for very complex projects, the conventional approach to FMEA may be unfeasible for the sheer size of the failure mode and the chains generated.

4) Top-management commitment to the process is necessary for sustained periods. This is often difficult since there are no tangible solutions but only problems (failure causes). In the initial stages the presence of an external consultant facilitates the difficult process of team integration.

5) The conventional FMEA method is weak for the purpose of organizational learning. Computer programmes have been developed which permit on-line cataloguing and record of the fault lines, potential weak areas, and suggested control measures (Harmon & Sawyer, 1990).

6) Often the team exercises judgment about the severity of the causes just to limit the number of alternatives being generated. This creative approach, though useful, may lead to sub-optimal choices.

7) It is author's experience that team members used to hardcore quantitative approaches and computer-based heuristics are uncomfortable with FMEA. It would have been observed that each sub-process of this technique *appears* quite subjective, however in reality it is not.

8) Often, after a brainstorming session it may be felt that no dramatic or useful results have been achieved. This is generally due to the system boundaries being defined too rigidly. The boundaries should be loosely defined such that any possible cause could be broken down till a point is reached *where the organization can no longer profitably exercise control.*

A recapitulation of the FMEA technique

To summarize, the FMEA process involves:

1) TEAMS: Forming a cross-functional team with participation of senior executives, supervisory staff, skilled workers , and sometimes suppliers.

2) DETECTION: Identification of all possible failure modes. Use of Pareto principle to limit the number of failure modes to manageable numbers.

3) ANALYSIS AND SYNTHESIS: Clubbing of the various failure modes to arrive at a list of mutually exclusive modes.

4) RATING: Rating the failure modes on three scales of severity of failure, frequency of occurrence, and chance of detection.

5) CUT-OFF POINT: The team has to establish a cut-off danger point.

6) COST-BENEFIT ANALYSIS: The modes above the cut-off point must be taken up and checked for the changes that are needed in the existing controls to pull down the danger score of the mode to below the cut off.

7) ITERATIVE RERATING: All the modes for which new level of controls have been installed must be rerated and the benefits of the new control systems in relation to the costs be decided. Iterate the process till all the modes are below the danger level.

8) TIME-BOUND ACTION PLAN: A time-bound action plan must be set up to implement the changes proposed during the analysis.

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