Proceedings of the
International Conference on Mechanical Engineering 2009
(ICME2009) 26- 28 December 2009, Dhaka, Bangladesh

ICME09-RT-34

AN INDUSTRIAL APPLICATION OF DMECA APPROACH TO MANAGEMENT PROCESS ANALYSIS

Azizur Rahman[1], M. Kutub Uddin[2]

[1]Dept. of IEM, KUET, Khulna, Bangladesh
[2] Dept. of ME, KUET, Khulna, Bangladesh.

ABSTRACT

This paper presents an industrial application of “Dysfunction Mode and Effects Critical Analysis” (DMECA) to determine and analyze possible dysfunctions in a complex management process. The approach conceptually derived from the Failure Mode and Effect Critical Analysis (FMECA) technique. DMECA enables user to analyze all possible dysfunctions of management processes, identify the subsequent effects of each potential dysfunction, make a list of priority interventions for all the dysfunctions, prioritize and classify the dysfunctions by the Risk Priority Number (RPN) which represents the severity of the consequences, investigate potential causes of dysfunctions and determine the improvement actions. In order to illustrate the performance of the technique, an industrial application concerning analysis of management process in a power plant is presented. It is identified 175 potential causes for the whole management processes and found that 60% of the dysfunctions can be corrected by solving only 15% of the causes.

Keywords: Dysfunction Mode and Effect Critical Analysis (DMECA); Failure Mode and Effect Critical Analysis (FMECA); Total Quality Management (TQM).

1. INTRODUCTION

Following the principles of the Total Quality Management (TQM) philosophy, the ISO 9000:2000 standard emphasizes the process approach to manage an organization’s quality system. ‘Process approach’ means that all the activities must be identified, managed and controlled. In particular, the organization must: (i) define the interrelations between processes, and (ii) monitor how a dysfunction in a process (or activity) influences the results of other processes (or activities). Another TQM concept emphasized by ISO 9000 norms is related to continuous improvement of processes, and involves applying Deming’s Plan-Do-Check-Act (PDCA) paradigm. Therefore, the organization must correctly select the most important and critical processes, which need improvement actions.

The literature to date does not provide a unique suitable technique that is able to represent a systematic and logical approach to (i) describe and analyze management processes, and (ii) select improvement actions. Two main classes of techniques are adopted to analyze processes. The first class constitutes methodologies to represent a process or more interrelated processes based on graphical methods [1]. Unfortunately, although this technique can identify the correlation between activities and define the ‘father-child’ relationship between processes, it cannot define the criticalities of possible dysfunctions, nor does it permit the establishment of criteria or the definition of priorities of improvement actions. According to Goulden and Rawlins (1995), by using this approach, activities could be mapped together to build an integrated picture, however this can be a time consuming task with visually confusing results and so can fail to engender a sense of ownership and widespread understanding of management processes[2]. Similar conclusions regarding the limitations of the IDEF type models for process analysis have been reached by Dale and Plunkett (2000)[3]. The second type of approach is represented by problem solving techniques, which are generally able to define the priorities and criteria of improvement actions by adopting structured approaches composed of brainstorming sessions, decision-making support methods, correlation and pondering matrixes and flow diagrams for example. Unfortunately, they neither permit the correlation of the results obtained from improvement actions with other processes, or the evaluation of their impact.

In summary, the literature to till date provide an approach name Dysfunction Mode and Effects Critical Analysis (DMECA) which is able to support description and analysis of processes and, contemporaneously, able to investigate dysfunction consequences, their impact on whole process efficiency, and also the definition of improvement actions. In this paper according to this new approach a case study is presented to evaluate the effectiveness of the DMECA approach.

2. DYSFUNCTION MODE AND EFFECT CRITICAL ANALYSIS (DMECA)

The DMECA method proposed is conceptually derived from the Failure Mode Effect and Criticality Analysis (FMECA) approach which was originally developed and used in reliability and maintenance activities [4]. Similar to FMECA, the DMECA methodology is fundamentally the result of two sequential phases:

1. DMEA phase:

A dysfunction modes and effects analysis (DMEA) is a procedure for analysis of potential failure modes within a system for classification by severity or determination of the effect of failures on the system.

- Management processes identification – the result is a list of the main processes in relation to the firm's organizational chart (functional department and their activities)
- Process Breakdown Structure (PBS) definition, where the functional structure of the processes consists of:
    a. System → macro-processes identification
    b. For each macro-process → processes identification
    c. For each process → sub-processes identification
    d. For each sub-process → activities identification.
- Criteria judgments definition – by applying DMECA, a new correlation matrix between value of probability, severity and detection parameters, and their relative evaluation criteria, has been determined in place of the value reported in product FMECA applications.

2. Criticality Analysis phase:

Criticality analysis is another component of Dysfunction Mode, Effects, and Criticality Analysis (DMECA). It is an extension of Dysfunction Mode and Effects Analysis (DMEA). In addition to the basic DMEA, it includes a criticality analysis, which is used to make the probability of failure modes against the severity of their consequences. They are as follows:

- Risk Priority Number (RPN) evaluation – dysfunction causes (instead of failure) and their relative weight can be defined for each activity in order to determine the most critical and decide improvement actions. The result is a list of critical activities and priorities.
- Corrective actions planning and design – DMECA method provides a structured approach to investigate, plan and apply improvement actions by using a corrective action worktable.

Corrective action results evaluation – on the basis of the results, the DMECA process can restart to implement new or reengineered activities.

3. RESEARCH INSTRUMENT

Based on the prepared questionnaire, data on the variables were considered and the information were summarized, complied to fit those into tables and finally analyzed in accordance with the objectives of the study. In this way overall picture of the study were identified to point out various dysfunctions of the managerial process.

4. MANAGEMENT PROCESS IDENTIFICATION

There are 60 management personnel who are directly involved in management process of the power plant but currently working 40 personnel, 28 of which are directly involved in operation and maintenance [5].

5. JUDGMENT CRITERIA, DYSFUNCTION DEFINITION AND CRITICALITY ANALYSIS OF DMECA

It is, necessary to redefine evaluation factors, acceptability limits and conversion criteria for the parameters utilized in order to determine RPNs context of the management process. Each dysfunction had thus been judged according to the following three factors: (i) Occurrence Dysfunction (O_D), (ii) Detectability of Dysfunction (D_D) and (iii) Severity Dysfunction (S_D). For Occurrence Dysfunction (O_D), six levels (reported in Table 5-1) was identified, ranging from 'irrelevant' to 'very high' and described through Arabic numerals 1 to 10 [4]. The Mean Time Between Dysfunction (MTBD) factor was introduced which is similar to the Mean Time Between Failure (MTBF) in FMECA and represents the mean time between two same dysfunctions [5]. The values in the third column of Table 5-1 were obtained by interviewing personnel. Generally, the MTBD values in days can change for different companies and depends on the annual number of jobs. A suitable way of calculating the MTBD value is as follows:

$MTBD=36500/(N_{c*}\ D_{100\ i})$ in days

where:

N_c = mean number of jobs per year (historical data)

$D_{100\ i}$ = number of dysfunctions of type i per 100 jobs.

Table 1: Conversion table for dysfunction occurrence factor

Qualitative evaluation of the dysfunction occurrence	MTBD value	Percentage happen (%)	O_D
Irrelevant	> 1 year (> 365 days)	< = 1	1
Remote	4, 5–11 months (132–331 days)	2 to 5	2–3
Low	2–4 months (66–121 days)	6 to 10	4–5
Moderate	1–2 months (27–60 days)	11 to 24	6–7
High	2 weeks–1 month (14–26 days)	25 to 49	8–9
Very high	< 2 weeks (< 13 days)	> = 50	10

For the Detectability of Dysfunction (D_D) judgment, a qualitative linguistic evaluation table was proposed as reported in Table 5-2. Based on these judgments, the detectability of dysfunction was divided into five classes, defined by Arabic numerals 10 to 1 and ranging from 'very low' to 'very high' [4].

Table 2: Conversion table for detectability of dysfunction factor

Qualitative evaluation of the dysfunction detection	Description	D_D
Very low	Customers detects dysfunction after commissioning	9–10
Low	Dysfunction detected at final test	7–8
Moderate	Dysfunction detected by inspection or after control	4–6
High	Dysfunction detected after work operation where born	2–3
Very high	Dysfunction detected during work	1

Finally, in traditional FMECA, when studying product reliability, the gravity factor was based on parameters such as security and safety [5]. For DMECA, on the other hand, in the management process the gravity factor can be based on productivity loss, high cost, delay in responding to customer needs and quality loss. This list is not meant to be exhaustive. For this case-study, the mission was suggested considering time and quality results (Table 5-3) as critical variables [4].

Table 3: Conversion table for the dysfunction severity factor (Time and quality parameter)

Qualitative/linguistic evaluation of the dysfunction severity	Description	S_D
Critical	Job delivery delay > 1 month OR Unacceptable quality level: significant risk to ship inadequate material to the customer	10
Very important	Job delivery delay from 15 days to 1 month OR Unacceptable quality level: unacceptable defect detected during final test	7–9
Important	Job delivery delay from 1 to 2 weeks OR Unacceptable quality level: unacceptable defect detected at its first occurrence	4–6
Unimportant	Job delivery delay from 2 to 6 days OR Acceptable quality but at the standard limit	2–3
Trivial	Job delivery delay < = 1 day OR Dysfunction mode does not influence quality	1

The next step was the evaluation of possible dysfunctions and the identification of the related causes, attributing a value to the three factors: probability, detection and gravity. In the process break-down structure defined during the process identification phase (reported in Figure 6-1 for the firms' processes), there are 09 sub-processes and 57 activities of job management process have been identified. Figure 6-2 shortly reported the detailed breakdown structure for the macro-process 'operations' of the function 'job management' located at Level 2 of firm-process as reported in Figure 6-1. For each activity, possible dysfunctions had established and 175 potential causes have been identified for the whole process of 'job management'. A code number was assigned to each dysfunction with the same criteria used to map the processes. Thus, it is possible to judge and evaluate the criticality of the dysfunction causes.

6. PROCESS BREAKDOWN STRUCTURE

The input to process mapping is the five–level organization chart reported in Figure 6-1 (processes breakdown structure). In Figure 6-1, the 4th and 5th levels of the operations macro-process were more detailed because this is the objective of the DMECA analysis. The second step consists of breaking down the sub-processes of Figure 6-1 to the level of detail needed for the analysis – that is, down to elementary activities as shown in Figure 6-2(short form). Each activity was distinguished by an alphanumerical identification symbol, which labels each decomposition level. There are 09 sub-processes and 57 activities of job management process have been identified (figure 6-2 shows some of these).

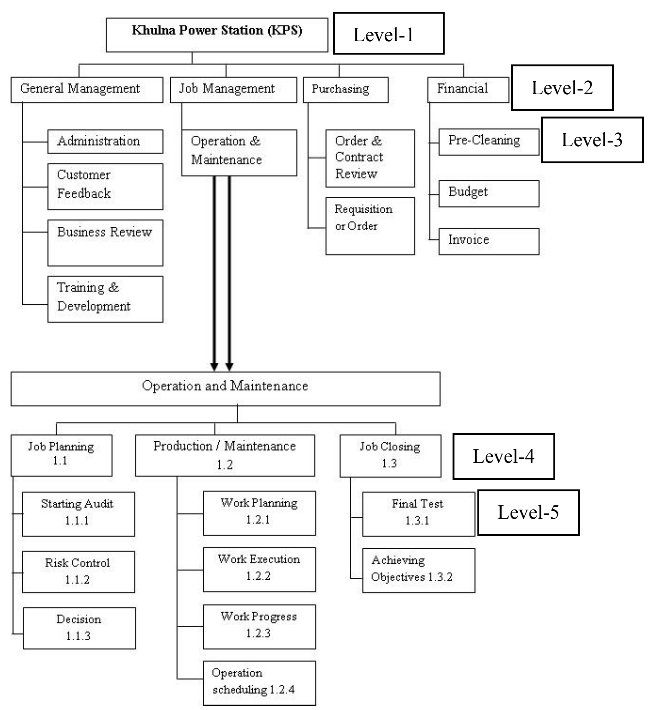

Fig 1. Process (Maintenance and/or Production) breakdown structure (General map of the process)

1st level – the firm; 2nd level – function; 3rd level – macro-process; 4th level – process; 5th level – Sub-process

ID	MACRO PROCESS	ID	PROCESS	ID	SUB PROCESS	ID	ACTIVITY
1	Operation and maintenance	1.1	Job planning	1.1.1	Starting audit	1.1.1.1	Integrated stock check
						1.1.1.2	Correspondence inventory and transport document
						1.1.1.3	Disassembly
						1.1.1.4	Cleaning components
						1.1.1.5	Visual and dimensional control
						1.1.1.6	Chemical composition analysis
						1.1.1.7	Certification data emission

Fig 2. Process breakdown structure (detailed map of the process but here it is in a short form)

7. DATA COLLECTION

Based on the DMEA phase described above, a Criticality Analysis (CA) phase was conducted for every dysfunction identified. As reported in Table 7-2, for each detailed activity, the following are determined:

- all possible and potential causes or problems that can cause dysfunction on activities
- modes of dysfunctions
- the effects of the dysfunction on the whole process or part of it.

To reduce the variability of the answer and the subjective judgment, each personnel completed a questionnaire (table 7-2) independently, with the support of Table 7-1.

Table 4: Indications to complete questionnaire

Column	Indications to complete questionnaire
a	How many times does this kind of cause (reported in the row) of dysfunction happen in every 100 jobs? Write your number.
b	What is the value of gravity of this kind of dysfunction as described in Table 4.4? Write your S_D value.
c	What is the value of detection of this kind of dysfunction as described in Table 4.3? Write your D_D value.

Mean values (from all questionnaires) of the three parameters (O_D, D_D and S_D) for each dysfunction then be calculated. Finally, the respective RPNs was obtained as follows: RPN = $O_D \times D_D \times S_D$. The calculated RPN value is given in table 7-2 (short form).

This product may be viewed as a relative measure of the management dysfunctions. Values for the RPN can range from 1 to 1000, with 1 being the smallest management dysfunction possible. This value was then used to rank the various causes in the dysfunctions. In case of process with a relatively high RPN, the engineering team must make efforts to take corrective action to reduce the RPN. Likewise, because of a certain concern has a relatively low RPN, the engineering teams not overlook the causes and not neglect an effort to reduce the RPN. In this case, a low RPN may be extremely misleading, not placing enough importance on a cause where the level of severity may be disastrous. In general, the purpose of the RPN was to rank the various cause. The smaller the RPN the better – and – the larger the worse.

Table 5: Detailed activities, dysfunction causes, modes and effects

ID	Activity	ID	Dysfunctional cause	Dysfunctional mode	Dysfunctional effect	Mean O	Mean D	Mean S	RPN
1.1.1.1	Integrated stock check	1.1.1.1.1	Wrong evaluation of integrity	Work interruption	Money penalty	8	5	8	320
		1.1.1.1.2	Wrong personnel involved			9	4	9	324
		1.1.1.1.3	Absence of advanced technology			9	6	7	378

8. IDENTIFICATION OF CRITICAL ACTIVITIES

The DMECA is a proactive tool, technique and quality method that enables the identification and prevention of management personnel errors. Defect, rework, and miss-management mean loss on material, loss in production time and cost as well. With the help of the DMECA method, it's easy to know what potentially may go wrong with the management personnel-management approach. DMECA can assist to improving overall efficiency of the management personnel. All the dysfunctions are not Sevier. So it was important to identify what are the dysfunctions in the management process that are mainly involved for the loss of material, loss in production time and cost as well. At this point in the structured DMECA process, criticality analysis according to the procedure described in article 2 was carried out and the critical activities (high RPN) where improvement actions are necessary were found. Dysfunction causes and their relative weights were investigated for each activity in order to determine the most critical and decide improvement actions. The result is shown in a list of critical activities and priorities (Table 8-1). On the basis of these results, the DMECA process can restart to implement on new activities. This will be helpful to run the power plant more effectively and efficiently. For example, Table 8-1 shows some of the activities that receive higher RPNs on its dysfunction causes, these are the critical activities.

Table 6: Some of the critical activities with higher RPN, dysfunction causes, modes and effects

ID	Activity	ID	Dysfunctional cause	Dysfunctional mode	Dysfunctional effect	Mean O	Mean D	Mean S	RPN
1.1.1.1	Integrated stock check	1.1.1.1.1	Wrong evaluation of integrity	Work interruption	Money penalty	8	5	8	320
		1.1.1.1.2	Wrong personnel involved			9	4	9	324
		1.1.1.1.3	Absence of advanced technology			9	6	7	378

9. IDENTIFICATION OF CORRECTIVE ACTION

Management of the Power Plant must focus on defining improvement actions to eliminate the dysfunctional causes of this activities described in table 8-1. A matrix can be used to create, design, plan and control the corrective actions. In the matrix, the following are summarized:

- the critical activity
- the dysfunction cause
- the improvement action proposed
- the frequency of the improvement action
- time necessary to implement action
- a flag to indicate possible interruption of the action implementation
- the responsibility to implement action
- the executor
- the predicted cost
- the benefit

The DMECA approach permits to identify how a corrective action can eliminate a particular dysfunction, also can be used to correct other problems or inefficiencies indirectly. Therefore, at the end of the DMECA structured process analysis, we obtained schemes where relatively few corrective actions can solve multiple dysfunctions (Table 8-2). This was because there is a strong interrelationship between management processes and activities.

This result is the most important of the DMECA method, as it permits the correction of a group of similar causes of dysfunctions through fewer corrective actions. Evidence of this is illustrated in Table 8-2 for some of the critical activities, where the improvement actions (i) 'introducing advanced technology and related training course' can eliminate three dysfunctional causes. The benefits related to the proposed improvement action are O_D and D_D reductions.

Table 7: Corrective action planning and design scheme for some of the critical activities

Critical activity				Corrective action						
ID	Activity	ID	Dysfunctional cause	Improvement action	Frequency	Time	Responsibl	Executor	Cost (Tk)	Benefit
1.1.1.1	Integrated stock check	1.1.1.1.1	Wrong evaluation of integrity	Introducing advanced technology and related training	6 Months	4 to 5 days	Plant Manager	Executive Engineer	Approximately 50000	Reduction of O_D
		1.1.1.1.2	Wrong personnel involved							
		1.1.1.1.3	Absence of advanced technology							

10. CONCLUTION

In every organization (industrial, commercial, services), it is necessary to utilize a method to evaluate possible dysfunctions in managerial processes that can result trouble free operation. The Dysfunction Mode Effects and Criticality Analysis approach which represents an interesting and complete structured tool to find inefficiencies in the management process and consequently define suitable improvement actions. The method allows the user to analyze a process of a power plant in a detailed and structured way. In this case study of the application of DMECA is presented to illustrate the technique in a real business situation of 110 MW, Khulna Power Station (KPS), Bangladesh Power Development Board (BPDB), Goalpara, Khalishpur, Khulna, Bangladesh. The application of DMECA to the power plant helped us (i) to highlight potential criticalities in terms of elementary activities that form the processes and (ii) to define the improvement actions that must be implemented to complete the analysis and the improvement processes. In particular, it will allow the managers to plan, to schedule and to control proposed actions in terms of responsibility, cost and time. In this study DMECA corrects about 60% of the dysfunction by solving only 15% of the causes. The method may also be useful for repeated applications and reiteration according to Deming's Plan-Do-Check-Act (PDCA) mentality to obtain an effective continuous improvement of the processes. In fact, organizations' needs changes rapidly and some activities can become more critical (i.e., greater RPN). Furthermore, the effects of improvement actions must be correctly evaluated continuously. To analyze the managerial dysfunction in any organization the DMECA approach is very effective and it involves low cost as found in the research work. So, it is cost effective and can be applied to identify management personnel deficiencies which will be helpful for uninterrupted production and/or maintenance. It identifies access and ranks of dysfunctions that are challenges to achieve. Thus, the method prevents the consumption of time and cost of production and/or maintenance.

An application of the DMECA technique in an important power station to analyze, to evaluate and to improve job management process efficiency has already been made. Some typical suggestions that must be looked into by the management personnel to implement the DMECA method are given below:

- Top management commitment is indispensable.
- A motivational campaign from top management is a must.
- Develop a clear cut plan for the use of DMECA.
- Ensure all personnel who are to be involved with the DMECA are made aware of the potential benefits arising out of DMECA and the necessity for corrective action.
- Make it a part of regular job, not an optional one when you are free.
- Make DMECA meetings short but regular, throughout the early stages of the managerial dysfunctions.
- Documents plan and what have been done, review/update plans as per changed requirements.
- It is better to involves personnel from various departments including suppliers for DMECA. In fact it is a recommended part of TQM.
- DMECA is more cost effective at the earlier stage of management plan than at later stage when the plan is almost at the final one.
- It is never wise to prepare DMECA for execution in isolation by one individual.

It is never wise to ignore participation of a less influential individual and allow important dysfunctions modes to be dismissed lightly with comment such as, "we have always done it like this", "don't talk like a fool etc", etc. let everybody to talk without shy and fear.

11. REFERENCES

1. Plaia, A. and Carrie, A. (1995) 'Application and assessment of IDEF3 – process flow description capture method', International Journal of Operations and Production Management, Vol. 15, No. 1, pp.63–73.
2. Goulden, C. and Rawlins, L. (1995) 'A hybrid model for process quality costing', International Journal of Quality and Reliability Management, Vol. 12, No. 8, pp.32–47.
3. Dale, B.G. and Plunket, J.J. (2000) "Quality costing" The TQM Magazine, Vol. 12. No. 3, pp.214-217.
4. Bertolini, M. Braglia, M. Carmignani, G. 'An FMEA based approach to process analysis", International Journal of Process Management and Benchmarking, Vol.1,No.2,2006.
5. Mr. Md. Rezaul Karim, SDE, KPS, BPDB, Khulna.
6. Lindemann, U. 'Specification Risk Analysis: Avoiding Product Performance Deviations Through an FMEA-Based Method', International Journal of Quality and Reliability Management, Vol. 10, No. 4, pp.9-16.

12. NOMENCLATURE

Symbol	Meaning
AE	Assistant Engineer
BPDB	Bangladesh Power Development Board
CA	Criticality Analysis
CE	Chief Engineer
D_D	Detectability of dysfunction
DMECA	Dysfunction Mode and Effect Critical Analysis
Ex-En	Executive Engineer
FMEA	Failure Mode and Effect Analysis
FMECA	Failure Mode and Effect Critical Analysis
ICAM	Integrated Computer Aided Manufacturing
IDEF	Integrated DEFinition
MTBD	Mean Time Between Failure
O_D	Occurrence Dysfunction
PBS	Process Break down Structure
S_D	Severity Dysfunction
SADT	Structured Analysis and Design Technique
SDE	Sub-Divisional Engineer
TQM	Total Quality Management

13. MAILING ADDRESS

Azizur Rahman
Dept. of IEM, KUET,
Khulna, Bangladesh