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An Industrial Application of DMECA Approach to Management Process Analysis

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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.

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. 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, it cannot define the criticalities of possible dysfunctions, nor does it permit the establishment of criteria or the definition of priorities of improvement actions [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)
Similar to FMECA, the DMECA methodology is fundamentally the result of following two sequential phases [4]:
1. DMEA phase:

- Management processes identification.
- 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.

2. Criticality Analysis phase:

1. Risk Priority Number (RPN) evaluation. 2. Corrective actions planning and design.

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. Maintenance Management process Identification

The term 'maintenance' means to keep the equipment in operational condition or repair it to its operational mode. Main objective of the maintenance is to have increased availability of production systems, with increased safety and optimized cost. Maintenance management involves managing the functions of maintenance. 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 management [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. 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) and $D_{100\ i}$= number of dysfunctions of type i per 100 jobs.

Table 5-1: 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 5-2: 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 5-3: 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.

6. Process Break Down Structure

The input to process mapping is the five–level organization chart reported in Figure 6-1 (processes breakdown structure).

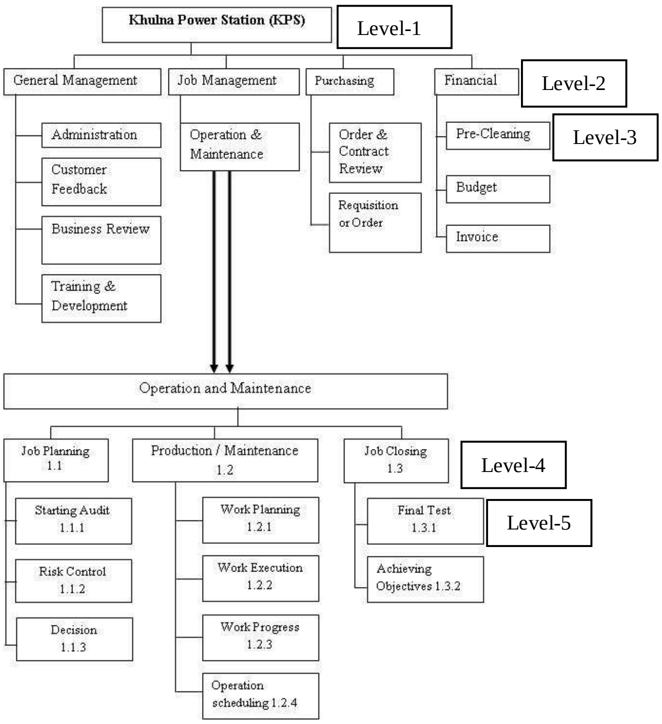

Figure 6-1: Process (Maintenance and/or Production) breakdown structure (General map of the process)

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

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).

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

Figure 6-2: 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: (i) all possible and potential causes or problems that can cause dysfunction on activities, (ii) modes of dysfunctions (iii) 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 7-1: 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 for O_D
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). The smaller the RPN value the better – and – the larger the worse.

Table 7-2: 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 8-1: 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

Table 9-1: 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	Responsible	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							

- 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.

10. Conclusion

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.

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Nomenclature

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