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Comparing the two techniques Tripod Beta and Mort at a critical accident analysis in power plant construction

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Abstract
Accidents are one of the leading causes of death and disability. Despite great efforts made to prevent accidents, there is still no coherent system to identify the root causes of industrial accidents. Selection of appropriate accident analysis techniques and their comparison can be useful in this regard. This research aimed to analyze a fatal accident in a power plant construction project using the two methods of MORT and Tripod-Beta, and the comparison of the analyses. First, the report of the selected accident was studied, and the accident was analyzed by the two methods of MORT and Tripod-Beta. The next step was followed by the comparison and assessment of the methods of MORT and Tripod-Beta with the measures of time, cost, training needs, the need for technical forces, the number of causes identified, quantifiable, and the need for software to conduct analysis. The Tripod-Beta accident analysis cost less and requires less time, and less technical experts. Thorough analysis of major accidents needs to identify all the possible causes of the incident, including human error and equipment failure. Therefore, the complimentary use of both techniques of industrial accident analysis is recommended.
Keywords: Accident analysis, power plant, technique, MORT, Tripod Beta

I. Introduction

Accidents are one of the leading causes of death and disability, so that after cardiovascular diseases and cancer it ranked as the third leading cause of death worldwide, and the second in Iran (1). Accidents ranked third in the construction industry worldwide (2).Despite various efforts made to prevent accidents, there is no coherent system to identify the root causes of industrial accidents (3).There was a significant point in the studies of the previous accidents,and that was the recurrence of similar events in anoperating-productionunit (4).To prevent recurrenceof similar accidents and their human, social, and economic consequences, it is necessary to adopt a systematic approach to detect the root causes of accidents and declarethe corrective actions.A variety of methods have been developed in recent decades, each having different applications, qualities, and efficiency to analyze the accidents from different perspectives (5).Root Cause analysis (RCA) is a methodused to identify what, how, and why the accident occurred.This method defines the fundamental weaknessesand their contribution tounsafeacts and conditionsleading to the accidents (6).If the method is not selected correctly, the results of the analysis may not only fail to find the root causes of accident, but by providing the researchers with false information will lead them in wrong direction. Selecting appropriate accident analysis methods and the comparison between the selected techniques is of great importance.

Z.S. Nivolianitou et al. (2004) conducted a studyto analyze the event of pipe break during the unloading of ammonia from the ship to the ammonia storage plant and the releasing of ammonia in the environment, using three techniques of Fault trees, Event trees, and Petri Nets. The techniques were compared with each other owing to their efficacy in the measurement and identification of a sequence of events, causes of events, event correlation, the interaction between events, and duration modeling (7). A study was conducted by Tom Kontogiannis et al. to compare the three techniques of Petri Nets, FTA, and STEP in the Piper Alpha (Crude Oil Refining Complex) accident analysis. The study resultsillustrated the strengths and weaknesses of the above techniques (8). Regarding the studies of accident analysis in Iran, a study was conducted as “Risk assessment of the chlorine gas leakage in Tehran’s drinking water chlorination stations using Fault Tree Analysis (FTA)” (9).

So far no study has been conducted to compare accident analysis techniques in Iran (10).This research aimed to analyze a fatal accident in a power plant construction project using the two methods of MORT and Tripod-Beta, compare the methods, and present control solutions and preventive actionsto improve the process.

II. Materials and Methods:

The report of the selected accident was investigated, andthe accident was analyzed by the two techniques of MORT and Tripod-Beta.

Management Oversight and Risk Tree (MORT) Technique

MORT method was developed by Johnson sponsored by the U.S. Atomic EnergyCommission. The method isbasically relied upon fault tree analysis (FTA). MORT is a comprehensive and disciplined method to determine the causes and factors contributing to the accident. It can be used in evaluating the existing safety programs.It can also be used to investigate the role of management and organization in the accident, and present a full report. MORT can be used to find out the root causes of an accident by detecting the faults and shortcomings of the control and management factors.MORT technique applies a pre-designed fault tree based on the“Ideal Management System”, which is the major difference between MORT and fault tree methods. The other difference between these two methods is that the MORT technique doesn’t simply show what happened during the accident, but it investigates the management factors leading to the accident to determine “why the accident happened?” MORT consists of eight sub-treeswhich can identify up to 1500 root causes, depending on the incidents under study.The first step in the MORT diagram involvesexpanding the incidentunder an OR logic gate, indicating that the accident is caused either by “Assumed Risks” or “Management Oversights and Omissions”. The risks that have been properly identified and accepted in adequate management levels are treated as assumed risks and those that are unknown and not yet analyzed are treated as management oversights and omissions(11).

Tripod-Beta Technique

Tripod-Beta is a conceptual method relied on building a tree structure which is a conceptual model, to define different risk management aspects leading to the accidents. The core model of the Tripod-Beta tree describes the accident mechanism in terms of Hazards, Targets, and Events. In the second phase, failed or missing preventive actions are added to the core model of the Tripod-Beta tree. The third phase of the Tripod-Beta tree is to identify the causal paths of the accident (leading from immediate failures to root causes) for each accident. The Tripod-Beta diagram features the sequence of events caused by inadequate risk control measures for each path.To complete the model it is necessary to determine the following:

1- What risk management measures failed to operate properly?
2- What other control measures were necessary in the accident scene?

For this purpose, all design and operational aspects must be considered and investigated properly. The Tripod Theory relies on the hypothesis that an accident is the sequence of events with multiple causes.Activefailures, namely unsafe acts do not occurin isolation. They are affected by some external factors (preconditions) leading from latent failures.The most frequent failures are the results of the improper decisions and actions taken by designers, planners or managers.

Fig.1 illustrates a Tripod-Beta causal path contributing to a control/defense failure.

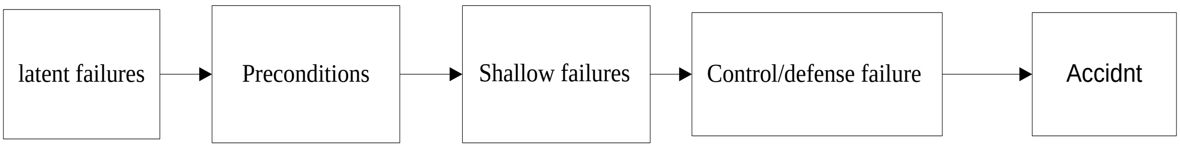

Fig. 1: The Tripod model

There is a path available for each control or defense failure. The implementation process of the method is listed in several references thoroughly (9-13), Therefore, it will not be mentioned here due to the length of its contents. The third phase of the study focused on defining the comparison and evaluation criteria for the two methods of MORT and Tripod-Beta according to the requirements of implementing a method and the expectations of a method in accident analysis. The above mentioned criteria include:

1- The time needed for accident analysis
2- Cost of accident analysis
3- Educational needs for implementation
4- The need for technicians
5- The number of identified accident causes
6- Quantifiable
7- The need for software

The Fourth Step

The fourth phase of the study involves determining the above mentioned criteria using the high-tech analytic hierarchy process (AHP) capabilities for analysis of catastrophic events in these industries.

Analytic Hierarchy Process (AHP)

The analytic hierarchy process is one of the most widely used methods of multiple- attribute decision making methods (MADM) developed by Saaty for allocating scarce resources and military planning

requirements. This method can be used when the decision making process facesrival alternatives and decision making criteria (14). These criteria can be both quantitative and qualitative. Thedecision making method is relied on pairwise comparisons. The decision making process begins with developing a hierarchical decision tree. The decision tree shows the comparison factors and rival alternatives evaluated in the decision making. Then a series of pairwise comparisons are carried out. These comparisons determine the weight of each factor and the rival alternatives. Ultimately, the AHP logic combines pairwise comparison matrix for making an optimal decision.
Once more the comparison of the two techniques was carried out without considering the quantifiable criterion.

III. Results:

The Construction of theAccident Analysis MORT Tree

In order to construct the MORT tree, first the main incident (the death of an employee) was placed within a rectangular symbol at the top of the tree. The accident analysis conducted by the MORT technique indicated that 27 underlying causes contributed to the accident. The most important ones are:

1- Inadequate security controls
2- Inappropriate energy path deviation
3- Impractical energy path deviation
4- Inappropriate barriers
5- Inappropriate emergency escape route
6- Functional errors in performing duties
7- Inappropriate pursuit

The active failures which have been resulted from accident analysis using the Tripod-Beta Technique include:

1- Excavation without digging trenches
2- Unfastened fire extinguishing pipeline in the wall
3- Lack of escape route, and the presence of people in the channel during excavation
4- Work without permit

Tables 1 and 2 illustrate the weight of each method according to the criteria andpairwise comparison and using the AHP logic. The ultimate weight of each technique was resulted from sum of the product of the criterion weight in the relevant alternative of the criterion.

Table 1: Weight of Techniques in Comparison with the Criteria

Selected Criteria	Accident Analysis Time	Accident Analysis Costs	Training Needs for Implementation	The Need for Technicians	The Number of Identified Causes	Quantify ability	The Need for Software
MORT	0.1	0.1	0.1	0.12	0.88	0.9	0.1
Tripod	0.9	0.88	0.9	0.87	0.1	0.1	0.9

Table 2: Pairwise Comparison Matrix of the Criteria

	Time of Analysis	Costs of Analysis	Training Needs for Implementation	The Need for Technicians	The Number of Identified Causes	Quantify ability	The Need for Software
Analysis Time	1	0.2	0.2	0.125	0.11	0.125	7
Analysis Costs	5	1	0.25	0.2	0.11	0.125	8
Training Needs for Implementation	5	4	1	0.25	0.11	0.125	6
The Need for Technicians	8	5	4	1	0.11	0.125	6
The Number of Detected Causes	9	9	9	9	1	8	9
Quantify ability	8	8	8	8	0.125	1	9
The Need for Software	0.143	0.143	0.167	0.167	0.11	0.11	1

Table 5 illustrates the calculated weights and the ultimate priority of the methods.

Table 5: The Ultimate Weight and Prioritization of the Two Methods

Priority	Technique	Weight
1	MORT	0.372
2	Tripod Beta	0.625

Accident analysis using Tripod-Beta technique indicated that 41 preconditions and 81 latent failures contributed to the accident. The most frequent preconditions were related to:

1- Unsafe working environment

2- Employees did not enjoy adequate knowledge or insight to the type of work, and did not know how to perform their duty.
3- Speed of workingled tocarelessness, and they ignoredparts of the executive procedures.
4- The personnel worked under pressure. (owing to production targets, social environment, or instructions of senior officials)
5- Lack of adequate supervision. (Supervisors were absent, or they were too busy, inappropriate completion of work permit, dangerous combination of activities were not detected by supervisors)
6- Wrong or irresponsible decisions were made. (On the wrong basis, short time, without permit, irrelevant people)
7- Inappropriate planning of the activities.(Error in estimation and coordination, delay or concurrence of multiple processes)

IV. Discussion

Findings showed that there are less time, less costs, and fewer technicians needed for accident analysis with Tripod-Beta method. It can also be implemented manually.While, more time, technicians, and training sharerequired when analyzing the accidents with the MORT technique.However, the number of identified causes contributing to the accident and their capabilities in accident analysis with the MORT technique outweigh those in the Tripod-Beta method. The statement above is in line with the findings of SnorSkelt and PanagiotaKatsakiori in comparison of accident analysis methods (8, 12). In a study conducted by Adl and Iraj Mohammad Fam (2007), using Fault Tree analysis. They used the technique for accident analysis as a quantitative and qualitative method. They determined the underlying causes of the accident by classifying the final events, determining the minimal cuts, and the probability of occurrence of the eventfor each year (9).Due to the limitation of this research, the technique was applied in a qualitative manner. In 2008, in a study conducted to analyze the fatal occupational accidents in a chemical industry using Tripod-Beta technique (10), the total number of identified preconditions and latent failures were 56 and 134, respectively. The results of the above mentioned analysis was reported qualitatively, such as the company's unhealthy safety culture and poor management commitment, and was compatible with the results of this research.The calculation of criteria weights for assigningthe contribution of each criterion in superiority showed that the number of detected causes weighing 0.435 ranked the highest followed by quantifiable0.07, analysis costs 0.059, accident analysis time 0.038, and the need for software 0.036.The criteria weights manifest their importance in assigning superiority, and the weight of each technique is the contribution of the technique in the criterion. Calculation of the methods' ultimate weight indicated the superiority of the MORT technique weighing 0.624 in fatal accident analysis compared to Tripod-Beta 0.350.

V. Conclusion

Accident investigations must be in line with discovering all causes contributed to the accident, and identify all hazards contributing to the accident. Experience has shown that great events do not occur only for one reason. Most of the time there is a causal relationship between accidents. Each of the methods discussed above have different efficiencies, capabilities, and application and have a different approach toward accident analysis.Apparently, thorough identification of causes of accidents will provide comprehensive preventive solutions for preventing accidents. Moreover,implementing a thorough investigation using various methods of accident analysis will provide an opportunity to learn how to prevent future accidents. The results of the studies using different methods can be used in interpreting different causes of accidents, hazardous procedures, interpreting the activities, and the promotion of occupational and management systems. To conduct thorough investigations on serious accidents, it is necessary to identify all failures contributing to accidents, including human errors and equipment failures. The complementary use of the two techniques of accident analysis in industries is recommended.It is also recommended to compare and evaluate the other methods of accident analysisto identify the capabilities and limitations, and application of accident analysis, and select our intended method according to the existing resources and our expectation from accident analysis.

The use of the above mentioned methods for analyzing minor incidents may not be economical, therefore, it is recommended to investigate the other methods of accident analysis to identify the most appropriate methods for such analyses.

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