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Designing a Model for Predicting and Analyzing Factors Affecting the Occurrence of Environmental Incidents: A Case Study in MAPNA Group

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ABSTRACT

Nowadays, environmental incidents are one of the most important problems around the world; therefore, it is of particular to manage these incidents. The aim of this study was to identify the causes of environmental incidents, analysis of their interactions, and the contribution of these factors in the occurrence of environmental incidents at Mapna group. Tripod Beta method was used to determine the effective factors occurrence of the environmental incidents after collecting data, screening and classifying. Thereafter, factor analysis was designed to provide a conceptual model. In order to analyze the relationship between the affecting incidents factors, a model was designed and the contribution rate of each factor was determined. So, the most effective causes of these incidents were determined for each identified causes. Finally, a goodnes of fit test was performed to determine the reliability of the model. By performing Tripod Beta analysis, it was found that 68.5% of the prerequisite causes and 71.3% of the identified latent causes were related to organizational factors, control and monitoring, audit and review, and production requirements. The results showed that the latent causes have the highest beta value; therefore, these had the highest impact on the occurrence of environmental incidents at Mapna group. It was also found that "insufficient commitment of management" was the most important cause of the environmental incidents. The organization management commitment and appropriate techniques are those key factors which should be taken into account in controlling the risk of environmental incidents.

KEYWORDS: *Environmental Incidents, Power Plant, Mapna group, Tripod Beta*

INTRODUCTION

Various environmental incidents have many adverse consequences and often they have irreversible effects on the environment, human health, assets, and the reputation of industries [1]. However, information on environmental incidents, their impact, as well as their numerous consequences around the world, especially in developing countries such as Iran are not available due to the lack of appropriate environmental incidents registration systems and well-organized information systems [2]; but data related to these few reported incidents are still used as a basis for a variety of scientific and technical activities and measures in the field of environment and to prevent or reduce the effective consequences of environmental incidents [3]. Despite significant technical, managerial and executive efforts to prevent or reduce these incidents and their consequences, the available evidence is still worrying [4].

The results of previous studies showed that many adverse environmental consequences have been attributed to industries and industrial activities [5]. Also, according to the published statistics and information, various environmental incidents occur in the Iranian industries that have destructive and adverse effects. The consequences of these incidents can threaten other neighboring countries of Iran [6].

Due to the retrospective nature of incident analysis techniques and the inefficiency of these methods in predicting and preventing such incidents, the complexity of industrial environments as well as socio-economic damage and other widespread consequences of environmental incidents, we require scientific tools and methods to investigate and predict these incidents to prevent the recurrence of such incidents and prevention of new environmental incidents [7].

It should be noted that although the data obtained from the few reported environmental incidents provide useful and significant information, but integrated information about the incidents that can determine the causes and influencing factors, hidden factors, actions and interactions and analyze the variables and show the path leading to various environmental consequences, will play a very important role in predicting, managing and controlling such incidents [8-9].

Therefore, a comprehensive approach should first applied to identify all causes of environmental incidents (including immediate, preconditions and underlying causes). Next level can be the analysis of these variables interactions, determining the effect and contribution of each of the causes in the occurrence of the incidents, and predicting a model for preventing such environmental incidents in industries.

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METHODS and MATERIALS

In the present study, a descriptive-analytical study was implemented at Mapna Group (such activities including development and construction of thermal power plants, oil and gas, and railways projects) over a period of 10 years.

This research was carried out in seven stages:

First stage:

All reports and data related to environmental incidents during 2006 to 2016 were collected among different production sites of Mapna Group.

Second stage:

Related data were collected throught screening and classification of environmental incidents.

Third stage:

Various factors affecting the occurrence of environmental incidents (immediate, preconditions and underlying causes) were analyzed and classified using Tripod beta model.

Fourth stage:

After extracting the results of the third stage (identifying the effective factors in the occurrence of environmental incidents), the identified causes were classified into individual, environmental, and organizational factors. A pairwise comparisons matrix and triangular fuzzy numbers method were used to identify the occurrence causes of these incidents based on the weighed numbers.

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Fifth stage:

The factor analysis was applied to obtain and validate the classifications of the factors.

Sixth stage:

A conceptual model was designed and developed to analyze the relationship between affecting environmental incidents factors and the contribution of each factor (immediate, preconditions and underlying causes).

Seventh stage:

Based on the results of the previous stage, the most effective path and causes of studied environmental incidents were identified and determined separately for each of the causes. Finally, a goodness of fit test of the designed model and the presentation of solutions and mechanisms to prevent the occurrence of environmental incidents were performed.

RESULTS

The results showed that 85 out of 197 environmental incidents were related to the electricity sector, 70 incidents were related to the production sector, 22 incidents were related to the oil and gas sector, 17 incidents were belonged to the rail transport sector and 3 incidents were related to the investment projects section.

By screening the incidents based on the special incident regulations and the risk matrix of Mapna group, 101 environmental incidents were extracted of the pre-analysis stage.

Ninety six environmental incidents were analyzed in total. 37 of these incidents were related to the electricity sector, 50 incidents were related to the production sector, 5 incidents were related to the oil and gas sector, 3 incidents were related to the investment projects sector and 1 incident was related to the rail transportation sector.

Based on the reports of the incidents and the comments of HSE experts and the Mapna Group incident analysis team, the immediate causes of the identified incidents were classified into 10 groups; The immediate cause of most incidents (42 incidents) is related to the leakage of toxic substances, chemicals, acids and bases, which mainly leads to environmental consequences including soil pollution and surface and groundwater resources. Fire and explosion (21 incidents) and emissions (17 incidents) were in the second and third ranks, respectively (Table 1).

Table 1. Active causes affecting the occurrence of environmental incidents (n=96)

Code	Active causes	Frequency
IC.1	Leakage of toxic substances, chemicals, acids and bases	**42**
IC.2	Fire and explosion caused by flammable materials and explosion/fire caused by electricity	**21**
IC.3	Emission of gases and vapors of toxic and chemical substances	**17**
IC.4	Failure of control and protection systems (due to natural disasters)	**4**
IC.5	Leakage and loss of stored water resources/increase in outlet water temperature	**3**
IC.6	The entry of aquatic animals, animals, etc. into the operational areas	**3**
IC.7	Objects fall and hit equipment and facilities	**2**
IC.8	Cave-in	**2**
IC.9	Increased pressure in pressurized tanks	**1**
IC.10	Increase/discharge of additional electric charge	**1**

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According to the analysis based on Tripod beta model, a total of ٥٤٩ preconditions were identified for ٩٦ analyzed incidents, so that the most common preconditions were in the organization and responsibility group (١١٩ cases.)

There are seven sub-categories In the group of organization and responsibility. The first sub-category (٩A) was related to inadequate and insufficient supervision, absence of supervisors or ,their busy schedule, defect of work permit system failure to recognize dangerous combination of activities, etc. It had the highest recurrence (٤٥ cases.) ,Of course, facilities, equipment and tool condition ,suitability and availability (including conditions appropriateness and accessibility, especially in the field of tool efficiency and optimal working conditions) had a significant frequency (١٠١ cases.) Also, a total of ١٦٨٩ underlying causes were identified in ٩٦ analyzed incidents. According to the analysis, the maintenance management group had the highest repetition in the ١٦٨٩ underlying causes. Of course, organizing and design groups had a significant frequency, so that these three groups have a total of ٦١,٥ % of the underlying causes in these ٩٦ incidents .(Table ٢)

Table 2. Latent causes identified by groups

Code	Title	Frequency	(%) Frequency
MM	Maintenance Management	409	24.22
OR	Organization	319	18.89
DE	Design	311	18.41
HW	Hardware	162	9.59
PR	Procedures	137	8.11
CO	Communications	104	6.16
TR	Training	81	4.80
IG	Incompatibility Between Goals	77	4.56
EC	Inadequate Imposed Conditions	62	3.67
DF	Defensive Layers	20	1.18
HK	Housekeeping	7	0.41
	Total	**1689**	**100**

In order to classify the identified causes in the form of individual, environmental and organizational factors, as well as, to determine the relative importance and priority of the causes, a checklist was compiled and provided to the experts. The results showed that 68.5% of the precondition causes and 71.3% of the underlying causes were related to organizational factors (management commitment, planning, organization, training, communication, etc.), control and monitoring, Audit and review and production requirements.

The factor analysis method was used to examine goodness of fit and confirm the classification of precondition and underlying causes in the form of

individual, environmental and organizational factors. According to the results, the KMO value for individual, environmental and organizational factors were 0.812, 0.737 and 0.743, respectively. This fact indicated that the data are suitable for factor analysis and the Bartlett test result is also significant with a 1.0% error (Sig<0.05).

According to the results, the amount of subscription for the identified variables (higher than 0.5), the relationship between the variables (causes of environmental incidents) and their factors (individual, environmental and organizational factors) was clear. This means that the identified variables are in the correct grouping and the variables are correlated with the factors.

After identifying and classifying the effective causes in the occurrence of environmental incidents, we used a path analysis in order to investigate and determine the extent of the impact (correlation) of immediate, precondition and underlying causes in the occurrence of the incidents.

According to the results of path analysis (Table 3) and the column related to standard Beta for different groups of underlying causes, it was found that the 8th group (communications) with a value of 0.984 has the highest Beta and the first group (hardware) with a value of 0.89 has the lowest Beta value. Thus, among the 11 groups of underlying causes, the 8th group (communication) had the most and the first group (hardware) had the least impact on the occurrence of environmental incidents.

Table 3. A summary of path analysis results for 11 groups of latent causes

Pate	**Title**	CODE	Model Summary			ANOVA		Coefficients		
			R	R Square	Adj.R Sq	F	Sig	t	St.Beta	Sig
X3	Hardware	HW	0890	0.793	0.789	225.708	0.000	15.024	0.890	0.000
	Design	DE	0.920	0.847	0.844	352.902	0.000	18.053	0.920	0.000
	Maintenance Management	MM	0.943	0.890	0.888	475.105	0.000	21797	0.943	0.000
	Procedures	PR	0.953	0.909	0.907	586.714	0.000	24.222	0.953	0.000
	Error-Enforcing Conditions	EC	0.965	0.931	0.929	791.026	0.000	28.125	0.965	0.000
	Housekeeping	HK	0.908	0.825	0.822	277.988	0.000	16.673	0.908	0.000
	Incompatible Goals	IG	0.948	0.898	0.896	519.200	0.000	22.786	0.948	0.000
	Communications	CO	0.948	0.969	0.968	1843.750	0.000	42.939	0.984	0.000
	Organization	OR	0.905	0.820	0.817	268.266	0.000	16.379	0.905	0.000
	Training	TR	0.915	0.836	0.834	301.514	0.000	17.364	0.915	0.000
	Defenses	DF	0.944	0.890	0.889	479.608	0.000	21.900	0.944	0.000

The effect of 11 groups of underlying causes on the occurrence of the environmental incidents based on the beta values of the path analysis model has been presented in Figure 1:

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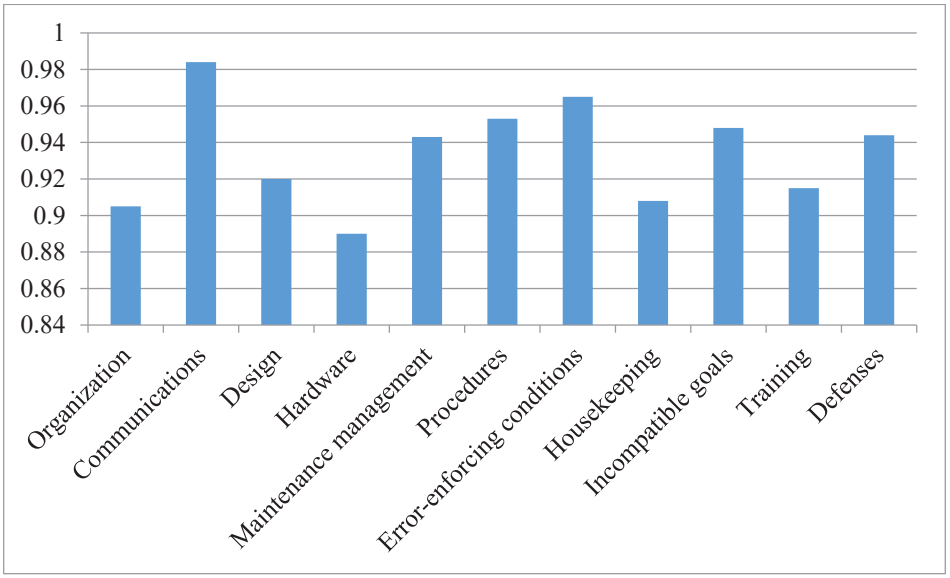

Fig 1. Latent causes impact on the occurrence of incidents based on the path analysis mode'sl beta values

DISCUSSION AND CONCLUSION

Although, due to the lack of appropriate environmental incidents registration systems, information on environmental incidents, their impact, as well as their numerous consequences around the world, especially in developing countries such as Iran are not available; but data related to these few reported incidents provide an applicable base for a variety of scientific and technical activities and measures in the field of environment and to prevent or reduce the effective consequences of incidents in industrial environments. The integrated information about the incidents can identify the immediate causes, underlying factors and interactions of causes and play a very important role in predicting, managing and controlling such incidents [11-12].

Therefore, it is necessary to use a comprehensive approach that can examine and identify all causes of the incidents (including immediate causes, preconditions and underlying causes), then analyze the interaction effects of the causes and to determine the effect and contribution of each of the causes in the occurrence of the environmental incidents.

The results of different studies showed that the social characteristics could be challenged, transformed, or intensified in different ways and at different times [13]. The results obtained in this study are in accordance with those studies and social factors examined in the form of environmental factors. The results of Boamah study indicated the validity and fit of two-factor and three-factor models defined in the study using the structural equation approach [14]. In a study conducted by Dou, the results showed that the proposed model has sufficient competence in terms of model quality and robustness, this model shows an accuracy of about 80% and a sensitivity of about 50% [15]. In addition to some characteristics related to road conditions, traffic situation and volume, some weather variables are important for predicting accidents [16]. The results of the present study were not consistent with this study and differ in the cases of organizational and environmental factors. The results of Field et al.,

study's showed that there is a pattern of disaster risk that still dominates disaster management in the region today [17].

It is proved that the risk of incidents is reduced in areas with slow conflict where the results of the present study were in line with this study and confirmed these foundings. In the study of Janike et al., the safety climate variable perceived by individuals was the best predictor of unsafe behavior among other effective factors and is effective on unsafe behavior in three ways [18]. The results of the present study were also relevant in the field of human or individual factors.

The study of Dou found that China has experienced a number of environmental incidents and problems from 1978 [19]. In addition, in this article, existing environmental incident prevention and risk control laws were reviewed and the existing requirements on chemicals, safety assessments, risk analysis and emergency preparedness were compared with international laws and some key points in environmental accident control were identified. The results of the present study confirmed this conclusion. The results of Yu's study showed that the application of structural equation model is superior due to its inherent ability to consider multiple risk factors using a systematic method [20]. Accident analysis in the study of Soltanzadeh et al. showed that important factors affect the occurrence of accidents in the group of prerequisites and latent causes and on the control and prevention of accidents based on their effects.

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CONFLICT OF INTERESTS

The authors declare no conflict of interest in this study.

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