



# The Use of Failure Mode Effects Analysis (FMEA) and Analytic Hierarchy Process (AHP) Methods to Determine the Most Important Safety Hazards

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## ABSTRACT

**Aims** Since the occurrence of hazards in the steel industry has often been multiple and complex, the aim of this study was to identify the risk assessment in this industry in order to study the roots and realities of the risks and the causes of their occurrence, as well as to find solutions to reduce these risks.

**Instruments & Methods** This descriptive-analytical research was conducted in the cement industry in Khorasan Razavi in 2017. FMEA and AHP methods were used to determine the most important safety hazards. The Risk Priority Number (RPN) was obtained from the multiplication of 3 factors including severity, probability of occurrence, and probability of discovery. Risk tolerance was used for the acceptable and unacceptable risks in the FMEA method.

**Findings** The fluctuation of the flange and its breakage due to excessive water pressure in the furnace and lack of lighting for installation of the equipment in the furnace had a high risk. In the AHP method, the risk of breaking the flange was due to excessive water pressure in the furnace and lack of lighting to install the equipment in the furnace, which had a higher weight than the other hazards.

**Conclusion** Although in the developing countries, the use of risk analysis methods with a preventive approach is not common, these problems have been resolved by communicating with the industry by recent studies.

It also emphasizes the use of decision-making methods to minimize the impact of judgments on risk assessment.

**Keywords** Risk Assessment; Hazard Analysis; Analytic Hierarchy Process; Multi-Criteria Methods

## CITATION LINKS

[1] General model of accident rate growth in the construction industry [2] Human ergology that promotes participatory approach to improving safety, health and working conditions at grassroots workplaces: Achievements and actions [3] TORAP- a new tool for conducting rapid risk-assessments in petroleum refineries and petrochemical industries [4] Identifying analysis of occupational hazards in a milk company [5] In-depth accident analysis of electrical fatalities in the construction industry [6] The investigation hazards make accidents in an oil refining company [7] Fuzzy risk assessment approach for occupational hazards in the construction industry [8] Environmental assessment: Marine fuel storage/distribution and biodiesel production facility, Kooragang Island/prepared by Umwelt (Australia) [9] Assessment of potential hazards by failure modes and effect analysis (FMEA) method in Shiraz oil refinery [10] Consistency of FMEA used in the validation of analytical procedures [11] Multiple failure modes analysis and weighted risk priority number evaluation in FMEA [12] Systematic failure mode effect analysis (FMEA) using fuzzy linguistic modeling [13] Accidents in the construction industry in the Netherlands: An analysis of accident reports using storybuilder [14] Using a delphi process and the analytic hierarchy process (AHP) to evaluate the complexity of projects [15] Risk assessment and crisis management in gas stations [16] The comparison of safety level in kilns in two gypsum production factories by failure mode and effects analysis (FMEA) [17] Fuzzy inference to risk assessment on nuclear engineering systems [18] Work zone noise levels at Aarti steel plant, Orissa and its attenuation in far field [19] Safety, health and environmental risk assessment and management of Ahwaz pipe manufacturing company via "William Fine" method

## Introduction

With the increasing growth of technology in the steel industry, we are always facing with the increased risks posed by work. The management of these risks requires a management system that reduces these risks and ensures greater safety, employee welfare, and environmental protection. Every day in the workplace, there are many incidents that can lead to death and injury. In addition, the economic and social damages are very alarming, with high-risk events reaching billions of dollars [1, 2].

According to the International Labor Organization (ILO), 5,000 people die every day in the world due to work-related accidents and illnesses, and 4% of the world's gross domestic product (US\$ 10, 2510, 353) is spent on the direct and indirect costs of illness and work-related accidents.

One of the key elements of safety management systems is the identification of hazards. Identifying environmental hazards leads to reasonable decisions to reduce the risk and severity of accidents and incidents. In OHSAS 18001, risk assessment is defined as a process for assessing the risks of workplace hazards, taking into account existing control measures and deciding whether or not they are acceptable. Risk analysis is possible with a variety of qualitative and quantitative methods. One of the characteristics of risk assessment methods is simple and convenient application for evaluations that can have a relatively uniform assessment of a certain degree of risk [3].

The results of Rezvani's study entitled "Risk Assessment for Job Risks in the Milk Company" indicated that the highest frequency of noise hazards is generated by equipment (64%) [4].

In a study conducted by Chi *et al.* in the Taiwanese construction industry during 1999 to 2004, 255 risks were identified and examined by Failure Mode Effects Analysis (FMEA) method [5]. In a study carried out by Asadi *et al.*, 4250 oil risks were identified with the most risks of falling (12%) and slipping hazard of (10%) [6]. The results of a study by Liu and Tsai showed that the most commonly reported hazards were associated with falling, slipping, and falling objects [7]. In a study by Crossly *et al.* on "The Fuel Tank Project" in Australia, the following were identified as the

most high-risk processes: re-inspection of the control system, design of the equipment, design of the leakage management program, monitoring the programs, provision of high-performance electrical equipment, and the AS2430 standard for high-risk sectors [8].

The study performed by Ebrahimzadeh *et al.* showed that the transportation of objects and goods has been subject to high-risk limits [9].

Incidents in the iron and steel industries are more than in other industries, which are related to the processes such as the spread of molten materials, gas explosions, large carriages, cranes, ladles, and other heavy loads. The steel industry often has multiple dangers such as a drop of a molten metal dust from a crane moving on the top of a busy road. The aim of this study was to identify the risk assessment in the steel industry in order to study the roots and realities of the risks and the causes of their occurrence, as well as to find solutions to reduce these risks.

## Instruments and Methods

This descriptive-analytical research was conducted in the Steel industry, in Khorasan Razavi, in 2017. One of the methods of systematic analysis is a half-way approach that can be used to identify hazards and control them. The proposed method is multi-criteria decision-making methods that can be used to prioritize hazards.

Failure Mode Effects Analysis (FMEA) and Analytic Hierarchy Process (AHP) methods were used to determine the most important safety hazards. The FMEA has been introduced as a credible technique among the risk analysis techniques [10]. A kinematic approach is to identify and track the occurrence of a problem in the product and process. This method focuses on preventing defects, increasing safety, and increasing customer satisfaction. However, this method requires accurate and timely information about the system being investigated [11]. For the first time in the 60s, due to the importance of safety and prevention of predictable events, this method was used in the aerospace industry for the Opulo Naval Air Force; it is now used in the defense industry, automotive, transportation, aerospace, and electronic industries [12]. This method improves the quality of the product and the environment in all stages of an industrial

project from production to the final stage [13]. The Risk Priority Number (RPN) is obtained from the multiplication of 3 factors including severity, probability of occurrence, and probability of discovery. The RPN is calculated based on the following formula:

Ability to discover  $\times$  probability of occurrence  $\times$  intensity = RPN

Risk tolerance was used for the acceptable and unacceptable risks in the FMEA method. The RPN is an indicator for the separation of acceptable and unacceptable risks of the system.

Analytical hierarchy process, developed by Thomas Al Stuity, is a multi-criteria decision making that enables the evaluation and prioritization of options [14]. The hierarchical analysis process begins with identifying and delegating decision-making elements. These elements include targets, criteria or characteristics, and possible options that are used in prioritizing. The process of identifying and linking them creates a hierarchical structure. In this method, the options are compared 2 by 2. According to the results of the comparisons, which can include the most desirable answers, very strong utility, strong utility, and a little more favorable or identical, a numerical order of 1 to 9 assignments is given. In the next step, we first get the sum of each column. Then, each element is divided into a paired matrix into its own column so that the paired matrix becomes normalized. These steps are performed similarly for the other criteria.

At this level, the criteria must be compared 2 by 2. In the next step, the matrix of paired

comparison of the criteria is presented. In the final stage, the weights of options for each criterion are calculated. Then, the weight of each criterion is obtained according to the target.

## Findings

In the industry, for identifying the existing hazards in the studied areas, document review methods, including regulations, safety guidelines, accident reports, and past statistics, as well as expert judgment were used to identify the identified risks. Finally, 105 emergencies were identified. Ten risks were identified as the most important hazards (Table 1).

**Table 1)** Introduction of the hazards investigated in the steel industry

Number	Dangers
1	Crane technical malfunction
2	No lighting for installing equipment in the furnace
3	Breaking of the flange in excess of the pressure of water in the furnace
4	Installing parts in height
5	Putting people in an inappropriate position on shipping
6	Defective air compressor system in the air cut cylinders
7	Non-enclosure of the test area of the overhead crane
8	Dropping the material from the papepenic operation into the water pipe
9	No safety belt to operate at high altitude
10	Excessive tilt at the crane's location

The FMAE method was, then, identified as the priority hazard risk number (Table 2). The lowest and highest priorities were the risk

**Table 2)** Calculating RPN using FMEA method

Control measures	RPN	Discoverable capability	Probability of occurrence	Severity of danger
1- The use of specialist personnel for a crane Mounted crane service	63	3	3	7
2- Creating lighting in the place of installation	245	5	7	7
3- Periodic examinations of equipment	288	6	6	8
4- Use of seatbelt Training Karknan	72	6	4	3
5- Staff training Using warning signs	60	6	5	2
6- Applying specialist services for airborne capsules A periodic review of airborne capsules	126	6	7	3
7- Staff training Using warning signs	100	5	4	5
8- Using protector on the device Using 9- personal protective equipment	60	6	2	5
9- Use of seatbelt-teaching staff	54	6	3	3
10- Periodic review of the crane storage location	150	5	6	5

associated with flushing and flapping by water pressure and the non-use of a safety belt for handling the electric appliances at the altitude.

In the next step, the hierarchical analysis process technique was used to assess and rank the hazards. In the beginning, 5 criteria were chosen. The weight of each criterion was determined (Table 3). In the next step, a comparison of the hazards was performed according to the criteria. In the final stage, priority was given to hazards (Table 4).

**Table 3)** The calculated weight of the criteria

Metrics	Relative weight
Frequency	0.1343
Possible cost	0.1591
Possibility to repel danger	0.2735
Severity of outcome	0.2642
Period of time	0.1686

**Table 4)** Weight and prioritization of dangers

Dangers	Relative weight	Priority
1	0.070052	8
2	0.15159	2
3	0.2182	1
4	0.9306	4
5	0.06289	9
6	0.09466	3
7	0.0522	10
8	0.0849	5
9	0.0795	7
10	0.08011	6

## Discussion

The incidents in the steel industry were investigated at various levels. In this method, the RPN in the company studied is between 1 and 400. Events such as breaking the flange as a result of excessive water pressure in the furnace and lack of lighting to install the equipment in the furnace pose high risk. In general, the RPN of these risks is 245.288. Then, the dangers of excessive tilt in the crane's storage area and defects in the compressed air system of the air-crop caps are ranked next.

The results of AHP method were similar to those of FMEA method. The fluctuation and flutter defects of the flange were due to excessive water pressure in the furnace and lack of lighting to install the equipment in the furnace with the highest weight than the other hazards. Air compression system defects in the compressed air cavities, installation of parts in height, and dumping of materials

from the papepenic operations inside the water pipe are at the top of the list.

Risk assessment is one of the most important problems in this regard. The judgment of the assessments is based on the results of the risk. The AHP method was used to minimize the impact of judgment of individuals on how to evaluate risks [15].

In 2009, a study was conducted to investigate the risks of a TBM drilling machine in a tunnel. Out of 48 failures studied, 7 had high-risk prevalence and were categorized as unacceptable failures.

Using the FMEA method, Alimohammadi and Adl attempted to identify and control the hazards in 2 gypsum factories, and compared the evaluation results in 2 factories. In this study, the most important risk was the pouring of refractory bricks inside the furnace [16]. In a study carried out by Rezvani and Gholami in 2005, 28 high-risk jobs and 380 risk numbers were identified. The highest frequency of hazards belonged to the noise caused by the equipment of the production line (64%), followed by the inhalation of acid vapors and burns [4]. In a study, the risks in a Brazilian nuclear power plant were identified and analyzed, using the FMEA method in 2007 [17]. Using the FMEA and AHP methods in the Indian steel industry, the highest risks were found to belong to the sound of mechanical ventilators and air blowers [18]. The study of Ebrahimzadeh *et al.* at Shiraz refinery showed that objects transportation and milling had a high risk level [9]. In a study by Asadi *et al.*, 4250 oil risky incidents were identified [6]. In 2010, Jozi *et al.* conducted a study on induction furnaces in Ahwaz, and the results were expressed. It is possible that the risk numbers in different parts be 300,240,200 [19]. The limitations of this study include long-term analysis of industrial hazards and analysis of data to prioritize risk assessments - risk assessment of risks to the individual's taste and experience.

To control the dangers of this industry, it is better to deal with the risks that are more risky as soon as possible to reduce its risk. Ziza can reduce the risks by increasing labor productivity, employee satisfaction, and also the high costs of occurring if they occur. It must be controlled because the costs incurred by the industry are very important.



## Conclusion

Although in the developing countries, the use of risk analysis methods with a preventive approach is not common, these problems have been resolved through communicating with the industry by recent studies.

The results of this study emphasize the use of decision-making methods to minimize the impact of judgments on risk assessment.

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