Original Article

An Interpretive Structural Model to Improve the Safety Performance of Employees of Industrial and Mining Plants in Shahr-e-Babak City, Iran

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Article Info

Abstract

Background: Today, occupational safety play the vital role to reduce the number of accidents. In other words, it is necessary to pay attention to improving the safety performance of employees in organizations. Indeed, safety performance is part of safety activities, describing the behavioral aspect of employees and being influenced by various factors. The purpose of this research is to provide a structural interpretation model for improving the safety performance behavior of employees in the industrial and mining city of Shahr-e-Babak.

Materials and methods: This research was applied in terms of purpose and descriptive in terms of data collection. Prioritization of research variables was performed using a fuzzy hierarchical process (AHP), and interpretive structural modeling was used to identify and develop a model for the association between variables. A pairwise comparison questionnaire was used to prioritize the factors. The statistical population was safety experts. In this study, a purposive sampling method with a sample size of 25 people was used.

Results: According to the results of data analysis, a total of 4 levels (first level: personality traits of conscientiousness; second level: safety climate; third level: safety knowledge, management, attitude, and motivation; fourth level: safety participation, training, and observance) were identified as effective factors in improving safety performance. Based on the results obtained in this study, except for safety participation as one of the dependent variables, all other factors were autonomous variables. These factors had poor conductivity and dependency.

Conclusion: It is concluded that by recognizing the factors affecting the improvement of employee safety performance at different levels of the structural model and considering their impact at each level, it is possible to provide programs to reinforce these factors for improving employee safety performance.

Keywords: Organizational Models, Performance at Work**,** Occupational Safety.

Introduction

Nowadays, in analyzing the causes of accidents by passing through the technical, human-technical error, and social stages, most organizations emphasize organizational factors as effective causes of industrial accidents [1]. According to some research, many work-related accidents are rooted in organizational factors [2]. According to the latest official statistics published by the Ministry of Cooperatives, Labor, and Social Welfare (MCLSW) regarding work-related accidents between 2017 and 2019, 10,697 such accidents and 843 deaths have been recorded in 2017 alone.

Also, the statistics provided by MCLSW show that in Kerman, as a leading province in the mining industry, the indicators of accidents at work in the industry and mining sector in 2019 have increased compared to the previous year [3]. Also, the rate of occupational injuries leading to death in the mining sector increased by eight percent in 2019 compared to the previous year [4].

By reviewing the results of safety audits in many industrial and mining companies, it is found that the implementation of safety, health, and environmental policies, as well as compliance with some requirements of the standard of occupational safety and health management, are not considered. The management needs to organize and prioritize operational plans required to prevent accidents and reduce deviations from safety and health policies. This is not possible unless there is a preliminary estimate of the current safety situation. In general, occupational safety in organizations is a vital issue that affects the personal, professional, and social life of individuals, as well as the economy of countries; thus, it is necessary to pay attention to improving the performance of organizations in the field of safety and prevent work-related accidents and diseases. Hence, occupational measures should be taken [5]. In order to take measures to control accidents and their injuries effectively, it is necessary to identify and study the factors affecting safety performance [6]. Therefore, identification of human and technical factors (direct or indirect) affecting safety seems necessary. Indeed, if safety performance improvement is considered, occupational accident statistics will be decreased. In this research, the question is which model is suitable to improve the safety performance of employees in industrial and mining plants in Shahr-e-Babak city?

Safety performance is generally repetitive and non-innovative behavior [7]. In other words, it is part of safety activities that describe the behavioral aspects of staffs safety [8], affecting directly or indirectly safety; thus, safety performance refers to the set of actions and behaviors of employees to maintain and improve safety and health level of themselves and their colleagues [9]. Indeed, a comprehensive performance of a safety management system is the same as safety performance [6]. Measuring employee safety performance is also a basis for assessing workplace safety [9]. Further, identifying the current issues of the organizations and strengthening the effective factors can lead to improving their safety performance in the future. On the one hand, safety performance has different organizational dimensions [10], i.e., the characteristics within the organization and its general characteristics affected by various factors. Organizational factors affecting safety performance include individual, teamwork, safety management, and organizational levels [7]. Safety performance evaluation is a complex issue. This complexity is, on the one hand, due to the number of variables involved in the subject and, on the other hand, due to the existence of linguistic words adding ambiguous components to the decision [10]. Therefore, recognizing organizational factors affecting safety performance based on the results of various researches is necessary.

Safety performance has a relatively strong relationship with safety motivation and knowledge. Also, the safety and psychological climate of the group have a vital effect on safety performance [11]. Safety climate is, indeed, the attitude of employees towards workplace safety, and its recognition and measurement are essential in assessing safety performance. The main reason for measuring safety climate is creating opportunities to improve the safety performance of organizations [12]. In other words, safety climate is the common understanding that employees have about their work environmant [13]. Research shows that, in addition to the safety climate, other factors such as knowledge and motivation also affect safety performance [12]. The importance of safety knowledge is that the person knows how to follow safety rules [14]. Safety knowledge has a positive relationship with safety performance, thus improving it since employees with safety knowledge about work do things more safely [11]. In fact, this knowledge is a part of personal characteristics that affect a person's safety performance, depending on the individual's understanding of safety risks, as well as ways to deal with and avoid them [8]. Safety knowledge is passed on to employees through safety training. This training is, indeed, information and knowledge given to a person to identify job risks, know how to control them, how to act in an emergency, what personal safety equipment to use for safe work, and how to prevent danger [15]. Therefore, safety training can also be an effective factor in safety performance in the organization.

Safety motivation is another factor affecting the improvement of safety performance. It is the motivation of employees to perform job duties in a safe manner [16]. In other words, safety motivation is the factor that causes a person to participate in safety activities effectively [17]; it is vital that employees have the necessary motivation to comply with safety [14].

Individual factors, physical, mental, or psychological, are among those affecting safety

performance. Some of these factors typically are related to a person's personality that is unchangeable; however, some others are related to skills, attitudes, risk perception, and motivation [18]. Postlethwaitea et al. (2009) and Clark et al. (2005), in their studies, showed the effect safety performance of personality traits. According to the results of some research, the conscience has a direct effect on safety performance [19, 20].

Other factors effective in improving safety performance include safety observance, attitude, and participation. Observance of safety are activities performed to maintain the workplace, consisting of the safety procedures and guidelines, safety equipment, and compliance activities with the safety standards [8]. According to job performance theories, participation in safety can be introduced as one of the dimensions of safety behavior [21]. It refers to behaviors that support organizational goals in this field, such as participation in voluntary safety activities or attending safety committee meetings [22]. According to some research, attitudes of staff and supervisors to safety and its performance have a significant relationship [18]. The attitude refers to the inner desire of individuals to evaluate people, objects, and situations, and their interpretation is both desirable and undesirable; also, safety motivation is defined as an individual's desire to show safe behaviors and the valued behaviors related.

Safety management and compliance with the requirements of health, safety, and environment (HSE) management system, human, safety acceptance (behaviors focused on accepting minimum safety standards in the workplace), job satisfaction, and safety leadership are other factors related to safety performance [21].

Materials and Methods

The present research was applied in terms of objectives and descriptive in terms of data collection. Data were collected through the review of previous studies, and interpretive structural modeling was used for the development of the model and identification of the relationship between variables. The sources were reviewed until theoretical saturation to ensure all components were extracted. This study aimed to find factors that improve the safety performance of employees in industrial and mining companies. The relationships between criteria and their type are determined through structural-interpretive modeling, which makes it possible to structure a set of different and related factors in a comprehensive and organized model, use some

basic concepts of graph theory, and describe the complex pattern of conceptual relationships between variables. In this modeling method, based on the judgment of groups (experts), it is decided how variables are related to each other, thus being considered an interpretation.

This method extracts a general structure from a complex set of variables based on their relationships; hence, it is structural. Particularly, it shows the specific relationships of the variables and the overall structure in a graphical model. Therefore, the present study was performed using the interpretive-structural modeling approach. A pairwise comparison questionnaire was used to prioritize the factors. Furthermore, human resource and safety managers of industrial and mining companies in Shahr-e-Babak city were selected as research experts. They all had the theoretical knowledge, practical experience, intention, and ability to participate in the research. Therefore, 25 experts in safety management were selected based on purposive sampling with respect to the research approach. They were selected from Shahr-e-Babak city, one of the mining and industrial cities of the country, with high-risk jobs.

The research process consists of three phases:

1. Criteria identification stage: in this stage, the criteria were collected by studying the research literature to improve safety performance. For this purpose, to prepare a list of criteria, non-repetitive ones were first collected. Then, among the criteria repeated in the researches with the same meaning, one case was mentioned in the list.

2. Criteria screening stage: in this stage, first, the effective criteria in the organization were identified through interviews with chiefs, and then, the fuzzy screening technique was used to determine the most important criteria.

3. The stage of determining the relationship between variables and their type (modeling): in this stage, the questionnaire for determining the relationship in the interpretive-structural modeling method was completed by the organization experts. Then, by converting the relationship matrix to interpretive-structural modeling and creating consistency in the relationship matrix, the corresponding graph was drawn, and the type of variables was determined using the Mick-Mac analysis. In this analysis, research variables are divided into four categories (autonomous, dependent, connected, independent variables) according to conductivity

(number of elements of the achievement set) and dependence power (number of elements of the prerequisite set).

Results

In this study, first, based on the theoretical foundation of research, repetitive and non-repetitive factors affecting safety performance improvement were reviewed, and then with the help of experts (specialists) and fuzzy screening, 9 were identified (C1:safety climate, C2:Safety motivation, C3:Safety knowledge, C4:Safety attitude, C5:Conscientiousness, C6:Safety training, C7:Safety Management, C8:Observe safety, C9:Safety partnership). The fuzzy AHP was used to prioritize the identified indices. Thus, 17 indices were acknowledged and classified into 9 main criteria (Table 1).

Table 1. Initial access matrix

Initial access matrix	C1	C2	C3	C4	C5	C6	C7	C8	C9
C1	1	0	0	0	0	0	0	0	0
C2	0	1	1	0	1	0	0	0	0
C3	0	0	1	0	1	0	0	0	0
C4	0	0	0	1	1	0	0	0	0
C5	1	0	0	0	1	0	0	0	1
C6	0	0	0	0	0	1	0	0	0
C7	0	1	0	0	0	0	1	0	0
C8	0	0	0	0	1	0	0	1	0
C9	1	0	0	0	0	0	0	0	1

A structural self-interaction matrix (SSIM) was formed, according to Warfield's (1974) instructions [23]. Experts' opinions were used to determine the type of relationship between variables. The experts' opinions were extracted from the questionnaires based on the majority vote rule, and then the relationship symbols of this matrix were converted to 0,1 and placed in the initial access matrix. The matrix obtained in this step shows how variables interact.

Next, with the compatibility of the initial access matrix, the final access matrix was formed. To match the matrix, mathematical rules were used to achieve the final access matrix; thus, the achievement matrix reached the power of K + 1

(K≥1). The matrix empowerment operation was performed based on the Boolean rule; according to this rule, 1+0=1and 0+1=1, 1+1=1 and 0+0=0. To determine the level and priority of variables, the set of achievements and prerequisites for each variable were determined. As presented in Table 2, by adding the numbers on each row, the conductivity power is determined, and by adding the numbers to each column, the degree of dependence is determined. The conductivity power of each variable is the final number of the variables (including itself) that can play a role in creating them, and the degree of dependence is the number of variables that affect the relevant variable and lead to its achievement.

Table 2. Formation of the final access matrix

Final access matrix	C1	C2	C3	C4	C5	C6	C7	C8	C9	Dependence power
C1	1	1	1	1	0	0	0	1	0	5
C2	0	0	1	0	0	0	0	1	1	3
C3	0	1	1	0	0	0	0	0	1	3
C4	1	0	0	1	0	0	0	0	1	3
C5	1	0	0	1	1	0	0	0	1	4
C6	0	0	0	0	0	0	1	0	1	2
C7	1	0	0	0	1	1	0	1	1	5
C8	0	0	0	0	0	0	1	0	0	1
C9	0	0	0	0	0	1	0	0	1	2
Degree of dependence	4	2	3	3	2	2	2	3	7	-

In the next step, the final access matrix was divided into several levels. This division helps clarify the role of each of the components and their two-way interaction, as well as facilitating the process of their analysis. Therefore, after

determining the set of achievements and prerequisites for each variable, common elements in the sets for each variable were identified. Later, the level of variables was determined. In the first table, the variable with exactly the same set of

achievements and their common elements was considered to have the highest level. After determining this variable or variables, they were removed from the table, and with the other remaining variables in the table, the second levels were identified; this continued until the level of all variables was determined (Table 3).

Table 3. Determining the levels of factors affecting the improvement of workers' safety performance

Level	Common set	Prerequisite	Achievement set	Factors
3	1	5,7,1,4	8,1,4	1
2	3	3,1	3,8,9	2
2	2.3	2,3,1	2,3,9	3
2	1.4	1,4,5	1,4,9	4
4	5	5,7	1,5,9,4	5
1	7.9	7,9	9,7	6
2	1.5	8,6	1,5,8,9,6	7
1	7	1,2,7	7	8
1	9.6	2,9,7	6,9	9

Finally, after determining the relationships and level of variables, an interpretive-structural model was drawn. For this purpose, first, the variables were arranged in order from top to bottom in terms of surface, and the relationships between them were drawn based on the initial achievement matrix. The direction of the arrows was determined from the final matrix (Fig 1).
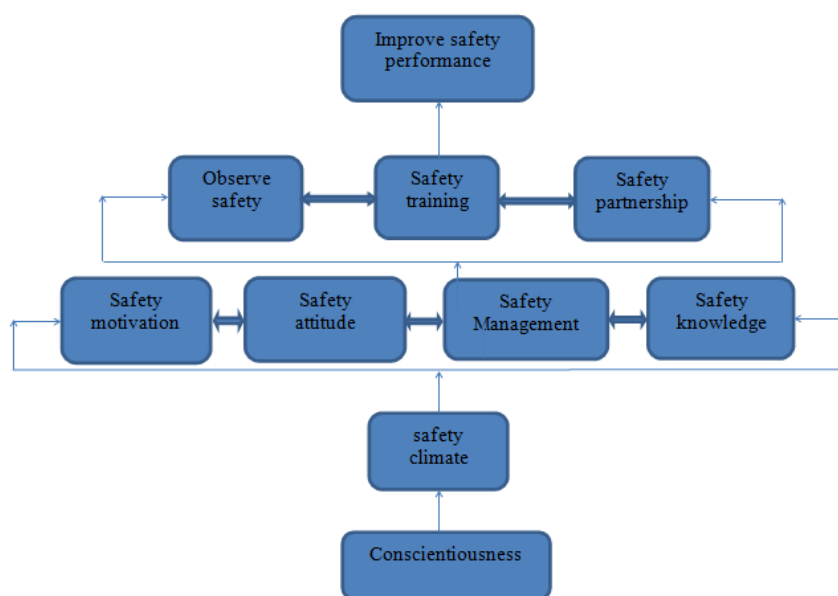

Fig. 1. ISM graph to improve workers' safety performance

Level one is the most influential level, and the last level is the most effective one, which acts as the foundation stone of the model. As shown in Fig. 1, the final model obtained in this study consists of four levels. In the ISM, the relationships and interrelationships between criteria, as well as their effectiveness at different levels, are well-demonstrated, leading to a better understanding of the decision-making by experts. The fourth level criteria of the lowest part of the graph have the most relevance and impact on the system by changing which the system changes. Criteria at higher levels are less effective and more influenced by other criteria. Thus, criteria 6, 8, and 9, known as the first level criteria, are placed in the model's first level. Therefore, they are more influenced by lower-level criteria. Similarly, other criteria are specified at other levels of the model.

Finally, structural analysis was performed using the Mik-Mak method. Factors with high penetrating power are called main factors. These factors fall into one of two groups of connected and independent criteria (Table 4).

Table 4. Degree of conductivity and dependence of safety performance improvement factors

Final access matrix	C1	C2	C3	C4	C5	C6	C7	C8	C9
Dependence power	5	3	3	3	4	2	5	1	2
Degree of dependence	4	2	3	3	2	2	2	3	7

As observed, all factors, except for 9 in the second (dependent) group, are in the first (autonomous) group. These factors have poor conductivity and dependence (Fig. 2).
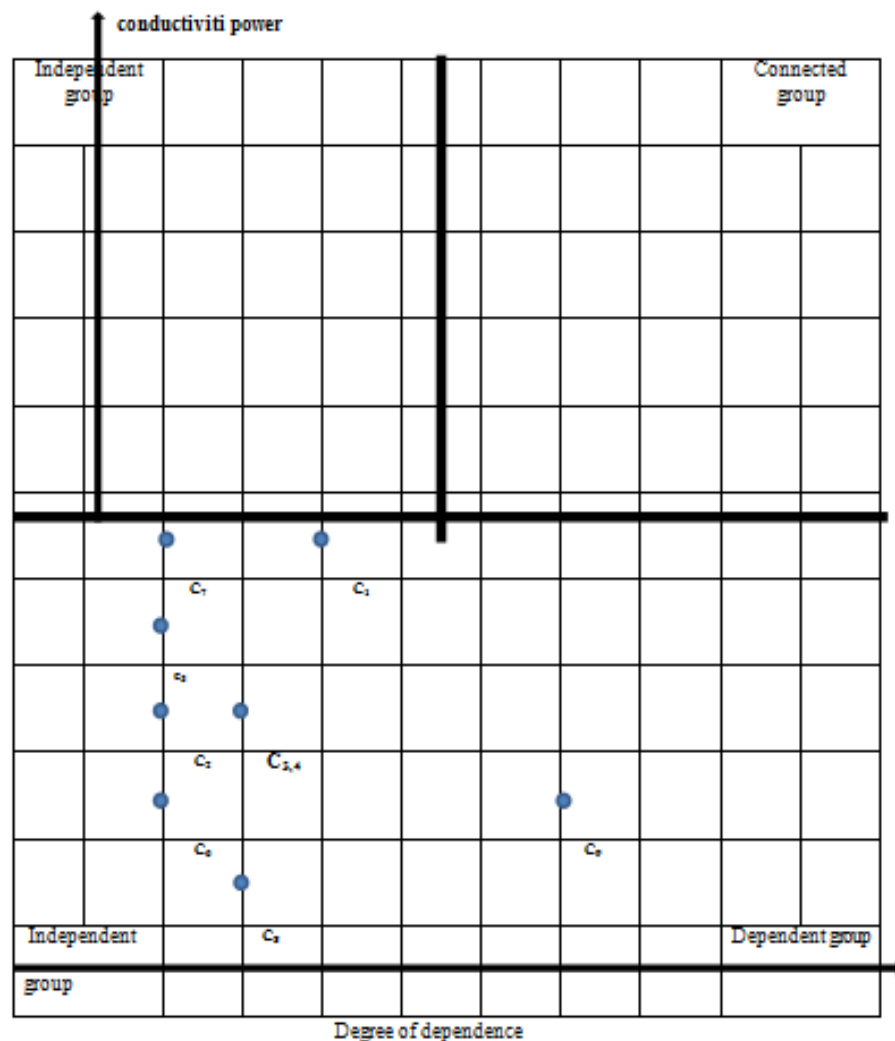

Fig. 2. Power_dependence chart (MIC-MAC chart)

Discussion

The purpose of this study was to explore the dimensions of safety performance using an interpretive-structural model in the spatial territory of industrial and mining companies in Shahr-e-Babak. In order to achieve this goal and based on the research results, it was found that the most fundamental context of safety performance is conscience and safety climate, the starting point and cornerstone of safety performance formation. According to this study results, conscience affects safety performance. Findings of past research have shown that safety climate and conscience have a direct effect on safety performance [6]. People with a high level of conscientiousness pursue general goals with purposeful methods and strictly consider themselves bound by safety rules, thus trying to participate in implementing related policies. Organizations are recommended to pay more attention to selecting people with this feature, trait for working in high-risk jobs.

Several studies, considering the safety climate a predictor variable of safety performance, have claimed that it is effective in adhering to safety rules and procedures and participating in safety-related activities in the workplace [8]. The earlier research results show that the safety climate has a key role in the safety performance of the organization [24]. According to other studies, safety training has an effect on improving the safety climate and consequently on safety results as a dependent variable [25]; also, the safety climate can be used as a predictive indicator to measure safety performance [26]. Based on this research and similar studies, it can be concluded that the safety climate affects the safety performance of individuals; thus, improving the safety climate can improve the safety performance of employees. The relationship between safety climate and safety performance evidently is positive, and safety equipment, policies, and rules cannot improve safety behaviors alone.

Moreover, the present study shows that safety knowledge and motivation affect safety performance. According to past research results [14], to achieve the desired performance, it is necessary to have related motivation and ability (knowledge and skills). Also, safety performance

has a relatively strong relationship with safety motivation and knowledge [11]. Since safety knowledge has a positive relationship with safety performance, it is an improving factor; this is because employees who have safety knowledge about work do jobs more safely [12].

This study also indicates that safety motivation affects safety performance. Therefore, efforts should be made to help improve safety performance by motivating safety. The authors believe that this can be done in different ways, such as developing incentives (e.g., identifying individuals or units with positive safety performance through monthly assessment or HSE competitions and rewarding them), encouraging employees to participate in voluntary safety activities and follow standard procedures, using equipment to protect individuals, observing safety warnings, promoting teamwork to perform the work safely, encouraging accountability and responsibility in creating safer workspaces, and promoting a safety culture.

Further, according to this study results, in addition to safety knowledge and motivation, safety management and attitude are among the factors affecting safety performance. Previous studies have shown that safety management systems create a positive atmosphere in which all systems and individuals have a reduction effect on risk, thus improving employee safety performance; these have been effective in improving occupational safety and health. For example, identifying hazards and tactics to deal with them can help reduce risky behaviors, thus minimizing hazards in the workplace [15]. According to earlier research, employees are aware of the dangers of work; however, managers and workers' inattention to safety issues is among the risk factors [17]. In other words, although safety knowledge affects the safety performance of people, safety management is considered more important in avoiding danger. Therefore, since this study shows that safety knowledge and training improve safety performance, to improve the safety knowledge of employees, it is also essential to enhance their knowledge about safety risks, appropriate safety equipment and how to use them, safety rules and regulations, harmful factors, and mechanical hazards of the workplace. Also, since in this study, the effect of safety training on safety performance has been evaluated positively, continuity in training programs is recommended.

Based on the present research findings, another effective factor in improving safety performance is the safety attitude; this result is consistent with that of some previous studies [18]. Another study hypothesizes that people's attitudes can probably

increase their commitment to safety; of course, people's commitment to safety is a factor related to the individual that can be influenced by organizational factors and safety climate [27]. According to various studies [26,28], more than 90% of all injuries and diseases in the workplace occur based on human behavior, and also one of the most important factors in safety is the attitude of employees and supervisors about safety; therefore, the most effective ways to change safety-related behaviors are programs such as training [18].

If safety performance is compared to an iceberg, the surface outside the water and its appearance is the safety. Further, according to the model based on experts' opinion, if all dimensions of safety performance are implemented, the necessary ecosystem for safety performance will be provided. If safety participation and training also aid this ecosystem, they accelerate improving safety performance, and in the absence of safety participation or lack of thereof, safety performance improvement will be reduced. The results of a study indicate that safety-related knowledge has a direct effect on promoting a safety culture in the organization, and the knowledge management system can be used as a factor to promote safety culture in the organization in the long run [29]. Findings of earlier studies have shown that increasing staff awareness and managing employee safety participation are effective in improving safety and ultimately reducing the incidence of unsafe behaviors [30].

Conclusion

Based on the findings in the proposed model, the most basic context in improving the safety performance of employees is conscience and safety climate. At the first level of the model, safety participation, training, and compliance are considered effective factors in improving safety performance, all of which are influenced by the criteria of the model's lower levels, i.e., safety knowledge, motivation, management, and attitude. Therefore, according to the research results, safety performance must be improved by improving the safety climate by emphasizing the desired value and safety training and establishing free communication in the workplace.

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