RISK RANKING MODEL OF HSE RISKS IN THE MANUFACTURING PROCESS - USING MULTI-CRITERIA DECISION-MAKING PROCESS

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ABSTRACT

The manufacturing process is considered as an unseperable component of large civil and industrial projects. Having reviewed the occurred damages and events statistics in current operation, the existance of an organizaed system of HSE seems necessary to manage the manufacturing operation in these kind of projects. The determined objectives of HSE includes to identify any unhealthy behavior in civil projects and provide a solution to healthy and safe implementation, and yet to consider the environmental consequences of the projects. In this regard, in present study to evaluate the HSE risks related to the construction in civil projects, the stratified analysis method (AHP) was used to evaluate and prioritize of the risks related to the fields of health, safety and environment. The results show that the risks related to safety problems (requirments and machines safety, safety of vital parts and safety of project workers), health (structural health against seismic forces) and environment (environmental polutions) are of great importance relating to other parameters.

Keywords: Rankings pattern, Importance of risk taking, HSE risk, multi-criteria decision-making

INTRODUCTION

One of the imortant factors of death, also loss of national capital is the lack of safety and health in structures and civil projects. The HSE expression is the short form of three words: Health, Safety and Environment. Today is the word of competition, and the rate of technologic evaluations and change in consuming pattern and markets requirements and increase in social expectations, social responsibility of organizations is getting tighter in competition areas. A condition of survival in such an environment, is to enjoy a competitive advantage in the organization. Accordingly, to achieve the organization's objectives in the field of competitiveness, addressing the HSE became one of the priorities of the organization in today's business.

Construction and development is always one of the most dangerous industries in the world with respect to inclusiveness and breadth and variety of activities and the risks and harmful factors in them, and in most countries is placed at the forefront of entrepreneurial activity with the incident. However, unlike other industries, civil and construction activities are physically scattered in different locations and it is very challenging to monitor their health and safety [1]. Therefore, assessment and management of risks in the projects aimed at reducing the risks of human, financial and time is always of significant issues.

It is necessary to identify the risks to be prioritized on the basis of certain criteria in the process of risk assessment and management [2]. The reason for this high frequency risks have been identified that is of the critical importance of them and especially their limited resources to control [3]. In addition, it has been highlighted always in dangerous industries such as oil, gas, petrochemical, power and control measures as a result of the risk assessment and best and most effective control measures also depends on the proper way to rank the risks have the lowest error and the highest accuracy.

Fazlullah et al. (2012) in an article, using ANP, have provided a method for ranking HSE risks in the process of construction of combined cycle power plants.

In this study, determining the overall structure and establishing relationships between elements and available criteria of HSE issues in the field of energy, first, the criteria and sub-criteria test were compared with the use of experts and in the final phase of the project HSE risks were identified and prioritized. The results showed that the usual method of risk assessment is not able to prioritize risks accurately, while the proposed approach could prioritize them on 7 categories [4].

Zahmatkeshan and colleagues (2013) conducted a case study released an article entitled "possible model for the study of disasters caused by earthquakes of varying intensity depending on the strength of the building of the environmental health safety point of view in higher education centers". The study utilizes the PSHA method and combining with AHP and FMEA techniques to design a model that is able to assess the risk [5].

According to the above-mentioned, this study offers a more accurate way to rank HSE risks related to development projects in the construction process. In this regard, it with raise the accuracy of ratings due to the flexibility and precision of analytical hierarchy process in the ranking of alternatives (risks) as well as the possibility of taking a series of criteria and sub-criteria relationships, using this approach makes it possible that it can be more accurate for ranking risks in HSE [6]. Studies show that in recent years to address the issues with interaction and feedback between the elements and options is widely used for their decisions from this process [7].

Establishment of systematic HSE in construction projects

Almost 90% of the events leading to injuries are predictable that occur in the workplace. Probably the same ratio can be anywhere there is potential for possible events, so using appropriate control methods is a top priority in development projects. Needless to say, if the application of existing knowledge, will prevent a large number of events leading to injuries. Modular construction and development is one of the riskiest workspaces and from the perspective of risk diversification is also considered dangerous due to their business practices among the sites. The reasons for the high statistics of injuries can be caused by several factors in the construction industry. What is the basis of the observations made in the workshops can be seen more in development projects, as follows:

- ✓ Focusing on safety, infrastructure for doing things safely and the infiltration of poor safety culture has no place in the thinking of managers.
- ✓ Incentive policies in differentiating between contractors has a better safety record that can be seen in most countries, it does still not exist in our country.
- ✓ There are forces byond the management in construction workshop that are also one of the causes of events.
- ✓ The low cultural level of the workers, especially in construction sites causes the cultural anomalies such as drugs

and other prohibited items to be common with a relatively high level. As a result of these cases, loss of consciousness, followed by work accidents.

✓ Modular construction and the specific situation in comparison with other industrial processes factory itself is the cause of many of the hazards and safety issues.

✓ Business environment in its development workshop is the origin of many hazards in confined spaces and reserved in other occupations and their industry.

HSE risk analysis in construction projects

The development projects in most countries are at the forefront of entrepreneurial activity event due to their comprehensive nature and their extent. There are risks and hazards in the implementation of various workshops, the construction industry has become one of the most dangerous industries in the world. With the advancement and development of technology, facilities and equipment was further developed and made for the construction industry and civil engineering work as a result of new and advanced equipment and facilities, the possibility of large and complex construction projects have also been provided. Accordingly, the larger and more complex construction projects, the safety and finding ways to reduce accidents in the workplace are increasingly required. In this regard, the establishment of the only ways to reduce possible risks and damage, and most important duty of project management and executive levels. Here are some of the common risks in this industry. There was a risk, on what is effective, it can be a risk classification as follows:

➢ **Risks related to performance, purpose, quality and technical issues of the project**: This category of risks may affect the completion and implementation of the project. If technical problems are increased costs and project time, operational risk will be the lead to cost and risks.

➢ **Time risk**: The risk of bias when the deadline is the end of the project. The effects of this class of risk influences operational and cost risks.

➢ **The cost risk**: This risk will be offset project costs of approved budget ceiling. Of course, the cost risk associated with the risk time. The risk can lead to operational risk.

➢ **Increasing Risk**: The risks themselves are less important, but by their accumulation, the significant risk is created. For example, a small increase in the cost of a contractor does not

have much effect on the budget, but if the project is faced with a wide range of contractors, the end result of this increased risk is important.

➢ **Catastrophic risk**: This risk includes all risks that could have a significant impact to-be single and influence on other risks. Odds of these risks are very low and the impact is very high. For example, it can be critical to technology-related waste disposal pointed to the need for special equipment.

➢ **Environmental risk, health and safety (HSE)**: This category of risks includes those that cause harmful effects on the environment are implementing the project. Under this type of risk of serious accidents, will have severe effects on time and budget.

Given that research has identified and comprehensive risks related to HSE does not have been done in construction projects, so in this paper, the latter risk analysis of environmental, health and safety is addressed through the AHP hierarchy.

Analytical Hierarchy Process (AHP)

In the science of decision making that the selection of a strategy is desicussed amoong prioritizing strategies and solutions, for a few years, the decision-making methods with multiple parameters

(MADM) have been largely replaced in engineering issues. Meanwhile, Analytic Hierarchy Process (AHP) has been used more than other methods in management. AHP is one of the most famous multi-use decision-making skills, first by Saati was developed in the 1970s. This behavior reflects the natural and human thinking and complex issues based on their interactions studied and they have turned to the simple way to solve them.

AHP in practice when the decision is faced with several competing options or multi-criteria decision-making faces, can be used both quantitative and qualitative criteria outlined in the applications. The method is based on paired comparisons and begins decision making by providing a hierarchical tree of its decision. Tree hierarchy of decision making shows factors to compare and evaluate competing options. Then carried out a series of paired comparisons. The weight of each factor shows in comparison to alternative options evaluated in the decision and finally AHP logic combined pairwise comparison matrices resulted from optimal decision making.

Fundamentals of Analytical Hierarchy Process

The founder of this method stated the following four principles as principles of AHP and all the calculations, rules and

regulations is based on these principles. These principles are [8]:

- ❖ **Adverse conditions**: if A preferred element is n fold of B element, A preferred element will be 1/n on B.

- ❖ **Homogeneity principle**: ingredient A should be homogeneous and comparable with ingredient B. In other words, superior element A to element B can be infinite or zero.

- ❖ **Dependence**: each element of hierarchy to higher level element can be linearly dependent and this dependence can be continued up to the highest level.

- ❖ **Expectations**: If no changes occur in the structure of the hierarchy, the evaluation process should be done again.

Making Hierarchy Process

The first step in AHP is a graphical representation of the desired target at the top of the next level, with criteria and alternatives. Although a final rule does not exist to draw the Hierarchy Process, but a series of general rules described by Dyer and Forman, which is one of the following ways:

- ▪ Objective-criteria-options
- ▪ Objective criteria, sub-criteria options

In general, we can say that building a Hierarchy Process method depends on the type of decision that should be made, for example, if the decision is to choose an option, we can start them at the lowest level options indicated and the next level of the criteria used to select the options that remain to be addressed at the highest level, the Hierarchy Process is a useful element [9]. Sometimes the criteria has to be more detailed analysis in this case, a surface which contains these criteria added to Hierarchy Process. There is no limit to the number of levels in the hierarchy. An example of a hierarchical tree structure is shown in the figure below.

Modeling

In this step, issue and objective decision making are brought in as a hierarchy of elements that are connected together. Design elements include "indicators of decision-making" and "making choices". AHP needed to break a problem with some indicators in a hierarchy of levels. High level represents the main objective of the decision-making process. The second level represents the major fundamental factors (which may be more detailed sub-indices to be broken in the future). The decision also provides the final level options. In Figure 1 diagram shows the hierarchical structure of a decision problem [10]. In this diagram, there is a four-level hierarchy

of objectives, criteria, sub-criteria and option.

Examined issue has become the most important part of hierarchical structure analytic hierarchy process. Because in this part, the analysis explains difficult issues and complex, hierarchical processes in a simple form that they comply with the mind and human nature. In other words, the process of hierarchical complex issues through the analysis of trace elements that are hierarchically interrelated and linked to the main purpose, the lowest level of the hierarchy is clear.

Calculating the weights

To calculate the weight to gain importance in the criteria and sub-criteria, all criteria and sub criteria were compared by paired comparison matrix in different ways, the

weight of each criteria and sub-criteria to their relative weight is said to be achieved. In the next step all options using paired comparison matrix to its high levels of which can be assessed by sub-criteria or directly from a standard.

The weight of each of the options is obtained to each of the criteria or sub-criteria, which is called the relative weight of options. In the next step, absolute or final weight of each item is calculated by multiplying the weight of each criterion in the choice of the standard weight. The final step is specified to achieve absolute weight, prioritize options. In general, a paired comparison matrix is shown as (1) that aij is the prefered i-th element to the j-th element [8].

$$(1)$$

$$A = \begin{bmatrix} a_{11} & a_{12} & a_{1n} \\ a_{21} & a_{22} & a_{2n} \\ a_{n1} & a_{n2} & a_{nn} \end{bmatrix}$$
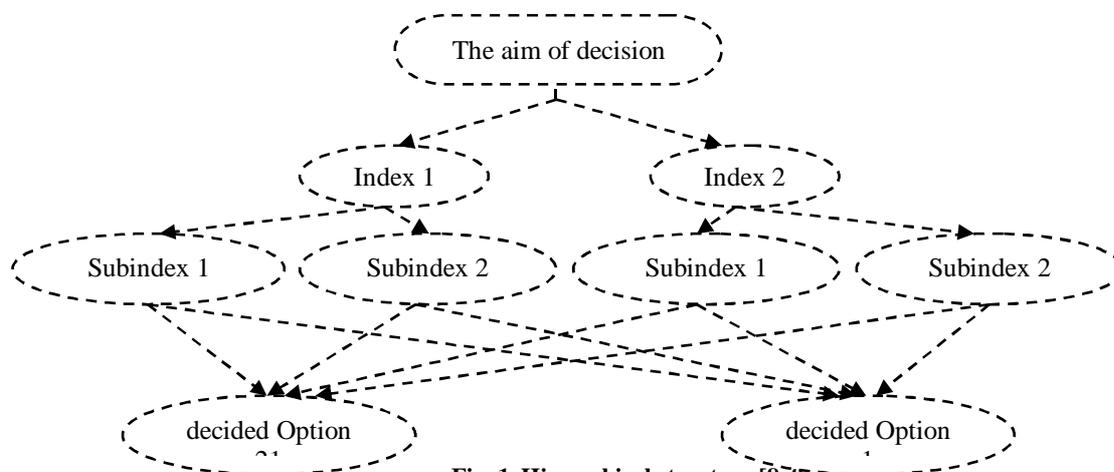

Fig. 1. Hierarchical structure [8, 9]

Based on the comparison and decision-makers have used of oral judgments. In this case, if i option compared with the option j, decision-maker says that the importance of i to j are small amounts of 1 to 9, which according to the inventor of this method (Saati) are stated in the table below. Other numbers not in the table, the values of the middle shows the preferred values, for example 8, indicative of more than 7 and less than 9 for i to j [9].

Consistency in judgments

Almost all the calculations of the Analytical Hierarchy Process carried out based on initial judgment decision that appears in the matrix of paired comparisons, and any errors and inconsistency in comparing the value of the options and parameters skew the final results obtained from the calculations. Inconsistency rate (IR) are presented in the following calculation, a device can be trusted that measures the consistency and shows the extent to which the priorities of comparisons.

Table 1: The value of the pair strongly preferred relative to the AHP analysis

Description	Comparison of i to j	Strongly preferred
Stock i to j are not of equal importance and priority	Equal importance	1
i to j index option is a little more important.	Relatively more important	3
Options or index i to j is more important.	More important	5
i have a much more preferable option or index j.	Very important	7
Options or index i quite comparable with j and j is more important.	Highly important	9
i indicator is absolutely more important than j and has a very special importance	Special importance	10
Intermediate values between the preferred values indicated. For example, 8, shows the importance of more than 7 and less than 9 for i to j.	Preferred interstitial	2 و 4 و 6 و 8

For example, if Option A to B above (preferred value 5) and B is relatively more important (preferred value 3), then it should be expected A than C (preferred value of 7 or more) or if preferred value of A to B, 2 and B to C, 3, then the value of A to C should provide the preferred 4. Comparing the two options, it may be easy at first, but when the number of comparisons increases, ensuring consistent comparisons simply is not possible and should be achieved by applying the rate of adjustment to the trust.

Experience has shown that if the inconsistency ratio is less than 0/10, consistency comparisons are acceptable and otherwise comparisons should be revised. It is worth noting that the model described above show inconsistency rate of 0/07 obtained that the data are compatible. In general, the following steps are used to calculate the mismatch rate [10]:

❖ **Step 1) Calculate the total weight vector**: matrix of paired comparisons in the column vector "relative weight"

multiplied, and new vector thus obtained, the vector sum of the weight (WSV) is called.

❖ **Step 2) Calculating adjustment vector:** elements of the vector sum of the weight is divided on the relative priority vector and the resulting vector adjustment (CI) is.

❖ **Step 3) Obtaining λ_Max:** mean vector elements adjustment, the amount would provide λ_{Max}.

❖ **Step 4) measure the consistency:** consistency index is defined as follows:

$$(2) \qquad I.I = \frac{\lambda_{Max} - n}{n - 1}$$

In this regard, n is the number of options available on the issue.

❖ **Step 5) calculation of adjustment or compatibility test:** The mechanism is intended to check the inconsistency in judgments, calculating the adjustment factor (CR) division of the index inconsistency random index obtained according to the following equation.

(3)

$$C.R = \frac{I.I}{R.I}$$

If this ratio is less than or equal to 0/1, compatibility judgment is acceptable, otherwise should appeal judgments [11].

METHODOLOGY EARCH AND MODELING

As already noted, the study "ranking risks HSE management is used in the process of construction projects", for modeling decision-making on priority issues identified risks using Analytical Hierarchy Process (AHP). Since an AHP model of "target", "network criteria and sub-criteria", "Options" and "pairwise comparisons between elements", for modeling the problem, the purpose, the overall structure of the model and the relationships between elements and each element have been paired compared to the third element associated with each of them. Then, they were entered to rank options, rating model development and options. Steps described in the following section. Therefore, the process of drawing up the tree to assess the risk of HSE in construction projects is presented below. Accordingly, in this study, three main parameters of health (H), safety (S) and the environment (E) considered as the main criteria in the rating model and for each of these three criteria, the criteria is determined for assessing options (risks HSE) as follows. Therefore, the research in different contexts and based on personal experience regarding HSE issues in the assessment of construction projects, each of the above criteria are divided into four sub-criteria in the table below, the criteria and sub-criteria. It is worth noting that the analysis of hierarchical tree in a case

study2 is shown in Figure 2. At this stage to make paired comparisons of scales set for each criterion and thus determine the value of each scale to the other, 12 risk assessment related to the performance of HSE management were included in project-development, in order to get the output of AHP proposals, as Expert Choice software. To use binary comparisons of specific software and setting priorities, enables researchers that their opinions reflect more accurate than other methods of decision making and acquire more accurate results.

DISCUSSION AND RESULTS

In general, a HSE risk may have implications for health and safety and environmental at the same time, so consider both these factors can be the results of the analysis and prioritization of risks in this area are more accurate. AHP method proposed in accordance with the ranking model in which there is the possibility of selecting any combination of measures and thereby risk assessment would consider all aspects of a risk and increase the accuracy of the results. On this basis, then, according to HSE risks in construction projects and the pattern followed for analysis of AHP, the assessment and scoring of these risks are discussed.

Table 2. The criteria and sub-criteria evaluation of HSE risks in the management of construction projects

Sub- criteria	Main criteria	Objective
Health structures against seismic forces (CH1)	)H(Health	HSE risk assessment in the management of construction projects
Health structures against subsidence and cracks in the structure (CH2)		
Health structure against deformation (CH3)		
Health structures against fire (CH4)		
Project Worker Safety (CS1)	)S(Safety	
Safety of equipment and machinery (CS2)		
Pedestrian safety (CS3)		
Safety Lifeline (CS4)		
Environmental pollution (CE1)	Environment (E)	
Air emissions (CE2)		
Improper ventilation (CE3)		
Damage to natural resources (CE4)		
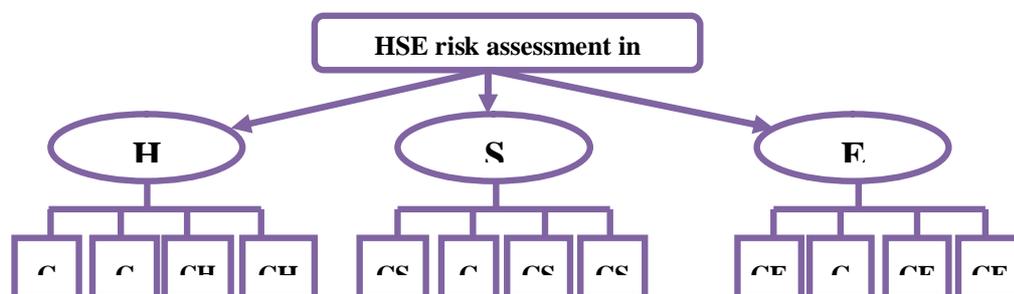
Fig. 2. the overall structure of criteria and sub-criteria AHP hierarchy including a risk assessment of HSE in construction projects

In order to assess the importance of each of the main criteria in the systematic HSE, these criteria are ranked (health, safety and environment) is identified in terms of the

different sub-criteria (risks and dangers) discussed and finally the most important risk.

In Fig. (3) ranking the HSE risks in construction projects is shown. According to the results, it can be seen that the safety risks associated with construction will remain in the highest priority. As well as measures related to health and the environment are on the next level. It should be noted that the results show that the risk of health issues and their impact on the environment are about the same degree of importance. Accordingly, it can be concluded that employers and contractors on large construction projects should be their objective primarily concerned with safety criteria to consider and factors related to health and the environment are on the next level.
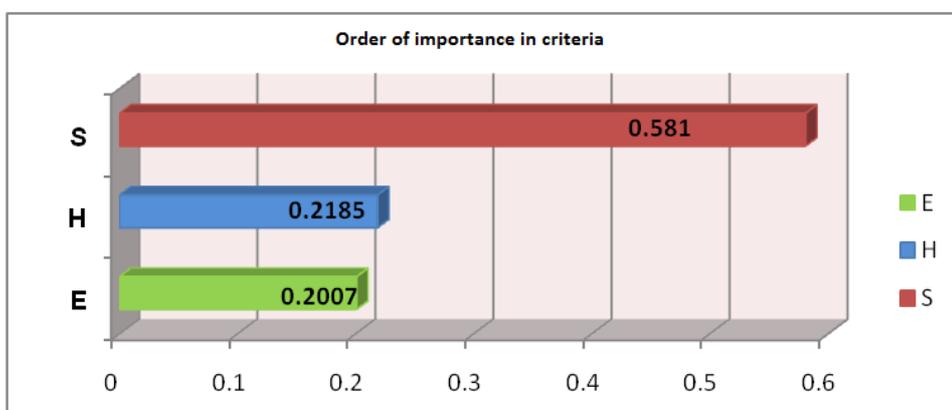

Fig. 3. weight evaluation criteria of HSE risks in construction projects

In Fig. (4) ranking of alternatives or risk sub-criteria HSE in construction projects is evaluated in terms of the degree of risk.

Fig. 4. The weight of sub-criteria evaluation of HSE risks in construction projects

In Fig. 5 the results are shown in descending order of importance of each sub. In addition to the degree of priority and importance of the results is provided

in Table 3. The results show that the sub-criteria of safety equipment, health structures against seismic forces, safety, Lifeline, project worker safety, health structures against subsidence and cracks in the structure and order of priority the risk rating of the HSE in construction projects and in the early stages of implementation issues worthy projects that include employers and contractors responsible for the construction of the agenda these issues in order of priority to this way, the risks identify and assess the relevant early stages of design and construction and their occurrence is prevented as much as possible.
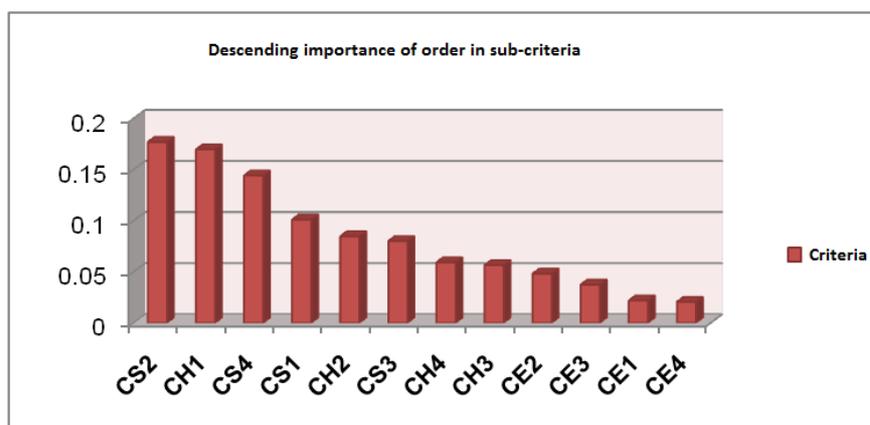

Fig. 5. The weight of sub-criteria assessment of downside HSE risks

Table 3. Priority Number HSE risks in construction projects

Priority number of AHP	HSE risks	Index
0/177	Safety equipment and machinery	)CS2(
0/1697	Health structures against seismic forces	)CH1(
0/1442	Safety Lifeline	)CS4(
0/1011	Project worker safety	)CS1(
0/0847	the health structures and Subsidence of structural cracks	)CH2(
0/08	Pedestrian safety	)CS3(
0/0592	Health structures against fire	)CH4(
0/0564	Health structure against deformation	)CH3(
0/0481	Sound pollution	)CE2(
0/0374	Improper ventilation	)CE3(
0/0219	Environmental pollution	)CE1(
0/0205	Damage to natural resources	)CE4(

Finally, in Figure (8) the risk of the triple risks of health, safety and the environment in development projects have been compared for combined results. The results show that the risks related to construction safety standard has more importance compared to the standard of health and the environment and is essential considering the importance of the project. However, as previously indicated, in some cases sub-criteria related to health and environmental risks are more important to comment on the situation was due to the

risks should consider all factors by comparing combination.

Fig. 5. triple combination prioritize the importance of HSE risks in construction projects

CONCLUSION

In this article we have tried to measure and rank the risks should be provided to the HSE in the projects. The main parameters of the systematic HSE (ie health, safety and environment) and sub-criteria is assessed risk and risk system is identified. Then, the use of AHP method to analyze the system has been studied and the results show that the risk of safety standards in projects is of higher priority. The sub-criteria, the parameters of safety equipment, health and safety structures against seismic forces Lifeline of enjoying a higher priority. Accordingly, the question of the establishment of systematic HSE in the project from the beginning stages of your projects in order of priority should be obtained in this study, their attention to the risk of the HSE in large construction projects.

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