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Implement a process safety management system based on the identification of the most critical factors in the establishment of safety programs; using fuzzy analytic hierarchy process

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Abstract

It is essential to Identify the critical success factors due to their direct effects on the establishment of safety programs. These factors should also be prioritized to facilitate the establishment of process safety management (PSM) system in process industries. The fuzzy analytic hierarchy process (FAHP) was employed in this study to weight the critical success factors in implementing and executing safety programs for establishing management system. For this purpose**,** a few prominent process safety management models were reviewed, and the critical success factors of safety programs establishment were extracted. After that, a questionnaire was developed and distributed among the experts. The fuzzy analytic hierarchy process was then adopted to calculate the weights of factors for prioritization. This study aimed to determine the most effective factors in implementing and improving process safety management systems in process industries. Other factors will be effected in establishing process safety management in subsequent priorities, one after another.

1. Introduction

At the side of the increase of the industrial revolution, technical and engineering sciences also grew and underwent tremendous adjustments, because the call for electricity providers elevated every day, requiring engineers to continuously research and expand to produce more energy resources. However the hassle right here became that with the boom of enterprise and generation, risks and fatal Commercial accidents additionally accelerated. In an overview, it can be said that the 1980s was the decade of "safety in facilities" where industries focused on improving hardware and equipment to reduce accidents. The 1990s was the decade of "process safety" that, after the "Clean Air Act" was passed in the US Congress, organizations such as the US Industrial Safety and Health Administration (OSHA) and the US Environmental Protection Agency (EPA) to reduce accidents and pollutants, they moved towards establishing models such as process safety management and risk management program (RMP) (Heidari and Ghasemi, 2016; Cheraghi and Khodadadi-Karimvand, 2023). The reason for this research is to review the Critical Success factors (CSF) in the implementation of protection packages which is the maximum essential thing in the established order of the system Safety Control system within the system industries. Analytical Hierarchy Process (AHP) can be relied upon a fantastic deal to efficacious installation a procedure safety management system.

2. Methodology

As mentioned in a take a look at through Ismail and Harun about the elements influencing the establishment of safety programs in operational web sites (Ismail and Harun, 2012), those CSFs can be used within the implementation of procedure safety control machine implementation ranges. In this text the CSFs in the implementation of safety Prioritization is done based on the scores given by the experts to each comparative pair. Teo et al. presented a model using the hierarchical Analytic Process method (AHP) to measure the effectiveness of the safety management system of construction sites, which mostly refers to the formulation of an audit checklist (Teo EAL, 2006).
Khodadadi-Karimvand and Taherifar, (2022) within the article "safety chance evaluation the usage of fuzzy good judgment, analysis of failure outcomes (FMEA) and Fault Tree evaluation (FTA)" addressed this difficulty to create a version for prioritizing threat and their outcomes the usage of fuzzy good judgment together with the combination of the two methods stated within the name of the thing; FMEA is a qualitative, inductive and it is effective for detecting mistakes and disasters in a machine, and fuzzy common sense can enhance that Approach with extra logical outputs. Also, FTA as a probabilistic danger evaluation method is one of the effective techniques for calculating the probability of mistakes, failure, and functionality.
In the research of Khodadadi-Karimvand and Shirouyehzad in 2021, fuzzy hierarchy is also mentioned. In this case study, using RPN, TOPSIS and FRPN techniques on the drilling operations of oil and gas wells and by integrating the FMEA method, fuzzy logic has been done. In this research, it has been tried to rank the risks by maintaining the fuzzy logical values at the level of simpler risks, and at more complex levels, helpful methods such as FTOPSIS have been used.

In other recent researches using the tools used in this paper Abdullah Zübeyr ŞEKERCİ and Nezir AYDIN, 2022, following the FAHP method, it is possible to bring the investigation closer to reality under conditions of uncertainty. Therefore, various scenarios can be examined and work can be made under conditions of uncertainty and Khodadadi-karimvand et al., 2024 used fuzzy logic for the analysis of CSFs in lean production, continued to present a conceptual model that proposed by interpretive structural modeling.

There are countless definitions of events (PSM), what is done about a program (PSM). Many similarities are observed in these definitions and basic principles, which are illustrated by the following examples:

• In the research conducted by (Norozi et al., 2013) on the feasibility of process safety management in a petrochemical unit, they found that after 6 to 10 years after the implementation of PSM, the risk of accidents decreased by 80%. After that, by adapting to OHSAS 18001 and HSE MS, most of the parameters in process safety management are consistent with these two standards.

• Naicker and Stoker defined process protection management as follows: "on every occasion there is a manner that causes modifications in temperature and stress to change the molecular shape or create new merchandise from chemicals, there may be the possibility of fire, explosion, or release of flammable or poisonous beverages." vapors, gases or current methods. The Manipulate of those undesirable activities requires a unique science called system safety management. The terms system safety and process protection control are broadly speaking used to explain the protection of employees, the public, and the surroundings from the consequence of unwanted events (Naicker K., Stoker P.W., 2014)."

•Shimada et al. have defined manner protection management as; "safety control is the process of a management gadget that focuses on stopping, getting ready for, mitigating, responding to, and remediating catastrophic releases of chemicals or resulting power (Shimada et al., 2009).

• DuPont, a global chief in Process Safety Management (PSM), said: "Process Protection Control is the usage of plans, procedures, audits, and assessments in a production or industry technique to become aware of, understand and manipulate procedure, risks, make enhancement every day in commercial enterprise and safety standards."

2.1 An overview of process safety management system models

In the situation of process safety management (PSM), numerous models with exclusive elements have been presented by international organizations and bodies with the purpose of paying special attention to the safety engineering approach in chemical processes. In this regard, a few PSM models are introduced.

2.1.1 Process Safety Management Model of the American Industrial Safety and Health Administration - OSHA[1]

The USA Congress established OSHA in 1970 based on the Occupational Safety and Health Act. The purpose of creating this structure became to ensure safe and healthy working conditions for employees by applying mandatory standards and providing training, counseling, education and development. The Occupational Safety and Health Agency is a part of the United States Department of hard work, and the director of the organization serves as an advisor to the Minister of Labor regarding occupational safety and health.
This employer has a national workplace, regional offices, state making plans offices and advisory offices and is actually the lawmaker of the USA. This organization is also responsible for the safety and rules of the work environment and organizes trainings, information and safety and health courses for the purpose of occupational health and creating safe conditions for employees. In order to establish safety at the process levels, this organization has provided a process safety management model.
The process safety management system within the OSHA Agency, as a national requirement at the level of American states, includes 14 elements (OSHA, 1990), which are: Table 1

Table 1. Elements of process safety management system OSHA.

Row	Title
1	Employee Participation
2	Operating procedures
3	Mechanical Integrity
4	Training
5	Pre-startup Safety Review
6	Incident Investigation
7	Trade Secrets
8	Process Safety Information
9	Process Hazard Analysis
10	Hot work permits
11	Contractors
12	Management of Change
13	Emergency Planning and Response
14	Compliance Audits

This model is not only specific to process industries and can be implemented in many industries such as power plants, steel industries, chemical production and other industries. Also, unlike other PSM models, it is based on federal OSHA regulations and requirements, while other models do not. The primary goal of the OSHA model is to maintain the safety of a workplace's personnel, through changing attitudes and behaviors, creating an organizational safety culture, and training to develop the necessary competencies in people who play a key role in process safety.
A safety program has been verified to be a preventive measure that can lead to stepped forward safety overall performance. Apart from that, this program can also provide a safe environment for employees and thus can help managers to prevent accidents. Since a safety program is interrelated with different dimensions of an organization, it is very important that Involve related safety programs. In addition, an organization can develop a safety culture by having a safety program because it requires mutual cooperation between managers and workers (Siti Milhan. et al., 2016).
After the formulation and notification of PSM regulations, mechanisms were established to evaluate the status of the process safety management system at the level of the United States of America. Oil and gas refineries were the priority industries in which the discussion of assessing the status of the process safety management system arose in them, and in this regard, there was an instruction from the OSHA organization in which the mechanism of planning and implementation of inspections and safety assessments of the processes of oil refineries, standards and criteria such as The qualifications of engineers and industrial health and safety officers were explained.
In the appendix of this instruction, the safety management evaluation checklists of the oil refineries process were presented, the use of this appendix is mandatory for the compliance safety and health officers (CSHO). The work of these officers was gap analysis, which was done based on a series of questions. The questions were designed to evaluate and confirm process safety management in specific topics such as design, construction, installation, pre-commissioning, operation, changes, executive and engineering controls, work methods, contractor safety and other methods for refineries.

[1] Occupational Safety and Health Administration (OSHA)

2.1.2 API[1] process safety management model

The National Petroleum Association of America is the most prestigious center for the oil and gas industry in the USA, with more than 400 companies from very large oil corporations to the downstream sectors of the oil industry as members. These industries include oil equipment manufacturers, refineries, oil transporters by land and sea, oil storage companies.
The main purpose of forming this association was to help and cooperate with the American government and Congress in all national issues related to oil and gas, to strengthen American oil products for use inside the country or for export, and to promote attention to oil and gas industries in all fields. This association has various codes and standards in the fields and disciplines in the oil industry, such as mechanics, chemistry, electricity, precision instruments, safety and HSE, control, civil, materials and metallurgy, which is the basis of a large number of codes and standards of the National Iranian Oil Company. It is derived from these codes and standards.
In the segment on safety standards and process engineering, there are Critical standards regarding PSM. Based on this widespread numbered API-RP-750, the process safety management model of this association, which is titled process risk management, consists of 11 elements as follows Table 2: (API, 1990)

Table 2. Elements of process safety management system API.

Row	Title
1	Process safety information
2	Process hazards analysis
3	Management of change
4	Operating procedures
5	Safe work Practices
6	Training
7	Assurance of the quality and mechanical integrity of critical equipment
8	Pre-startup safety review
9	Emergency response and control
10	Investigation of process-related incidents
11	Audit of Process hazards management systems

The main approach in this standard is to prevent the unwanted release of toxic substances in processes. The scope of application of this standard and recommended code to all upstream and downstream petroleum industries in the United States of America that produce, refine, or store the following materials in their process is stated as follows:
• Flammable or explosive materials whose surprising and catastrophic release may create more than 5 tons of gases or vapors within a few minutes and primarily based on common failure scenarios.
• Toxic substances that have a Substance Hazard Index (SHI) greater than 5000 and are present in amounts above the threshold value at the process level.

2.1.3 Process Safety Management Model of the American Center for Chemical Process Safety - CCPS

After the publication of the PSM model and guidelines of the American commercial Safety and Health Organization and the private sector "American Center for Chemical Process Safety (CCPS)", based on the experience of implementing this system in various industries in different states of the United States, a more complete model was created under his own name and with centrality and basic attention to the category of risk, published as risk-based process safety management (RBPSM).
The attitude of CCPS participants in this model is that all hazards and risks in different chemical processes and facilities are not the same, therefore the financial and cost resources of organizations should be directed to the larger and more important hazards and risks.
In this model, there is a very important element of process safety culture independently, which suggests the importance that this intellectual system attaches to the safety culture in the company. Additionally, CCPS believes that the tips and experiences gained from accidents are very valuable, and using preventive and corrective measures due to the root cause of accidents can prevent the repetition of similar accidents and many other factors that cause other accidents.
Competence and ability of all relevant staff is important to the powerful implementation of PSM. It is important that all employees, including contractors, truly and completely recognize their roles and responsibilities in the PSM system, prevention and management of integrity risks and hazards. Adequate resources are essential to effectively implement PSM requirements. Management has taken all measures to ensure that the resources in the

[1] American Petroleum Institute (API)

asset/team are sufficient, qualified and have the necessary level of competence to deliver the PSM requirements (Mastan Shaikh, 2015).
The model provided by the American Governmental Industrial Occupational Health Conference (AIchE/CCPS), includes the following 20 elements Table 3: (CCPS, 2007)

Table 3. Elements of process safety management system CCPS.

Row	Title
1	Process safety culture
2	Compliance with standards
3	Process safety Competency
4	Workforce Involvement
5	Stakeholder Engagement
6	Process Safety Information
7	Hazard Identification & Risk Analysis
8	Operating Procedures
9	Safe Work Practices
10	Asset Integrity & Reliability
11	Contractor Management
12	Training
13	Management of change
14	Operational Readiness
15	Conduct of operations
16	Emergency Management
17	Incident Investigation
18	Measurement & Metrics
19	Auditing
20	Manage Review & Continuous Improve

In general, the model provided by CCPS is much richer in terms of content than other models provided by PSM, because the experiences of years of research in industrial accidents at the level of the United States of America and other countries, together with the expert safety committee in the American chemical industry, as the support of its model. Due to its specific elements, this model is much more practical in the oil, gas and petrochemical industries than the implementation in other process industries (Silaipillayarputhur and Karthik, 2018).
Process safety management system audit added in two API and CCPS models; it contributes to the goals and priorities by considering the following:

- Operational requirements
- The goals of the organization
- Risk tolerance
- Risk management requirements
- Legal requirements
- And other considerations

A detailed design of the process safety management system audit program with an effective strategy in improving the system performance will help a lot to ensure the effectiveness of PSM (David. et al., 2014).
According to the models mentioned in the research, (Chizaram et al., 2020) compared different PSM models, the results of which are collected in the following Table 4:

Table 4. Summary of PSM Models.

Title	CCPS	OSHA	API
Risk Identification	Process Safety Information	Process Safety Information	Process safety information
	Hazard Identification & Risk Analysis	Process Hazard Analysis	Investigation of process-related incidents
Risk Management	Contractor Management	Contractors	-
	Operating Procedures	Operating procedures	Operating procedures
	Management of change	Management of Change	Management of change
	Training	Training	Training
	Emergency Management	Emergency Planning and Response	Emergency response and control
	Conduct of operations	Pre-startup Safety Review	Pre-startup safety review

	Asset Integrity & Reliability	Mechanical Integrity	Assurance of the quality and mechanical integrity of critical equipment
	Safe Work Practices	Hot work permits	Safe work Practices
	Operational Readiness	-	-
Commitment of management and employees to process safety	Process safety culture	Employee Participation	-
	Compliance with standards		
	Process safety Competency		
	Stakeholder Engagement		
	Workforce Involvement		
Learn of events	Incident Investigation	Incident Investigation	Process hazards analysis
	Measurement & Metrics	Compliance Audits	Audit of Process hazards management systems
	Auditing	Trade Secrets	-
	Manage Review & Continuous Improve	-	-

In this study, by comparing 21 process safety management (PSM) models in various industries, they reached an integrated model called (IPSM), which is currently the latest process safety management model Table 5 (Theophilus et al., 2018, Chizaram et al., 2020).

Table 5. 21 Process Safety Management Models

Model	Year of design	Theory Behind Model Design	Industry for the Model	Deficiency of Model	References
Responsible Care Process Safety Code (RCPSC)	1984	It was designed to prevent the unintended release of hazardous substances by using technical improvements	Petrochemical	• It does not consider several human factors • There is no road-map for implementation of the elements within its framework	(Howard. et al., 2000)
CIMAH regulations	1984	It was designed to curb the consequences of major accidents on people and the environment	All industrial sectors except nuclear and armed-forces installations	• No safety reports • Changes to safety management systems not addressed • Emergency planning issues	(Cassidy, 2013)
API RP 750	1990	It was designed as the first framework for managing process hazards in the oil and gas industry	Oil and Gas Petrochemical Refining	• It did not set out indicators for measuring process safety performance • Human factors are not well addressed	(COMAH, 2000)
US OSHA PSM Program	1992	It was designed to mitigate the accidental release of hazardous chemicals	Manufacturing Chemical Transport	• It has remained unchanged and has few human factor elements in its framework	(API, 2017)
Safety Case	1992	It requires companies in offshore installations to produce a safety document to show that there is an efficient safety management system in place	Offshore	• It focuses only on paper safety and not real safety in practice. • They are compliance-driven • They reduce the level to which risks are being considered within organizations as they feel they already have a safety case	(Beale, 2000)
ExxonMobil OIMS	1992	It was designed to improve personnel, health, security and process safety performance	Petroleum	• It is quite complex to be understood by people that are not part of the company	(Belke, 2001)

				• It does not certify employee compliance to standards.	
ILO PSM Framework	1993	It was designed to prevent major industrial accidents in the hazardous industries	All major hazard installations except nuclear, military and transport other than pipeline	• It does not incorporate key human factors like safety culture into its framework • It does not focus on performance measurement and management review	(HSE Offshore: Safety Cases, 2017)
API RP 75	1993	It was developed as a safety and environmental program for offshore operations and facilities	Oil and gas	• It does not incorporate human factors fully into its framework	(ExxonMobil, 2017)
EPA RMP	1994	It was designed to monitor companies involved in the use of regulated toxic or flammable substances for prevention of accident release	Chemical Petroleum	• Human factors aren't adequately addressed • No certified method of implementation	(CAPP, 2014)
COMAH regulations	1999	It allows competent authorities to assess the safety of designated sites using safety reports.	All hazardous industries	• Cost of compliance • Public information may affect commercial confidentiality and site security • Consent for hazardous substances • Different attitudes to implementing the Seveso II Directive across Europe	(Safety Management Systems for Major Hazard Facilities, 2011)
AIChE/CCPS Risk Based Process Safety (RBPS) Model	2007	It was designed after the Bhopal tragedy in 1984 to offer improved results with less funds and as a benchmark for the industry	Chemical Process Industries	• It does not address all human factors. • There is no road-map for implementation of the elements within its framework	(Ufner and Igleheart, 2017)
BP OMS	2007	It was designed after the Deepwater Horizon blowout to ensure compliance of BP's industry standards with legislative requirements	Oil and gas	• It does not incorporate all safety management system elements in it framework	(Schneider R. J. et al. 2004)
SEMS Regulation	2010	It was enacted to make mandatory the API RP 75 rule in order to enhance environmental protection and safety of offshore oil and gas activities	Offshore oil and gas	• It does not fully incorporate all human factors into its framework	(API, 2004)
Energy Institute High-Level PSM Framework	2010	It was designed to provide a basic and organized approach for small and large organizations across all energy sectors	Energy industry	• Human factors are not fully integrated into the framework • There is no adequate route map for implementation	(Yew. et al., 2014)
DuPont Operational Risk Management (ORM) Model	2010	It was initially designed to ensure safety of their facilities, but later was used as benchmark for other companies within and across various industries	Conglomerate comprising of various industrial sectors	• Its basic wheel-like structure shows no line of action or implementation of elements within its framework	(Fernández-Muñiz, Montes-Peón, and Vázquez-Ordás, 2007)
CSChE PSM Guide	2012	It was created as a more	Chemical	• It does not consider	(Amyotte,

4th edition		efficient framework for the prevention of accidents in the Canadian chemical industries		involvement of the workforce and stakeholders • It does not also take into account the manner in which operations are conducted.	2011)
IOGP/IPIECA OMS Framework	2014	It was designed to improve the development and application of health, safety and environmental management systems.	Oil and Gas	• It does not fully address human factors within its framework • It totally relies on human compliance and does not provide enforcement actions	(IOGP, 2014)
Process Safety Information Management System (PSI4MS)	2014	It was designed as an OSHA PSM compliance system for managing process chemicals, technology and equipment information in pilot plant.	Chemical	• The PSM system focuses solely on process safety information which is one of many elements in a PSM system	(Aziz. et al., 2014)
Contractor Management System (CoMS)	2015	It was designed to provide a structured and easy technique to plan and implement a practical and comprehensive contractors' management system	All hazardous industries	• The PSM system focuses solely on contractor management which is one of many elements in a PSM system	(Abdul Majid, Mohd Shariff, and Rusli, 2015)
Emergency Planning and Response (EPR) model	2016	It was designed to provide a structured and easy technique for organizations to plan and implement emergency planning and response based on PSM requirements	All hazardous industries	• This PSM model is solely based on emergency planning and response, which is one of many elements in a PSM system	(Abdul Majid, Mohd Shariff and Mohamed Loqman S, 2016)
IPSMS model	2017	It was designed as a robust and holistic alternative to the previous PSM models by integrating their elements into one PSM system and including the human factors missing from them	Oil and Gas	• This model was only validated using literature, without any input from industry professionals • It failed to consider factors such as impact of climate change on oil and gas operations in its design	(Theophilus. et al., 2018)

3. Critical success factors

Consistent with the definition of success by Oxford dictionaries, achievement means the completion of a goal. In fact, the success of the project means meeting everything that was expected and anticipating all the needs of the project and having enough resources on time.

CSFs is a management term for an element that is essential to the achievement of an organization or project. The definition of success factors by Rokart was published in 1979 and stated that the CSFs are really necessary for a manager to achieve his goals.

ISO 45001 occupational health and safety management system (ISO 45001) is a new worldwide standard that gives a framework for the organization to prevent and manage risks that damage employees; In this regard, it gives a safe and healthy workplace for people. ISO 45001 is intended to help organizations, irrespective of industry size, design proactive systems, and all of its requirements are designed to integrate into an organization and prevent accidents and injuries.

CSFs in the implementation of occupational safety management in this field have been carried out in some countries, including several neighboring countries and Middle Eastern countries. It was first written in a journal in Thailand in 2008, then the same case was investigated in Malaysia and Cambodia, as well as in Saudi Arabia, Iran, Pakistan, Hong Kong, China and the United States. Based on CSFs from several countries, 13 CSF elements have been examined that have a major impact on the successful implementation of safety management. The 13 elements of CSF are given in the picture below Table 6.

Table 6. KSF Elements (13 Elements) Implementation of Work Safety Program (Anwar Ali and et al., 2019)

Key Success Factors	Worker Participation	Worker Motivation
		Safety Meeting
	Preventive &Control System Safety	Effective Reinforcement of Regulation
		Eligible Supervision
		Safety Equipment &Maintenance
		Safety Training
		Personnel Competence
		Program Evaluation
	Safety Regulation	Delegation, Authority, & Responsibility
		Sufficient Resources Allocation
	Management Commitment	Management Supporting
		Team Work
		Clear &Realistic Target

The main focus of this study is to search for influential factors in the successful implementation of safety management. It also shows which factors are the most important in the success of safety management in this field. By studying magazines and standards and complying with the existing conditions and after determining the variables and sampling in this field from contractors or using the results of accurate sampling conducted by occupational safety experts in this field, the analysis of the AHP mathematical method, to analyze and Ranking analysis and priority level were used. Then the inconsistencies were analyzed. These results are done with the final ranking with dominant role with analysis as the key ranking. Finally, the verification phase is carried out to check whether the ranking of the final result is related to the implementation of the project or not (Guimaraes and Lapa, 2001).

4. Choosing the fuzzy membership function to complete the questionnaire and fuzzy calculations

For all Factors, five linguistic variables including (Very high, High, Moderate, low, Very low) have been used; in which 5 language variables are assigned according to the following Table 7 according to rank (Anwar Ali and Albert Eddy Husin, 2019).

Table 7. Fuzzy values of linguistic variables

Rank	Verbal Variable	Fuzzy Number
9	VH	(0.9,1,1)
7	H	(0.7,0.85,1)
5	M	(0.4,0.6,0.8)
3	L	(0.2,0.35,0.5)
1	VL	(0,0.15,0.3)

The set of values related to the set of values related to the linguistic variable = {VH, H, M, L, VL} = T(x)
Set change scope Range = [0,1] = U

Performing calculations with fuzzy numbers is very complicated due to their special structure, special fuzzy numbers are used in calculations to facilitate and apply them. These special numbers are bell, triangular, trapezoidal, trapezoidal L-R, triangular L-R.
* Triangular fuzzy numbers are used in this article.

4.1 Prioritizing Factors

AHP became proposed by Saati in 1980 and has been significantly expanded in all areas related to decision-making in the last 20 years (Ho. W, 2008). AHP is an effective tool for analyzing complex decision problems. This method organizes the decision-making problem with a hierarchical structure at several levels. The hierarchical structure of AHP includes of the goal function (first level), criteria and sub-criteria, and decision options (last level) (Jablonsky, 2007) (Zandin, 2001). In the AHP method, the multiple criteria of the trouble are converted into the components of each option in hierarchical levels. After that, the clusters are located at the same levels through pairwise comparisons and based on information, knowledge and experience that can be investigated (Ho. W, 2008). The developmental analysis method consists of the following steps (Singh, 2016):
1- Breaking and building the problem hierarchy
2- Performing fuzzy comparisons for each of the decision criteria
3- Calculating the relative weight of each element in relation to every criterion
4- Combining the relative weights of each option and calculating the final weight
Each of the criteria of the decision matrix consists of pairwise comparisons. Pairwise comparisons are based on triangular fuzzy numbers, where the value of each element is obtained from each triangular fuzzy number from the range of 0.1111 to 9. The following relations are defined for two triangular fuzzy numbers.

$$M_1 + M_2 = (L_1 + L_2, m_1 + m_2, U_1 + U_2) \tag{1}$$

$$M_1 \times M_2 = (L_1 \times L_2, m_1 \times m_2, U_1 \times U_2) \tag{2}$$

$$M_1^{-1} = (\frac{1}{U_1}, \frac{1}{m_1}, \frac{1}{L_1}) \tag{3}$$

$$\begin{cases} V(M_1 \geq M_2) = 1, if\,(m_1 \geq m_2) \\ V(M_1 \geq M_2) = \dfrac{u_1 - l_2}{(u_1 - L_2) + (m_2 - m_1)}, if\,(m_1 < m_2) \end{cases} \tag{4}$$

$$C(V_1 \geq V_2, ..., V_k) = Min\big(C(V_1 \geq V_2), ..., C(V_1 \geq V_k)\big) \tag{5}$$

In the fuzzy hierarchy analysis process, for each row of the matrix of pairwise comparisons, the SK value, which is a triangular fuzzy number, is calculated as follows.

$$S_k = \sum_{j=1}^{n} M_{kj} \times \left[\sum_{i=1}^{m} \sum_{j=1}^{n} m_{ij} \right]^{-1} \tag{6}$$

In relation (6), K represents the row number i and j represent the rows and columns, respectively in this method, after calculating each SK, their magnitude relative to each other is obtained from relations (4 and 5), and finally, the weight of each element in the decision matrix is obtained from relation (7).

$$w'(x_i) = Min\{\ V(S_1 \geq S_k)\ \}, K = 1,2,...,n, K \neq i \tag{7}$$

The vector resulting from the weights of the criteria shown in equation (8) and it should be normalized.

$$w' = [w'(x_1), w'(x_2), ..., w'(x_n)]^T \tag{8}$$

The weight of each choice in a hierarchical path is received by multiplying the weights of that option with respect to the elements of that path. Finally, the total weight of each option in each path determines its abnormal final weight. The final weight of each option will be obtained by normalizing the non-normalized final weight vector. Finally, if needed, the values obtained from the matrix of pairwise comparisons can be made non-fuzzy by using the scoring method to the left and right of the fuzzy number in order to convert the fuzzy numbers (Zimmermann, 1996).

4.2 Prioritizing the CSFs in the establishment of process safety management

According to Table 8 and thinking about the CSFs in process management programs, we will arrive at the priorities regarding these Factors. The priority of these Factors is given in Table 7. In the implementation stage, the management plan and prioritization for CSFs are very important, although the establishment of CSFs in process industries will reduce catastrophic events; however, by applying priorities, a better result of their deployment can be seen.

Table 8. Result of prioritization

Row	Title
1	Management Supporting
2	Worker Motivation
3	Team Work
4	Clear & Realistic Target
5	Sufficient Resources Allocation
6	Personnel Competence
7	Delegation, Authority and Responsibility
8	Safety Meeting
9	Safety Training
10	Effective Reinforcement of Regulation
11	Safety Equipment & Maintenance
12	Eligible Supervision
13	Program Evaluation

5. Conclusion

The main goal of this research is to establish safety management models, after presenting the main concepts of PSM models and models in this field, it is necessary to identify and apply CSFs in establishing PSM. Therefore, by reviewing the literature, 21 cases of process safety management models were examined. Then, by examining the fuzzy logic approach, thirteen CSFs were identified according to Table 7 in establishing safety programs. These factors were prioritized with the approach of establishing process safety management. The weight of these factors was calculated by the fuzzy hierarchical analysis method, and three factors have the most importance. These three factors include management support, employee motivation and teamwork. Focusing on these factors, other factors will be effective in establishing process safety management in the next Priorities.

Contribution of Researchers
Mazdak Khodadadi-Krimvand presented the idea and managed the research steps. Zahra Sojoudi and Hamidreza Zakeri reviewed the literature and summarized the results.

Conflicts of Interest
The authors declared that there is no conflict of interest.

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