Identifying hazards and presenting HSE risk management program using Bow-Tie and SOWT-ANP methods at the urea unit of Shiraz petrochemical complex

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Abstract

Introduction: Hazard Identification, risk assessment and management have an important role in reducing potential risks in industrial settings. This research was done with the aim of identifying the hazard and evaluating HSE risks and providing a HSE management program for the Urea Unit of Shiraz Petrochemical Complex.

Method: Firstly, hazard identification and qualitative risk assessment was done using FMEA technique and risky units were identified. Then, main events were identified and analysed as inputs of the Bow-Tie method. By identifying the strength, weakness, opportunity and threat factors, ranking and weighting them using the ANP method and Super Decisions software, a SWOT matrix was prepared and HSE management strategies were extracted.

Findings: The results showed that chemical leakage, falling from height and slipping were the most important incidents, and defect of control equipment, lack of attention to instructions, non-compliance with safety principles and human error were causes of these events. Also, ranking of weaknesses, strengths, opportunities and threats were 0.58, 0.2, 0.16 and 0.05, respectively.

Conclusion: Organizational opportunities with a weight of 0.124 were 4.8% higher than threats with a weight of 0.076. This shows that the company had a good situation in terms of achieving its goals.

Keywords: Risk Assessment, Bow-Tie Analysis, SWOT-ANP, Urea Unit of Shiraz Petrochemical

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1. Introduction

To have a life devoid of dangers has been the wish and purpose of all people of all ages [1]. According to data from the U S National Safety Council, there are about 2,200 deaths and 22,000 disabling injuries due to occupational accidents each year with a considerable direct and indirect costs [2].There are various methods for accident investigation and risk assessment, including OACA, OATA, William Fine, JSA, FMEA, and Bow-Tie. The Bow-Tie method is one of the most useful approaches in the field of risk management. The Bow-Tie risk assessment method, does a cause and consequence analysis of accidents to prevent, control, and reduce adverse events [3-5].

2. Materials and Methods

The purpose of this study was to evaluate HSE risks using the Bow-Tie method and to present HSE management program using the SWOT-ANP hybrid model in Urea Unit of Shiraz Petrochemical Complex. The process of this study consisted of two phases as follows.

Phase I: Implementation of the Bow-Tie Method

Step 1. Complete definition of the under study unit including: geographical location, process maps and operating and maintenance procedures of the unit, and physical and chemical properties of the materials in the unit.

Step 2. Risks identification: Investigating individual and process accident reports and HAZOP studies, analysing, ranking, determining and identifying the level of risk using the FMEA method and the Bow-Tie proposed risk matrix

Step 3. Identifying the main event: Considering the range of accident consequences, six hazards were considered as the main event of the implementation of the Bow-Tie method in the high-risk areas.

Step 4. Implementing the Bow-Tie method: Bow-Tie process involves identifying, evaluating, controlling, and retrieving; for each event, identifying factors such as threats, controls, aggravating factors of control failures, consequences, recovery measures, failure of recovery measures and control of failure

of recovery measures were done and specified tasks and responsibilities were determined. Then, all of the mentioned items were entered in the software and the corresponding charts were drawn.

Phase II: Implementation of the Network Analysis Method and presentation of HSE management plan using the SWOT-ANP integrated model

Step 1. Holding meetings with experts, analyzing the outputs of events using the Bow-Tie method, identifying opportunities, threats, strengths and weaknesses of the organization

Step 2. Identifying the SWOT factors and comparing these factors in pairs and determining the priority of the factors.

Step 3. Creating the paired comparison matrix.

Step 4. Ranking the main criteria using Super Decisions software and determining the incompatibility rates of the matrix elements.

Step 5. Creating the initial super-matrix and weighting the super-matrix to determine the final weight of the criteria and to identify the interdependence and intrinsic dependence of the criteria and options.

Step 6. Creating the SWOT matrix based on the results extracted from the Super Decisions software, analysing the network and extracting organizational strategies to implement the HSE objectives.

3. Results and Discussion

Major risks of the studied unit were identified by performing the risk assessment and obtaining the views of the experts presented at the meetings,. Then, considering the range of accidents' consequences occurring in terms of safety, health, environment, finance and credit, the high-risk segments of the unit and major events were identified as inputs of the Bow-Tie method as shown in table 1.

4. Consequences

According to Bow-Tie software, consequences of major events were included explosions, deaths, fractures, injuries and environmental contaminants. According to severity of the effects of these

Table 1. Major hazards and events of the urea unit

No.	Risk type	Repeatability	Names of high risk segments	Main event
1	Chemical leakage	50 items	Ammonia and carbon dioxide compression	Ammonia leakage from equipment and fittings
2	Fires in pumps, electric motors, switchboards	21 items	Synthesis	Ammonia and carbamate leakage
3	Slippery surfaces and falling from a height	10 items	Purification	Molten urea leakage
4	Increased heat and pressure	21 items	Filtration of process condensates	leakage of hot vapors and liquids from the joints
5	Soil and air pollution	17 items	Repair and maintenance	Falling from height
6	Health risks and ergonomics	16 items	Product loading and storage	Slipping and falling from height

consequences, necessary control measures were suggested to reduce the risk level to an acceptable level. The suggested control measures include inspection, maintenance, training, review of operating instructions and executive methods, employing specialist personnel, collecting response plans in emergency conditions, developing the organization's HSE culture, and providing personal protective equipment.

Results of Paired Comparison Matrix

Using the Bow-Tie diagrams output, such as purification segment diagram (Figure 2), identifying strengths, weaknesses, opportunities and threats, interviewing with experts and comparing the SWOT factors in pairs using Likert method, a paired comparison matrix was finnaly constructed, as shown in Table 2. Also, the results of the Super Decisions software showed that the incompatibility rate of the paired comparison matrix elements is 0.0523 which is a good value. Also, the experts' views are quite alike, and as seen in Figure 1, intra-organizational weaknesses with a value of 0.582277 gained a higher rank compared to the strengths, opportunities and threats.

Identifying the rank of sub-criteria

Each of the SWOT sub-criteria was ranked and weighted using the super decision software and the ANP network analysis process. Table 3 shows which sub-criteria are ranked first for S, W, O and T criteria.

The results of the super matrices show that opportunities of the organization are in a

Table 2. Paired Comparison Matrix

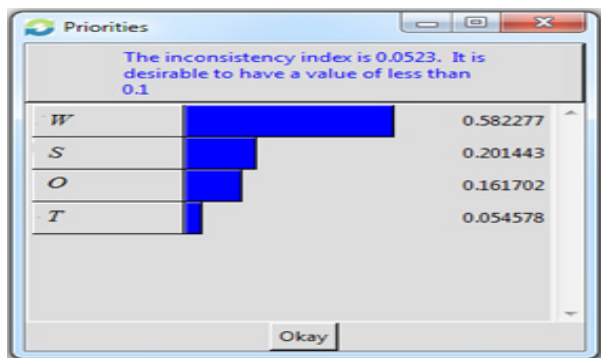|	W	S	O	T
W	1	4.65	3.14	7.03
S	0.22	1	1.51	4.82
O	0.32	0.66	1	3.46
T	0.14	0.21	0.29	1

Fig. 1. Ranking of the main criteria

better position than threats with a weight of 0.124. Weaknesses with a weight of 0.8 need necessary actions to be executed urgently.

A study by Rezaee et al. showed that Bow-Tie method is a powerful method for managing and evaluating risks and analyzing events both quantitatively and qualitatively [6]. In this study, it was found out that by identifying, evaluating and quantifying the risks using Bow-Tie software and performing control measures such as inspection, maintenance, training, etc., the risk criteria can reach an acceptable level. Timoori et al showed risk evaluation of pollution in Isfahan industrial zone [7]. Kamaee et al. also suggest that using the Bow-Tie risk method and modelling can reduce
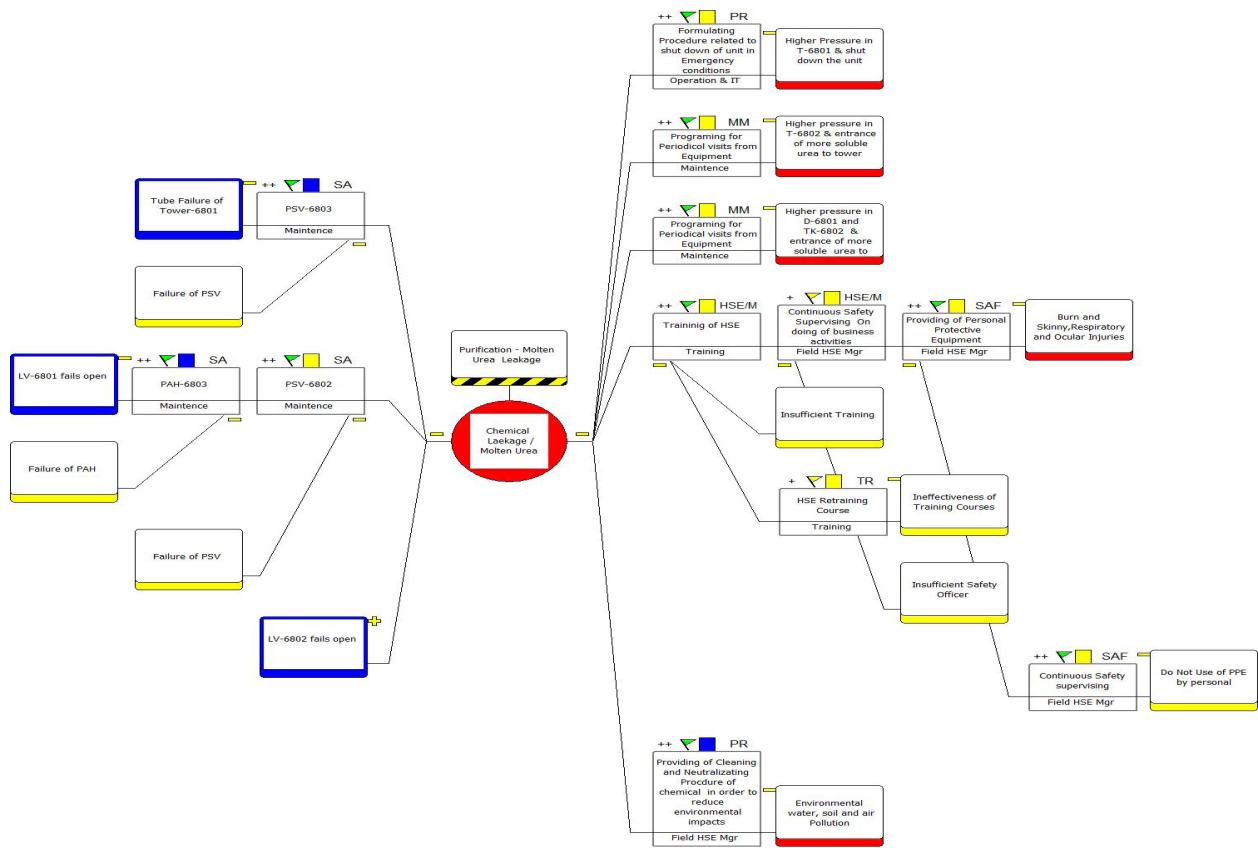
Fig. 2. Bow-Tie Chart of Purification

Table 3. Ranking of the SWOT Criteria and Sub-Criteria

No.	Criterion	Rank	Sub-criterion	Rank
1	weakness	0.58	Weaknesses in the implementation of HSE and other guidelines in organization	0.28
2	strengths	0.20	Establishment of equipment maintenance and repair system	0.48
3	opportunities	0.16	providing a control equipment development and prevention of process accidents	0.40
4	threat	0.05	Lack of awareness of the accuracy of the performance of faulty control systems	0.40

the damage and its effects on human resources to an acceptable level, and by taking measures such as periodically technical inspections of the tanks and formation of response team in an emergency condition [8]. Findings of this research showed that weaknesses of the organization with 0.58 score gain the highest rank while strengths, opportunities and threats follow with scores of 0.2, 0.16 and 0.05 respectively. Accordingly, 21 strategies were developed, among which, using the ST strategy can have an effective role in advancing HSE goals and preventing accidents.

4. Conclusions

It can be said that the Bow-Tie method is one of the most effective graphical methods in which the relationship between all relevant factors to the risk assessment and management process are well investigated and used to evaluate and demonstrate risk control. The results of the network analysis process showed that the organization's opportunities with a final weight of 0.124 are in a better position, and the company is in a good position in terms of achieving its executive goals. Meanwhile, it can execute the control policies timely to neutralize or transfer the organizational risks, and compare to the intra-organizational weaknesses, the organization's weaknesses with a final weight of 0.8 is in the first rank. Therefore, in order to correct and eliminate weaknesses, it

is necessary to consider the managerial policies appropriate for the overall goals in organization.

5. References

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