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Fuzzy Approaches to the Risk Assesment Methods for the Occupational Health and Safety

Murat GULBAY
Technical Sciences Vocational School, Gaziantep University

Abstract: Turkey's "Occupational Health and Safety Law" numbered as 6331 has been published in June 2012. According to the Occupational Health and Safety Law companies are categorized in three sections as Less Risky, Risky, and High Risky Companies. Based on this law, a regulation called "Occupational Health and Safety Regulation" has become operative and all of the companies compassed by this regulation are forced to prepare a risk assessment report in order to provide occupational health and safety, and increase their occupational health and safety levels. In the literature, there are about two hundreds of risk assessment methodologies. Among these methodologies, the mostly used ones are 5 by 5 L-type matrix method, Fine Kinney Method, and Hazard and Operability Analysis (HAZOP) which is proposed for the analysis of the risks in the chemical industry. These methods include strict lines and are not reflecting the practical issues of the real world applications. For this reason, these methods are to be adopted by the use of fuzzy logic. In this study, risk assessment methods used in the risk rating are evaluated and fuzzy approaches are proposed to provide more efficient and realistic results.

Keywords: Occupational health and safety, Fuzzy risk assessment, Fuzzy risk scores, Fuzzy 5x5 matrix method

Introduction

Risks are unavoidable in any activity. Over the years, risk management has gradually become an important part of work health and safety for each organization. To provide for a balanced and nationally consistent framework to secure the health and safety of workers and workplaces by protecting workers and other persons, providing for fair and effective workplace representation, encouraging unions and employer organizations to take a constructive role in promoting improvements in work health and safety practices, ensuring appropriate scrutiny and review of actions, providing a framework for continuous improvement, and maintaining and strengthening the national harmonization of laws relating to work health and safety Turkey's "Occupational Health and Safety Law" numbered as 6331 has been published in June 2012. Based on this law, a regulation called "Occupational Health and Safety Risk Assessment Regulation" has become operative and all of the companies compassed by this regulation are forced to prepare a risk assessment report in order to provide occupational health and safety, and increase their occupational health and safety levels. For this aim, all the companies are categorized in three sections as Less Risky, Risky, and High Risky Companies; and they are gradually forced to prepare a risk assessment report for their companies.

Risk assessment is the overall process of risk identification, risk analysis, and risk evaluation. In the literature, there are about two hundreds of risk assessment methodologies, such as Brainstorming, Delphi technique, Checklists, Preliminary hazard analysis (PHA), HAZard and OPerability study (HAZOP), Toxicity assessment, Structured "What-if" Technique (SWIFT), Scenario analysis (SA), Business impact analysis (BIA), Root cause analysis (RCA), Failure modes and effects analysis (FMEA), Fault tree analysis (FTA), Event tree analysis (ETA), Cause-consequence analysis, Cause-and-effect analysis, Decision tree analysis, Human reliability assessment (HRA), and Consequence/probability matrix methods. These methods include strict lines and are not reflecting the practical issues of the real world applications. For this reason, these methods are to be adopted by the use of fuzzy logic. In this study, 5x5 L-type matrix method is analyzed and a fuzzified 5x5 matrix type risk assessment method is proposed. In the next section, an overview of the 5x5 matrix method, also known as

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L-type matrix method, is presented. Then, a fuzzified 5x5 matrix method is proposed. Finally, a conclusion and future study recommendations are given.

5x5 Matrix Method for the Risk Analysis

It's a two-variable risk matrix whose variables are "consequence" and "likelihood" derived from the formal definition of the term "Risk" given by Turkey's "Occupational Health and Safety Law" numbered as 6331 and "Occupational Health and Safety Regulation". In this type of risk assessment matrix each variable is scored by the numbers between 1 and 5. The physical meaning of each score is given in the Table 1 and 2
.

Table 1. Scores for the variable "Consequence (C)"

Score (C)	Meaning
1	Slight (insignificant) effects
2	Minor effects
3	Moderate effects
4	Major effects
5	Severe effects

Table 2. Scores for the variable "Likelihood (L)"

Score (L)	Meaning
1	Rare
2	Unlikely
3	Possible
4	Likely
5	Almost certain

Risk score, R, for the method is defined as:

$$R = CxL$$

It is clear that R ranges from 1 to 25. The resultant R can be interpreted as shown in Table 3.

Table 3. Overall risk scores for R

L / C	**1**	**2**	**3**	**4**	**5**
1	1	2	3	4	5
2	2	4	6	8	10
3	3	6	9	12	15
4	4	8	12	16	20
5	5	10	15	20	15

Scores between 1 and 6 (green) may be interpreted as "Low Risks" that does not require taking precautions in the short time of period, while scores ranging from 8 to 12 may be identified as "Medium Risks" that require taking precautions in the short time of period. On the other hand, scores between 15 and 25 are called as "High (Critical) Risks" that results in taking precautions, immediately, as soon as possible. Detailed precautions for different levels of the overall risk scores are listed in Table 4.

Table 4. Preventive actions for different score levels of R.

Result (R)	**Necessary Preventive Action**
Cannot be tolerated (R=25)	Any ongoing activity must be immediately stopped. Work should not be started until the risk is reduced.
Important Risks (R=[15-20])	Any ongoing activity must be immediately stopped. After preventive measures are applied, work can be continued.
Moderate Risks (R=[8-12])	Risk mitigation measures should be applied. Work can be carefully continued.
Foldable Risks (R=[2-6])	Since the risk is low, there is no necessity to take preventive actions in the short term of period. However, existing controls should be continued.
Insignificant Risk (R=1)	Existing controls should be continued.

Fuzzified 5x5 Matrix Method for the Risk Analysis

Instead of using strict lines for scoring C and L, we may use fuzzy intervals to identify them. Minimum fuzzy interval for each score becomes [0,1], while its maximum is [4,5]. Namely, each score is identified by fuzzy interval numbers as [0,1], [1,2],[2,3], [3,4],[4,5]. Since the risk score R, is not only affected from two single and subjective measures it should be defined as an interval. The resultant score R can be obtained by using the the property for multiplication of the fuzzy intervals as:

$$[a,b] * [c,d]= [\min (ac, ad, bc, bd), \max (ac, ad, bc, bd)$$

The minimum of R is [0,1] and the maximum is [16,25]. Representation of the C and L are shown in Tables 5 and 6, respectively.

Table 5. Fuzzy scores for the variable "Consequence (C)"

Score (C)	Linguistic Meaning
[0,1]	No work-hour loss. First aid is sufficient.
[1,2]	No work-day loss, no permanent effect. First-aid with outpatient treatment is required.
[2,3]	Results in Simple battery, simple personal injury. Treatment is necessary.
[3,4]	Causes serious personal injury. Long-term treatment is needed.
[4,5]	Causes to death, long-term disability or dismemberment

Table 6. Fuzzy scores for the variable "Likelihood (L)"

Score (L)	Linguistic Meaning
[0,1]	Very small, nearly never
[1,2]	Little, once in a year, in abnormal conditions
[2,3]	Medium, 3-5 times in a year
[3,4]	High, once in a month
[4,5]	Very high, every day to once in a week, in normal conditions

Finally, The resultant fuzzy R can be interpreted as shown in Table 7

Table 7. Overall fuzzy risk scores for R

L C	**[0,1]**	**[1,2]**	**[2,3]**	**[3,4]**	**[4,5]**
[0,1]	[0,1]	[0,2]	[0,3]	[0,4]	[0,5]
[1,2]	[0,2]	[1,4]	[2,6]	[3,8]	[4,10]
[2,3]	[0,3]	[2,6]	[4,9]	[6,12]	[8,15]
[3,4]	[0,4]	[3,8]	[6,12]	[9,16]	[12,20]
[4,5]	[0,5]	[4,10]	[8,15]	[12,20]	[16,25]

Table 8. Preventive actions for different score levels of fuzzy R

Fuzzy Risk Level, R	**Action**
[0,1] to [0,5]	**Insignificant to tolerable**: There is no need to plan further control processes, keep and control the existence of the current precautions/measures
[1,4] to [2,6]	**Medium**: New precautions neceessary to reduce risk level
[3,8] to [6,12]	**Important (serious):** Start taking actions to reduce risk level as soon as possible, stop normal works, allow only risk prevention precations/measures
[8,15] to [16,25]	**Unbearable**: Stop instantly. Act to reduce risk level. Never start any work until risk level is out of this level.

Preventive actions for different score levels of fuzzy R is illustrated in Table 8. If the company's overall health and safety risk level with respect to its sector's average, then when taking precautions the resultant R should be considered as if it belongs to the one level higher. For example, if t he company's overall health and safety risk level is low and R is decided as [6,12] which is categorized as "Important", then it can be seen as "Unbearable" in order to take the trigger effects of the other risks into consideration.

Results and Discussion

When determining risk scores for occupational health and safety, it is very difficult to score the variables and it is subjectively defined. Furthermore, reducing the risk score determination to only two parameters may not be correct and generally result in the loss of information due to the its subjectivity. In order to handle this uncertainty in the parameters, a useful fuzzy 5x5 matrix type risk assessment method is proposed. It is more powerful than the classical 5x5 matrix type risk assessment methods and can be easily linked to the company's overall risk level.

Conclusion

The proposed fuzzified 5x5 matrix risk assessment method can be applied to the most of the companies. Using fuzzified risk levels and their corresponding actions allows better prevention of work injuries and/or occupational health and safety risks. It allows taking proactive actions and more powerful interpretations.

Recommendations

The same approach can be proposed for other risk assessment methods especially to the Fine-Kinney Method. Since it is not only two or three parameters which affect the risk score, the effect of the other parameters should be considered in the risk score determination.

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Author Information

Murat Gulbay
Technical Sciences Vocational School, Gaziantep University, Turkey
Üniversite Bulvarı P.K. 27310 Şehitkamil / Gaziantep, TÜRKİYE
Contact e-mail: *gulbay@gmail.com*