TEHRAN UNIVERSITY OF MEDICAL SCIENCES

IJOH INTERNATIONAL JOURNAL OF OCCUPATIONAL HYGIENE

2008-5435/14/63-1-8

IRANIAN OCCUPATIONAL HEALTH ASSOCIATION IOHA

REVIEW ARTICLE

Application of Cost Justification Index of Safety Control Measures (J) In William Fine's Method in the Iranian Studies: A Systematic Review

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Received February 11, 2020; Revised June 23, 2020; Accepted July 01, 2020

This paper is available on-line at http://ijoh.tums.ac.ir

ABSTRACT

In the current study, we examined how to use William Fine method, as one of the risk assessment methods in the cost justification index for the control measures, in risk assessment studies in Iran. The present study was aimed to provide a better understanding of the benefits and limitations of this method and to develop a platform for improving the cost factor table in this method. A literature review was done using the PRISMA database toolkit. The purpose of the study was to evaluate the risk using William Fine's method, so general keywords including safety, risk assessment, William Fine were searched in Persian databases and their English equivalents in English databases. The results were analyzed qualitatively. A total of 357 related articles were observed however, 30 qualified studies were included in the systematic review process. A majority of previous studies only applied William Fine's method to rank the risk score whereas the cost justification index of control measures only calculated the risk score in a limited number of studies. William Fine's method has a high score in evaluating corrective strategies in economics and engineering, due to utilizing the cost justification index. One of the strengths of William Fine's method is the cost justification index. The cost index table uses relatively outdated numbers which may causes for limited application of justification index in the studies.

KEYWORDS: *Safety, Risk Assessment, William Fine's Method, J Index, Cost Justification*

INTRODUCTION

The growing development of the industry and the creation of new work environments have increased the need for safety improvement and accidents minimization. In order to prevent accidents, we must first examine and process the causes of accidents to prevent the recurrence of similar accidents [1]. Risk identification and risk assessment are the most important tools of an active safety approach [2]. Risk assessment is a general term used to refer to a set of logical methods for estimating and assessing the risk of hazards identified in an environment or system. The risk magnitude, evaluation, importance, and decision making should be taken into account for risk assessment determination [3-4].

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Risk assessment is one of the most important methods of targeted risk control in the industry. In 2014, Pinto et al. noted that risk management is one of the most important tools for determining control strategies that should be considered at different levels and dimensions of a work process [5]. In fact, risk assessment is an organized and systematic way of estimating risk and evaluation to prioritize decisions and to reduce the risk to an acceptable level of the system [6].

Over the past few decades, a variety of methods have been proposed in many studies to assess the safety risk [7]. These methods often assess the risk of identified hazards using two parameters, consequences and probability, and in some cases, using a third parameter, such as detection rate, or exposure [8]. The two-parameter methods including MIL-STD 882 and Rolin Geronsin [9-10] methods, and William Fine, Melborne-3D, and FMEA [11-13] methods are examples of three-parameter methods for risk assessment. These methods are commonly used in conjunction with well-known risk identification methods such as ETBA, HAZOP, What if…? , PHA and others [7]. FMEA is one of the common methods in risk assessment studies that has been widely used in the recent studies in Iran. For example, Geramian et al., Ghasemi et al., Ebrahim Zadiyeh et al., and Hekmatpanah et al. have used this method to assess safety risks in the automotive, gas, steel and oil industries, respectively [14-17]. The MIL-STD-882 method has also been widely used in various studies [9-18-19].

Regardless of whether the risk is assessed qualitatively, quantitatively or semi-quantitatively, in each method, decisions are made about whether the risk is acceptable or unacceptable to the organization and how to deal with risk using an index. If the estimated risk does not fall within the range of acceptable risks for the organization, experts and evaluators should provide methods and measures to reduce the level of risk to an acceptable level. It is expected that the implementation of these measures will provide the expected level of safety in the organization [20-22].

However, one of the challenges to control risk is deciding to choose one or more of the proposed control measures. Many risk assessment methods do not provide a systematic method to decide on the efficiency or cost-effectiveness of control measures and leave the decision to the experts. Thus, the lack of a systematic approach to evaluate the latest and perhaps the most important steps in risk management remains uncertain. Choosing the right action or control measures is a decision-making issue, and the right response is very important in terms of risk management [23-25].

Among the common methods of risk assessment, William Fine's method is one of the few ones that has introduced an index to evaluate control measures. William Fine's method was one of the most well-known and widely used methods of risk assessment, and was introduced in 1971 by William T. Fine, head of the safety department at the Maritime War Laboratory in Maryland, USA [26]. In this method, the risk score (RS) was calculated based on the product of the consequences (C), the exposure (E) and the probability (P) of the risk according to Eq. 1:

Eq. 1: $RS = C \times E \times P$

Using the three basic tables presented in this method, the experts group assigns a score to each of these factors according to the existing conditions. When a risk is identified, the corrective measure should be taken as planned and estimated. Therefore, after determining the risk score, the acceptable costs are calculated according to Eq. 2, in which J is the cost justification index, RS is the risk score, CF is the cost factor, and DC is the degree of correction. The numerical values of DC and CF have been shown in Tables 1 and 2.

Eq. 2: $J = \frac{RS}{DC \times CF}$

Published online: July 30, 2020

Table 1. Cost factor (CF)

Definition of criterion	CF factor
Over $50000	10
$25000-50000	6
$10000-25000	4
$1000-10000	3
$100-1000	2
$25-100	1
Below $25	0.5

Table 2. Degree of correction (DC)

Definition of criterion	DC factor
The risk is completely eliminated (100%)	1
At least 75% of the risk is eliminated	2
75 to 50 percent of the risk is eliminated	3
50 to 25 percent of the risk is eliminated	4
Less than 25% of the risk is eliminated	6

Published online: July 30, 2020

The cost factor is the estimated cost of the proposed corrective measure. The degree of correction is the degree of corrective action (measure) proposed to eliminate or reduce the risk or to prevent the occurrence of the risk. Estimates were based on experience and knowledge related to the relevant activity. The classification of the correction table varies from low impact on risk (less than 25%) to complete elimination (100%). William Fine's method suggests that if J is greater than or equal to 10, costs of control or elimination of the risk are acceptable, and if J is less than 10, these costs are not acceptable [26].

Since, the majority of risk assessment procedures do not provide a process for assessing economic justification. The risk correction cost justification is one of the strengths of William Fine's method. Given that, this method can provide advantages for users compared to other methods. However, some preliminary observations show that this technique in previous studies has not always been complete and the J index has not been used by researchers in some cases. Moreover, a review on resources and previous studies showed that the cost coefficient table in this method has not been updated. Therefore, in this study, we examined those studies which applied this method in risk assessment in Iran between 2000-2020 years. The aim of this study was to provide a better understanding of the advantages and limitations of this method and to provide a platform for improving the cost factor table in this method.

MATERIALS AND METHODS

Search strategy:

This study was based on the reporting system of systematic reviews and meta-analyses (PRISMA).

In order to access the relevant texts, a comprehensive search was carried out considering national and international databases including Magiran, Iranmedex, CIVILICA, SID, Google scholar, Science Direct, Web of Science, Springer, Scopus, and the New Information System of Iranian Medical Research. Dissertations that used William Fine's method were searched on Irandoc's website, but were ignored because the article could not be cited. A review of all articles related to the topic was also performed. The purpose of the study was to evaluate the risk using William Fine's method. For this purpose, general keywords including safety, risk assessment, and William Fine were searched in Persian databases and their English equivalents, such as safety, risk assessment, William Fine, Iran and all of its possible combinations in English databases. It should be noted that articles reviewed had the identified keywords in their title or abstract.

Inclusion and exclusion criteria:

In this study, the inclusion criterion of the study was to conduct risk assessment using William Fine's method in Iranian industries studies. In fact, William Fine's method was used as the main approach for conducting risk assessment in this research. The exclusion criteria included studies conducted outside Iran.

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Selection of studies:

In the initial searching, 357 possible related articles on risk assessment were found using William Fine's method (after duplicates removed). The full text of 85 articles was reviewed, of which 55 articles were deleted for the following reasons: studies conducted outside Iran, poor quality and lack of sufficient information. Finally, 30 eligible studies entered the systematic review process (Fig. 1).

Data extraction:

All final papers included in the study process were prepared for extraction by a pre-determined checklist. The checklist was included the title of the article, year of publication, names of the authors, methodology, industry studied, and the use/non-use of the J index.

Data analysis:

After reviewing articles, they were classified in terms of risk assessment based on various criteria such as the use or non-use of the J index, the cost control measures checking method and the purpose of using William Fine method. Due to differences in measurement criteria in different studies, quantitative analysis of the data by meta-analysis was not possible and the obtained data were qualitatively synthesized and statistical tests were not used.

Published online: July 30, 2020

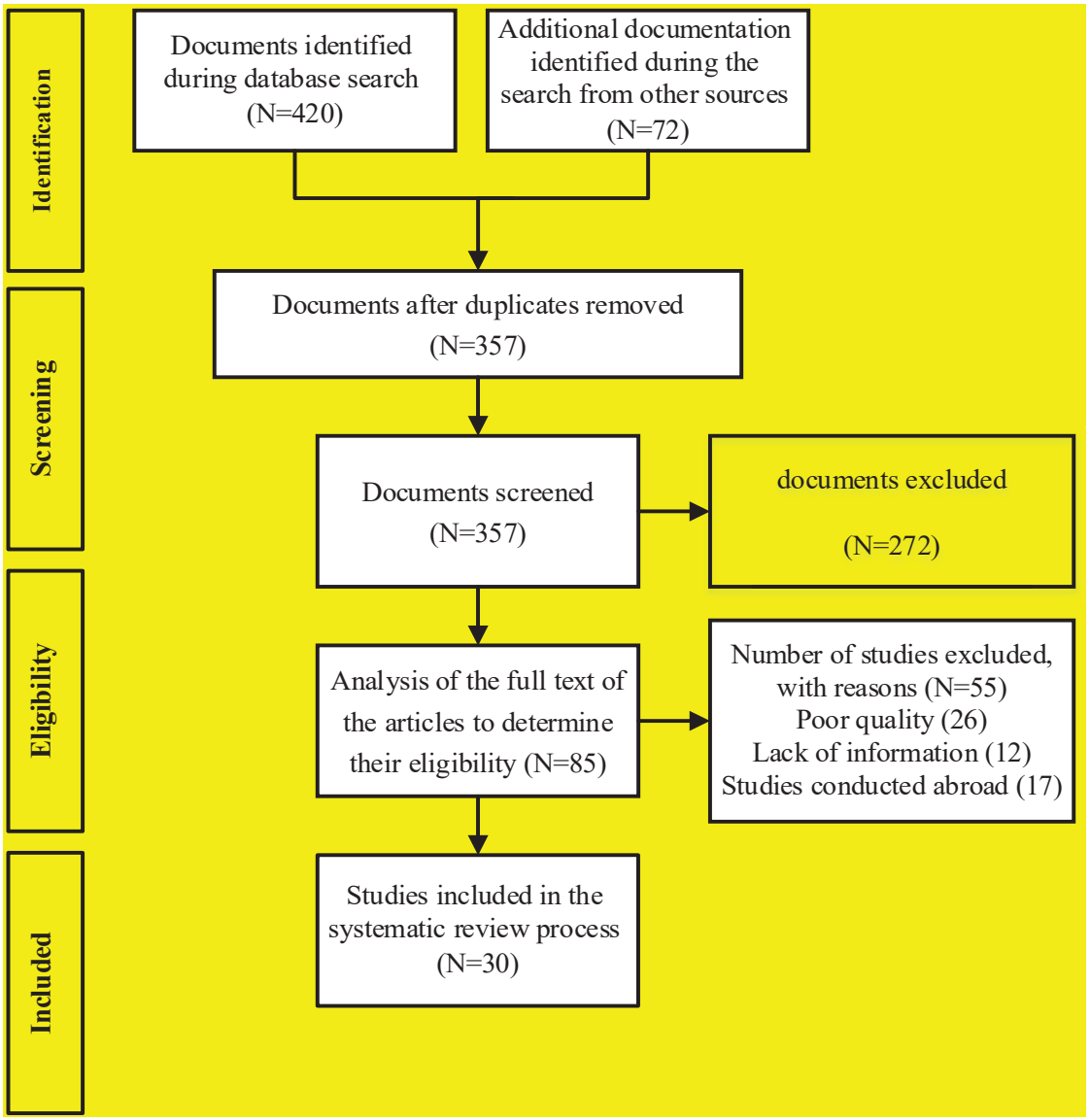

Fig1. Studies structure selecting process diagram based on the PRISMA model

Published online: July 30, 2020

Table 3. Systematic review of included articles studies to investigate the use of William Fine risk assessment method in Iranian industry

Reference number	Title	Author's Name	Methodology	Industry under study	Calculation/ non-calculation of J index
27	Assessing the Safety and Health Risk of Acid Reduction Unit of Abadan Oil Refining Company by William Fine method	Hafezi et al.	1. Identification of risks 2. Prioritization of risk and risk level by William Fine method 3. Calculating the J index	Oil Refinery	Calculation of J index
28	Evaluation and prioritization of the effect of environmental pollution in demographic centers (Case study: Isfahan metropolis)	Saghaei et al.	1. Identifying and evaluating environmental risks using AHP and William Fine methods 2. Prioritizing environmental crises affecting the environment of Isfahan	Demographic centers	Non-calculation of J index
29	Assessing the risks of firefighting in Region 2 of Alborz Station 106 by William Fine method	Qujalu et al.	1. Identification of risks by JHA method 2. Risk assessment by William Fine method3. Prioritization of identified risks	Fire station	Non-calculation of J index
30	Identification, evaluation, and prioritization of existing or potential hazards in the automotive industry by combining three methods: William Fine, FMEA, and AHP.	Ba-Esmat et al.	1. Identifying and evaluating risks with FMEA, AHP and William Fine methods 2. Prioritization of risks based on risk score	Auto making	Non-calculation of J index
31	Identification and evaluation of the important aspects of the environment related to the effluent of Yazd Solar Thermal Power Plant	Mousavi et al.	1. Identification of environmental risks 2. Prioritization and classification of risks by William Fine method 3. Providing control strategies	Thermal power plant	Non-calculation of J index
32	Risk assessment in Ilam gas refinery using William Fine method	Kakai et al.	1. Selecting 9 refinery units at random 2. Risk Identification and Assessment 3. Providing Control Strategies for Emergency and non-natural Risks	Gas refinery	Non-calculation of J index
33	Safety risk assessment in the automotive industry using the combined method of William Fine and ANP-DEMATEL	Nawai Aznaveh et al.	1. Risk assessment by William Fine's method 2. Determining the weight of the importance of each of the risk parameters using the ANP-DEMATEL method 3. Combining the results with the William Fine method 4. Risk reassessment with the same industry pattern	Auto making	Non-calculation of J index
34	Identification of the environmental risks of the hot rolling industry equipments of Kavir Steel company by What if? and William Fine's methods	Ahrampush et al.	1. Identification of environmental risks using the What if? Method. 2. Risk assessment by William Fine method 3. Classification of the risk score according to Pareto's law at three levels 4. Corrective measures for unacceptable risks	Hot steel rolling	Non-calculation of J index
35	Application of William Fine and PHA methods in environmental risk management and estimation of control costs in Kavir Steel Company	Ahrampush et al.	1. Classification of environmental risks in the Preliminary Hazard List (PHL) and Risk Identification 2. Risk Assessment by William Fine method 3. Ranking the risk score according to Pareto's law at three levels 4. Calculating the J index and providing corrective measures for unacceptable risks	Steel	Calculation of J index (cost tables and risk correction are not expressed according to what is mentioned in William Fine's method)
36	Environmental risk management of Mad Kansar iron ore mine, Khorrambid County, using integrated methods of EFMEA and William Fine	Jozi et al.	1. Risk identification 2. Risk assessment by EFMEA and William Fine methods, and 3. Providing control measures and performing secondary risk assessment 4. Providing environmental risk management programs	Iron Ore Mine	Explaining the J index in the Methodology but no calculations

Published online: July 30, 2020

37	Investigating the risk and the impact of non-flammable solvent replacement on risk assessment code using William Fine's method at plastic manufacturing plant	Gholami et al.	1. Factory job classification using JSA method 2. Risk identification 3. Risk assessment by William Fine method 4. Calculation of J. index.	Plastic making	Calculation of J index
38	Application of William Fine occupational risk analysis and risk assessment techniques in Identifying and evaluating occupational risks in steel hot rolling industry at Kavir Co.	Halvani et al.	1. Risk identification by job risk analysis method 2. Risk assessment by William Fine method 3. Ranking of risk score according to Pareto Law at three levels: Acceptable, Medium and Unacceptable 4. Providing corrective measures for unacceptable risks	Hot steel rolling	Non-calculation of J index
39	Risk assessment using William Fine's method in a tile factory in Kermanshah	Sohrabi et al.	1. Risk identification 2. Determining the priority of risk and risk level using William Fine method	Tile factory	Explaining the J index in the Methodology but no calculations
40	Assessing occupational safety and health risks in a metal industry company using occupational safety analysis and William Fine methods	Suri Laki et al.	1. Risk identification and assessment using JSA and William Fine methods 3. Provide corrective measures for unacceptable risks	Metal Industry	Non-calculation of J index
41	Evaluation and management of safety, health and environmental risk areas in coastal drilling rigs of the Iranian National Drilling Company using William Fine's method	Pir Saheb et al.	1. Risk identification 2. Determining risk priority and level by William Fine's method	Coastal drilling	Non-calculation of J index
42	Risk analysis of of noise pollution in Larestan Cement Factory using William Fine method	Sakhavati et al.	1. Investigation of factory processes and preparing acoustic maps 2. Risk assessment at any acoustic zone using the William Fine method. 3. Classification of zone to determine the level of risk	Cement factory	Non-calculation of J index
43	Evaluation of the environmental risk of Behshahr compost plant by William Fine method	Rostamkolaei et al.	1. Identification of environmental risks 2. Risk prioritization and classification by William Fine method 3. Providing control measures	Compost factory	Non-calculation of J index
44	Application of Job Safety Analysis (JSA) Techniques and William Fine's Method in identifying and controlling risks in one of the Uranium Mines in Central Iran	Ebrahimzadeh et al.	1. Risk identification 2. Risk prioritization and classification by William Fine method 3. Providing control measures	Uranium mines	Non-calculation of J index
45	Assessing the safety, health and environmental risks of Kermanshah Motor Oil Purification Plant, Mahestan, by using William Fine method and job safety analysis	Jozi et al.	1. Risk classification at three levels: high, normal, and abnormal. 2. Providing control strategies and corrective measures.	Engine oil refinery	Non-calculation of J index
46	Risk analysis in military organizations (Identifying and prioritizing critical risks in air defense bases)	Mughali et al.	1. Risk identification and evaluation using EFMEA, and William Fine methods. 2. Risk classification. 3. Identification and prioritization of the components with highest risk potentials to continue the operation of the defense bases	Military organizations	Non-calculation of J index
47	Identification and evaluation of job risks in a foam manufacturing company using William Fine method	Kuhnavard et al.	1. Risk identification and assessment 2. Calculation of the J index for the highest risk score	Foam manufacturing	Calculation of the J index for the highest risk score (despite 13 risks with high risk levels)

Published online: July 30, 2020

48	Safety risk assessment using the modified William Fine Model by combining DEMATEL in a fuzzy environment in the machining process	Meknatjo et al.	1. Risk identification using JSA method 2. Risk assessment using William Fine method 3. Calculation of J index 4. Combination of William Fine model with fuzzy DEMATEL model to prioritize corrective measures (due to limited resources)	Machining	Calculation of J index
49	Risk assessment of the environment of Bandar Anzali industrial complex by William Fine method	Ghanbari et al.	1. Risk identification 2. Risk assessment by William Fine method	Complex environment	Non-calculation of J index
50	Identifying and evaluating environmental risks from high voltage power transmission lines in urban areas by William Fine	Jozi et al.	1. Risk identification 2. Prioritization of risk and risk level by William Fine method 3. Calculation of the J index.	High voltage power transmission lines	Calculation of J index
51	Health, safety and environmental risk management in North Cement Factory using William Fine method	Jozi et al.	1. Calculation of the priority score of the risk 2. Classification of the risk score to the high, medium and low risks	Cement factory	Non-calculation of J index
52	Providing a model for assessing the health risk of being exposed to chemicals in the oil and gas industry (Case study: Pars Energy Special Economic Zone)	Heydari et al.	1. Providing a model by combining AHP with William Fine's method 2. Instead of using William Fine's qualitative tables, the values of consequences, potential, and exposure were calculated quantitatively 3. Calculation of risk score 4. Calculation of J index	Oil and gas industries	Although in the William Fine method the cost justification index is expressed as the J index, in this study it is referred to as the G index.
53	Environmental risk assessment of Azar Abadgan Cement Factory in Khoy using PHA, William Fine and GIS integrated method	Jozi et al.	1. Risk identification using the PHA method 2. Risk assessment using the William Fine method 3. Providing corrective measures for unacceptable risks	Cement factory	Non-calculation of J index
54	Evaluation of health and safety risk in East Cement Company using William Fine method (Case study in manufacturing and renovation workshop unit)	Kenarroudi et al.	1. Risk identification and assessment 2. Calculation of the J index	Cement factory	Calculation of J index (the risk score created has been changed but the same J index has been used)
55	Evaluation and management of HSE risk of dry drilling rigs using William Fine method (Case study of Iranian National Drilling Company)	Moradi et al.	1. Risk identification 2. Risk assessment by William Fine method	Dry drilling	Explaining the J index in the Methodology but no calculations
56	Assessment and management the safety, health and environmental risks of Ahwaz Pipe Manufacturing Company by William Fine method	Jozi et al.	1. Risk identification 2. Risk classification by William Fine method 3. Providing control measures	Pipe manufacturing	Explaining the J index in the Methodology but no calculations

RESULTS

As a result of the systematic review, 30 articles were included in the study. The articles were reviewed qualitatively and classified according to the year of publication, and finally recorded in Table 3:

William Fine method includes the economic justification of safety interventions and the cost justification of risk correction in risk assessment, which enables experts to judge the cost justification of risk elimination (financial risk). Consequently, this could be a reason for distinguishing this method from other risk assessment methods, where in most risk assessment methods, there is no economic justification for risk. In many of the articles studied, the cost justification index of control measures was not calculated and only William Fine method was used to determine the risk score. Only a limited number of studies have calculated this index.

William Fine method states that the J values and the risk score rating table are somewhat optional on the decision-making stage and can be replaced by other defined values relative to the industry and ultimately, the decision-making process can be performed using other J values [26]. Review of literature showed that this important point has been overlooked in almost all of them, although they have changed the risk score level, the same value of J index has been used. Among the articles reviewed, only Kuhnavard et al. mentioned this method in their research. Another noteworthy point in this study was that the J index was calculated only for the highest risk index, while 13 risks were identified at a higher level.

In William Fine method, after determining the risk score, it is classified into three levels. In a number of studies, Pareto's law (80/20 Law) was used to classify the risk score, but the J index was not calculated. Ahrampoosh et al. used the William Fine and PHA methods to manage the environmental risk and estimate control costs in Kavir Steel Complex. This method has not been properly expressed and is used only to prioritize control measures. The J index has not been calculated.

Studies have also shown that by combining William Fine method with multi-criteria decision-making methods (e.g., AHP and fuzzy DEMATEL, which was used in Heydari et al., and Meknatjo et al, respectively), control measures can be prioritized, which plays an important role in justifying expenditure management in the safety sector [48-52]. In addition, although in William Fine method, the acceptable cost index is referred to as J index, in the study of Heydari et al. it is referred to as G index, and in a number of studies, the J index is mentioned in the Methodology section. Furthermore, the cost of corrective measures in the study has not been estimated and the cost justification index has not been calculated.

DISCUSSION AND CONCLUSION

Risk assessment is a systematic process for evaluating and comprising that focuses on the key assets of an organization or, more broadly, a community. Threats and vulnerabilities that may occur also include potentials and consequences, and preventive and control measures can be taken to eliminate or control the risks [57].

In general, the main purpose of risk analysis and evaluation is to determine the system uncertainty, resulting cost, and to provide solutions for risk and cost reduction [58]. William Fine method includes the economic justification of safety interventions and the cost of risk correction in risk assessment, which is one of the advantages of this method because in most risk assessment methods there is no economic justification at all.

William Fine method suggests that the values of J and the risk rating table in the decision-making stage are somewhat optional and can be replaced with other defined values relative to the industry and ultimately the decision-making process using other values of J [26].

A review of studies conducted William Fine Risk Assessment Method application in Iran showed that this method has been used mostly to prioritize risks and in a limited number of studies, the justification index of control measures has been calculated. However, William Fine method has a high score in evaluating and comparing corrective and economical correction strategies to reduce the level of risk due to the cost factor, degree of correction and cost justification index. In fact, one of the strengths of William Fine's method, which distinguishes it from

Published online: July 30, 2020

other risk assessment methods is the cost justification index, which enables experts to judge the justification of the costs of risk elimination (financial risk). It seems that one of the reasons for not calculating the J index in the studies is that the numbers provided in the table of factors are outdated and its application in Iranian studies can be controversial. Therefore, researchers do not use the J-index to assess the economic justification of safety measures.

Since 1971, when William Fine presented his method, the principle cost tables have been used in studies to calculate the justifiability of corrective measures. Also, its values are provided in dollars for different industries and are not provided for Iranian industries. At the same time, the economic potential of various Iranian industries to pay for corrective measures varies. In Iranian studies, only Mohammad Fam, in the fourth chapter of the book "Generalities of Management and Safety Engineering" has converted the cost invoice table into Iranian currency (Tomans), taking into account the dollar rate of the day. However, this method did not take into account exchange rate fluctuations over time (especially in the Iranian economy), the use of these tables can be associated with a large error [59]. It is generally recommended that in future studies, safety researchers use the potentials of J index to economically evaluate the proposed corrective measures to increase the effectiveness of risk assessment projects and facilitate the decision-making process for managers. Also, the calculation tables of this index should be provided for different sectors of Iranian industries and in accordance with economic indices, so that it is possible and logical for researchers and managers.

ACKNOWLEDGMENT

This article provided the first part of the results of a research project registered at one of the country's medical universities and has received the permission of the ethics committee.

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