Applied Mathematics & Information Sciences
An International Journal

http://dx.doi.org/10.18576/amis/100226

A New Model Suggestion to Estimate the Probability Value in Occupational Health and Safety Risk Assessment

Omer BIYIKLI[1] *and Emel Kizilkaya AYDOGAN* [2,*]

[1] Department of Industrial and System Engineering,Turkish Military Academy, Devlet Mah. Dikmen Cd., 06654 Ankara, Turkey
[2] Department of Industrial Engineering, Faculty of Engineering, Erciyes University, 38039, Kayseri, Turkey

Received: 23 Aug. 2015, Revised: 10 Nov. 2015, Accepted: 11 Nov. 2015
Published online: 1 Mar. 2016

Abstract: The basis of activities in Occupational Health and Safety (OHS) is risk assessment in the workplace. Risk assessment allows the execution of OHS activities within a plan. The ranking of activities in this plan is done according to the risk value. As this plan may require 3-4 years or more, on condition that the calculation of the plan is correct, sources may be used effectively. The guidelines regarding the risk assessment task are outlined by national and international regulations. How is the risk value calculated? Many methods have been developed for the calculation of the risk value. It can be calculated correctly by proper calculation of the risk component.This component has often been reported in the literature and limited to the value of probability and severity. In studies in the literature, due to the risk value generally being calculated by safety experts? who use a narrow assessment scale subjective approach, there is a possibility that some risks will share the same risk value with each other. In this study, a new artificial-regression probability value calculation model, which was developed on the basis of actual data arranged according to the laws of Heinrich, was proposed to both expand this narrow scale and prevent subjectivity. The proposed model and the classical probability assessment approach used in the literature was integrated and applied to a factory, that has been operating for many years with various workshops, and the results were compared.

Keywords: Risk assessment, Probability Value, Safety Management, Artificial Neural Network

1 Introduction

In workplaces, many studies have been done and methods have been developed to provide these productivity [1]. These methods developed for the effective and efficient operation of the system ignore the most important factor of the system. That factor is human. Employees dependence of workplace, love of job and motivation is the most important component of productivity.As a matter of course, the most important factor providing humans happiness and motivation is his/her health and job security. Health and security is basic need and nothing (promotion, participation to management and higher salaries) can compensate them. Occupational accidents and diseases emerge because of the deficiencies in health and safety issues. They cause some big non-productiveness. The only solution and prevention for them is to eliminate or decrease the risks at a reasonable level.

The origin of the term risk is the french word risque. The ISO 31000 (2009) / ISO Guide 73:2002 definition of risk is the 'effect of uncertainty on objectives'. The objective of OHS activities is health and health and safety of employees. According to the definition of oxford english dictionary, risk is (Exposure to) the possibility of loss, injury, or other adverse or unwelcome circumstance; a chance or situation involving such a possibility. There is a close relationship between risk and probability. The more accurate the predictions regarding the future are, the better risks can be managed and kept under control. The greater the uncertainty about a subject, the harder it is to control. Safety management has dramatically increased in importance in recent years, as companies and institutions realized the social and environmental impact of injuries at work. Moreover, the consistency of the problem of safety in workplaces is emphasized by the statistics reported by several institutions (National Safety Council, 2004;

* Corresponding author e-mail: ekaydogan@erciyes.edu.tr

Health and Safety Executive, 2005a). As a consequence, safety management problems are today addressed by companies, mainly for two reasons. Firstly, industry is moving towards a revaluation of human factor by basing its decisional policies on ethical grounds. To this extent, human factor is not only considered as a productive element but ever more the central factor of productivity. Secondly, modern regulations of an industrialized state impose the adoption of policies to tackle safety issues. [2].

The most important stage of safety management is risk assessment. In this context, all hazardous activities which are potential causes of injuring workers are primarily identified. Later, the level of risk is calculated. The data indicating the level of risk are known as the Risk Priority Number (RPN). An action plan is created with this RPN value. Risks are sorted by RPN value in the action plan. Starting from the highest risk, preventive actions are initiated. If the action plan is created incorrectly, companies may waste their resources significantly.

The RPN can be calculated by this formula

$$RPN = P * M \tag{1}$$

Today, this formula is the most widely used one by companies. RPN is the mathematical index, P is Probability (Probability of accident occurring) and M is the Magnitude of injury(Expected loss in the case of the accident.).

Although this formula is simple and easily applicable, it has the following limitations:

Generally, the probability and magnitude values are calculated based on experts subjective approach.

Due to the narrowness of the rating scale, some risks share the same RPN value. This situation makes it difficult to plan.

Different combinations of risk assessment on the parameter can lead to an identical risk index even though they have completely different meanings. For example, risk with a high probability and low magnitude, and risk with a low probability and high magnitude could be classified at the same RPN value.

Assessment uses only two parameters; therefore, the risk of other major issues influencing risk (i.e. environmental impacts, measures) are ignored.

Limits on the risk assessment are mentioned above. An important methodology has been developed to resolve those related limits. The failure mode, effects and criticality analysis (FMECA) which was developed for the maintenance of industrial plants has been used in many different areas [3,4,5,6,7] .This methodology is very similar to risk assessment. It utilizes a criticality index and the RPN, computed via the probability, magnitude and delectability of the considered failure mode. This method is used by many researchers to overcome the related limits [8,9,10,11,12].Different parameters have recently been added to risk assessment [2].

In recent years, many risk assessment qualitative, quantitative and hybrid methods have been developed and applied to different sectors [13] ,

When we examine the studies in the literature, a detailed study on the direct calculation of the probability value was not found. In fact, before calculation of risk, it is necessary to find out whether there is risk. The value revealing the presence of risk is the probability value. The probability of risk is assessed in a particular scale. In this scale, the closer the probability value is to zero, the smaller the presence of risk is. This study will focus only on calculating the value of probability. It is very difficult for an expert who aims at assessing the risk to calculate the probability value. The expert who conducts risk assessment determines this probability value subjectively by also considering the precautions taken. Probability is equipped with several sub-parameters even though it is not immediately noticed. That is, the probability value is influenced by many sub-parameters. In this present study, it will be shown what those parameters are and how the probability value is calculated with those parameters. The ”probability score” concept will be introduced instead of the assessment of probability value with the help of a scale. The determination of these parameters and how to calculate the probability value with the help of these parameters are focused on in this study. The probability score” concept will be proposed instead of probability values assessment with the help of a scale.

A model suggestion to estimate the probability value in occupational health and safety risk assessment, based on Artificial Neural Networks (ANNs), is proposed. ANNs have recently been used a lot, especially in estimation work. The proposed model is in fact an estimation work. To accomplish the estimation work with ANN a data set of inputs and outputs are needed. What the input data should be is determined by the person performing the work. It is also able to do this kind of work, but perhaps the most challenging part is to collect the necessary data.To obtain the data in this study involved considerable difficulties.

ANN has been applied for accident, risk, and safety issues and their estimation in many different areas. These include the following: traffic safety analysis[14] , fire safety assessment [15], prediction as to the likelihood of the type of vessel accidents [16] , employment of the statistics of bulk carrier loss to predict overall risk [17] , the application of a neural network for ship domain assessment, [18], use in analyzing vessel accidents for pattern recognition [19], the incorporation of an ANN into a risk estimation model [20] ,test case based risk predictions using artificial neural networks for navigational safety [21] , classifying industrial jobs in terms of risk of low back disorders [22].

The rest of the work is divided as follows. The proposed model and the parameters to be used are described in Section 2. Information about the workplace in which the proposed model is to be applied, application of the model, and the results obtained are presented in Section 3. Finally, the evaluation and discussion of the results obtained are presented in Section 4.

2 Proposed Model

We will focus on determining the probability value closest to the real situation in this article. Risk assessment is usually carried out at the workplace by one or two experts. The probability and magnitude values to be estimated are not actually values that can be determined easily. Scales, which were developed in order to facilitate the experts task, actually make it more difficult as the purpose of risk assessment is to create a hierarchy of risks and take preventive actions in accordance with the hierarchy. However, narrow scales lead to calculations sharing the same risk value. For example, a 5x5 scale can produce only 14 different values. If there are 300 risks in a workplace, a value corresponds to about 20 risks. So, in this case, which risk should be given priority and against which risk should preventive actions be taken? This is one aspect of the matter. The other is to what extent the values successfully represent the real situation. The magnitude of injury value can only partly be estimated accurately. However, it is difficult to say the same for the probability value. It is very difficult to determine the probability value in advance. The best method to estimate the probability value is to make use of past records. To this end, accident and incident records must be well kept for a long period of time. Nowadays, due to the constant renewal of workplaces, it is not possible for the vast majority of businesses to have access to data covering such a long time. To obtain the required data in accordance with the real situation of the probability value, an establishment must have the following characteristic:

The workplace must continue to operate for a long time Accident and incident records must be kept for a long time or If accident and incident data are collected through interviews with workers, it is necessary that workers be working there for a long time.

In this study five sub-parameters will be utilized to determine the probability value closest to the real situation (Fig. 1). A new probability value will be obtained through these five sub-parameters.

This new probability value is called the ”probability score”.

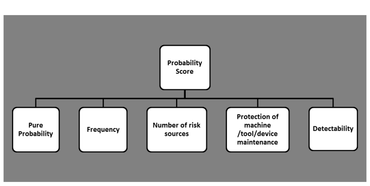

Fig. 1: Probability score evaluation model

The five collected sub-parameter values of risks will be used as input data to the ANN. The probability score will be used as output data to the ANN and the ANN will be trained. Finally, in order to make the model applicable, parameter coefficients will be found through regression analysis (Fig.2.)

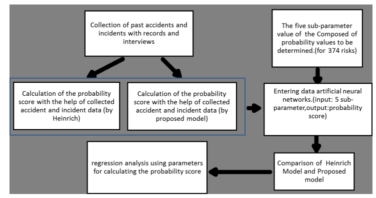

Fig. 2: General structure of the proposed model

This new probability value is called the ”probability score”.

The parameters used in the article and their descriptions are given below.

2.1 Pure Probability

An expert aiming to assess this parameter needs to ask the question:

Supposing that no action is taken regarding this activity, what is the percentage possibility of an accident occurring in a year? For example, suppose that there is no machine maintenance, early warning system, supervisory measures etc.. Someone assessing this parameter must evaluate the possibility of an accident as if no preventive measure has been taken.

The evaluation score used for this parameter and the scores used in the literature [23,24,25,26,27] are as follows table-1.

2.2 Frequency

To assess this parameter, the expert has to answer the following question:

How often is this study carried out?

This parameter is added for the following reasons:

Each job is not performed made at the same frequency in the workplace. Some tasks, such as maintenance, are carried out only once a year. Some tasks, such as manufacturing, are performed day. The accident risk of these tasks cannot be identical.

The evaluation score is shown for this parameter in table-2:

Table 1: Terms, ranking and corresponding frequencies (per year) for accident likelihood in literature

Definition		**Present Study**	**Gurcanli and Mungen(2009)**	**HSE (2003)**	**Raafat (1995)**	**Sii and Wang (2002)**	**Sii et al. (2001)**
Occupational accident is unlikely but may possible during project lifetime under special circumstances	Value	1	Very Low	1	1	1,2,3	1
	Definition	Very low	<1	Incredible	Almost impossible	Very Low	
	Illustration	<1	......	$<10^{-7}$	$<10^{-6}$	$<10^{-6}$	$<10^{-8}$
Likely to happen once during project lifetime	Value	2,3	Low	2	2	4	2,3
	Definition	Low	2.5	Remote	Very very low	Low	Low
	Illustration	5	.....	$10^{-5}>F>10^{-7}$	10^{-5}	$0.25*10^{-5}$	$10^{-6}-10^{-7}$
Between low and average	.....	Reasonably low	.....	2	.....	5	4,5
	Definition	.....	5	.....	.....	Reasonably low	Reasonably low
	Illustration	.....	......	......	.....	$0.25*10^{-4}$	$10^{-4}-10^{-5}$
Occasional accident	Value	4,5,6	Average	3	3	6	6,7
	Definition	Moderate	10	Unlikely	Very unlikely	Average	Average
	Illustration	20	.....	$10^{-3}>F>10^{-5}$	10^{-4}	10^{-3}	$10^{-2}-10^{-3}$
Will probably occur in most circumstances	Value	7,8	Frequent	4	4	7	.....
	Definition	High	20	Occasional	Unlikely	Reasonably frequent	.....
	Illustration	50	.....	$10^{-1}>F>10^{-3}$	10^{-3}	$0,25*10^{-2}$	......
Repeated accidents	Value	.....	.....	5	5	8,9	8,9
	Definition	.....	......	Likely	Likely	Frequent	Frequent
	Illustration	.....	.....	$10>F>10^{-1}$	10^{-2}	$0,12*10^{-1}$	$1-10^{-1}$
Expected to occur (very likely to occur) in most circumstances in the project time	Value	9,10	Highly frequent	6	6	9,10	9.5-10
	Definition	Very high	>25	Frequent	Frequent	Highly frequent	Highly frequent
	Illustration	>50	.....	$F>10$	10^{-1}	$0,25*10^{-1}$	>1

Table 2: The evaluation table of the frequency parameter

Numerical Value	**Linguistic Value**	**Definition (frequency)**
1	Very low	Done several times a year
2,3	low	Done several times a month
4,5,6	Moderate	Done several times a week
7,8	High	Done several times each day
9, 10	Very High	Done almost every moment of the day

Table 3: The evaluation table of the number of risk sources parameter

Numerical Value	**Linguistic Value**	**Definition (number of risks source/bench)**
1	Very low	1
2,3	low	2,3
4,5,6	Moderate	$10>NRS\geq 4$
7,8	High	$20>NRS\geq 10$
9, 10	Very High	$NRS\geq 20$

2.3 Number of risk sources

The expert assessing this parameter has to answer the following question:

In how many benches or studies may this risk appear?

One of the major problems in risk assessment in the workplace is ignorance of the actual study. For example, in a workshop, there may be 20 benches engaged in the same process. In addition, there may be benches that are used less frequently. Now, we need to ask this question: As the number of risk sources increase, does the probability of risk increase? Of course, the answer is yes.

The evaluation score used for this parameter is shown in table-3.

2.4 Protection of machine /tool/device maintenance

To assess this parameter, the expert has to answer the following questions:

Are precautions in place against this risk? Do these precautions eliminate this risk or to what extent do they

Table 4: The evaluation table of protection of machine maintenance parameter

Numerical Value	Linguistic Value	Definition (protection machine/tool/device maintenance)
1	Very high	The effect of maintenance is very high for probability of accident
2,3	High	The effect of maintenance is high for probability of accident.
4,5,6	Moderate	The effect of maintenance is moderate for probability of accident.
7,8	Low	The effect of maintenance is low for probability of accident.
9, 10	Very low	The effect of maintenance is very low for probability of accident.

Table 5: The evaluation table of detectability parameter

Numerical Value	Linguistic Value	Definition (frequency)
1	Very High	Detectability of potential cause of the error and the following error is very high
2,3	High	Detectability of potential cause of the error and the following error is high
4,5,6	Moderate	Detectability of potential cause of the error and the following error is moderate
7,8	low	Detectability of potential cause of the error and the following error is low
9, 10	Very low	Detectability of potential cause of the error and the following error is very low

reduce the risk? Sometimes, risks may stem from the bench. With regular maintenance to benches, the risks can be completely eliminated. Therefore, after taking of this parameter into account, it is possible to see that risk probability decreases to an acceptable level. This parameter is used to calculate the risk value directly by Grassi et al. [2] as this parameters direct effect on the probability value was evaluated. However, they used this parameter in a different way as Sensitivity to maintenance non-execution.

The evaluation score used for this parameter is shown in table-4.

2.5 Detectability

To assess this parameter, an expert has to answer the following questions:

Can I pre-determine the reasons for the emergence of this risk? Can I realize these reasons? If the reason for the occurrence of a hazard is easy to recognize, it is easy to prevent the hazard as well. This parameter is used to calculate the risk value for a long period of time (FMEA,FMECA). However, in all studies, it was considered as a parameter that directly determines the risk. As previously recognized causes of accidents are prevented, the number of accidents is reduced. Indirectly, the probability value decreases.

The evaluation score used for this parameter is shown in Table-5.

3 Case study

One of the most important problems in occupational and safety actions in the world is the habit of not keeping records. Estimating future accidents/incidents therefore becomes difficult when previous data are missing. The most important problem encountered in the course of this study was obtaining records of major accidents, minor accidents, and incidents / near misses since such a study can only be conducted with the help of accident records kept for a long period of time.

3.1 Workplace

The proposed model is applied in a complex workplace. The fact that there are different workshops and risk groups in the workplace studied makes it possible to use findings in wider areas. In our study, 385 people are employed in the workplace, which includes 17 different workshops and 374 risks (table-6). The workplace is a state-owned factory, for this reason, it was easy to obtain past accident records. Moreover, circulation of workers changes very little in state-owned factories so knowledge of incidents (near misses) was obtained via surveys conducted among senior workers. The workplace has been operating for nearly 60 years. The collected data cover the last 30 years. As the field of activity of the workplace has not changed since its establishment, the collected data are homogeneous. Otherwise, this work could not have been done.

Classical risk assessment was carried out at the workplace. A 5x5 matrix was used in the risk assessment. When we examine the table of statistics of workplace risks, it can be seen that there are many risks sharing the same risk value(table-7). In this case, some serious problems may appear in planning.

3.2 Probability score

Many accidents and incidents occur in the workplace. When calculating the number of accidents and incidents

Table 6: The information table of complex workplace

No	Name of workshop	Number of risks
1	Vehicle disassembly	18
2	First wash	10
3	Vehicle blast	14
4	Vehicle mechanical parts revamping	22
5	Vehicle assembly	19
6	Electric-hydraulic part revamping	21
7	Dyehouselow	19
8	Engine-transmission disassembly	19
9	Engine assembly	18
10	Carpenter workshop	27
11	Machine maintenance and repair	25
12	Welding	27
13	Foundry	37
14	Spare parts manufacturing workshop(lathes, milling, drilling)	27
15	Rubber parts manufacturing	21
16	Metal plating	35
17	Non-destructive testing	15

Table 7: Workplace risk assessment statistics

Risk Value	Number of Risks	%
2	4	1.1
3	6	1.6
4	6	1.6
5	1	0.3
6	43	11.5
8	27	7.2
9	91	24.3
10	15	4.0
12	72	19.3
15	32	8.6
16	57	15.2
20	12	3.2
25	8	2.1
	374	100

(near misses) of a risk, is it correct to summarize them classically? Is it correct to consider all of the accidents in the same category? Of course not. Then, how should the different terms be summarized and evaluated? To this end, the Heinrich pyramid [28] will be used.

The heinrich pyramid (Fig. 3) is utilized for the calculation of the probability score. The heinrich pyramid can be briefly explained as follows: if, in a workplace, 300 incidents (near misses) happen, 29 minor and one major accident happen. Is this always the case? In our opinion, it is not. Definitions of minor-major accidents and incidents are very important. This topic will be discussed in the case study.

However, here we can say that major accidents, minor accidents and incidents are weighted. The probability score will be obtained by multiplying these weights by

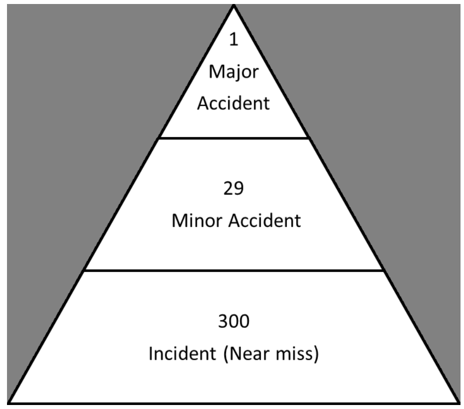

Fig. 3: Heinrich Pyramid [28]

the number of accidents and incidents and the sum of their result. Are the numerical values mentioned in this rule, which is known as 1-29-300 rule, correct? For example, do a mine, a carpentry business, a construction firm or milk processing factory have the same values? Is the definition of major accident the same for all? The probability prediction model that we propose can be applied to all kinds of workshops where any production is carried out. The study was conducted in the 17 different workshops shown in Table 6 and the definitions of major accidents, minor accidents and event definitions are as follows:

Major accidents: accidents that require 10 days or more leave,

Minor accidents: accidents that cause the employee to take leave of less than 10 days, injure the employee in some way and lead to functional impairment accidents for the materials,

Incidents (near misses): accidents that do not injure the employee, but come close to doing so damage the material which, however, still keeps functioning and requires no adjustment,

According to these definitions, 169 major accidents, 1,689 minor accidents and 11,594 incidents (near misses) related to 374 risks occurred in the workplace.

When compared with the 1-29-300 rule, the new rule becomes 1-10-68.

If major accidents, minor accidents and incidents are weighted based on this rule, the weights will be as follows (Table-8). When these weights are detirmined assuming minor accidents weight is 1 and the two other calculated accordingly.

The probability score is calculated by multiplying these weights with the number of major accidents, minor accidents and incidents. For example,

If 1 major accident, 4 minor accidents and 25 incidents occurred in the last 30 years at a risky activity,

Probability Score: 29 x major accidents + 1 x minor accident + 0.10 x incidents (Heinrich)

Table 8: Weights of major/minor accidents and incidents (near misses)

	Major accident	Minor accident	Incident
Heinrich	29	1	0.1
Proposed model	10	1	10.5

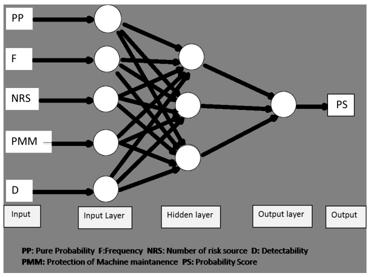

Fig. 4: Neural network figure of the proposed model

Probability Score: 10 x major accidents + 1 x minor accident + 0.15 x incidents (Proposed model)

Probability Score (Heinrich) : 35.5

Probability Score (Proposed model) :17.75

3.3 Evaluation with artificial neural networks

Analysis of the input and output of artificial neural networks and the computing power of the degree of relationship between them is very high. For this reason, in this study, in order to calculate the strength of the relationship between the proposed 5 sub-parameters with probability score, artificial neural networks are utilized. (Fig.4)

The MATLAB program is utilized for evaluating the data. ANN was trained by the Levenberg-Marquardt backpropagation algoritm. It was previously mentioned that 374 risks were identified in the workplace. Of these data 300 were used for training and 74 for testing. The number of iterations was 100.

Input data (PP,F,NRS,PMM,D) given to the neural network output that the probability scores of the Heinrich and proposed model were calculated separately. The correlation value of the results of the Heinrich model is 0.72 and the proposed models result is 0.93. The next actions (regression analysis) were carried out based on the proposed model (probability score calculation model). The results of the proposed model are presented in table-9.

Five different input data sets were entered into the artificial neural network model. Probability score that calculated by the Heinrich model and proposed model was entered as output data. Two models are run separately. Correlation value between the results that calculated by Heinrich's model and the real situation is

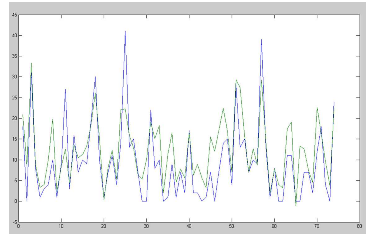

Fig. 5: Probability score (real situation)-Probability score (Regression) results

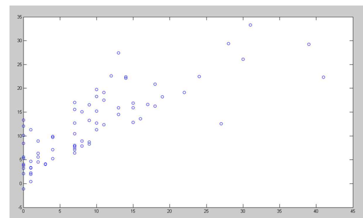

Fig. 6: Probability score (real situation)-Probability score (Regression)

0.72 at test data. The others result is 0,93. Due to the success of the proposed model, the following actions has been carried out using proposed model. Table-9 gives the 40 of the 74 results of the proposed model.

3.4 Regression analysis

The artificial neural network works like a black box. It is not clear how it finds the results. Thus, it is difficult or impossible to explain how decisions were made based on the output of the network. Regression analysis was performed in order for the experts to use the proposed model to determine the coefficients of the 5 sub-parameters. The determined coefficient values are given in Table-10

The correlation between the old method and the new method with the actual situation actually explains a lot of things.

While the correlation is very high between the probability score (ANN) and probability score (real situation), the correlation is relatively low between probability score (Regression) and probability score (real situation). The probability value (Classic model) correlation value is very different (Table -11). The coefficients of parameters can be defined by other methods than regression analysis. The relationship between probability score (real situation) and probability score (Regression) can be seen in Fig. 5 and Fig.6.

Briefly, this model has the potential to play a leading role in the determination of measures to be taken.

Table 9: Results

Sorting (Probability score-regression)	Sorting (Classical model)	Pure probability	Frequency	Number of risk source	Protection of machine maintenance	Detectability	Probability Value (Classical Model)	Probability score (real situation)	Probability score (ANN)	Probability score (Regression)
1	12	7	10	10	10	2	3	31.75	35.56	33.31
2	47	7	7	7	10	2	3	28	35.28	29.38
3	49	8	10	7	10	2	3	39	42.68	29.25
4	8	3	2	7	10	2	4	13.75	15.39	27.46
5	26	6	9	6	10	2	3	30.5	32.06	26.11
6	59	5	7	4	10	2	3	12.75	20.64	22.57
7	63	6	10	4	10	2	3	24	26.24	22.45
8	44	8	1	1	10	2	3	14.25	17.17	22.43
9	3	10	10	8	5	8	4	41.5	39.56	22.31
10	30	2	10	6	10	2	3	14	18.93	22.11
11	10	6	5	2	10	2	3	18.5	16.72	20.87
12	17	7	6	1	10	2	3	10.5	17.2	19.77
13	32	7	8	1	10	2	3	22	18.16	19.08
14	54	7	8	1	10	2	3	11.9	18.16	19.08
15	68	6	2	1	9	3	2	10.9	11.14	18.27
16	25	6	8	4	7	3	3	19.5	15.68	18.2
17	53	8	8	1	9	4	3	11.5	19.05	17.51
18	43	3	2	1	10	3	3	7.5	7.93	17
19	45	6	3	1	9	5	3	15	12.54	16.91
20	37	5	7	1	10	4	3	17.25	13.83	16.6
21	70	5	3	1	9	4	2	9.5	10.23	16.5
22	60	7	9	1	9	4	3	18.5	16.89	16.25
23	71	7	10	1	9	4	2	15.25	17.3	15.9
24	66	3	10	5	8	7	2	13.75	16.77	15.88
25	41	5	7	1	10	6	3	7.25	14.57	15.59
26	65	4	7	1	10	5	2	10.5	12.24	15.18
27	33	3	9	1	10	2	3	8.5	10.18	15.08
28	50	7	4	1	7	5	3	13.5	10.9	14.52
29	21	7	8	1	7	4	3	16.5	12.12	13.63
30	56	1	3	1	10	6	3	0	6.97	13.32
31	24	5	8	1	8	4	3	9.5	10.42	13.29
32	67	7	8	2	6	6	2	15	12.88	12.8
33	9	9	7	3	3	5	4	10.9	1126	12.7
34	57	3	3	1	8	5	3	7.5	6.37	12.69
35	20	8	9	3	4	5	3	27	12.53	12.57
36	2	9	8	3	3	5	4	11.45	11.83	12.35
37	42	2	5	1	8	3	3	0	5.31	12.09
38	69	3	6	2	7	6	2	1.45	7.3	11.32
39	23	3	7	1	9	8	3	10.5	9.96	11.27
40	22	3	8	1	7	3	3	7.5	6.14	10.48

Table 10: Coefficents of 5 sub-parameters

Pure probability	**Frequency**	**Number of risk source**	**Protection of machine maintenance**	**Detectability**
0.9143	0.3473	1.6581	1.4812	-0.5039

Table 11: Correlation value with probability score (real situation)

Probability score (ANN)	**Probability score (Regression)**	**Probability value (Classical model)**
0.9143	0.3473	1.6581

4 Conclusions

There are millions of workplaces in the world and more or less some risks can be seen in each workplace. The prevention of these risks is possible with a good risk management. These workplaces need experts that can manage such risks. On the other hand, experts must determine properly realization probabilities and the possible losses or risks. This is possible with experience in time. It is not so easy to increase the level of expertise of these many experts. So, providing easy methods to experts as in classical risk analysis does not bring benefit but harm because the evaluations are done subjectively. In fact, precautions will be taken with high costs for the risks that might not occur; no precautions will be taken for the ones that might occur and unpleasant events might constantly occur. There are many studies related to risk assessment in Occupational Health and Safety. Few parameters are used in these studies. It is important to use simple risk assessment methods that can be understood and implemented by everyone. However, it should be noted that the purpose of these studies is human health and the protection of life. Additionally, the measures that need to be taken during and after studies of risk analysis can be very expensive. Therefore, more detailed studies are vital for companies. For this reason, it is very important to determine the risk value so that it is as close to the real value as possible. The most permanent way to prevent this is to reduce the subjectivity. Especially probability parameter includes an uncertainty. Resolving this uncertainty is possible only with finding sub-parameters/reasons causing occurrence and identifying the relations between them. An increase in the number of sub-parameters will allow not only all aspects of the current situation to be recorded but also the measures to be determined in a clearer and more precise manner. This study offers an effective and practicable risk analysis method for the experts. It has proven with the data of workplace which has been studied. As a continuation of this work, it can be evaluated with intuitive methods by increasing the number of parameters which cause the events that cause physical injuries.

References

[1] E. Atmaca, S.S. Girenes, Qual Quant, **47** 2107-2127 (2013).
[2] A. Grassi , R. Gamberini, C. Mora ,B. Rimini, Safety Science, **47**, 707-716 (2009).
[3] MIL-STD-1629A, Procedures for Performing a Failure Mode, Effects and Criticality Analysis. Department of Defense, United States of America (1980).
[4] Ford Motor Company, Potential failure mode and effects analysis in design (Design FMECA) and for manufacturing and assembly process (Process FMECA) instruction manual. Internal Report -Detroit, USA (1988).
[5] W. Gilchrist, International Journal of Quality and Reliability Management, **10.5**, 16-23 (1993).
[6] S.H.Teng, S.Y. Ho, International Journal of Quality and Reliability Management, **13**, 8-26 (1996).
[7] C.L. Chang, P.H. Liu, C.C. Wei, Failure mode effects analysis using grey theory. Integrated Manufacturing Systems, **12**, 211-216 (2001).
[8] J.B. Bowles, C.E. Pelaez, Reliability Engineering and System Safety **50**, 203-213 (1995).
[9] M. Ben-Daya, A. Raouf, International Journal of Quality and Reliability Management, **13**, 43-47 (1996).
[10] C.L. Chang,C.C. Wei,Y.H. Lee, The International Journal of Systems and Cybernetics, **28.9**, 1072-1080 (1999).
[11] M. Braglia, M.Bevilacqua, Technology, Law and Insurance, **5**, 125-134 (2000).
[12] M. Braglia, M. Frosolini, R. Montanari, Quality and Reliability Engineering International, **19**, 425-443 (2003).
[13] P.K. Marhavilas, D. Koulouriotis, V.Gemeni, Journal of Loss Prevention in the Process Industries, **24**, 477-523 (2011).
[14] H. T. Abdelwahab and,M. A. Abdel-Aty, Transportation Research Record: Journal of the Transportation Research Board **1784**, 115-125 (2002).
[15] W.W. Lee, K.K. Yuen, S.M. Lo, K.C. Lam, K. C.,G.H. Yeoh, Fire Safety Journal, **39**, 67-87 (2004).
[16] R.R. Hashemi, L.A. Le Blanc, C.T. Rucks, A. Shearry, Expert Systems with Applications, **9**, 247-256 (1995).
[17] I.L. Buxton, B.R. Cuckson, G.P. Thanopoulos, Conference Proceedings of Marine Risk Assessment: A Better Way to Manage Your Business Part 2, **109** London, England, April 8-9, 1-8 (1997).
[18] J. Lisowski, A. Rak, W. Czechowicz, Mathematics and Computers in Simulation, **51**, 399-406 (2000).
[19] L.A. Le Blanc, R.R. Hashemi, C.T. Rucks, Expert Systems with Applications **20**, 163-171 (2001).
[20] J. Wang, H.S. J.B. Yang, A. Pillay, D. Yu, J. Liu, et al.,. Risk Analysis, **24.4**, 1041-1063 (2004).
[21] S.T. Ung, V. Williams, S. Bonsall, J. Wang, Journal of Safety Research **37**, 245-260 (2006).
[22] S.A.Cuesta, J.A.D. Mas, J.A. Marzal, International Journal of Industrial Ergonomics **40**, 629-635 (2010)
[23] G. E. Gurcanli, U. Mungen, International Journal of Industrial Ergonomics **39**, 371-387 (2009).
[24] HSE, Hazardous Installations Directorate, HID Safety Report Assessment Guide: Explosive (2003).
[25] H. Raafat, Machinery Safety: The Risk Based Approach. Practical Guidelines on Risk Assessment. Standards and Legislation Technical Communications (Publishing) Ltd. (1995).
[26] H.S. Sii, J. Wang, Safety assessment of FPSOs: the process of modellling system safety and case studies. Report of the Project the Application of Approximate Reasoning Methodologies to Offshore Engineering Design. EPSRC GR/R30624 and GR/R32413, Liverpool John Moores University, U.K. (2002).
[27] H.S. Sii, T. Ruxton, J. Wang, Reliability Eng. Syst. Safety **73**, 19-34. (2001).
[28] H. Heinrich, Industrial accident prevention, 4th ed., New York, McGraw-Hill (1959).

Omer BIYIKLI received his B.S. degree in Industrial Engineering at Istanbul University in 2006,after he completed his M.S. degree in the same field at Erciyes University in 2011. Now he is pursuing his PhD degree at Erciyes University. Between 2007-2013, he held management positions of Occupational Health and Safety in military factories. He is now the lecturer of industrial and system engineering at Turkish Military Academy. His research interests include optimization theory, applied mathematics, ergonomic, information sciences, knowledge-based systems. He is referee of several international journals.

Emel Kizilkaya AYDOGAN received the PhD degree in industrial engineering from the University of Gazi in 2008, She is Associate Professor of industrial engineering at University of Erciyes. Her research interests include optimization theory, applied mathematics, information sciences, decision support systems, data mining, knowledge-based systems, computational intelligence. She is referee and Editor of several international journals.