

Research Article

A New Risk Analysis Model Proposal for Determining the Economic Effects of Occupational Accidents on Businesses

İş Kazalarının İşletmelere Olan Ekonomik Etkilerinin Tespitine Yönelik Yeni Bir Risk Analiz Modeli Önerisi

ULAS CINAR

Dr., Canakkale Onsekiz Mart University

Occupational Health and Safety Education Application and Research Center

ulas.cinar@comu.edu.tr

<https://orcid.org/0000-0003-3924-0768>

Makale Geliş Tarihi	Makale Kabul Tarihi
13.01.2023	12.08.2023

Abstract

In addition to being an important social problem, occupational accidents also cause significant economic losses for businesses. Around 4% of the total economic resources in the world are lost due to work accidents and occupational diseases. The proposed method aims to determine the risk priorities of the departments with the TOPSIS method by using the "Risk Potential", "Accident Frequency Rate", "Accident Severity Rate" and "Average Cost Per Occupational Accident" parameters. In this direction, the proposed method creates a risk map according to the period covered by the department activities in the total workflow. Since expert decisions are effective in the evaluation of the "Risk Potential" parameter, a fuzzy approach was preferred in order to minimize subjectivity. Other methods applied are computationally independent of expert judgments. A sample application was carried out with the proposed method and the steps of the method were tested in practice. There is no analysis method in the literature that focuses on the economic effects of occupational accidents on businesses by focusing on the occurrence of accidents and the costs that will occur after the accident. In this direction, it is thought that the proposed model will fill an important gap in the literature.

Keywords: Occupational Accidents, Economy, Risk Analysis, Cost Analysis, Occupational Health and Safety

Öz

İş kazaları önemli bir toplumsal sorun olmasının yanı sıra işletmeler için önemli ekonomik kayıplara da neden olmaktadır. İş kazalarının tazmini için Sosyal Güvenlik Kurumu ve dolayısıyla ülke ekonomisi önemli maliyetlerle karşı karşıya kalmaktadır. Dünyadaki toplam ekonomik kaynakların yaklaşık %4' ü iş kazaları ve meslek hastalıkları nedeniyle kaybolmaktadır. Önerilen yöntem, "Risk Potansiyeli", "Kaza Sıklık Oranı", "Kaza Ağırlık Oranı" ve "İş Kazası Başına Ortalama Maliyet" parametrelerini kullanarak bölümlerin risk önceliklerini TOPSIS yöntemi ile belirlemeyi amaçlamaktadır. Bu doğrultuda önerilen yöntem, departman faaliyetlerinin toplam iş akışı içerisinde kapsadığı alana göre bir risk haritası oluşturmaktadır. "Risk Potansiyeli" parametresinin değerlendirilmesinde uzman kararları etkili olduğu için sübjektifliği en aza indirmek amacıyla bulanık bir yaklaşım tercih edilmiştir. Uygulanan diğer yöntemler, uzman kararlarından bağımsız hesaplamalardır. Önerilen yöntem ile örnek bir uygulama gerçekleştirilmiş ve yöntemin adımları uygulamalı olarak test edilmiştir. Literatürde kazaların meydana gelmesi ve kaza sonrasında oluşacak maliyetlere odaklanarak iş kazalarının işletmeler üzerindeki ekonomik etkilerine odaklanan bir analiz yöntemi bulunmamaktadır. Bu doğrultuda önerilen modelin literatürde önemli bir boşluğu dolduracağı düşünülmektedir. Ayrıca farklı parametreler eklenerek veya

Önerilen Atıf /Suggested Citation

Çınar, U., 2023 A New Risk Analysis Model Proposal for Determining the Economic Effects of Occupational Accidents on Businesses, *Üçüncü Sektör Sosyal Ekonomi Dergisi*, 58(3), 1930-1944.

mevcut parametreler değiştirilerek modelin farklı uygulama alanlarına entegre edilebileceği ve bu yönüyle önerilen modelin yeni geliştirilecek modellere referans niteliğinde olacağı düşünülmektedir.

Anahtar Kelimeler: İş Kazaları, Ekonomi, Risk Analizi, Maliyet Analizi, İş Sağlığı ve Güvenliği

1. Introduction

Occupational accidents are a global problem in terms of their effects. The World Labor Organization defines an occupational accident as “an unplanned unexpected event that causes specific harm or injury” (ILO, 1983). In addition to the loss of life worldwide, it is estimated that approximately 4% of all material resources are lost due to work accidents and occupational diseases (Güllüoğlu and Taçgım, 2018). In line with the recorded data, our country ranks 3rd in the world in terms of occupational accidents and 1st in Europe (Ceylan, 2011).

Occupational health and safety is all of the methodical studies carried out in order to investigate and prevent the dangers, damages and disruptions arising from the working conditions in the workplace, to the employees, machinery and facilities or to the production. Occupational health and safety is a planned and regular set of measures in itself, and although its priority is to protect people, it also includes the prevention of deterioration or damage to production elements in the workplace. The basis of occupational health and safety is to protect workers from work accidents and occupational diseases and to provide a healthy working environment, as well as ensure the safety of the enterprise and the continuity of its operation (Rikhardsson, 2004).

Occupational accidents primarily affect employee and their relationships. The harm to humans is naturally much ahead of the economic factors. This situation often prevents the calculation of the real values of the costs of work accidents to the business. Occupational accidents are an important socio-economic problem that causes great costs to businesses and therefore negatively affects the economic parameters of countries (Ucan and Ucan, 2021).

The costs that arise as a result of occupational accidents can be handled in two groups direct and indirect costs. Indirect costs are expected to be 4-10 times higher than direct costs. Direct costs of work accidents are first aid, ambulance and treatment expenses, temporary or permanent incapacity and death payments, material and moral compensation paid to the worker or their relatives, and compensations paid to insurance. Indirect costs are the cost incurred as a result of stopping production after the accident, the cost of the overtime required by the accident, the cost of the wages paid to the arrangements made after the accident, the cost of post-accident visitors and staff investigating the accident and time spent on grounds such as claims for compensation, reflections of demoralization and anxiety in other employees and the cost of effort and time spent to eliminate them, administrative fines, the cost incurred as a result of the decrease in the productivity of the worker who has had a work accident after returning to work, time and expenses for training and adaptation of the new worker, and uninsured treatment costs (Bekar et. al., 2017).

Occupational accidents also have negative effects on the productivity of employees. It is thought that correct risk management and effectively designed occupational health and safety practices will increase the productivity of employees and thus provide significant economic contributions to businesses (Karamik and Seker, 2016). The individual productivity of the employees increases the productivity of the enterprises, and the efficiency of the enterprises has a positive effect on the economic development of the countries. This is an example of organizational efficiency in a chain order (Unsar, 2004).

Occupational health and safety risk analyses are carried out proactively to prevent occupational accidents, but in conventional applications, the costs of work accidents are not included in the analysis in principle (Boyle, 2002; Cinar and Cebi, 2022). However, for effective risk management, analysis and optimization methods are suggested in the literature to reduce the costs of precautions and accidents (Cinar and Ugurlu, 2019).

Prevention or reduction of occupational accidents has an important effect on both the protection of the living conditions of the employees, the reduction of labour and production losses and the prevention of damage to the country's economy. Therefore, it is vital to identify risks and take necessary precautions before an accident occurs. For this reason, risk analysts evaluate the qualitative and quantitative data they have obtained as a result of measurement and observation with various analysis methods and aim to ensure a safe operation in the working environment with various measures to eliminate the negativities they have determined (Özkılıç, 2005).

The aim of this study is to express the magnitude of occupational accident risks from a socioeconomic point of view by considering the costs of work accidents to businesses and the factors that affect them. In this direction, a risk assessment model that combines the parameters that determine the economic effects of occupational accidents and classical risk assessment principles in the literature has been proposed.

2. Method

"The Interdepartmental Risk Mapping" method aims to determine the risk priorities of the departments with the TOPSIS method by using the "Risk Potential", "Accident Frequency Rate", "Accident Severity Rate" and "Average Cost Per Occupational Accident" parameters. In this direction, proposed method creates a risk map according to the period covered by the department activities in the total workflow. Since expert decisions are effective in the evaluation of the "Risk Potential" parameter, a fuzzy approach was preferred in order to minimize subjectivity. Other methods applied are computationally independent of expert judgments. The flow chart containing the steps of the proposed method is given in Figure 1.

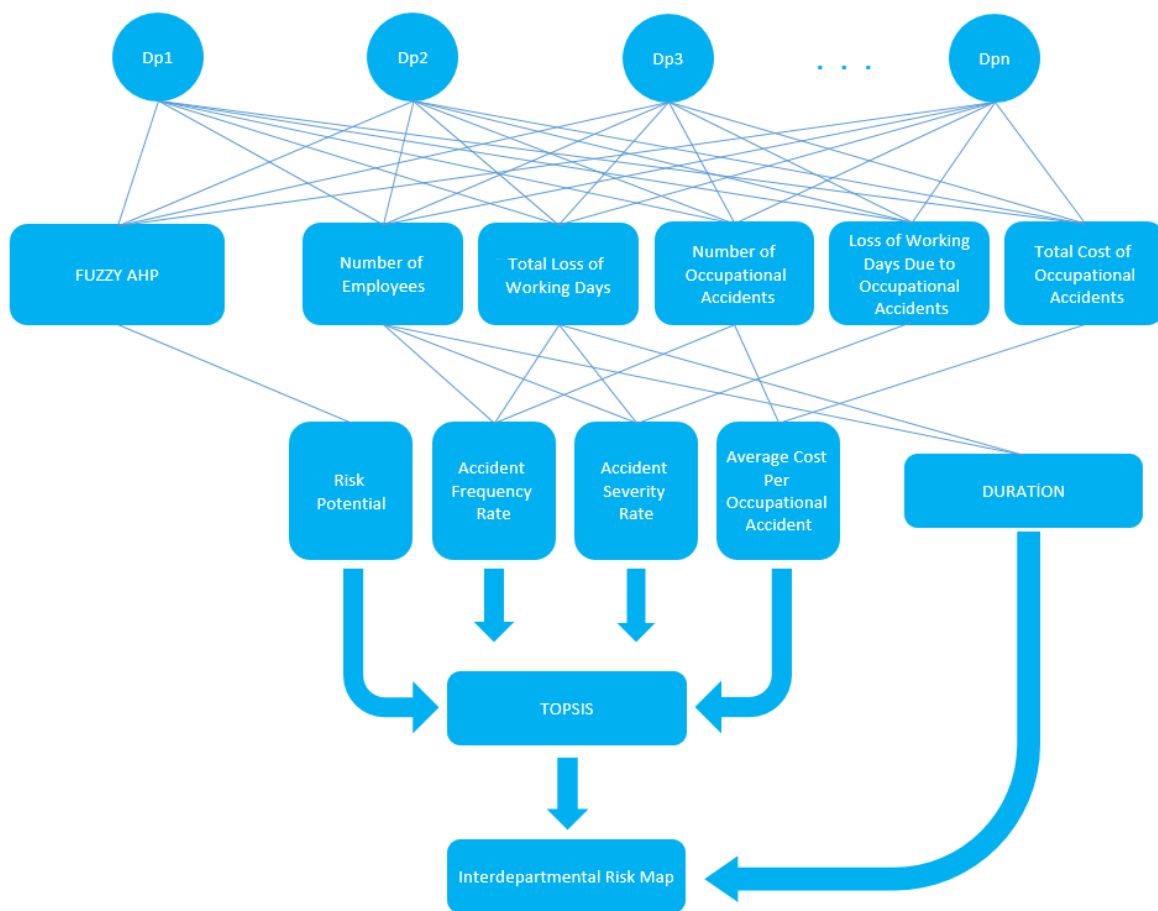


Figure 1. The Flow Chart of the Proposed Approach

2.1. Weighting of Risk Potentials

In this step, departments are compared with each other according to their risk potential. In this comparison, the risk factors of the activities carried out in the department are kept in the foreground. This step is the only stage where expert evaluations are effective. The expert performing the evaluation creates the pairwise comparison matrix in Equation 1 by using the fuzzy numbers corresponding to the linguistic expressions in Table 1 (Hsieh et.al., 2004).

Table 1. Linguistic Scale and Fuzzy Numbers

Linguistic Scales	Fuzzy Numbers
Almost Equal Risk Potential	(1,1,3)
Slightly More Risk Potential	(1,3,5)
More Risk Potential	(3,5,7)
High - Risk Potential	(5,7,9)
Very High - Risk Potential	(7,9,9)

$$\tilde{X}_i = \begin{bmatrix} 1 & \tilde{x}_{12} & \dots & \tilde{x}_{1n} \\ \tilde{x}_{21} & 1 & \dots & \tilde{x}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{x}_{n1} & \tilde{x}_{n2} & \dots & 1 \end{bmatrix} \tag{1}$$

According to the comparison matrix created, fuzzy weights are calculated using Equations 2 and 3. In Equation 2, \tilde{r}_i shows the geometric mean value of the i^{th} result that may occur as a result of the risk, compared to the other results, and in Equation 3, \tilde{w}_i shows the weight of the i^{th} department (Buckley, 1985; Chen and Hwang, 1992).

$$\tilde{r}_i = (\tilde{x}_{i1} \otimes \tilde{x}_{i2} \otimes \dots \otimes \tilde{x}_{in})^{1/n} \tag{2}$$

$$\tilde{w}_i = \tilde{r}_i \otimes (\tilde{r}_1 + \tilde{r}_2 + \dots + \tilde{r}_n)^{-1} \tag{3}$$

Since the obtained values are fuzzy numbers, the defuzzification process is performed using Equation 4. Then, the relative weight values of each department are calculated by applying Equation 5 and the weights of each department are determined for the "Risk Potential" parameter (Cinar and Cebi, 2020).

$$w_i = \frac{\tilde{w}_i}{\sum_{j=1}^n \tilde{w}_j} = \frac{(w_{il}+w_{im}+w_{iu})}{\sum_{j=1}^n \tilde{w}_j} \tag{4}$$

$$RP_i = \frac{w_i}{\sum_{i=1}^n w_i} \tag{5}$$

2.2. Calculation of Accident Frequency Rates

Accident Frequency Rate (AFR); is calculated with the formula given in Equation 6 using the Number of Employees (NOE), Working Days Per Year (WDY), Working Hours Per Day (WHD), Total Loss of Working Days (TLWD) and Number of Occupational Accidents (NOA) parameters. As a result of this calculation, it is determined how many work accidents occur in each million working hours. This calculation method, which is normally applied to the enterprises totally, is applied separately, assuming each department is independent in the proposed method. After calculating the AFR values of each department, the relative AFR weights for each department are determined by Equation 7 (Aritan and Ataman, 2017).

$$AFR_i = \frac{NOA_i}{[(NOE_i * WDY_i) - TLWD_i] * WHD_i} * 1000000 \tag{6}$$

$$AFR_i = \frac{AFR_i}{\sum_{i=1}^n AFR_i} \tag{7}$$

2.3. Calculation of Accident Severity Rates

Accident Frequency Rate (AFR); is calculated with the formula given in Equation 8 using the Number of Employees (NOE), Working Days Per Year (WDY), Total Loss of Working Days (TLWD) and Loss of Working Days Due to Occupational Accidents (LWDOA) parameters. As a result of this calculation, the number of days lost due to work accidents is determined for each thousand working days. This calculation method, which is normally applied to enterprises totally, is applied separately, assuming that

each department is independent of the proposed method. After calculating the ASR values of each section, the relative ASR weights for each section are determined by Equation 9 (Soltanzadeh et.al., 2016).

$$ASR_i = \frac{LWDOA_i}{[(NOE_i * WDY_i) - TLWD_i]} * 1000 \tag{8}$$

$$ASR_i = \frac{ASR_i}{\sum_{i=1}^n ASR_i} \tag{9}$$

2.4. Calculation of Average Costs Per Occupational Accident

The costs of occupational health and safety practices are not considered in general judgment since life safety is in question. However, each occupational accident has indirect costs such as labor losses, work stopped until safety is achieved, and equipment damage. These costs affect the tolerability of existing risks. For this reason, in this step, unit costs of occupational accidents occurring in each department are included in the system. Average Cost per Occupational Accident (ACOA) values are determined for each department, as given in Equation 10, using the Number of Occupational Accidents (NOA) and Total Cost of Occupational Accident (TCOA) parameters. Then the relative weights are obtained by applying Equation 11.

$$ACOA_i = \frac{TCOA_i}{NOA_i} \tag{10}$$

$$ACOA_i = \frac{ACOA_i}{\sum_{i=1}^n ACOA_i} \tag{11}$$

2.5. Determining the Risk Priorities of the Departments

The parameters table (Table 2) is created in order to create the decision matrix in the classical TOPSIS method to be applied using the data obtained up to this step.

Table 2. Parameters Table for Decision Matrix

W_i	W_{RP}	W_{AFR}	W_{ASR}	W_{ACOA}
D_i	RP_i	AFR_i	ASR_i	$ACOA_i$
D_1	RP_1	AFR_1	ASR_1	$ACOA_1$
D_2	RP_2	AFR_2	ASR_2	$ACOA_2$
D_3	RP_3	AFR_3	ASR_3	$ACOA_3$
...
D_n	RP_n	AFR_n	ASR_n	$ACOA_n$

In Table 2, D_i refers to departments and W_i refers to parameter weights to be used in the next steps. The data in the shaded area in the table are placed in the matrix in the order in which they are found. The generated decision matrix is normalized using Equation 12 (Zulqarnain et.al., 2020.).

$$X_{ij} = \frac{x_{ij}}{\sum_{i=1}^n x_{ij}^2} \tag{12}$$

After the decision matrix is normalized, it is weighted by applying Equation 13 with parameter weights (Pavic and Novoselac, 2013).

$$V_{ij} = X_{ij} * W_j \tag{13}$$

The ideal solutions for each parameter column in the weighted normalized decision matrix are determined using Equations 14 and 15. Since the proposed method is based on risk prioritization and all parameters have a positive effect on risk formation, the ideal solution of all parameters is determined as maximum values (Papathanasiou and Ploskas, 2018).

$$V_i^+ = \max, V_{ij} \tag{14}$$

$$V_i^- = \min, V_{ij} \tag{15}$$

The distances to the ideal and negative ideal points are calculated by applying the “Euclidean Distance Formulas” given in Equations 16 and 17 (Sa, 2013).

$$S_i^+ = [\sum_{j=1}^n (V_{ij} - V_j^+)^2]^{1/2} \tag{16}$$

$$S_i^- = [\sum_{j=1}^n (V_{ij} - V_j^-)^2]^{1/2} \tag{17}$$

After determining the distances to the ideal points, Equation 18 is applied to calculate the Risk Priority Level (RPL) for each department (Hwang and Yoon, 1981). The linguistic scale corresponding to the score ranges are given in Table 3.

$$RPL_i = \frac{S_i^-}{S_i^+ + S_i^-} \tag{18}$$

Table 3. Linguistic Scale of the Risk Priority Level

0,80 ≤ RPL _i	Very High	VH
0,60 ≤ RPL _i < 0,80	High	H
0,40 ≤ RPL _i < 0,60	Middle	M
0,20 ≤ RPL _i < 0,40	Low	L
RPL _i < 0,20	Very Low	VL

2.6. Creating the Risk Maps According to the Duration

In this step, risk maps are created on the graphs in the Microsoft Excel program by using the Total Working Days (TWD) of the departments and the calculated risk priority levels of the departments. Equations 19 and 20 are used to calculate the "Duration (D)" parameter. In this direction, interpretations can be made regarding the total risk levels of the enterprises according to the total areas covered by the risk levels in the entire enterprise.

$$TWD_i = (NOE * WDY) - TLWD \tag{19}$$

$$D_i = \frac{TWD_i}{\sum_{i=1}^n TWD_i} \tag{20}$$

3. Application

In an enterprise consisting of 5 departments, for each department Number of Employees (NOE), Total Loss of Working Days (TLWD), Number of Occupational Accidents (NOA), Loss of Working Days Due to Occupational Accidents (LWDOA) and Total Cost of Occupational Accident (TCOA) parameters were determined. In addition, it is known that there are 365 days of work in a year in this enterprise and the normal working time of an employee is 7.5 hours in a day. The data are given in Table 4.

Table 4. Application Data

	NOE	TLWD	NOA	LWDOA	TCOA
A	297	40618	67	396	17240
B	301	39221	91	272	14520
C	186	29940	34	162	4260
D	144	22213	29	102	2750
E	72	10724	18	28	690

3.1. Weighting of Risk Potentials

In order to identify risk potentials, a comparison matrix based on pairwise comparison was created with expert evaluations as given in Equation 1. The created binary comparison matrix is given in Table 5. Then, by applying Equations 2, 3, 4 and 5, the relative weights given in Table 6 expressing the risk potentials were obtained.

Table 5. Comparison Matrix

	A			B			C			D			E		
A	1,00	1,00	1,00	1,00	3,00	5,00	3,00	5,00	7,00	3,00	5,00	7,00	7,00	9,00	9,00
B	0,20	0,33	1,00	1,00	1,00	1,00	1,00	3,00	5,00	1,00	3,00	5,00	3,00	5,00	7,00
C	0,14	0,20	0,33	0,20	0,33	1,00	1,00	1,00	1,00	1,00	1,00	3,00	1,00	3,00	5,00
D	0,14	0,20	0,33	0,20	0,33	1,00	0,33	1,00	1,00	1,00	1,00	1,00	1,00	1,00	3,00
E	0,11	0,11	0,14	0,14	0,20	0,33	0,20	0,33	1,00	0,33	1,00	1,00	1,00	1,00	1,00

Table 6. Weighted Risk Potentials

				w_i	RP_i
w_A	0,22	0,52	1,08	0,61	0,48
w_B	0,09	0,24	0,65	0,33	0,26
w_C	0,05	0,10	0,32	0,16	0,12
w_D	0,04	0,08	0,23	0,12	0,09
w_E	0,02	0,05	0,13	0,07	0,05

3.2. Calculation of Accident Frequency Rates

The accident frequency rates were obtained by applying Equations 6 and 7 for each department. The relative accident frequency rates obtained are given in Table 7.

Table 7. Accident Frequency Rates

	NOE	WDY	WHD	TLWD	NOA	AFR	Relative AFR
A	297	365	7,5	40618	67	131,79	0,19
B	301	365	7,5	39221	91	171,75	0,24
C	186	365	7,5	29940	34	119,46	0,17
D	144	365	7,5	22213	29	127,42	0,18
E	72	365	7,5	10724	18	154,28	0,22

3.3. Calculation of Accident Severity Rates

The accident severity rates were obtained by applying Equations 8 and 9 for each department. The relative accident severity rates obtained are given in Table 8.

Table 8. Accident Severity Rates

	NOE	WDY	TLWD	LWDOA	ASR	Relative ASR
A	297	365	40618	288	4,25	0,27
B	301	365	39221	252	3,57	0,23
C	186	365	29940	122	3,21	0,21
D	144	365	22213	82	2,70	0,17
E	72	365	10724	28	1,80	0,12

3.4. Calculation of Average Costs Per Occupational Accident

In this step, average costs per occupational accidents occurring in each department are calculated by applying Equations 10 and 11. Relative weights are given in Table 9.

Table 9. Average Costs Per Occupational Accident

	NOA	TCOA	ACOA	Relative ACOA
A	67	17240	257,31	0,38
B	91	14520	159,56	0,24
C	34	4260	125,29	0,19
D	29	2750	94,83	0,14
E	18	690	38,33	0,06

3.5. Determining the Risk Priorities of the Departments

By using the data obtained up to this step, the decision matrix in the TOPSIS method to be applied for risk prioritization was created. Parameter weights were determined as 0.30 for Risk Potential (RP), 0.25 for Accident Frequency Rate (AFR) and Accident Severity Rate (ASR), and 0.20 for Average Cost of Occupational Accidents (ACOA). The Parameters Table for Decision Matrix are given in Table 10.

Table 10. Parameters Table for Decision Matrix

W_i	0,3	0,25	0,25	0,2
	RP	AFR	ASR	ACOA
A	0,48	0,19	0,27	0,38
B	0,26	0,24	0,23	0,24
C	0,12	0,17	0,21	0,19
D	0,09	0,18	0,17	0,14
E	0,05	0,22	0,12	0,06

The created decision matrix was normalized using Equation 12. The normalized decision matrix is given in Table 11. Then, the weighted normalized decision matrix was obtained by using Equation 13 with parameter weights and given in Table 12.

Table 11. Normalized Decision Matrix

	RP	AFR	ASR	ACOA
A	0,84	0,41	0,59	0,75
B	0,45	0,54	0,50	0,46
C	0,22	0,38	0,45	0,37
D	0,16	0,40	0,38	0,28
E	0,09	0,49	0,25	0,11

Table 12. Weighted Normalized Decision Matrix

	RP	AFR	ASR	ACOA
A	0,25	0,10	0,15	0,15
B	0,14	0,13	0,12	0,09
C	0,07	0,09	0,11	0,07
D	0,05	0,10	0,09	0,06
E	0,03	0,12	0,06	0,02

Positive and negative ideal solution points were determined by applying Equations 14 and 15 to the data in the weighted normalized decision matrix. Ideal solution points are given in Table 13.

Table 13. Ideal Solution Points

V⁺	0,25	0,13	0,15	0,15
V⁻	0,03	0,09	0,06	0,02

The distances to the positive and negative ideal solution points were determined by applying the Euclidean distance formulas in Equations 16 and 17 for each department. Then, the risk priority levels were calculated by applying Equation 18 and given in Table 14.

Table 14. Risk Priority Levels

	S_i⁺	S_i⁻	RPL_i
A	0,03	0,27	0,90
B	0,13	0,15	0,53
C	0,21	0,08	0,27
D	0,23	0,05	0,18
E	0,27	0,03	0,09

To create the graphs, firstly, the duration parameter was calculated using Equations 19 and 20 and given in Table 15.

Table 15. Durations

	NOE	WDY	TLWD	TWD	D
A	297	365	40618	67787	0,30
B	301	365	39221	70644	0,32
C	186	365	29940	37950	0,17
D	144	365	22213	30347	0,14
E	72	365	10724	15556	0,07

Coloured linguistic terms corresponding to risk priorities by durations are given in Table 16. In Table 17, the areas covered by each priority statement as a whole are determined.

Table 16. Coloured Linguistic Terms

	D	RPL	
A	0,30	0,90	VH
B	0,32	0,53	M
C	0,17	0,27	L
D	0,14	0,18	VL
E	0,07	0,09	VL

Table 17. Covered Areas by the Priority Levels

VH	0,30
H	0
M	0,32
L	0,17
VL	0,21

In the last step, based on the data in Table 16, a pie chart was created according to the durations and the risk priority levels covered by each department and given in Figure 2. Then, “*The Total Risk Priority Level Map*” was created with the data in Table 17 and given in Figure 3.

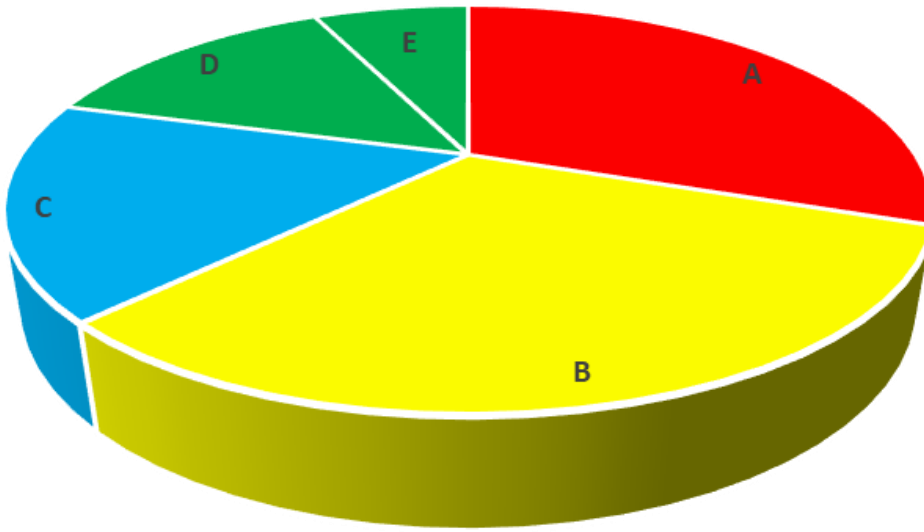


Figure 2. Interdepartmental Risk Priority Levels Diagram

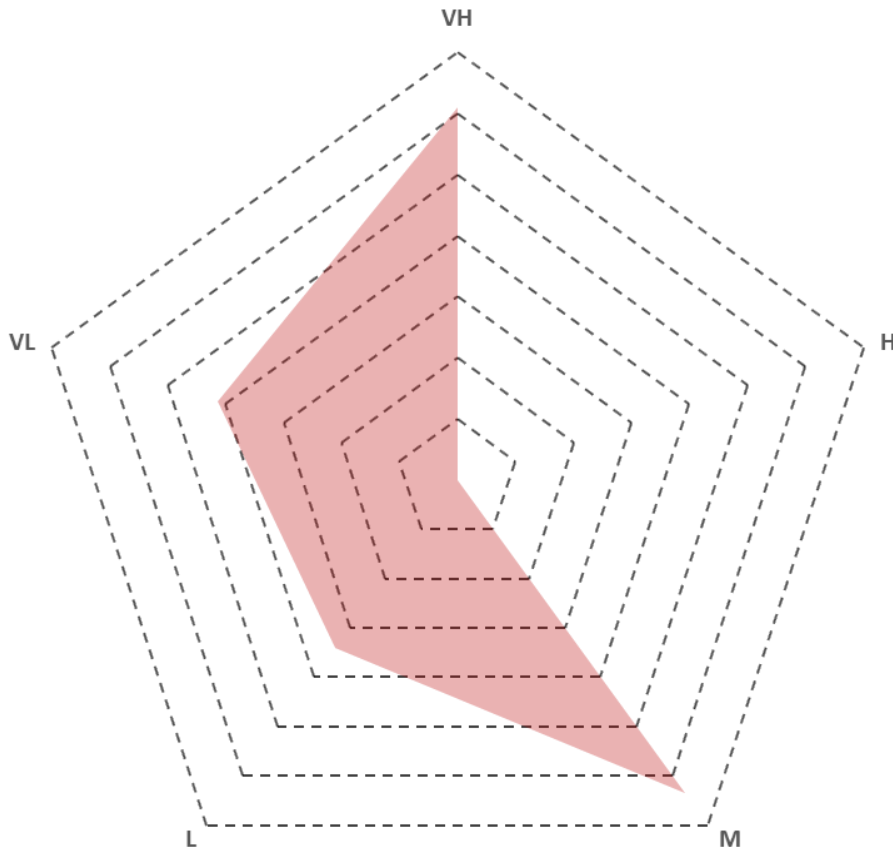


Figure 3. Total Risk Priority Levels Map

4. Conclusion

In this study, in which the economic negative effects of occupational accidents on businesses are discussed and the magnitude of risks is characterized from this point of view, a new analysis model has been proposed in the literature.

Conventional risk analyses focus on the probability of an occupational accident risk occurring and, in case of realization, the extent of damage to the employee, or in other words, its severity. The financial risks of occupational accidents to the business are directly proportional to the damage to the employee. Therefore, it can also be a reference for classical risk analysis applications.

When only the effect of occupational accidents on the employee is considered, all indirect costs as a result of the accident are neglected. In addition, accidents that do not harm the employee and are described as near misses in the literature often cause material damage when they occur. However, the harm not done to the employee is always neglected in classical analysis. Considering work accidents only as a cost will not reflect the safety risk analysis correctly.

The proposed model offers a comprehensive analysis of both occupational safety and operating costs by combining the risk potential in the working environment, occupational accidents occurring in a certain time period, the labor lost due to these accidents and the unit costs of the accidents. The costs that will occur depend on the realization of work accidents and the magnitude of the violence is explained by the economic effect. When businesses apply the proposed model, they will be able to determine both the risk of an occupational accident and the financial burden it will create in case it occurs.

Considering that occupational accidents have not only social but also economic effects, it is more appropriate to describe them as a socio-economic problem. As with all other analysis techniques, analyzing only financial or only safety risks does not provide an assessment of the entire enterprise. Since the proposed analysis model deals with these two parameters in relation, it is thought to fill an important gap in the literature. In addition, since the scope of the analysis can be expanded by adding different parameters, it will be an important reference for future studies.

References

- Aritan, A. E., & Ataman, M. (2017). Kaza Oranları Hesaplamalarıyla İş Kazası Analizi. *Afyon Kocatepe Üniversitesi Fen ve Mühendislik Bilimleri Dergisi*, 17(1), 239-246.
- Bekar, İ., Oruç, D. & Bekar, E. (2017). İş Kazası ve Meslek Hastalıklarının Maliyeti (2005-2014). *Uluslararası Ekonomik Araştırmalar Dergisi*, 3(3), 479-489.
- Boyle, T. (2002). *Health and Safety: Risk Management*. Taylor and Francis Group. London.
- Buckley, J. J. (1985). Ranking Alternatives Using Fuzzy Numbers. *Fuzzy Sets Systems*, 15(1), 21-31.
- Ceylan, H. (2011). Türkiye'deki İş Kazalarının Genel Görünümü ve Gelişmiş Ülkelerle Kıyaslanması. *International Journal of Engineering Research and Development*, 3(2), 18-24.
- Chen, S. J. & Hwang, C. L. (1992). *Lecture Notes in Economics and Mathematical Systems: Fuzzy Multi Attribute Decision Making: Methods and Applications*. Springer-Verlag. New York.
- Cınar, U. & Cebi, S. (2020). A Hybrid Risk Assessment Method for Mining Sector Based on QFD, Fuzzy Inference System, and AHP. *Journal of Intelligent & Fuzzy Systems*, 39(5), 6047-6058.
- Cınar, U. & Cebi, S. (2022). A Novel Approach to Assess Occupational Risks and Prevention of Hazards: The House of Safety & Prevention. *Journal of Intelligent & Fuzzy Systems*, 42(1), 517-528.
- Cınar, U. & Ugurlu, O. M. (2019). Cost Optimization of Risk Evaluation of Occupational Safety Risks. *International Symposium On Occupational Health And Safety In Mining Proceeding Book*. 17-27.
- Güllüoğlu, E. N. & Taçgın, E. (2018). Türkiye Tekstil Sektöründe İstihdam ve İş Kazalarının Analizi. *Tekstil ve Mühendis*, 25(112), 344-354.

- Hsieh, T. Y., Lu, S. T. & Tzeng, G. T. (2004). Fuzzy MCDM Approach for Planning and Design Tenders Selection in Public Office Buildings. *International Journal of Project Management*, 22, 573–584.
- Hwang, C. L., & Yoon, K. (1981). *Multiple Attribute Decision Making: Methods and Applications*. Springer. Berlin.
- ILO (1983). *Encyclopaedia of Occupational Safety and Health*. Geneva.
- Karamik, S. & Seker, U. (2016). İşletmelerde İş Güvenliğinin Verimlilik Üzerine Etkilerinin Değerlendirilmesi. *Gazi University Journal of Science Part C: Design and Technology*, 3(4), 575-584 .
- Özkılıç, Ö. (2005). *İş Sağlığı ve Güvenliği, Yönetim Sistemleri ve Risk Değerlendirme Metodolojileri*. TİSK Yayınları, İstanbul.
- Papathanasiou, J., & Ploskas, N. (2018). *Topsis. In Multiple Criteria Decision Aid* . Springer, Cham.
- Pavić, Z., & Novoselac, V. (2013). Notes on TOPSIS method. *Int. J. Res. Eng. Sci*, 1(2), 5-12.
- Rikhardsson, P. M. (2004). Accounting for the Cost of Occupational Accidents. *Corporate Social Responsibility and Environmental Management*, 11(2), 63-70.
- Sa, W. (2013). The Mean Error Estimation of TOPSIS Method Using a Fuzzy Reference Models, *J. Theor. Appl. Comput. Sci*, 7(3), 40–50.
- Soltanzadeh, A., Mohammadfam, I., Moghimbeigi, A., Akbarzadeh, M., & Ghiasvand, R. (2016). Key Factors Contributing to Accident Severity Rate in Construction Industry in Iran: A Regression Modelling Approach. *Arhiv Za Higijenu Rada I Toksikologiju*, 67(1), 47-53.
- Ucan, R. & Ucan, A. (2021). *Örneklerle İş Kazalarının İşverene Maliyeti*. Efe Akademi Yayınları. İstanbul
- Unsar, A. S. (2004). İş Kazaları ve Örgütsel Verimlilik. *Verimlilik Dergisi*. 3, 89-101.
- Zulqarnain, R. M., Saeed, M., Ahmad, N., Dayan, F., & Ahmad, B. (2020). Application of TOPSIS method for decision making. *International Journal of Scientific Research in Mathematical and Statistical Sciences*, 7(2), 76-81.

Arastırma Makalesi

A New Risk Analysis Model Proposal for Determining the Economic Effects of Occupational Accidents on Businesses

İş Kazalarının İşletmelere Olan Ekonomik Etkilerinin Tespitine Yönelik Yeni Bir Risk Analiz Modeli Önerisi

ULAS CINAR

Dr., Canakkale Onsekiz Mart University

Occupational Health and Safety Education Application and Research Center

ulas.cinar@comu.edu.tr

<https://orcid.org/0000-0003-3924-0768>

Geniş Özet

İş kazaları, etkileri açısından küresel bir sorundur. Dünya Çalışma Örgütü, iş kazasını “belirli bir zarara veya yaralanmaya neden olan, planlanmamış, beklenmeyen bir olay” olarak tanımlamaktadır (ILO, 1983). Dünya çapındaki can kayıplarının yanı sıra iş kazaları ve meslek hastalıkları nedeniyle tüm maddi kaynakların yaklaşık %4'ünün kaybolduğu tahmin edilmektedir. Kaydedilen veriler doğrultusunda ülkemiz iş kazaları açısından dünyada 3., Avrupa'da 1. sırada yer almaktadır. İş kazaları öncelikle çalışanı ve ilişkilerini etkiler. İnsana verdiği zarar doğal olarak ekonomik faktörlerin çok önündedir. Bu durum çoğu zaman iş kazalarının işletmeye olan maliyetlerinin gerçek değerlerinin hesaplanmasını engellemektedir. İş kazaları, işletmelere büyük maliyetlere neden olan ve dolayısıyla ülkelerin ekonomik parametrelerini olumsuz etkileyen önemli bir sosyoekonomik sorundur. İş kazalarını önlemek amacıyla iş sağlığı ve güvenliği risk analizleri proaktif olarak yapılmakta ancak klasik uygulamalarda prensip olarak iş kazalarının maliyetleri analizlere dahil edilmemektedir. Bu çalışmanın amacı, iş kazalarının işletmelere maliyeti ve etkileyen faktörler dikkate alınarak iş kazası risklerinin büyüklüğünü sosyoekonomik açıdan ortaya koymaktır. Bu doğrultuda literatürde iş kazalarının ekonomik etkilerini belirleyen parametreler ile klasik risk değerlendirme ilkelerini birleştiren bir risk değerlendirme modeli önerilmiştir.

Önerilen model, "Risk Potansiyeli", "Kaza Sıklık Oranı", "Kaza Ağırlık Oranı" ve "İş Kazası Başına Ortalama Maliyet" parametrelerini kullanarak bölümlerin risk önceliklerini TOPSIS yöntemi ile belirlemeyi amaçlar. Bu doğrultuda önerilen yöntem, departman faaliyetlerinin toplam iş akışı içerisinde kapsadığı alana göre bir risk haritası oluşturmaktadır. "Risk Potansiyeli" parametresinin değerlendirilmesinde uzman kararları etkili olduğu için sübjektifliği en aza indirmek adına bulanık bir yaklaşım tercih edilmiştir. Uygulanan diğer yöntemler, uzman kararlarından bağımsız hesaplamalardır. Modelin ilk adımında departmanlar risk potansiyellerine göre birbirleriyle karşılaştırılır. Bu karşılaştırmada departmanda yürütülen faaliyetlerin risk faktörleri ön planda tutulmaktadır. Bu adım, uzman değerlendirmelerinin etkili olduğu tek aşamadır. Analizler için bulanık analitik hiyerarşi prosesinin ilişkilendirme ve yöntem adımları uygulanır. İkinci adımda her bir departman için kaza sıklık oranları belirlenir. Hesaplamalar sonucunda her bir departmanda bir milyon çalışma saatinde kaç iş kazası gerçekleştiği belirlenir. Üçüncü adımda her bir departman için kaza ağırlık oranları belirlenir. Hesaplamalar sonucunda her bir departmanda bin çalışma gününde iş kazaları nedeniyle kaç günlük iş günü kaybının olduğu belirlenir. Dördüncü adımda, iş kazası başına işletmeye olan maliyetler her bir departman için hesaplanır. Tüm elde edilen veriler için ağırlıklar belirlenerek çok kriterli karar verme tekniklerinden TOPSIS yönteminin adımları uygulanır ve her bir departmanın risk düzeyleri belirlenir. Belirlenen risk skorlarına göre departmanlar arası risk haritaları oluşturur. Önerilen analiz modeli için örnek bir uygulama gerçekleştirilerek yöntemin adımları test edilmiştir.

İş kazalarının işletmeler üzerindeki ekonomik olumsuz etkilerinin ele alındığı ve risk büyüklüklerinin bu bakış açısıyla karakterize edildiği bu çalışma ile literatüre yeni bir analiz modeli önerilmiştir. Konvansiyonel risk analizleri, bir iş kazası riskinin meydana gelme olasılığına ve gerçekleşmesi durumunda çalışanın uğradığı zararın boyutuna, yani şiddetine odaklanır. İş kazalarının işletmeye olan finansal riskleri, çalışana verdiği zararla doğru orantılıdır. Bu nedenle klasik risk analizi uygulamaları için de referans olabilir. Sadece iş kazalarının çalışan üzerindeki etkisi düşünüldüğünde, kaza sonucu oluşan tüm dolaylı maliyetler ihmal edilmektedir. Ayrıca çalışana zarar vermeyen ve literatürde ramak kala olarak nitelendirilen kazalar meydana geldiklerinde sıklıkla maddi hasara yol açmaktadır. Ancak klasik analizde çalışana verilmeyen zarar her zaman göz ardı edilir.

İş kazalarını sadece bir maliyet olarak değerlendirmek risk analizini doğru bir şekilde yansıtmaz. Önerilen model, çalışma ortamındaki risk potansiyeli, belirli bir zaman diliminde meydana gelen iş kazaları, bu kazalar nedeniyle kaybedilen işgücü ve kazaların birim maliyetlerini birleştirerek hem iş güvenliği hem de işletme maliyetleri için kapsamlı bir analiz sunmaktadır. Oluşacak maliyetler iş kazalarının gerçekleşmesine bağlıdır ve şiddetin büyüklüğü ekonomik etkisiyle açıklanmaktadır. İşletmeler önerilen modeli uyguladıkları zaman hem iş kazası riskini hem de meydana gelmesi durumunda yaratacağı mali yükü belirleyebileceklerdir. İş kazalarının sadece sosyal değil ekonomik etkilerinin de olduğu düşünüldüğünde, onları sosyoekonomik bir sorun olarak tanımlamak daha doğru olacaktır. Diğer tüm analiz tekniklerinde olduğu gibi, sadece finansal veya sadece güvenlik risklerinin analiz edilmesi, işletmenin tamamının değerlendirilmesini sağlamaz. Önerilen analiz modelinin bu iki parametreyi ilişkili olarak ele alması nedeniyle literatürdeki önemli bir boşluğu dolduracağı düşünülmektedir. Ayrıca farklı parametreler eklenerek analizin kapsamı genişletilebileceğinden sonraki çalışmalar için önemli bir referans olacaktır.