

RESEARCH ARTICLE

A regional perspective for work accidents: Evaluating the amount of work accidents on a city basis by the help of multi-criteria decision-making methods

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Abstract

Occupational accidents have become a globalized problem not only in certain countries but also all over the world. The structure of the construction sector developing in integration with technological change shaped by the necessity of meeting the human needs reaching serious dimensions emerges as a result of globalization and for this reason, it makes occupational health measures more important every passing day. Thus, the construction sector which is the leading sector with regards to the cause of occupational accidents, needs the required field works and academic studies in order to take indispensable measures and precautions in terms of occupational health and safety culture and discipline. In this study, it is aimed to evaluate the trends of occupational accidents on city basis and to obtain risk ranking. In this direction, the contributions of cities to occupational accidents have been evaluated by multi-criteria decision-making methods, which cities required the most measures in terms of occupational health and safety (OHS) have been determined and the data have been evaluated specific to the construction industry. ENTROPY weighting method has been used to determine the significance of interaction between years and occupational accident years. According to the results of PROMETHEE II, GRA and OCRA MCDM (Multi Criteria Decision Making) methods, the cities where occupational accidents are of the highest importance have been identified as Istanbul, Izmir and Ankara, respectively.

Keywords

OHS (Occupational Health and Safety); Occupational accident; MCDM (Multi Criteria Decision Making), Construction management; PROMETHEE, OCRA

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1. Introduction

Occupational accidents affecting many stakeholders, primarily the individual who had an work accident, in terms of material and moral consequences [1] ensue in major human and economic damage such as occupational disease, labour force loss, and productivity reduction [2].

From a firm perspective, it can also have a great impact on competitiveness and the reputation of firms [3]. The fact that the construction sector, which is in a very important position in terms of staffing despite being one of the most dangerous fields of employment worldwide [4,5] and labour force potential in the world [6], having momentous risks in terms of working conditions [7] entails the

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necessity of applying OHS measures sensitively since the increase in the number of employees in the construction sector affects the increase in the number of injuries and deaths due to occupational accidents [8]. Worldwide, an average of 1.2 million people die each year due to occupational accidents [9]. Occupational accidents, which account for over 6000 deaths every day, affect the lives of approximately 2.3 million individuals worldwide [10]. Social Security institutions of the Republic of Turkey [11] refers that 1 out of every 5 occupational accidents (20%) occurs in the construction sector and the construction sector causes about 37% fatal occupational accidents. The construction sector classified as a high-risk industry [12,13] due to its high burden of occupational dangers [14] and decentralised structure [15] is a priority in matters give rise to fatal occupational accidents than other sectors [16]. The unparalleled turnout structure and dynamics of the sector adversely influence the OHS performance of the construction sector recognisedly [17]. Construction workers are 3 to 4 times more likely to encounter occupational accidents compared to other sector workers [18]. In addition, occupational safety is understood to be of critical importance, considering the construction sector range (tunnels, dams, viaducts, buildings, etc.), the necessity of production in all seasons, and the excess of non-institutionalized construction companies which generally carry on a business in the form of subcontractors [7]. This situation necessitates the evaluation of occupational accidents and suggestions for suitable solutions corresponding specific to construction sector's characteristics. Considering the literature studies conducted to evaluate work accidents' causes, work accidents depend on many factors such as employment rates in terms of gender and various age groups in employment [19], employee status (migrant, local) [20], object impact and equipment related accident [21] etc. In addition, along with the studies in which the general international causes of work accidents are determined, there are also studies in which work accidents are analysed on a country basis, for example [22-25]. City-based

evaluation shows the perspective considered in this study. The use of multi-criteria decision-making methods for the analysis of occupational accidents and the sectoral evaluation of the accidents are the motivation sources of the study that addresses the gap in the literature. In the light of those mentioned, the main purpose of this study is the determination of work accident trends on city basis and to rank the work accident risk of cities.

2. Methodology

Studies on work accidents mainly focus on accident causes, accident statistics and accident prevention policies [26]. The fact that occupational accidents occur in many sectors, requires determining the trend of the occupational accident data group and evaluating it on the basis of each sectors. When the accidents are concentrated in a specific sector, it is necessary to manage this industry with more focus [27] and to take appropriate measures for the sector's dynamics. For this reason, the main motivation of this study is to make a city-based work accident evaluation after the compiled work accident data is evaluated by MCDM methods. Brief research framework can be summarised as follows.

- Step 1. Gather the data between 2014-2019 from the Turkish Republic Social Security Institution.
- Step 2. Form the decision matrix.
- Step 3. Obtain the weight of the criteria by ENTROPY MCDM Method.
- Step 4. Apply the OCRA, PROMETHEE and GRA MCDM Methods to the problem.
- Step 5. Rank the cities and compare the results.

In the light of data collected from the Turkish Republic Social Security Institution, the proportional distribution of provinces that cause occupational accidents in 2018-2019 cumulatively is shown in Fig. 1, and the amount of occupational accidents in 7 provinces that cause the highest number of occupational accidents in this proportional distribution is shown in Fig. 2, respectively.

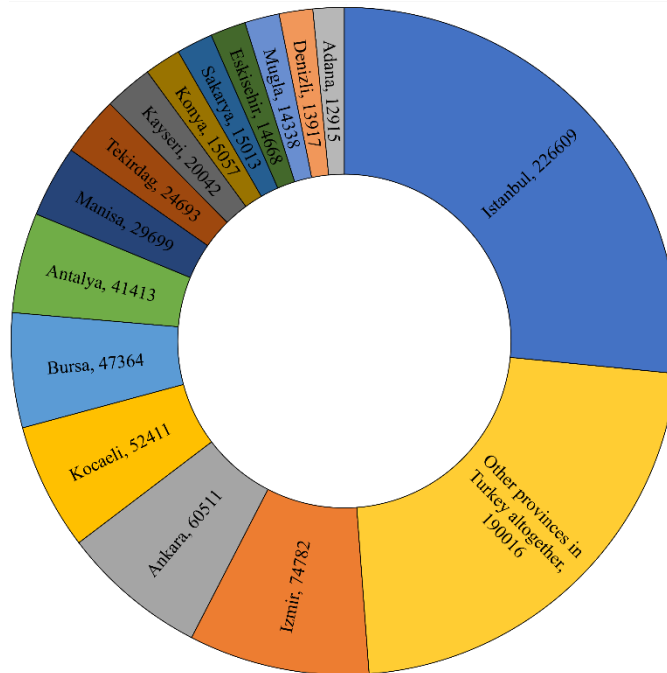


Fig. 1. The Cumulative Total Amount of Work Accidents in Turkey Between the Years 2018-2019 by Provinces

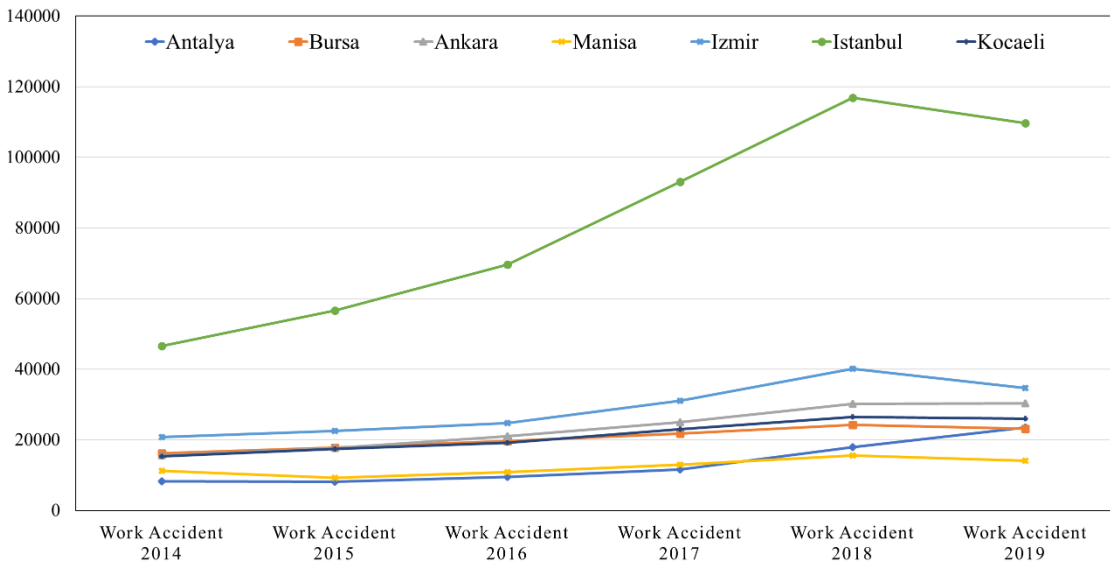


Fig. 2. The amount of occupational accidents by cities and years in 2014-2019

As can be seen in Fig. 1, the provinces with the highest cumulative contribution to occupational accidents amongst 81 provinces in Turkey in 2018-2019 are Istanbul, Izmir, Ankara, Kocaeli, Bursa,

Antalya and Manisa, respectively. In addition, in terms of percentage, among all provinces, Istanbul has 27%, Izmir 9%, Ankara 7%, Kocaeli and Bursa 6%, Antalya 5% and Manisa 3% work accident rate.

While Istanbul provides the largest contribution in terms of the amount of accidents, it is summarized in Fig. 2 that other cities have encountered an average of 15.000-25.0000 occupational accidents per year. Cumulative evaluation of the data may cause scientific deficiencies. Evaluating the contributions to the work accident as performance over the years and obtaining the risk ranking will make a great contribution to the literature in order to produce solutions in a regional sense in terms of OHS measures. In this direction, the application of MCDM methods to OHS problems adds originality to the literature not only by looking at the amount of accidents in recent years, but also by determining the purpose of producing a compromised solution that includes all years in the solution process. The purpose of multi-criteria decision-making problems is to determine the best alternative and rank all of the alternatives but the issue to be solved in this study is occupational accidents. Therefore, the worst alternative objectively determined should be interpreted as the alternative that poses the greatest risk in terms of contribution to the work accident. In studies where independent variables such as the number of occupational accidents occurring over the years are accepted as criteria, the use of methods that allow the analysis of independent alternatives of multi-criteria decision-making methods will ensure that the solution of the problem is consistent. As a result, in this study, occupational accident performances of provinces over the years have been examined comparatively using OCRA, GRA and PROMETHEE II MCDM methods.

2.1. The OCRA (Operational Competitiveness Rating) method

The OCRA method, which is one of the methods used in this study which aims to determine the occupational safety performance on the basis of cities by years' interaction is a multi-criteria decision making method developed for solving performance and efficiency analysis problems [28]. Although it is not a frequently used MCDM method [29], it has yielded successful results in selection problems, performance and efficiency analysis [30]. The opportunity to make independent

evaluation of alternatives [31] is another issue in its application to the problem mentioned in this study. The procedures of the OCRA method are listed as follows [31,32].

Step 1. Determine the initial decision matrix, X.

$$X = [X_{ij}]_{m \times n} = \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ \dots & \dots & \dots & \dots \\ x_{m1} & x_{m2} & \dots & x_{mn} \end{bmatrix} \quad (1)$$

Step 2. The aggregate performance of each alternative with respect to all non-beneficial criteria and beneficial criteria are calculated.

$$\bar{I}_i = \sum_{k=1}^q w_k \frac{\max(x_i^k) - x_i^k}{\min(x_i^k)}; (i=1,2,\dots,m) \quad (2)$$

$$\bar{O}_i = \sum_{h=1}^b w_h \frac{x_i^h - \min(x_i^h)}{\max(x_i^h)}; (i=1,2,\dots,m) \quad (3)$$

where,

q: The number of non-beneficial criteria,

\bar{I}_i : The measure of the relative performance of i-th alternative for non-beneficial criteria

x_i^k : The performance score of i-th alternative with respect to k-th criterion

w_k : Weight of the k-th non-beneficial criterion.

b: The number of beneficial criteria,

\bar{O}_i : The measure of the relative performance of i-th alternative for beneficial criteria

w_h : Weight of the h-th beneficial criterion.

Step 3. Determine the linear preference rating for beneficial and non-beneficial criteria

$$\bar{\bar{I}}_i = \bar{I}_i - \min(\bar{I}_i) \quad (4)$$

$$\bar{\bar{O}}_i = \bar{O}_i - \min(\bar{O}_i) \quad (5)$$

Step 4. Calculate overall preference ratings of competitive alternatives

$$P_i = \bar{\bar{I}}_i + \bar{\bar{O}}_i - \min(\bar{\bar{I}}_i + \bar{\bar{O}}_i) \quad (6)$$

2.2. The GRA (Grey Ratio Analysis) method

GRA method being one of the most popular methods used to analyse various relationships between discrete data sets and make decisions in

multiple attribute situations [33], also which is a classification, rating and decision-making technique, developed by J. Deng in 1982 [34] and has been successfully applied in the solution of many multi-criteria decision making problems [35-41]. In addition, [42] used the GRA method for prioritizing the cities in Turkey according to facility location and [38] used to measure occupational health and safety performance. One of the reasons for using the GRA method in this study is that the GRA method takes into account the correlation between the alternative and the ideal alternative in order to create alternative sequences [43] by using existing data [44], since the correlation between years of work accident and the choice of the alternative taking this correlation into account is very essential. The ranking procedure of this method can be summarized by the following steps [45,46].

Step 1. Determine the initial decision matrix, develop normalised decision matrix by normalized value r_{ij}

$$r_{ij} = \frac{x_{ij}}{\max(x_{ij})} ; i=1,2,\dots,m, j=1,2,\dots,n \quad (7)$$

(For beneficial criteria)

$$r_{ij} = \frac{\min(x_{ij})}{x_{ij}} ; i=1,2,\dots,m, j=1,2,\dots,n \quad (8)$$

(For non-beneficial criteria)

Step 2. Identify the reference series R_0 and form the distance matrix

$$R_0 = r_{01}, r_{02}, \dots, r_{0n} \quad (9)$$

$$\delta_{ij} = r_{0j} - r_{ij} \quad (10)$$

where

$$r_{0j} = \max_j r_{ij} , j=1,2,\dots,n$$

The distance matrix Δ can be formed as:

$$\Delta = \begin{bmatrix} \delta_{11} & \delta_{12} & \dots & \delta_{1n} \\ \delta_{21} & \delta_{22} & \dots & \delta_{2n} \\ \dots & \dots & \dots & \dots \\ \delta_{m1} & \delta_{m2} & \dots & \delta_{mn} \end{bmatrix} \quad (11)$$

Step 3. Calculate the grey relational coefficient

$$\xi_{ij} = \frac{\delta \min + \zeta \delta_{\max}}{\delta_{ij} - \zeta \delta_{\max}} , i=1,2,\dots,m; j=1,2,\dots,n \quad (12)$$

where

$\zeta \delta_{\max/\min}$: Maximum and minimum δ_{ij}

ζ : Distinguishing coefficient $0 \leq \zeta \leq 1$, usually supposed 0,5

Step 4. Estimate the grey relational grade, rank the alternatives. The bigger value is the better alternative.

$$\gamma_i = \sum_{j=1}^n w_j \xi_{ij} ; i=1,2,\dots,m \quad (13)$$

Where w_j is the weight of the j -th criterion
 $w_j \geq 0, \sum_{j=1}^n w_j = 1$

2.3. The PROMETHEE II (The Preference Ranking Organization Method for Enrichment of Evaluations II) method

PROMETHEE II, being a decision aid method based on pairwise comparisons [47] and one of the members of “The Preference Ranking Organization Method for Enrichment of Evaluations” family developed by Brans and Vincke [48,49] aims at classifying the alternatives according to the most preferred options [50] by including an indifference and a preference threshold [51]. PROMETHEE II method is generally used more than other PROMETHEE family members by researchers because it provides complete ranking [52]. In this study main approach is to consider the worst in terms of occupational accidents. Therefore, PROMETHEE II not only provides complete outranking but also helps to take into consideration the worst alternatives. A brief description of the PROMETHEE II method steps is as follows [53-55].

Step 1. Determine the initial decision matrix, develop normalised decision matrix

$$R_{ij} = \frac{x_{ij} - \min(x_{ij})}{\max(x_{ij}) - \min(x_{ij})} \quad \begin{matrix} i=1,2,\dots,m \\ j=1,2,\dots,n \end{matrix} \quad (14)$$

(For beneficial criteria)

$$R_{ij} = \frac{\max(x_{ij}) - x_{ij}}{\max(x_{ij}) - \min(x_{ij})} \quad \begin{matrix} i=1,2,\dots,m \\ j=1,2,\dots,n \end{matrix} \quad (15)$$

(For non-beneficial criteria)

Step 2. Calculate the evaluative differences for each alternative and determine the preference function. Although six types of general functions are proposed, the following function can be used to eliminate the complexity of its application to real life problems.

$$D(Ma - Mb) = R_{ija} - R_{ijb} \quad (16)$$

$$P_j(Ma, Mb) = 0 \text{ if } R_{ija} \leq R_{ijb} \quad (17)$$

$$P_j(Ma, Mb) = (R_{ija}, R_{ijb}) \text{ if } R_{ija} > R_{ijb} \quad (18)$$

Step 3. Determine the aggregated preference function, calculate the leaving (positive) and entering (negative) outranking flows

$$\pi_{Ma, Mb} = \frac{\sum_{j=1}^m w_j \times P_j(Ma, Mb)}{\sum_{j=1}^m w_j} \quad (19)$$

$$\varphi^+ = \frac{1}{n-1} \sum_{b=1}^m \pi(a, b) \quad (20)$$

$$\varphi^- = \frac{1}{n-1} \sum_{b=1}^m \pi(a, b) \quad (21)$$

where n is the number of alternatives

2.4. The ENTROPY method

The weight of selection criteria representing the relative importance of each criterion in a decision making process [56] is essential to obtain reliable results. The basic approach of the entropy algorithm is to analyse the difference between index values in the data [57]. Therefore, it is considered that relative weights to be taken from this method contributes to the solution for this study, in which the interaction between years is very fundamental. The entropy algorithm is briefly as follows [58,59].

Step 1: In the Entropy method, for each criterion in the decision matrix, the criterion must be determined as beneficial or not beneficial. The decision matrix is normalized according to the type of criteria same as Eqs. (7) and (8)

Step 2: Determine entropy level for each criterion E_j

$$E_j = -k \sum_{i=1}^m y_{ij} \ln y_{ij} \text{ and } 0 \leq E_j \leq 1 \quad (22)$$

$$\text{In which entropy index } k = \frac{1}{\ln(m)} \quad (23)$$

Step 3: The weight of the criteria is determined as follows.

$$w_j = \frac{1 - E_j}{\sum_{j=1}^n 1 - E_j} \quad (24)$$

3. Results and discussions

The data sets published by Turkish Republic Social Security Institution annually between 2014 and 2019 have been brought together and the decision matrix shown in Table 1 has been developed. Within the scope of the study, occupational accidents that occurred over the years have been accepted as criteria for each city and all criteria have been determined as "cost type" since it is expected to have less occupational accidents. Cities, on the other hand, represent alternatives in the initial decision matrix.

Weights shown in Table 2 have been determined with Entropy Method which includes the determination of interaction and relative importance between years in its algorithm that aims to solve the problems having high uncertainty and less specificity.

The weights obtained were applied as weights of the criteria in the PROMETHEE, GRA and OCRA methods. Due to the principle that the article is understandable without being too detailed, only the important solution steps in the methods used in the article are given under this heading. In addition, PROMETHEE II performance differences are given in appendix 1, preference functions in appendix 2. PROMETHEE II leaving and entering flows and final rank results are shown in Table 3.

The GRA method deviation sequences are shown in Table 4, grey relation coefficients in Table 5, grey rational grades and final ranks in Table 6, respectively.

By following the OCRA method solution steps the Table 7 is formed and final rank has been determined.

The final rankings obtained from the methods have been evaluated comparatively and are shown in figure 3.

Table 1. Initial decision matrix

Work Accident/ City	2014	2015	2016	2017	2018	2019
Antalya	8255	8100	9493	11565	17930	23483
Bursa	16133	17801	19615	21743	24289	23075
Ankara	15559	17693	21041	24970	30225	30286
Manisa	11283	9285	10869	12914	15571	14128
Izmir	20814	22572	24774	31024	40164	34618
Istanbul	46559	56623	69637	93003	116914	109695
Kocaeli	15300	17426	19185	23065	26467	25944

Table 2. Ej Results and obtained weights based on ENTROPY method

	Ej	1-Ej	Wj
2014	0,919793	0,080207	0,113734
2015	0,894287	0,105713	0,149902
2016	0,882903	0,117097	0,166044
2017	0,86282	0,13718	0,194522
2018	0,861328	0,138672	0,196638
2019	0,873653	0,126347	0,17916

Table 3. PROMETHEE II results

	Φ^+	Φ^-	$\Phi(a)$	Rank
Antalya	1,62716	0,76608	0,86108	2
Bursa	0,79341	0,24444	0,54897	4
Ankara	0,91094	0,36949	0,54145	5
Manisa	1,64105	0,01967	1,62138	1
Izmir	1,48641	1,40741	0,079	6
Istanbul	0	4,38022	-4,3802	7
Kocaeli	0,99382	0,26547	0,72835	3

Table 4. The GRA method deviation sequences

	2014	2015	2016	2017	2018	2019
Antalya	0,000	0,000	0,000	0,000	0,023	0,098
Bursa	0,206	0,200	0,168	0,125	0,086	0,094
Ankara	0,191	0,198	0,192	0,165	0,145	0,169
Manisa	0,079	0,024	0,023	0,017	0,000	0,000
Izmir	0,328	0,298	0,254	0,239	0,243	0,214
Istanbul	1,000	1,000	1,000	1,000	1,000	1,000
Kocaeli	0,184	0,192	0,161	0,141	0,108	0,124

Table 5. The GRA method grey relation coefficients

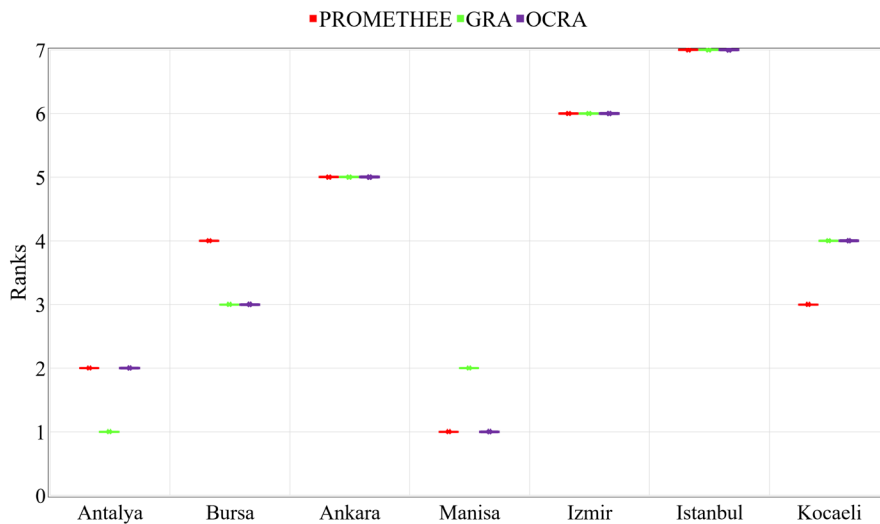
	2014	2015	2016	2017	2018	2019
Antalya	1,000	1,000	1,000	1,000	0,956	0,836
Bursa	0,709	0,714	0,748	0,800	0,853	0,842
Ankara	0,724	0,717	0,723	0,752	0,776	0,747
Manisa	0,863	0,953	0,956	0,968	1,000	1,000
Izmir	0,604	0,626	0,663	0,677	0,673	0,700
Istanbul	0,333	0,333	0,333	0,333	0,333	0,333
Kocaeli	0,731	0,722	0,756	0,780	0,823	0,802

Table 6. The GRA method grey rational grades and final rank

	Antalya	Bursa	Ankara	Manisa	Izmir	Istanbul	Kocaeli
Grey Rational Grade	0,96530	0,77777	0,73973	0,95685	0,65719	0,33333	0,76904
Rank	1	3	5	2	6	7	4

Table 7. The OCRA Method Results and Final Rank

	\bar{I}_i	$\bar{\bar{I}}_i$	\bar{o}_i	$\bar{\bar{o}}_i$	P_i	Rank
Antalya	6,190782162	6,190782162	0	0	6,190782162	2
Bursa	5,479342664	5,479342664	0	0	5,479342664	3
Ankara	5,243622414	5,243622414	0	0	5,243622414	5
Manisa	6,228799144	6,228799144	0	0	6,228799144	1
Izmir	4,733356815	4,733356815	0	0	4,733356815	6
Istanbul	0	0	0	0	0	7
Kocaeli	5,419157294	5,419157294	0	0	5,419157294	4

**Fig. 3.** Comparative results

As it is understood from Fig. 3, the rankings obtained have been calculated similar in all 3 methods. According to these results, Istanbul, which causes the highest number of occupational accidents in the cumulative sense, has been found to have the worst performance with multi-criteria decision-making algorithms. In addition, Izmir and Ankara follow Istanbul in terms of work accident risk. However, Bursa, Manisa, Kocaeli and Antalya provinces are in different ranks in the methods used. While the province of Antalya has been determined as the second least risky province in PROMETHEE and OCRA methods, it is the least risky province according to the GRA method. It is very important to use solution algorithms generating consensual solutions in the correct analysis of cities such as Manisa, which have the potential to cause variable number of accidents. Hundreds of occupational accidents caused by mine collapses in Manisa city, especially in some years, can be considered as one of the main reasons for this variability. Therefore, it can be deduced that factors such as the mining accident that occurred in Soma district of Manisa province in 2014 caused Manisa to rank in different places in methods. From the perspective of the construction sector, Manisa should be the least risky city considering the construction capacity, number of projects and labour force potential of the construction sector. However, multi-criteria decision-making methods that incorporate the effect of deviations in their algorithm show that occupational accidents in this city is least risky amongst other cities ranked. Other provinces that show variation in the ranking are Bursa and Kocaeli. Considering the construction investment data of the city of Bursa, it is more prominent than Kocaeli, and it is a city where construction projects and construction potential are higher. In addition, the share of the construction sector among the production sectors is more important in Bursa compared to Kocaeli. However, Kocaeli province, where the industry is highly developed, is a very dynamic city where the construction sector investments have increased in recent years, has a strategic position and at the same time the construction sector is in the development trend.

Considering all these issues, it is thought that the result obtained from the algorithm of PROMETHEE focusing on the preferred criteria method is more significant. It is clear that the population factor has an effect on occupational accidents because Turkey's most populated provinces which are Istanbul, Ankara, Izmir, Bursa, Antalya are in the first places amongst other cities in terms of work accidents. In this direction, considering the population, Istanbul is likely to rank first, but Ankara, with the second largest population, has been identified less risky than Izmir. Besides, although Kocaeli's population is less than Antalya, it has been determined to be riskier. Therefore, it has been concluded that different criteria rather than population affect the results. This situation is thought to be a research topic for future studies. Additionally, Istanbul, which is Turkey's construction sector locomotive, is a city suffering from occupational accidents as a result of many numbers of construction projects, construction capacity and construction labour force. Antalya, Bursa, Kocaeli, Izmir and Ankara are other important cities where the construction sector is dynamic and has an intense work potential. From this point of view, the construction building stock concentrated in these cities and hundreds of construction projects require labour and site work. Thus, the increasing number of projects and construction increase the need for workforce. This situation plays a triggering role in the increase of work accident risk. This increased risk is the primary factor in the increase of work accidents specific to construction sector in the cities evaluated in this study.

4. Conclusions

The construction sector differs from other sectors with its unique working structure, which significantly increases the risk of accidents, although occupational accidents are in a very important position in all sectors. It is obvious that construction works, which are also very risky in terms of causing death, need special precautions with regards to occupational safety climate. The main purpose of this study is evaluating the trends

of occupational accidents on city basis and to obtain risk ranking. According to the results of the study, Istanbul, Izmir, and Ankara provinces have been determined as the most dangerous provinces in terms of occupational accidents in all 3 methods. It is thought that factors such as regional construction investments, number of construction projects and dynamism of the construction sector, as well as factors related to many sectors such as labour force potential, population, industry density, number of workers, employment opportunities affect the results obtained. According to the PROMETHEE method, the 4th most risky province is Bursa, and the 5th is Kocaeli, while the opposite results have been obtained in GRA and OCRA methods. Similarly, Antalya has been identified as the least risky province in other words the 7th risky province in the GRA method, but Manisa has been ranked the least risky province in PROMETHEE and OCRA methods. The integration of occupational accidents that have occurred over the years into the multi-criteria decision-making algorithm forms the basis of the original approach of the study. In this respect, this study has provided a resource for city-based performance in terms of occupational accidents by using multi-criteria decision-making methods in the field of occupational health and safety, and also for researchers conducting city-based occupational accident reduction studies. It is thought that the availability of data to be trusted on a provincial basis in terms of occupational health and safety and the resources that analyse these data are considered to be very important for future studies and subject researchers who aim to offer separate solutions for each location.

5. Limitations

This study was limited to some of the regional factors that affect the occurrence of city-based occupational accidents.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Appendix

A1. PROMETHEE II performance differences

D12	0,20567	0,199926	0,168296	0,124979	0,062747	-0,00427
D13	0,190685	0,1977	0,192006	0,164604	0,121321	0,071186
D14	0,079052	0,024421	0,022878	0,016565	-0,02328	-0,09789
D15	0,327877	0,29825	0,254074	0,238943	0,219394	0,116515
D16	1	1	1	1	0,976723	0,902111
D17	0,183923	0,192198	0,161147	0,141212	0,084239	0,025752
D21	-0,20567	-0,19993	-0,1683	-0,12498	-0,06275	0,004269
D23	-0,01499	-0,00223	0,02371	0,039625	0,058573	0,075455
D24	-0,12662	-0,1755	-0,14542	-0,10841	-0,08602	-0,09362
D25	0,672123	0,70175	0,745926	0,761057	0,757329	0,785595
D26	0	0	0	0	0	0
D27	-0,02175	-0,00773	-0,00715	0,016233	0,021491	0,030021
D31	-0,19069	-0,1977	-0,19201	-0,1646	-0,12132	-0,07119
D32	0,014985	0,002226	-0,02371	-0,03963	-0,05857	-0,07545
D34	-0,11163	-0,17328	-0,16913	-0,14804	-0,1446	-0,16908
D35	0,137192	0,10055	0,062068	0,074339	0,098073	0,045329
D36	0,809315	0,8023	0,807994	0,835396	0,855402	0,830925
D37	-0,00676	-0,0055	-0,03086	-0,02339	-0,03708	-0,04543
D41	-0,07905	-0,02442	-0,02288	-0,01656	0,023277	0,097889
D42	0,126619	0,175504	0,145418	0,108414	0,086025	0,09362
D43	0,111633	0,173279	0,169127	0,148039	0,144598	0,169075
D45	0,248825	0,273829	0,231195	0,222378	0,242671	0,214405
D46	0,920948	0,975579	0,977122	0,983435	1	1
D47	0,104872	0,167776	0,138268	0,124647	0,107516	0,123641
D51	0,672123	0,70175	0,745926	0,761057	0,757329	0,785595
D52	-0,12221	-0,09832	-0,08578	-0,11396	-0,15665	-0,12078
D53	-0,13719	-0,10055	-0,06207	-0,07434	-0,09807	-0,04533
D54	-0,24883	-0,27383	-0,2312	-0,22238	-0,24267	-0,2144
D56	0,672123	0,70175	0,745926	0,761057	0,757329	0,785595
D57	-0,14395	-0,10605	-0,09293	-0,09773	-0,13515	-0,09076
D61	-1	-1	-1	-1	-0,97672	-0,90211
D62	-0,79433	-0,80007	-0,8317	-0,87502	-0,91398	-0,90638
D63	-0,80931	-0,8023	-0,80799	-0,8354	-0,8554	-0,83092
D64	-0,92095	-0,97558	-0,97712	-0,98344	-1	-1
D65	-0,67212	-0,70175	-0,74593	-0,76106	-0,75733	-0,7856
D67	-0,81608	-0,8078	-0,83885	-0,85879	-0,89248	-0,87636
D71	-0,18392	-0,1922	-0,16115	-0,14121	-0,08424	-0,02575
D72	0,021747	0,007728	0,00715	-0,01623	-0,02149	-0,03002
D73	0,006762	0,005503	0,030859	0,023392	0,037082	0,045434
D74	-0,10487	-0,16778	-0,13827	-0,12465	-0,10752	-0,12364
D75	0,143954	0,106053	0,092927	0,097731	0,135155	0,090764
D76	0,816077	0,807802	0,838853	0,858788	0,892484	0,876359

A2. PROMETHEE II preference functions

	2014	2015	2016	2017	2018	2019
D12	0,023392	0,029969	0,027945	0,024311	0,012339	0
D13	0,021687	0,029636	0,031881	0,032019	0,023856	0,012754
D14	0,008991	0,003661	0,003799	0,003222	0	0
D15	0,037291	0,044708	0,042187	0,04648	0,043141	0,020875
D16	0,113734	0,149902	0,166044	0,194522	0,192061	0,161622
D17	0,020918	0,028811	0,026757	0,027469	0,016565	0,004614
D21	0	0	0	0	0	0,000765
D23	0	0	0,003937	0,007708	0,011518	0,013519
D24	0	0	0	0	0	0
D25	0,076443	0,105193	0,123857	0,148043	0,14892	0,140748
D26	0	0	0	0	0	0
D27	0	0	0	0,003158	0,004226	0,005379
D31	0	0	0	0	0	0
D32	0,001704	0,000334	0	0	0	0
D34	0	0	0	0	0	0
D35	0,015603	0,015073	0,010306	0,014461	0,019285	0,008121
D36	0,092046	0,120266	0,134163	0,162503	0,168205	0,148869
D37	0	0	0	0	0	0
D41	0	0	0	0	0,004577	0,017538
D42	0,014401	0,026308	0,024146	0,021089	0,016916	0,016773
D43	0,012696	0,025975	0,028083	0,028797	0,028433	0,030292
D45	0,0283	0,041047	0,038389	0,043257	0,047718	0,038413
D46	0,104743	0,146241	0,162245	0,1913	0,196638	0,17916
D47	0,011927	0,02515	0,022959	0,024247	0,021142	0,022152
D51	0,076443	0,105193	0,123857	0,148043	0,14892	0,140748
D52	0	0	0	0	0	0
D53	0	0	0	0	0	0
D54	0	0	0	0	0	0
D56	0,076443	0,105193	0,123857	0,148043	0,14892	0,140748
D57	0	0	0	0	0	0
D61	0	0	0	0	0	0
D62	0	0	0	0	0	0
D63	0	0	0	0	0	0
D64	0	0	0	0	0	0
D65	0	0	0	0	0	0
D67	0	0	0	0	0	0
D71	0	0	0	0	0	0
D72	0,002473	0,001158	0,001187	0	0	0
D73	0,000769	0,000825	0,005124	0,00455	0,007292	0,00814
D74	0	0	0	0	0	0
D75	0,016372	0,015897	0,01543	0,019011	0,026577	0,016261
D76	0,092815	0,121091	0,139287	0,167053	0,175496	0,157009

A3. PROMETHEE II reference matrix

	Antalya	Bursa	Ankara	Manisa	İzmir	İstanbul	Kocaeli	Φ^+
Antalya	0,000	0,118	0,152	0,020	0,235	0,978	0,125	<u>1,627</u>
Bursa	0,001	0,000	0,037	0,000	0,743	0,000	0,013	<u>0,793</u>
Ankara	0,000	0,002	0,000	0,000	0,083	0,826	0,000	<u>0,911</u>
Manisa	0,022	0,120	0,154	0,000	0,237	0,980	0,128	<u>1,641</u>
İzmir	0,743	0,000	0,000	0,000	0,000	0,743	0,000	<u>1,486</u>
İstanbul	0,000	0,000	0,000	0,000	0,000	0,000	0,000	<u>0,000</u>
Kocaeli	0,000	0,005	0,027	0,000	0,110	0,853	0,000	<u>0,994</u>
Φ^-	<u>0,766</u>	<u>0,244</u>	<u>0,369</u>	<u>0,020</u>	<u>1,407</u>	<u>4,380</u>	<u>0,265</u>	