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Research article

Comparison of main metal industry sub-business lines from occupational health and safety perspective using CIRITIC and EDAS methods

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Abstract

The basic metal industry is one of the most economically important business lines in the manufacturing industry. According to the Social Security Institution (SSI) 2020 data, the basic metal industry in Türkiye is represented by 16 sub-businesses lines. In this study, it is aimed to evaluate the risk levels of the sub-business lines of the basic metal industry class, which is included in the SSI economic activity classification. Occupational Health and Safety data included in the 2020 SSI statistics were used to determine risk levels. The number of employees who have an occupational disease, the number of deaths because of work accidents, the period of temporary incapacity for work (inpatient), the period of temporary incapacity for work (outpatient), and the number of employees who have had a work accident are the criteria selected from these data. In the evaluation made according to these criteria, Multi-Criteria Decision-Making methods were used. Criteria Importance Through Intercriteria Correlation (CRITIC) and Evaluation Based on Distance from Average Solution (EDAS) methods were used to determine and classify the importance levels of the criteria determined for 16 sectors. As a result of the analysis, it has been determined that the riskiest sector among the main metal industry sub-business lines is the "Manufacture of basic iron and steel products and ferrous alloys" and the most important criterion is the number of insured persons with occupational diseases.

Keywords: *Base metal industry; CRITIC; EDAS; occupational health and safety*

1. Introduction

The manufacturing industry has a large share among the income sources of the countries and is one of the most important sectors in terms of economic growth. One of the most economically important business lines in the manufacturing industry is the basic metal industry. The basic metal industry plays an important role in the manufacturing sector when the areas in which it is used in the industry are considered (Sengul, 2020).

One of the most important sectors contributing to the development of Türkiye both economically and as a workforce is the basic metal industry sector. This sector provides important inputs to many fields in Türkiye thanks to its productions with 16 different business lines (Eyuboglu and Bayraktar, 2019).

As seen in Fig. 1, when analyzed in terms of production according to TUIK's 2020 statistics, monthly production indices of manufacturing industry and basic metal industry show a parallel performance.

In an increasingly competitive environment, it has become

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an important issue to protect, maintain and improve the status of businesses. Due to the information shared instantly with the technological developments experienced, businesses have entered a competition obligation not only across the country but also on a global scale. To keep up with the global competitive environment, it is of great importance for businesses to ensure the continuity of efficiency and quality in their activities and increase their performance (Uygurturk and Korkmaz, 2012). In addition, this competition forces businesses to act by considering the developments in global rival businesses as well as their own activities. (Yildirim et al., 2019). For this reason, determining their performance according to the future can be shown among the plans that businesses will make in order to maintain their existence and increase their efficiency (Bakirci et al., 2014).

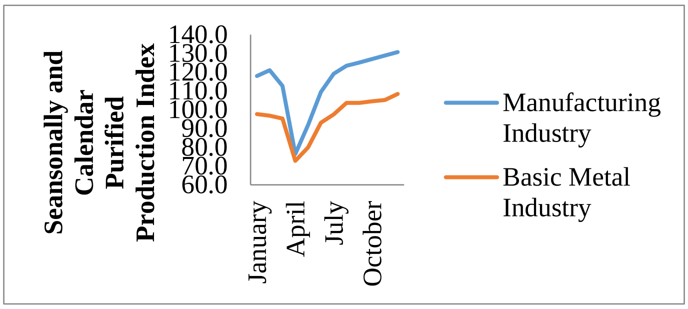

Fig. 1. Production indices (TUIK 2020).

According to the Social Security Institution (SSI) 2020 data, the basic metal industry in Türkiye is represented by 16 sub-business lines and there are 6,803 workplaces operating in this field and 175,994 employees working in these workplaces. This sector is a very risky sector due to the high need for manpower in the activities carried out and being in the very dangerous class in terms of working conditions. If the dangers and risks in the working environment cannot be reduced to reasonable levels, losses will occur because of accidents that may occur, and both the sector and the country will have to bear the consequences. For this reason, it is necessary for business managers to exhibit rational behaviors in the plans they will carry out according to the results of the risk assessments to be made. These behaviors should include adopting a proactive approach to any accident that may occur in workplace environments and providing the necessary occupational safety conditions by taking the necessary precautions. Thus, because of creating safe working environments in enterprises, a great step will be taken to ensure and maintain continuity and increase productivity.

Occupational Health and Safety (OHS) is a phenomenon that has emerged not only for the needs of employees and working environments, but also to increase social welfare and to protect and observe all segments. For this reason, Occupational Health and Safety Law No. 6331 came into force to improve health and safety conditions for all segments and to overcome existing problems. Thus, a new era has started for the studies to be carried out in the field of OHS, and the activities to be carried out have been desired to have a holistic structure. With this Law, great importance was attached to risk assessment as a proactive approach to prevent negative situations that may occur in workplaces (Can and Kargi, 2019).

Work-related accidents attract attention in the global context, among the deaths that occur because of occupational accidents. The high number of deaths because of work accidents in Türkiye is an indication that the activities carried out within the scope of OHS are insufficient and the problems continue. To prevent these problems, it is important to determine the existing or potential risks in the working environment and to decide on the measures to be taken.

In this study, it is aimed to determine the riskiest sector among these sectors by examining the OHS indicators in the SSI 2020 statistical yearbook of 16 different sectors, which are sub-branches of the Basic Metal Industry sector, which is in the very dangerous business line. In this context, two methods were used from Multi-Criteria Decision-Making (MCDM) approaches: Diakoulaki et al. (1995) CRITIC (Criteria Importance Through Intercriteria Correlation) and Ghorabaee et al. (2015) EDAS (Evaluation Based on Distance from Average Solution).

2. Materials and methods

The CRITIC method used in the study was developed by Diakoulaki et al. (1995). Through CRITIC, one of the MCDM methods, the degree of importance of the problems is shown objectively according to the determined criteria. The weights of the criteria are derived from the concentration of contradiction and contrast, which is the basis of all decision-making situations. Correlation analysis is used to determine the contrast of the criteria determined in this method (Zardari et al., 2015). Therefore, first, it is necessary to create the correlation matrix for weighting. There is a directly proportional relationship in the matrix created between the degree of accordance with the determined criteria and the correlation value. In other words, the higher the accordance between the two criteria, the higher the correlation of these criteria will be. In this method, in order to obtain the value of the decision criteria, the standard deviation and correlation of all decision criteria should be taken into account (Wang and Luo, 2010). The application steps of the CRITIC method are listed below (Wu et al., 2020; Maruf and Ozdemir, 2021; Omurbek et al., 2021; Ozkan and Ag, 2021; Dogan, 2022).

Step 1. Generating the decision matrix:

In this step, the decision matrix *X* is created, which includes criteria corresponding to different alternative situations. The decision matrix X, consisting of "n" criteria and "m" alternatives, prepared with the help of the data in the decision problem, is as follows (Alp and Engin, 2011):

$$X = \left\lfloor x_{ij} \right\rfloor_{m \times n} = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \tag{1}$$

Step 2. Generating the normalized decision matrix:

In the second step, normalization process is performed to convert the criteria values to common values. In this way, criteria with different measurement values will be made dimensionless. In this step, the criteria are determined as cost-oriented or benefit-oriented criteria in terms of their purposes. While the equation given in Equality (2) is used for benefit-oriented criteria, the equation given in Equality (3) is used to calculate values for cost-oriented criteria (Bulgurcu, 2019).

$$r_{ij} = \frac{x_{ij} - x_j^{\min}}{x_j^{\max} - x_j^{\min}} \quad (2)$$

$$r_{ij} = \frac{x_j^{\max} - x_{ij}}{x_j^{\max} - x_j^{\min}} \quad (3)$$

Step 3. Calculation of multiple correlation (ρjk):

The relationship between the criteria is obtained by calculating with the help of correlation coefficients. The amount of information in the criteria shows the relative importance of the criteria (Vujicic et al., 2017). By means of the r_{ij} value obtained because of the normalization process, the ρ_{jk} correlation value between the "*j*" and "*k*" criteria is calculated using Equality (4) (Akcakanat et al., 2018).

$$\rho_{jk} = \frac{\sum_{i=1}^{m}(r_{ij} - \bar{r}_j) * (r_{ik} - \bar{r}_k)}{\sqrt{\sum_{i=1}^{m}(r_{ij} - \bar{r}_j)^2 * (r_{ik} - \bar{r}_k)^2}} \quad j,k=1,2\ldots,n \quad (4)$$

Step 4. Calculation of relationship density (Cj) value:

In the first stage of the fourth step, the standard deviation values of the criteria are obtained with the help of Equality (5). Then, the *Cj* value, which is the total amount of information belonging to the criteria, is obtained with the help of Equality (6).

$$\sigma_j = \sqrt{\frac{\sum_{i=1}^{m}(r_{ij} - \bar{r}_j)^2}{m-1}} \quad (5)$$

$$C_j = \sigma_j \sum_{k=1}^{n}(1 - \rho_{jk}) \quad j=1,2,\ldots,n \quad (6)$$

The criteria with low correlation and high standard deviation among the criteria are the criteria with high total amount of information and have the greatest importance (Madic and Radovanovic, 2015).

Step 5. Calculation of criterion significance weights (Wj):

In this step, Equality (7), which is the method of dividing the "*Cj*" value of each "*j*" criterion by the sum of all criteria values, is used to calculate the criterion weights. The objective critical weight shows the conflict and contrast intensity of the criteria (Jahan et al. 2012).

$$w_j = \frac{C_j}{\sum_{k=1}^{n} C_j} \quad (7)$$

Step 6. Calculation of score value (sk_i):

In the last step, necessary calculations are made by using Equality (8) to determine criterion weights.

$$sk_i = \sum_{j=1}^{n} w_j \times x_{ij} \quad (8)$$

Another method utilized in the study is the EDAS method which is one of the MCDM methods and was developed by Ghorabaee et al. (2015). The logic of this method is basically like the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method, but there is a fundamental difference. This difference is that, unlike VIKOR and TOPSIS methods, in this method, analyses are made according to their proximity to the positive and negative ideal solution. In other words, the analysis in the EDAS method is not with the ideal solution approach; is performed with an average solution with negative and positive distance values.

There are two different values in the EDAS method: (1) the negative distance to the average solution and (2) the positive distance to the average solution. These values are the values that guide the existing alternatives. As a result of the analyzes made, it is desired that the positive distance value is the highest and the negative distance value is the lowest for the most appropriate result (Trinkūnienė et al., 2017).

EDAS method analyzes are performed in seven steps. These steps are listed below (Ghorabaee et al., 2015; Ulutas, 2017; Trinkūnienė et al., 2017):

Step 1. Generating the decision matrix (X):

In the first step of this method, the initial decision matrix for the decision problem is generated as in Equality (9).

$$X = \left[X_{ij}\right]_{m \times n} = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1m} \\ x_{21} & x_{22} & \cdots & x_{2m} \\ \cdots & \cdots & \cdots & \cdots \\ x_{m1} & x_{m2} & \cdots & x_{nm} \end{bmatrix} \quad (9)$$

Step 2. Generating the average values matrix (AVj):

In the second step, a matrix of average values is generated for the criteria determined with the help of Equality (10).

$$AV_j = \frac{\sum_{i=1}^{n} X_{ij}}{m} \quad (10)$$

Step 3. Obtaining positive and negative distance matrices from the average:

In the third step of the method, a matrix of positive and negative distances from the average is generated. For the determined criteria, the average positive distance matrix (*PDA*) is formed by means of Equality (11) and the average negative distance matrix (*NDA*) by means of Equality (12). It is resolved by Equality (13) and (14) if the criteria determined are benefit-oriented, and by Equality (15) and (16) if the criteria are cost-oriented.

$$PDA = \left\lfloor PDA_{ij} \right\rfloor_{mxn} \tag{11}$$

$$NDA = \left\lfloor NDA_{ij} \right\rfloor_{mxn} \tag{12}$$

$$PDA_{ij} = \frac{\max(0, (X_{ij} - AV_j))}{AV_j} \quad j \in \text{benefit criterion} \tag{13}$$

$$NDA_{ij} = \frac{\max(0, (AV_j - X_{ij}))}{AV_j} \quad j \in \text{benefit criterion} \tag{14}$$

$$PDA_{ij} = \frac{\max(0, (AV_j - X_{ij}))}{AV_j} \quad j \in \text{cost kriteri} \tag{15}$$

$$NDA_{ij} = \frac{\max(0, (X_{ij} - AV_j))}{AV_j} \quad j \in \text{cost kriteri} \tag{16}$$

In the equalities given above, the cost criterion expresses the criteria that are desired to be minimum, and the benefit criterion expresses the criteria that are desired to be maximum.

Step 4. Calculation of weighted total values:

In the fourth step of the method, the weighted total positive distances (SP_i) and negative distances (SN_i) are calculated using Equality (17) and (18) by means of the positive and negative distance matrices obtained from the previous step. The w_j value given in the equalities indicates the importance weight of each evaluation criterion.

$$SP_i = \sum_{j=1}^{m} w_j PDA_{ij} \tag{17}$$

$$SN_i = \sum_{j=1}^{m} w_j NDA_{ij} \tag{18}$$

An increase in the SP_i value and a decrease in the SN_i value indicate that the alternatives are at the desired level. In other words, in this step, the highest SP_i value and the lowest SN_i value will show that the alternative is the alternative that is suitable.

Step 5. Normalizing weighted total distances:

In the fifth step of the method, the weighted total values of SP_i and SN_i obtained in the previous step are normalized with the help of Equality (19) and (20).

$$NSP_i = \frac{SP_i}{\max_i (SP)_i} \tag{19}$$

$$NSN_i = 1 - \frac{SN_i}{\max_i (SN_i)} \tag{20}$$

Step 6. Calculation of evaluation scores of alternatives:

In the sixth and last stage of the method, the average of the NSP_i and NSN_i values obtained in the fifth step is taken and performance evaluation is made for each alternative. Success values are obtained by means of AS_i Equality (21). Among the obtained results, it is decided that the alternative with the highest AS_i value is the best alternative.

$$AS_i = \frac{1}{2}(NSP_i + NSN_i) \tag{21}$$

AS_i value, it must be ensured $0 \le AS_i \le 1$ condition.

3. Results and discussion

According to the SSI 2020 data used in the analyzes, the list of sub-activity branches of the Basic Metal Industry is given in Table 1.

Table 1
Business lines included in the evaluation.

Manufacturing of main iron and steel products and ferrous alloys	X_1
Manufacturing of steel tubes, pipes, hollow profiles, and similar fittings	X_2
Cold drawing of bars	X_3
Cold rolling of narrow strips	X_4
Cold forming or folding	X_5
Cold drawing of wires	X_6
Precious metal production	X_7
Production of aluminum	X_8
Lead, zinc and tin production	X_9
Production of copper	X_{10}
Production of other non-ferrous metals	X_{11}
Processing of nuclear fuels	X_{12}
Iron casting	X_{13}
Steel casting	X_{14}
Casting of light metals	X_{15}
Casting of other non-ferrous metals	X_{16}

Table 2
Evaluated criteria.

Number of insured persons with work accidents by incapacity for work (days)	C_1
Total temporary incapacity for work (outpatient)	C_2
Total temporary incapacity for work (inpatient)	C_3
Number of insured persons with occupational diseases	C_4
Number of insured deaths because of work accident	C_5

The list of criteria determined for the sub-activity branches of the Basic Metal Industry is given in Table 2.

3.1. CRITIC method analysis

3.1.1. Generating the decision matrix

The first step to be taken to solve the decision problem is to generate the decision matrix that the determined criteria and alternatives take together. A decision matrix is generated in which 16 alternatives and 5 selected criteria are included together. 16 different business lines (alternative) belonging to the basic metal industry and the "Number of Insured Persons with Work Accidents by Incapacity for Work (days)" (C1), "Total Temporary Incapacity for Work (Outpatient)" (C2), "Total Temporary Incapacity for Work (Inpatient)" (C3), "Number of Insured Persons with Occupational Diseases" (C4), and "Number of Insured Deaths as a result of Work Accident" (C5) (five different Cj, j=1,…) were evaluated according to 5 criteria.

Within the framework of the evaluations because of the analysis performed with the CRITIC method, the initial decision matrix was created as in Equality (1) and presented in Table 3.

Table 3
Initial decision matrix.

	Number of Insured Persons with Work Accidents by Incapacity for Work (days) C_1	Total Temporary Incapacity for Work (Outpatient) C_2	Total Temporary Incapacity for Work (Inpatient) C_3	Number of Insured Persons with Occupational Diseases C_4	Number of Insured Deaths because of Work Accident C_5
X1	5267	70200	1349	11	11
X2	2177	29182	378	4	6
X3	174	2153	16	0	0
X4	44	421	1	0	0
X5	447	6539	151	2	0
X6	458	6733	80	2	0
X7	26	272	7	0	0
X8	1906	21228	380	1	1
X9	38	557	34	2	0
X10	367	4729	69	1	0
X11	146	2317	115	0	2
X12	2	172	2	0	0
X13	2758	35459	686	20	8
X14	921	9892	175	2	1
X15	756	8621	89	2	1
X16	295	4579	113	1	2

3.1.2. Normalized decision matrix (r_{ij})

To carry out the objective weighting process, the second step was generated according to the benefit/cost orientation of the normalized decision matrix criteria. Since all the criteria determined at this stage are cost-oriented, the necessary procedures were carried out using Equality (3) and the results obtained are shown in Table 4. Since all calculated values affect the cost situation, the minimization process has been carried out.

3.1.3. Calculating multi-correlation (ρjk)

Table 4
Normalized decision matrix.

Criteria Alternative Criteria	C1 min	C2 min	C3 min	C4 min	C5 min
X1	0,000	0,000	0,000	0,450	0,000
X2	0,587	0,586	0,720	0,800	0,455
X3	0,967	0,972	0,989	1,000	1,000
X4	0,992	0,996	1,000	1,000	1,000
X5	0,915	0,909	0,889	0,900	1,000
X6	0,913	0,906	0,941	0,900	1,000
X7	0,995	0,999	0,996	1,000	1,000
X8	0,638	0,699	0,719	0,950	0,909
X9	0,993	0,995	0,976	0,900	1,000
X10	0,931	0,935	0,950	0,950	1,000
X11	0,973	0,969	0,915	1,000	0,818
X12	1,000	1,000	0,999	1,000	1,000
X13	0,477	0,496	0,492	0,000	0,273
X14	0,825	0,861	0,871	0,900	0,909
X15	0,857	0,879	0,935	0,900	0,909
X16	0,944	0,937	0,917	0,950	0,818

After the normalization process performed in the third step of the application, the multi-correlation matrix showing the correlation levels between the criteria was calculated by means of Equality (4) and given in Table 5.

Table 5
Relationship coefficient matrix.

Criteria	C1	C2	C3	C4	C5
C1	1,000	0,998	0,985	0,733	0,925
C2	0,998	1,000	0,988	0,735	0,938
C3	0,985	0,988	1,000	0,749	0,931
C4	0,733	0,735	0,749	1,000	0,817
C5	0,925	0,938	0,931	0,817	1,000

3.1.4. Calculating correlation density (C_j)

At this stage, the *1-ρjk* value presented in Table 6 was calculated by using the data in Table 5 to calculate the *Cj* value. Then, using the normalized values calculated in Table 4 for the standard deviation values of the criteria, the calculation was made by means of Equality (5) and presented in Table 7. Finally, using the standard deviation values, the correlation density (*Cj*) values of the criteria were calculated by means of Equality (6) and the results are given in Table 8.

Table 6
(1-ρjk).

Criteria	C1	C2	C3	C4	C5
C1	1,000	0,998	0,985	0,733	0,925
C2	0,998	1,000	0,988	0,735	0,938
C3	0,985	0,988	1,000	0,749	0,931
C4	0,733	0,735	0,749	1,000	0,817
C5	0,925	0,938	0,931	0,817	1,000

Table 7
Standard deviation values for criteria.

Standard deviation sj, j=1,….,5				
s_1	s_2	s_3	s_4	s_5
0,2698	0,2665	0,2603	0,2633	0,3042

3.1.5. Calculating criterion importance weights (W_j)

Table 8
Correlation density.

Business Line	C_j
Number of insured persons with work accidents by incapacity for work (days) (C_1)	0,0969
Total temporary incapacity for work (outpatient) (C_2)	0,0910
Total temporary incapacity for work (inpatient) (C_3)	0,0905
Number of insured persons with occupational diseases (C_4)	0,2542
Number of insured deaths because of work accident (C_5)	0,1183

The importance weights (W_j) calculated by Equality (7) in the penultimate step of the CRITIC method are given in Table 9.

Table 9
Importance weight values.

Business Line	W_j
Number of insured persons with work accidents by incapacity for work (days) (C_1)	0,148
Total temporary incapacity for work (outpatient) (C_2)	0,139
Total temporary incapacity for work (inpatient) (C_3)	0,139
Number of insured persons with occupational diseases (C_4)	0,390
Number of insured deaths because of work accident (C_5)	0,181

When the findings in Table 9 are examined, it has been determined that the importance weights of the criteria determined for the basic metal industry vary between 0.139 and 0.390. According to these results, it has been concluded that the most important performance criterion for the basic metal industry is "Number of Insured Persons with Occupational Diseases". The criterion of "Total Temporary Incapacity for Work (Inpatient)" is the lowest performance criterion in terms of importance weight.

3.1.6. Calculating the score value (sk_i)

In the last step of the application, using the values obtained from the alternatives, the score value (sk_i) was calculated by means of Equality (8) and given in Table 10.

Table 10
Score weights.

Business Line	sk_i
X1	10790,59
X2	4458,40
X3	329,08
X4	65,54
X5	1002,35
X6	1021,24
X7	42,86
X8	3304,43
X9	89,02
X10	725,65
X11	361,96
X12	24,62
X13	5471,73
X14	1545,12
X15	1330,94
X16	700,44

When Table 11 is examined, it is seen that the "Manufacturing of main iron and steel products and ferrous alloys" sector is the business line with the highest risk level among the main metal industry sub-business lines, within the framework of the evaluation criteria considered. This sector is followed by the manufacture of cast iron, machine and steel tubes, pipes, hollow profiles, and similar fittings, respectively.

Table 11
Ranking of score weights.

Business Line	sk_i	Ranking
Manufacturing of main iron and steel products and ferrous alloys	10790,59	1
Iron casting	5471,73	2
Manufacturing of steel tubes, pipes, hollow profiles and similar fittings	4458,40	3
Production of aluminum	3304,43	4
Steel casting	1545,12	5
Casting of light metals	1330,94	6
Cold drawing of wires	1021,24	7
Cold forming or folding	1002,35	8
Production of copper	725,65	9
Casting of other non-ferrous metals	700,44	10
Production of other non-ferrous metals	361,96	11
Cold drawing of bars	329,08	12
Lead, zinc, and tin production	89,02	13
Cold rolling of narrow strips	65,54	14
Precious metal production	42,86	15
Processing of nuclear fuels	24,62	16

3.1.7. EDAS method analysis

Table 12
Decision matrix.

	Number of Insured Persons with Work Accidents by Incapacity for Work (Days) C_1	Total Temporary Incapacity for Work (Outpatient) C_2	Total Temporary Incapacity for Work (Inpatient) C_3	Number of Insured Persons with Occupational Diseases C_4	Number of Insured Deaths as a result of Work Accident C_5
	0,1489	0,1398	0,1390	0,3906	0,1818
X1	5267	70200	1349	11	11
X2	2177	29182	378	4	6
X3	174	2153	16	0	0
X4	44	421	1	0	0
X5	447	6539	151	2	0
X6	458	6733	80	2	0
X7	26	272	7	0	0
X8	1906	21228	380	1	1
X9	38	557	34	2	0
X10	367	4729	69	1	0
X11	146	2317	115	0	2
X12	2	172	2	0	0
X13	2758	35459	686	20	8
X14	921	9892	175	2	1
X15	756	8621	89	2	1
X16	295	4579	113	1	2
AVj	986	12691	228	3	2

In the first step of the method, the decision matrix was generated with the help of Equality (9) by using the data belonging to the Basic Metal Industry sub-business lines from the SSI 2020 data and shown in Table 12. The average values (AVj) obtained for the criteria determined in the second step of the analysis were calculated with the help of Equality (10) and given in Table 12.

After the decision matrix and the average weight calculation, the average positive and negative distance matrices were calculated by means of Equality (11) and (12). It has been taken into account whether the criteria determined in the creation of these matrices are benefit-oriented or cost-oriented. Since the criteria are benefit-oriented, matrices for positive and negative distances were generated using Equality (13) and (14) and presented in Tables 13 and 14.

Table 13
Average positive distance matrix.

	C1	C2	C3	C4	C5
X1	4,34	4,53	4,92	2,67	4,50
X2	1,21	1,30	0,66	0,33	2,00
X3	0,00	0,00	0,00	0,00	0,00
X4	0,00	0,00	0,00	0,00	0,00
X5	0,00	0,00	0,00	0,00	0,00
X6	0,00	0,00	0,00	0,00	0,00
X7	0,00	0,00	0,00	0,00	0,00
X8	0,93	0,67	0,67	0,00	0,00
X9	0,00	0,00	0,00	0,00	0,00
X10	0,00	0,00	0,00	0,00	0,00
X11	0,00	0,00	0,00	0,00	0,00
X12	0,00	0,00	0,00	0,00	0,00
X13	1,80	1,79	2,01	5,67	3,00
X14	0,00	0,00	0,00	0,00	0,00
X15	0,00	0,00	0,00	0,00	0,00
X16	0,00	0,00	0,00	0,00	0,00

Table 14
Average negative distance matrix.

	C1	C2	C3	C4	C5
X1	0,00	0,00	0,00	0,00	0,00
X2	0,00	0,00	0,00	0,00	0,00
X3	0,82	0,83	0,93	1,00	1,00
X4	0,96	0,97	1,00	1,00	1,00
X5	0,55	0,48	0,34	0,33	1,00
X6	0,54	0,47	0,65	0,33	1,00
X7	0,97	0,98	0,97	1,00	1,00
X8	0,00	0,00	0,00	0,67	0,50
X9	0,96	0,96	0,85	0,33	1,00
X10	0,63	0,63	0,70	0,67	1,00
X11	0,85	0,82	0,50	1,00	0,00
X12	1,00	0,99	0,99	1,00	1,00
X13	0,00	0,00	0,00	0,00	0,00
X14	0,07	0,22	0,23	0,33	0,50
X15	0,23	0,32	0,61	0,33	0,50
X16	0,70	0,64	0,50	0,67	0,00

In the next step, the weighted total negative distances (SN_i) and positive distances (SP_i) are calculated with the help of Equality (17) and (18). In this study, EDAS and CRITIC methods were preferred and the weights of the criteria reached in the CRITIC method were used in the weighting process performed in Equality (17) and (18). After calculating the weighted total distances, the (NSP_i) and (NSN_i) values were obtained by normalizing the (SP_i) and (SN_i) values by means of Equality (19) and (20).

As the last step of this method, scores were obtained by evaluating the performance of the alternatives determined. Evaluation score of the criteria (AS_i) is calculated by Equality (21) and given in Table 15. The alternative with the highest (AS_i) value is accepted as the optimal state.

The results obtained when the relevant steps were performed using the EDAS method are given in Table 15.

Table 15
Results.

	SP_i	SN_i	NSP_i	NSN_i	AS_i	Ranking
X1	3,823	0,000	1,000	0,000	0,500	1
X2	0,947	0,000	0,248	0,000	0,124	16
X3	0,000	0,940	0,000	0,943	0,472	5
X4	0,000	0,988	0,000	0,991	0,496	4
X5	0,000	0,508	0,000	0,510	0,255	12
X6	0,000	0,548	0,000	0,549	0,275	10
X7	0,000	0,989	0,000	0,992	0,496	3
X8	0,326	0,351	0,085	0,352	0,219	13
X9	0,000	0,707	0,000	0,709	0,355	8
X10	0,000	0,720	0,000	0,723	0,361	7
X11	0,000	0,700	0,000	0,703	0,351	9
X12	0,000	0,997	0,000	1,000	0,500	2
X13	3,556	0,000	0,930	0,000	0,465	6
X14	0,000	0,294	0,000	0,295	0,148	15
X15	0,000	0,385	0,000	0,387	0,193	14
X16	0,000	0,524	0,000	0,526	0,263	11

When Table 15 is examined, as in the CIRITC method, within the framework of the analyzed evaluation criteria, it has been determined that "Manufacturing of main iron and steel products and iron alloys" has the highest risk level among the main metal industry sub-business lines in the EDAS method.

According to the findings obtained as a result of the analysis, the "occupational disease", which is the riskiest criterion, overlaps with the findings obtained as a result of the study in which Can and Kargı (2019) evaluated the OHS risk levels of 17 different sectors with the EDAS and CRITIC methods. In their research, Ayrim and Can (2017) examined 14 different business lines and aimed to determine the one with the highest risk using the CRITIC method. As a result of their studies, they concluded that the textile manufacturing sector is the riskiest sector. Although the criteria examined are the same, this study differs in terms of the business line examined in our study because the determined business lines are different.

Elmas-Atay and Yildirim (2022) considered 7 different OHS indicators as criteria in their study and determined 88 different sectors as alternatives. As a result of the study carried out with the CIRITIC method, the authors concluded that the riskiest sector is the construction sector. In this study, "death numbers due to occupational diseases" were excluded because they were considered low. In this respect, this study also differs from our study.

4. Conclusion

Despite the developing technology, labor-intensive human workforce studies are still carried out in the basic metal industry. This situation requires the basic metal industry to be included in the very dangerous workplace classification. This requirement also necessitates that the basic metal industry sector should be taken very seriously in terms of occupational safety. When the sector is examined, there are many risks arising from chemical and physical hazards. Due to the existence of these risks and the fact that it is a very dangerous business line, the measures to be taken in terms of OHS will prevent great material and moral losses.

Within the SSI workplace classification, the basic metal industry is represented by 16 sub-business lines. According to SSI 2020 statistics, there are 6803 workplaces operating in the basic metal industry and 175.994 employees working in these workplaces. In this study, the basic metal industry was handled, and its sub-business lines were examined by CRITIC and EDAS methods.

As a result of the examination made with the CRITIC method, it was determined that the weight of importance was the highest in the criterion of "Number of insured persons with occupational diseases" with 39%. In other words, the most important criterion when evaluating business lines is the number of insured persons with occupational diseases. This criterion was followed by the number of insured deaths because of work accidents (18%), the number of insured persons with work accidents by an incapacity for work (14%), total temporary incapacity for work (inpatient) (13%) and total temporary incapacity for work (outpatient) (13%).

Since EDAS and CRITIC integrated methods were used in the study, the weights of the criteria reached in the CRITIC method were used in the weighting process. In both methods, it was concluded that the riskiest business line among the basic metal industry business lines is "Manufacturing of main iron and steel products and iron alloys".

When the deaths occurring in the world are examined, work-related deaths come to the fore. According to SSI 2020 data, 384,262 work accidents, and 908 occupational diseases have occurred in Türkiye. As a result of these incidents, 1231 employees died because of work accidents and 5 employees died because of occupational disease. In order to eliminate or minimize these accidents and the resulting deaths, the riskiest business lines should be identified, and necessary measures should be taken for these business lines. The measures to be taken are a necessity for employees, employers, and countries. With the study, the basic metal industry sub-branches, which are among the riskiest sectors, were examined and it was aimed to draw attention to minimizing the deaths and injuries caused by the results achieved.

In this context, providing the necessary training on accidents and injuries to the basic metal industry workers, applying collective protection methods, and following up on the personal protective methods will greatly contribute to the reduction of the cases that will occur. In addition, employees should be taught that the training provided, the measures taken, and the planned practices are not a necessity. For this, it is of great importance to make safe behaviors a culture in workplace environments. Considering that work accidents are caused by the unsafe working environment and unsafe employee behaviors (Sadullah, 2021), it can be suggested to examine in detail the characteristics of workplaces, working environments, and the size of workplaces (Alli, 2008) in the prevention of work accidents and occupational diseases.

There are some limitations in the study. One of these limitations is that the criteria considered in terms of occupational health and safety of the examined sectors are not similar for each sector. Another limitation is that the study only belongs to a business line in Türkiye, this business line is not evaluated globally, and the necessary comparisons cannot be made.

As a result, in this study, 16 different sectors, which are sub-business lines of the basic metal industry, which is one of the SSI business lines, were evaluated by considering 5 different criteria. Examining the different criteria that cause work accidents and occupational diseases belonging to these sectors and using different criteria such as working environment and safety culture will make a more comprehensive contribution to the solution of the problem.

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Informed consent: The authors declare that this manuscript did not involve human or animal participants and informed consent was not collected.

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