



Research Article

Evaluation of Natech risk after landslide disaster in the scope of mines located in districts: An application for Zonguldak province

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ABSTRACT

Natech accidents are called technological accidents triggered by natural disasters. Disasters are natural events that can cause material loss and moral damages at any time. Natech accidents have the effect of increasing the losses and damages caused by disasters. The characteristics of Natech accidents vary depending on the type of disaster. In this study, landslide disasters will be considered. Landslides are one of the disasters that cause severe damage to Natech. On 13 February 2024, a Natech accident occurred in the Çöpler Gold Mine in Erzincan province after a landslide and caused a loss of life and property. Based on this accident, the districts of Zonguldak province will be evaluated in terms of the risk of the Natech accident after the landslide disaster. Zonguldak province, located in the Black Sea Region, is one of the provinces with a high risk of landslides, considering past accidents. The presence of active mines throughout the province increases the likelihood of Natech accidents. In the study, the criteria that may cause Natech accidents after landslides will be determined and weighted. Then, the districts of Zonguldak province will be ranked according to the risk of Natech accidents, considering the mines they contain. Pythagorean Fuzzy Analytical Hierarchy Process and Pythagorean Fuzzy Technique for Order of Preference by Similarity to Ideal Solution methods will be used in problem-solving. Uncertainties in the disaster environment also affect decision-making processes. For this reason, fuzzy sets are preferred when solving problems. As a result of the study, districts with high risk of Natech accidents in mines after landslide disasters were obtained. According to the results, the most important Natech risk criterion was 'Past Landslide Percentage' with a weight of 0.25234. Among the districts evaluated within the scope of the criteria, the riskiest district was Devrek. The study aims to draw attention to Natech accidents that may occur in mines. It is thought that determining the possible risky regions will be supportive for the studies to be carried out in this field.

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INTRODUCTION

Disasters are natural occurrences that result in substantial material losses and psychological impacts. [1]. Türkiye's geographical position makes it highly susceptible to a range of natural disasters [2]. This situation makes the studies that are carried out on disasters more critical. Risk mitigation activities carried out to prevent disasters and the adversities caused by disasters play a crucial role in this process. The disaster management process includes organizing and managing the activities required to reduce the negative effects of disasters [3].

While disasters cause damages in themselves, they also cause different negativities. One of these is Natech accidents, which refer to technological accidents triggered by natural disasters [4]. Natech accidents increase the negative effects of natural disasters and may also cause new events. This situation triggers chaos in the unexpected process and increases the damage to be encountered. When the Natech accidents experienced in the past are analyzed, the seriousness of the situation becomes clearer.

In the past, many different Natech accidents have occurred both in Türkiye and internationally. Gas and chemical substance releases following Hurricanes Rita and Katrina in 2005–2006 in the United States are among notable examples of Natech accidents [5]. However, a large gas explosion occurred in Oxfordshire, also in the United Kingdom, on 2 October 2023 as a result of a lightning strike at a food waste recycling facility during a severe storm. A forest fire in Chile on 3 February 2024 spread to industrial facilities, and numerous explosions occurred in chemical warehouses, paint factories, and other warehouses. Flooding in Daraa province of Libya on 10 September 2023 caused much more significant damage with the collapse of two dams.

Natech accidents have also occurred in Türkiye. For instance, during the Kocaeli earthquake on August 17, 1999, a significant fire erupted at the TÜPRAŞ refinery, which necessitated prolonged firefighting efforts. Furthermore, a chemical release took place at the AKSA Acrylic plant [6]. Again, two Natech accidents were recorded after the Kahramanmaraş earthquake on 6 February 2023. The first one was the fire that occurred in İskenderun marina. The second was the natural gas explosion and fire that happened at two separate points 200 meters underground and 3 kilometers apart in Topboğazı Village of Kırıkhan district of Hatay. Another Natech accident occurred recently. This occurred after a landslide disaster at a mine in İliç district of Erzincan province on 13 February 2024. Following the landslide disaster, approximately 10 million cubic meters of soil flowed rapidly down a 200-meter slope and caused a cave-in at the nearby Çöpler Mine Site.

Past accidents also show that each type of disaster can cause different Natech accidents [7]. Within the scope of this study, landslide disasters will be taken into consideration. After the Natech accident in Erzurum province, it has been observed that the mines are a significant risk in

terms of Natech accidents that will occur after the landslide disaster. For this reason, landslide disasters and mines are considered as the problem set of the study. Zonguldak province has been selected as the application province due to the fact that it has a large number of mines and the risk of landslides is relatively high. To support problem-solving, risk criteria that could lead to Natech accidents as a result of landslide disasters were identified and prioritized using the Pythagorean Fuzzy AHP method. Then, the districts of Zonguldak province were evaluated using the Pythagorean Fuzzy TOPSIS method within the scope of these criteria and ranked according to the risk of Natech accidents in mines after a landslide disaster. Although there are studies in the literature that distinguish Natech accidents according to disasters and equipment, no studies were found that made a distinction based on sector. It is thought that the study will contribute to the literature in terms of evaluating Natech accidents in the mining industry.

The second section continues the study with a literature review. The third section details the methods used. The fourth section presents implementation data and results. The last section evaluates the results.

Literature Review

Many studies in the literature address Natech accidents. In their study, Steinberg et al. [8] assessed Natech risks in the United States, examining current management approaches. The research outlines the characteristics of Natech accidents, presents case examples, and explores future mitigation strategies. Girgin [6], discusses the Natech accidents triggered by the August 17 earthquake. Following the earthquake, a major fire erupted at the TÜPRAŞ refinery in Kocaeli, which required prolonged efforts to bring under control. Additionally, a chemical leak occurred at the AKSA acrylic fiber production facility. The study analyzes these Natech incidents and emphasizes the significance of addressing Natech risks. Fabbrocino et al. [9], conducted a representative case study of an oil storage facility with an atmospheric steel tank containing flammable materials. In the study, they addressed the issue of integrating structural seismic risk into a quantitative probabilistic seismic risk analysis (QpsRA).

Girgin and Krausmann [10] introduced RAPID-N, a scalable web tool that performs swift local and regional Natech risk assessment and mapping using minimal data inputs. Suarez-Paba and Cruz [11], proposed Natech RateME, a comprehensive, area-wide risk management and rating system framework to inform governments and the public about the industry's Natech risk management practices. Son and Jung [12], quantitatively analysed the risks caused by flooding in industrial plants that handle large quantities of hazardous materials.

Rossi et al. [13], introduced the first vulnerability model applicable to QRA studies for process pipelines and industrial facilities affected by flooding. Guven et al. [4], addressed the Natech accident risk for Gaziantep province,

which has the most significant organized industrial zone in Turkey. Firstly, the risks that may cause Natech accidents after the earthquake disaster were determined, and then the sectors serving in the organized industrial zone were evaluated according to the risk of Natech accidents. Thus, organized industrial zones divided into five sections were ranked according to Natech risk.

Yu et al. [14], examined how people perceived risks and responded behaviorally after the Natech accident at the Sendai oil refinery following the 2011 earthquake and tsunami in Japan. Find-Natech, proposed by Luo et al. [15], is a web-based GIS tool for managing historical data on Natech events. Guo et al. [16], analyzed successive disasters in a chemical industrial park around Wenchuan after the Wenchuan earthquake. Guven et al. [17], identified the Natech risky sectors in Kırıkkale organized industrial zone after the earthquake disaster by determining the criteria to create a Natech accident.

In the literature, there are studies detailing Natech accidents, performing risk analyses, creating a database, and including evaluations performed on different equipment. In general terms, there are distinctions in terms of disaster and equipment rather than a sectoral distribution. Especially in terms of sector, this study deals with the mining sector, which has not been evaluated before. Within the scope of the literature review, there is no study evaluating Natech accidents that may occur in mines after a disaster. The study will likely contribute to the literature in this respect. In this context, it is aimed to draw attention to the mining sector and Natech accidents that may occur in this sector and to include them in risk mitigation plans.

MATERIALS AND METHODS

Pythagorean Fuzzy AHP

The AHP method is based on the pairwise comparison in problem-solving [18]. However, it is insufficient in

problems involving subjective and linguistic expressions or in cases where decision-makers cannot make a clear decision. To overcome this deficiency, AHP method was combined with fuzzy logic and Fuzzy AHP method was introduced. [19]. There are various types of sets used in fuzzy logic, and one of them is the Pythagorean Fuzzy Set, proposed by Yager [20]. These sets provide greater flexibility in handling uncertainty compared to traditional fuzzy sets. Evaluating linguistic expressions on a broader scale enables decision-makers to conduct more comprehensive assessments, thereby yielding more realistic and reliable outcomes [21]. In the application of the method, the linguistic variables used to construct the decision matrix and their corresponding Pythagorean fuzzy numbers are presented in Table 1 [22].

The steps of the Pythagorean fuzzy AHP method are given below [17].

Step 1: Experts construct $A = (r_{ik})_{m \times m}$ matrix using linguistic evaluation criteria

Step 2: Using Equation 1 and Equation 2, construct the difference matrix $D = (D_{ik})_{m \times m}$ for the low, high, and non-membership membership degrees. Here μ_{ikL} , i^{th} column, k row element with low membership degree, μ_{ikU} , element with high membership degree in column i , row k , V_{ikL} , represents the low non-membership item in column i , row k , V_{ikU} , column i^{th} represents the element with the highest member degree.

$$d_{ikL} = \mu_{ikL}^2 - V_{ikU}^2 \quad (1)$$

$$d_{ikU} = \mu_{ikU}^2 - V_{ikL}^2 \quad (2)$$

Step 3: At this stage, the multiplicative matrix is reached with the help of Equation 3 and Equation 4.

$$s_{ikL} = \sqrt{1000^{d_{ikL}}} \quad (3)$$

Table 1. Linguistic variables and Pythagorean fuzzy scales [22]

Linguistic Variables	Pythagorean Fuzzy Numbers			
	μ_L	μ_U	V_L	V_U
Certainly low important (CL)	0	0	0.9	1
Very low important (VL)	0.1	0.2	0.8	0.9
Low important (L)	0.2	0.35	0.65	0.8
Below average important (BA)	0.35	0.45	0.55	0.65
Exactly equal (EE)	0.1965	0.1965	0.1965	0.1965
Average important (A)	0.45	0.55	0.45	0.55
Above average important (AA)	0.55	0.65	0.35	0.45
High important (H)	0.65	0.8	0.2	0.35
Very high important (VH)	0.8	0.9	0.1	0.2
Certainly high important (CH)	0.9	1	0	0

$$s_{ik_U} = \sqrt{1000^{d_{ik_U}}} \quad (4)$$

Step 4: Creation of hesitation levels using Equation 5, $H = (\mu_{ik})_{mxm}$.

$$h_{ik} = 1 - (\mu_{ik_U}^2 - \mu_{ik_L}^2) - (V_{ik_U}^2 - V_{ik_L}^2) \quad (5)$$

Step 5: The unnormalized weights $T = (t_{ik})_{mxm}$ are calculated with Equation 6.

$$t_{ik} = \left(\frac{s_{ik_L} + s_{ik_U}}{2} \right) h_{ik} \quad (6)$$

Step 6: In the last step, the criterion weights w_i are created using Equation 7.

$$w_i = \frac{\sum_{j=1}^m w_i}{\sum_{i=1}^m \sum_{j=1}^m w_i} \quad (7)$$

Pythagorean Fuzzy TOPSIS

TOPSIS, a multi-criteria decision-making method, was developed by Hwang and Yoon in 1981 [23]. In the method, problems are analyzed by ranking the alternatives according to the positive and negative ideal solutions. [24]. Pythagorean fuzzy TOPSIS is a technique based on the concept of selecting the solution with the closest distance to the positive ideal solution and the farthest distance to the negative ideal solution within Pythagorean fuzzy sets [25]. While applying the method, linguistic variables and Pythagorean fuzzy numbers corresponding to these variables are used in the created decision matrix. Linguistic variables and fuzzy numbers are listed in Table 2 [4].

The stages of the Pythagorean Fuzzy TOPSIS method are given below [26].

Step 1: Establishment of criteria and alternatives by decision-makers

Step 2: Obtaining the standard decision matrix with Equation 8.

$$R = (C_j(x_i))_{mxn} = \begin{pmatrix} P_{u_{11},v_{11}} & P_{u_{12},v_{12}} & \dots & P_{u_{1n},v_{1n}} \\ P_{u_{21},v_{21}} & P_{u_{22},v_{22}} & \dots & P_{u_{2n},v_{2n}} \\ \vdots & \vdots & & \vdots \\ P_{u_{m1},v_{m1}} & P_{u_{m2},v_{m2}} & \dots & P_{u_{mn},v_{mn}} \end{pmatrix} \quad (8)$$

Step 3: Calculation of Pythagorean fuzzy positive ideal solution and negative ideal solution using Equations 9 and 10.

$$\begin{aligned} x^+ &= \{C_j, \max_i \langle s(C_j(x_i)) \rangle \mid j = 1, 2, \dots, n\} \\ &= \{\langle C_1, P(u_1^+, v_1^+) \rangle, \langle C_2, P(u_2^+, v_2^+) \rangle, \\ &\quad \dots, \langle C_n, P(u_n^+, v_n^+) \rangle\} \end{aligned} \quad (9)$$

$$\begin{aligned} x^- &= \{C_j, \min_i \langle s(C_j(x_i)) \rangle \mid j = 1, 2, \dots, n\} \\ &= \{\langle C_1, P(u_1^-, v_1^-) \rangle, \langle C_2, P(u_2^-, v_2^-) \rangle, \\ &\quad \dots, \langle C_n, P(u_n^-, v_n^-) \rangle\} \end{aligned} \quad (10)$$

Step 4: Step 4: With Equations 11 and 12, the distances of the alternatives from the Pythagorean fuzzy positive ideal and negative ideal solutions are obtained.

$$\begin{aligned} D_{(x_i, x^+)} &= \sum_{j=1}^n w_j d((C_j(x_i), C_j(x^+))) = \frac{1}{2} \sum_{j=1}^n w_j \left(|(u_{ij})^2 \right. \\ &\quad \left. - (u_j^+)^2| + |(v_{ij})^2 - (v_j^+)^2| + |(\pi_{ij})^2 - (\pi_j^+)^2| \right) \end{aligned} \quad (11)$$

$$\begin{aligned} D_{(x_i, x^-)} &= \sum_{j=1}^n w_j d((C_j(x_i), C_j(x^-))) = \frac{1}{2} \sum_{j=1}^n w_j \left(|(u_{ij})^2 \right. \\ &\quad \left. - (u_j^-)^2| + |(v_{ij})^2 - (v_j^-)^2| + |(\pi_{ij})^2 - (\pi_j^-)^2| \right) \end{aligned} \quad (12)$$

Step 5: Calculate the relative closeness indices of each alternative using Equation 13.

$$\xi(x_i) = \frac{D_{(x_i, x^-)}}{D_{(max)}(x_i, x^-)} - \frac{D_{(x_i, x^+)}}{D_{(min)}(x_i, x^+)} \quad (12)$$

Step 6: Determination of the best order of alternatives and method application is completed.

Application

Problem definition

Natech accidents have an increasing effect on the losses and damages caused by disasters. Natech accidents caused by each disaster are different. Within the scope of this study, landslide disasters are taken into consideration. In the study, the five criteria that may cause Natech accidents after landslides were weighted using the Pythagorean Fuzzy AHP method. Then, eight districts of Zonguldak province were ranked by the Pythagorean Fuzzy TOPSIS method according to the risk of Natech accidents, considering the mines they contain.

Table 2. Linguistic variables used in the Pythagorean fuzzy TOPSIS method

Linguistic Variables	Pythagorean Fuzzy Numbers	
	u	v
Overly Low (OL)	0.10	0.99
Very Little (VL)	0.10	0.97
Little (L)	0.25	0.92
Middle Little (ML)	0.40	0.87
Middle (M)	0.50	0.80
Middle High (MH)	0.60	0.71
High (H)	0.70	0.60
Very High (VH)	0.80	0.44
Extremely High (EH)	0.10	0.00

The reasons for selecting Zonguldak province as the problem's application location can be listed below.

- High landslide risk in Zonguldak province
- The presence of active mines in the province
- High precipitation rate due to its location in the Black Sea region
- High number of landslide events in the past. When the number of landslides in the past in Türkiye was examined, it was seen that the highest number of landslides

occurred in the Black Sea region. This situation is given in Figure 1 within the scope of 2018-2024 data.

Figure 1 shows the annual distribution of landslide events in seven geographical regions of Türkiye between 2018 and 2024. While the Black Sea Region stands out with the highest number of events each year, the Southeastern Anatolia Region remains at the lowest levels. Figure 2 shows the provinces in the Black Sea Region that experienced the most landslide disasters between the same years.

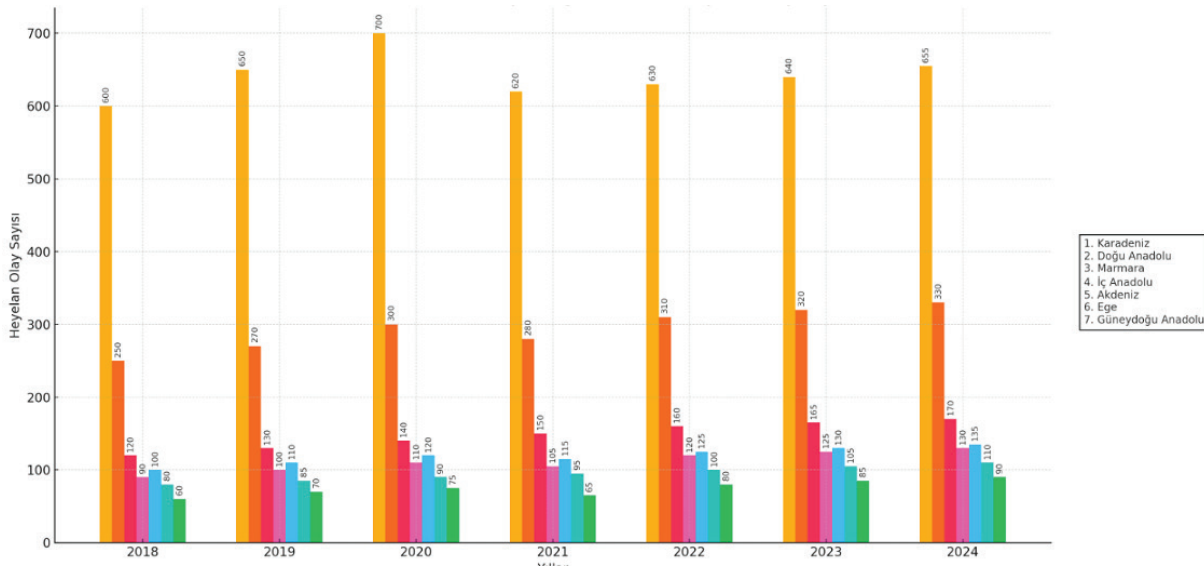


Figure 1. Past landslide numbers in Türkiye 2018-2024.

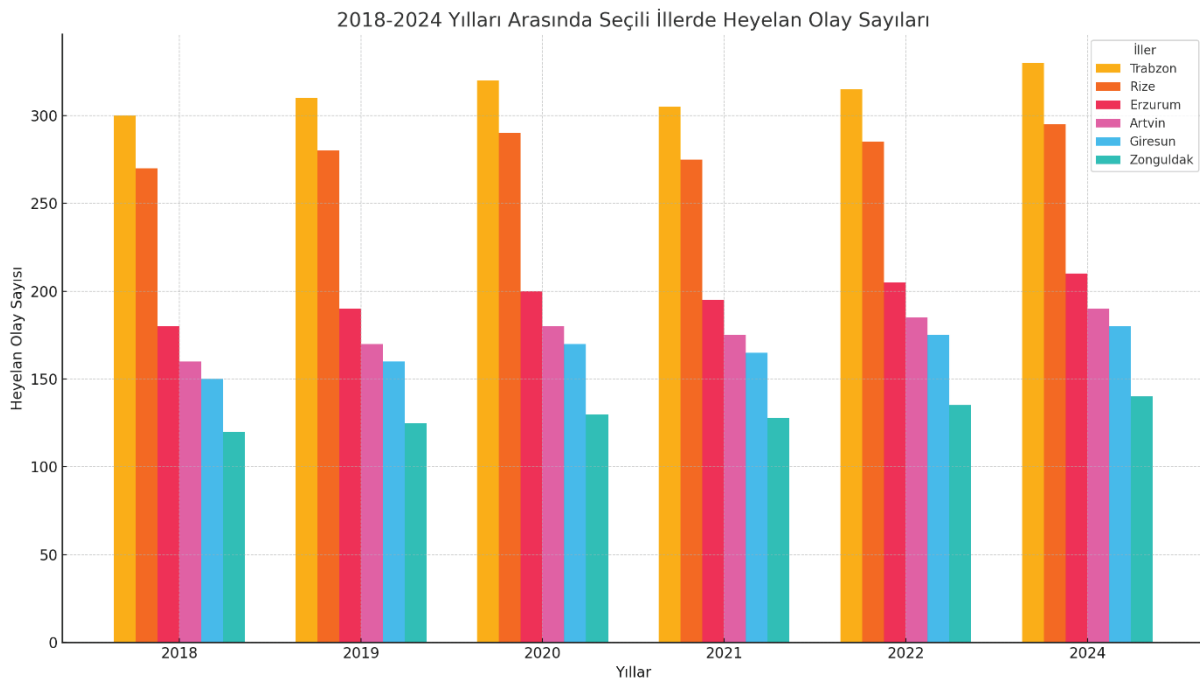


Figure 2. Provinces with the highest number of landslides in the Black Sea Region between 2018-2024.

Figure 2 shows the distribution of representative landslide events in Trabzon, Rize, Erzurum, Artvin, Giresun and Zonguldak provinces by year from 2018 to 2024. In 2024, the highest number of landslides were seen in Trabzon, with Zonguldak again at the bottom. According to these data, Zonguldak province, which has a very high number of landslides in its history, was selected because it contains many mines.

Criteria

Following the landslide disaster, five criteria that could cause a Natech accident were identified. These criteria were determined by four experts, including an occupational safety expert, an AFAD volunteer, an engineer, and an academician.

C1—Number of Mines: This number expresses the number of active mines in the district. A high number of mines increases the risk.

C2—Past Landslide Percentage: This represents the percentage of landslides that occurred in the district in the past. The data included in the Provincial Disaster Risk Reduction Plan (PDRR) of Zonguldak province were accepted.

C3—Landslide Risk: It includes the prevailing landslide risk in the districts

, taking into consideration the data included in IRAP.

C4—Area: This includes the area covered by the districts. The growth of the area has a risk-increasing effect.

C5—Elevation: This is the criterion covering the elevations of the districts. High elevations increase the effect of landslides and accidents.

Alternatives

Eight districts of Zonguldak province (Alaplı, Çaycuma, Devrek, Gökçeşey, Ereğli, Kilimli, Kozlu, Centre) were determined as alternatives. The information on the alternatives for the determined criteria is given in Table 3. This information was obtained from the Mineral Research and Exploration Organisation and the Zonguldak Provincial Disaster Risk Reduction Plan.

Table 4. Pythagorean fuzzy AHP decision matrix with linguistic variables

	C-1	C-2	C-3	C-4	C-5
C-1	EE	AA	AA	BA	L
C-2	BA	EE	EE	H	A
C-3	BA	EE	EE	AA	AA
C-4	AA	L	BA	EE	L
C-5	H	BA	BA	H	EE

Weighting of Criteria with Pythagorean Fuzzy AHP

After the landslide, the criteria that may cause the Natech accident were evaluated with the help of 4 experts specified by group collective decision-making. In this evaluation, the decision matrix given in Table 4 was formed by using the linguistic variables given in Table 1.

After creating the decision matrix with linguistic variables, Table 5 was created with the fuzzy numbers corresponding to the linguistic variables.

After creating the Pythagorean fuzzy matrix, the interval multiplication matrix in Table 6 was created.

After the interval multiplication matrix was obtained, Pythagorean Fuzzy AHP process steps were applied respectively. The weights determined using this method are listed in Table 7.

The ‘Past Landslide Percentage’ criterion has the highest weight among the criteria, with 0.25234. The number of landslide disasters experienced in the past in a district is data affecting the possibility of future disasters. Likewise, ‘Elevation’, which is a criterion that may cause landslide disasters, ranks second with 0.23717. These two criteria were ranked high since they were effective in the realization of the disaster, which was the basis for the Natech accident. The last criterion in the criterion ranking is ‘Area’ with 0,12380.

Table 3. Information on alternatives

District	Mines	Past Landslide Percentage	Risk	Area (km ²)	Elevation (mt)
Alaplı	Dolomite	11%	Middle	383	18
Çaycuma	Bauxite (kokaksu, güdüllü), Quartzite	31%	High	492	36
Devrek	Phosphate, Manganese	35%	High	953	103
Gökçeşey	—	6%	Middle	183	62
Ereğli	Quartz sand, Manganese, Hard coal	10%	Middle	736	12
Kilimli	Phosphate, Quartz Sand, Shifertone, Hard Coal	1%	Low	145	14
Kozlu	Phosphate, Quartz Sand, Shifertone, Hard Coal	1%	Low	177	18
Centre	Bauxite (Aydındere, Rüzgarlımeşe, Sapanlıdere), Phosphate (Sofular), Quartz sand (Uzungüney), Chifertone (Kokurdan), Hard coal (Asma)	5%	Low	272	10

Table 5. Pythagorean fuzzy AHP decision matrix

		C-1	C-2	C-3	C-4	C-5
C-1	MI	0.1965	0.35	0.35	0.55	0.65
	Mu	0.1965	0.45	0.45	0.65	0.8
	VI	0.1965	0.55	0.55	0.35	0.2
	Vu	0.1965	0.65	0.65	0.45	0.35
C-2	MI	0.55	0.1965	0.1965	0.2	0.35
	Mu	0.65	0.1965	0.1965	0.35	0.45
	VI	0.35	0.1965	0.1965	0.65	0.55
	Vu	0.45	0.1965	0.1965	0.8	0.65
C-3	MI	0.55	0.1965	0.1965	0.35	0.35
	Mu	0.65	0.1965	0.1965	0.45	0.45
	VI	0.35	0.1965	0.1965	0.55	0.55
	Vu	0.45	0.1965	0.1965	0.65	0.65
C-4	MI	0.35	0.65	0.55	0.1965	0.65
	Mu	0.45	0.8	0.65	0.1965	0.8
	VI	0.55	0.2	0.35	0.1965	0.2
	Vu	0.65	0.35	0.45	0.1965	0.35
C-5	MI	0.2	0.45	0.55	0.2	0.1965
	Mu	0.35	0.55	0.65	0.35	0.1965
	VI	0.65	0.45	0.35	0.65	0.1965
	Vu	0.8	0.55	0.45	0.8	0.1965

Table 6. Interval multiplication matrix

	C-1		C-2		C-3		C-4		C-5	
	DI	Du	DI	Du	DI	Du	DI	Du	DI	Du
C-1	0.000	0.0000	0.1000	0.3000	0.1000	0.3000	-0.3000	-0.1000	-0.6000	-0.3000
C-2	-0.300	-0.1000	0.0000	0.0000	0.0000	0.0000	0.3000	0.6000	-0.1000	0.1000
C-3	-0.300	-0.1000	0.0000	0.0000	0.0000	0.0000	0.1000	0.3000	0.1000	0.3000
C-4	0.100	0.3000	-0.6000	-0.3000	-0.3000	-0.1000	0.0000	0.0000	-0.6000	-0.3000
C-5	0.300	0.6000	-0.3000	-0.1000	-0.3000	-0.1000	0.3000	0.6000	0.0000	0.0000

Table 7. Criteria weights

Criteria	Criteria Weights
Past Landslide Percentage	0.25234
Elevation	0.23717
Landslide Risk	0.20825
Number of Mines	0.17844
Area	0.12380

Ranking of Alternatives with Pythagorean Fuzzy TOPSIS

8 districts in Zonguldak province were evaluated by the group decision-making method of experts in line with the determined criteria. The decision matrix obtained by using the linguistic variables in Table 2 is given in Table 8.

After the creation of the decision matrix, linguistic variables were placed into the matrix. Then, the Pythagorean fuzzy positive ideal solution and negative ideal solutions in Table 9 were calculated.

Then, the relative closeness indices of each alternative were calculated using the equation in Equation 13, and then the final ranking in Table 10 was obtained.

When the results are analyzed, Devrek district is determined as the district with the highest risk of occurrence of landslides and Natech risk in mines after landslides. It is followed by Çaycuma district. The information contained in the Irap reports supports the results. The districts with the lowest risk are Kilimli and Kozlu districts. There is also a risk in these districts. However, it is less than other districts. For this reason, when evaluating Natech accidents within

Table 8. Pythagorean fuzzy TOPSIS decision matrix

Decision Matrix	C1	C2	C3	C4	C5
Alaplı	L	ML	M	MH	L
Çaycuma	M	H	VH	MH	ML
Devrek	ML	VH	VH	H	H
Gökçeşey	OL	VL	ML	ML	M
Ereğli	M	ML	M	H	L
Kilimli	MH	OL	VL	L	L
Kozlu	MH	OL	VL	ML	L
Merkez	H	VL	ML	M	L

Table 9. Pythagorean fuzzy positive and negative ideal solutions

	Positive Ideal Solution			Negative Ideal Solution		
	μ	ν		μ	ν	
Number of Mines	0.70	0.60	0.39	0.10	0.99	0.10
Past Landslide Percentage	0.80	0.44	0.41	0.10	0.99	0.10
Landslide Risk	0.80	0.44	0.41	0.10	0.97	0.22
Area	0.70	0.60	0.39	0.25	0.92	0.30
Elevation	0.70	0.60	0.39	0.25	0.92	0.30

Table 10. Ranking of alternatives by Pythagorean fuzzy TOPSIS

Ranking	Province	E
1	Devrek	0
2	Çaycuma	-2.1098
3	Ereğli	-5.2327
4	Alaplı	-6.1006
5	Merkez	-6.11343
6	Gökçeşey	-7.32096
7	Kozlu	-7.51503
8	Kilimli	-7.69267

the scope of risk reduction studies in mines, it is thought that it would be useful to prioritize according to the relevant ranking.

CONCLUSION

Many material and moral damages occur during and as a result of disasters. Other accidents and natural events that occur at these times increase the negative effects of the disaster. Natech accidents are one of them. The characteristics of Natech accidents vary depending on the type of disaster. In this case, the criteria that cause Natech accidents

also vary. In this study, the landslide disaster was taken into consideration, and the study was carried out within the scope of the mining sector.

When the studies in the literature are examined, it is seen that the studies are focused on equipment rather than the studies carried out by making a sector-based distinction. However, there are a few studies carried out within the scope of the chemical sector. Salzano and Cozzani [27], Necci et al. [28] and Campedel et al. [29] carried out a Natech risk assessment for chemical and industrial facilities. Reniers et al. [30] developed a conceptual framework to improve Natech safety in the chemical industry. Güven et al. [4] ranked the sectors in the Gaziantep organized industrial zone according to Natech accidents, while Güven et al. [17] ranked the sectors in the Kırıkkale organized industrial zone according to Natech risks. When these studies and others in the literature are examined, no study was found in the mining sector. It is thought that the study will contribute to the literature in this respect. The fact that there was a Natech accident in the mine due to a landslide disaster in the recent past in our country also reveals that this study is a real-life problem.

In the study, the risks that may have caused the Natech accident after the landslide disaster were evaluated first. 'Percentage of past landslides' was determined as the most critical risk criterion. The last criterion was the 'Area' criterion. Then, eight districts of Zonguldak province, which was selected as the application province, were ranked according

to the risk of Natech accidents in mines after the landslide disaster. As a result of the applied method, the ranking is Devrek, Çaycuma, Ereğli, Alaplı, Centre, Gökçebey, Kozlu, and Kilimli.

Suggestions that can be made in line with the results obtained can be listed as follows.

1. One of the practices carried out within the scope of the disaster management process is the creation of provincial disaster risk reduction plans. Natech accidents should be included in the provincial risk reduction plans.
2. Studies should be initiated in line with the district rankings obtained according to Natech accident risks. Meetings should be held with the authorities in the relevant districts and situation analyses and risk analyses should be conducted in the mining areas with the participation of authorized personnel such as engineers, disaster teams, occupational health, and safety experts, etc.
3. Natech accidents should be included in risk assessments in the mining sector. Natech risks and precautions should be determined within the scope of risk analyses prepared with the participation of occupational safety specialists, mining engineers, authorized personnel in the mines and employers.
4. After a landslide disaster, the criteria that may cause Natech accidents should be taken into consideration in risk reduction studies and precautions should be determined. Especially considering the Natech accidents that occurred in the past, the necessary occupational health and safety measures should be increased. The creation of retaining walls, more careful ground surveys, opening of drainage wells, creation of work areas away from landslide risk areas, etc.

Natech accidents are an essential event that poses a risk for every sector. Therefore, it should be included in risk reduction studies. Diversification and elaboration of the studies will both increase attention to this issue and support the measures to be taken. Different sectors can be addressed in future studies. However, different disasters can be taken into consideration when evaluating the mining sector. Since the criteria will differ in each disaster and sector, the scope of the study can be increased by elaborating at this point.

AUTHORSHIP CONTRIBUTIONS

Authors equally contributed to this work.

DATA AVAILABILITY STATEMENT

The authors confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

CONFLICT OF INTEREST

The authors declared no conflict of interest.

ETHICS

There are no ethical issues with the publication of this manuscript.

STATEMENT ON THE USE OF ARTIFICIAL INTELLIGENCE

Artificial intelligence was not used in the preparation of the article.

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