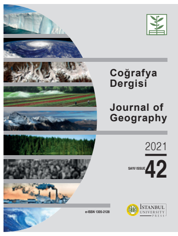

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A New Approach to the Fine Kinney Method with AHP Based ELECTRE I and Math Model on Risk Assessment for Natural Disasters

Doğal Afetler için AHP Tabanlı ELECTRE I ve Matematik Model ile Risk Değerlendirmesine Ilişkin Fine Kinney Yöntemine Yeni Bir Yaklaşım

Onur DERSE[1]

[1]Lecturer, Tarsus University, Department of Management and Organization, Logistics, Mersin, Turkey

ORCID: O.D. 0000-0002-4528-1999

ABSTRACT
Natural disasters impose enormous risks on human living and the environment. Researchers have given more attention to evaluating these risks in the context of disasters. Studies focus on the risk assessment of only one of the natural disasters for the regions. However, a risk assessment should be conducted that includes all-natural disasters for these regions. This risk assessment is dealt with by 8 different provinces in the Aegean region of Turkey in the work. A case data (1990-2020) on natural disasters such as earthquake, fire, landslide, flood, storm/typhoon has been considered for the cities covered. By revising the Fine Kinney risk assessment method for natural disasters, a risk score is obtained for each province. Then, the AHP based ELECTRE I method is applied to these provinces. As a result of this method, the riskiest region is obtained. The location of a crisis center in the riskiest region obtained should ensure effective solutions to the regions which are affected by the results of the disasters. Thus, the problem of choosing the most suitable location in the crisis center is handled with a goal programming approach.
Keywords: Risk Assessment; Mathematical Modelling; Natural Disasters

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Corresponding author/Sorumlu yazar: Onur DERSE / onurderse@tarsus.edu.tr

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1. INTRODUCTION

Natural disasters are undoubtedly one of the most complicated events in the modern era. As the uncertainty involved increases, the variables need to be examined further (Li et al., 2013). Data on natural disasters were collected in different ways by various groups for different purposes (Dilley et al., 2005). Natural disasters have consisted of earthquakes, floods, landslides, fire, storm/typhoon, and many more, etc. Many papers have been conducted related to natural disasters in the world (Guo et al., 2017, Supriyadi et al., 2018, Ivčević et al., 2019, Eyre et al., 2020, Lee et al., 2020). **Figure 1** depicts the distribution of several natural disasters in the world (Dilley et al., 2005).

Natural disasters are usually indistinguishable; which destroys everything in their way (Guidry and Margolis, 2005). However, assessment of the risks caused by natural disasters is known as the most important step to take precautions instead of preventing natural disasters. Luchuan (1999) and Xu et al., (2015) deals with risk assessment in a region for natural disasters. Emblemsvåg (2008) conducts risk analysis for a region in Norway for rock falls from natural disasters. Osipov et al. (2019) conduct a risk assessment for natural disasters such as earthquakes, floods and landslides.

In the field of risk assessment, the Fine Kinney method is widely used in practice (Kokangül et al., 2017). Kokangül et al. (2017) use the Fine Kinney method using a new approach to the classification of hazards in the health sector. Gul et al. (2018) discuss the Fine Kinney method in the arms industry. Ersoy et al. (2019) use the Fine Kinney method for the excavation process that is observed in the marble quarry, possible accidents, and their determined effects. Yılmaz and Özcan (2019) conducted a risk assessment and ranking integrating the AHP and the Fine Kinney method in their study. By this application, a different priority rank is created and which risk to be eliminated primarily was determined. The regional risk of natural disasters is a critical MCDM problem in the literature due to the complicated and usually conflicting evaluation index system (Chen et al., 2019). Yilmaz and Ozcan (2019) propose that the AHP method is one of the multi-criteria decision making (MCDM) methods used for risk. There are many different studies related to risk using the AHP method (Ganguly and Guin, 2013, Mabrouki et al., 2014; Dagsuyu et al., 2021). Also, ELECTRE, PROMETHEE, TOPSIS, VIKOR have been used for many years. Chen et al. (2019) use TOPSIS and VIKOR techniques to assess the risk of regions to natural hazards. The proposed approach not only ensures the listing of regions but also reveals the impact of indicators on regional risk. Sukcharoen et al. (2016) use GIS and MCDM practices to create a flood risk model in a region in Thailand. Being in the optimum position at the time of a natural disaster is very important for the quick access of the aid. For these reasons, various mathematical programming models are recommended for natural disasters. Hong and Jeong (2019) propose network design with a multi-purpose programming model for natural disasters. Ma et al. (2019) present site selection models for natural disaster shelters.

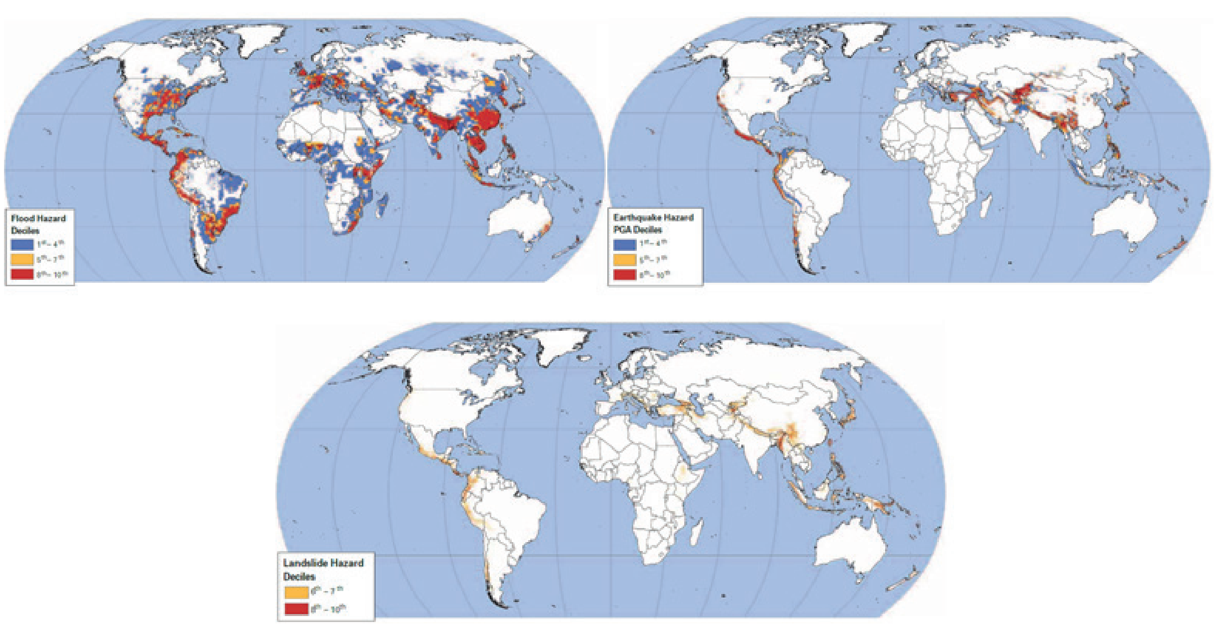

Figure 1: Distribution of Hazardous Areas by Hazard Type (Flood/Earthquake/Landslide) (Dilley et al., 2005).

Natural disasters are generally evaluated on their own. However, it will be more accurate to determine the general risk value of the region by considering all-natural disasters together. The original contribution of the study is the consideration of natural disasters together for the region under consideration. In this study, the provincial natural disasters in Turkey's Aegean region (earthquakes, fires, landslides, storm/typhoons, landslides) are dealt with on a yearly basis. The Fine Kinney method, which is one of the risk analysis methods, was revised and used with a new approach for natural disasters. The revised Fine Kinney risk scores are obtained for all provinces. Among the risk scores obtained, to choose the riskiest region, and using different methods is needed since the risk score values were close. The ELECTRE I method, which is one of the MCDM methods, is used with the weights obtained from the AHP method. For the riskiest region, considering the set covering and population goals, the most suitable residential area is selected with the goal programming approach. In this study, other important original contributions are to bring a new approach to the Fine Kinney method and Besides, using different methods together.

2. MATERIAL AND METHODS

The present study develops a new approximation based on the Fine Kinney. Also, provinces are compared with an AHP based ELECTRE I approach. As a result, the selection of the most suitable region with the goal programming for the selected province is discussed.

2.1. Fine Kinney method

Kinney and Wiruth (1976) developed the Fine Kinney method. In this method, three parameters (probability, exposure, and possible results) are taken into consideration for each hazard detected and the risk score is obtained by multiplying these values. The parameters of probability, exposure, and possible results are depicted in **Table 1, Table 2,** and **Table 3**. **Table 4** shows the risk score values (Kinney and Wiruth, 1976).

Table 1: Likelihood of Hazardous Event.

Probability	Value
Might well be expected	10
Quite possible	6
Unusual but possible	3
Only remotely possible	1
Conceivable but very unlikely	0.5
Practically impossible	0.2
Virtually impossible	0.1

Table 2: The Exposure Factor.

Frequency	Value
Continuous	10
Frequent (daily)	6
Occasional (weekly)	3
Unusual (monthly)	2
Rare (a few per year)	1
Very rare (yearly)	0.5

Table 3: Factors for Possible Consequences.

Severity	Value
Catastrophe (many fatalities)	100
Disaster (few fatalities)	40
Very serious (fatality)	15
Serious (serious injury)	7
Important (disability)	3
Noticeable (minor first aid accident)	1

Table 4: Risk Score.

Fine Kinney Risk Score	Fine Kinney Risk Situation
> 400	Very high risk; consider discontinuing operation
200 – 400	High risk; immediate correction required
70 – 200	Substantial risk; correction needed
20 – 70	Possible risk; attention indicated
> 20	Risk; perhaps acceptable

2.2. MCDM methods

2.2.1. AHP method

AHP method, which was introduced in Saaty (1980), uses the comparison values in **Table 5** below to compare the effects of different criteria on each other. The values in **Table 5** will be used to weight the criteria.

Table 5: AHP comparison matrix.

Importance intensity	Definition
1	Equal importance
3	Moderate importance of one over another
5	Strong importance of one over another
7	Very strong importance of one over another
9	The extreme importance of one over another
2,4,6,8	Intermediate values

2.2.2. ELECTRE I

Pang et al. (2011) ELECTRE I steps in are applied.
Step 1 – Constructing the Decision Matrix
Step 2 – Construction of the Normalized Decision Matrix
Step 3 – Construction of the Weighted Normalized Decision Matrix
Step 4 – Determination of Concordance and Discordance Sets

Step 5 – Calculation of Differentiation Measures
Step 6 – Superiority Comparison
Step 7 – Calculation of Net Concordance and Discordance Indices
As a result of these steps, there is the most suitable alternative.

2.3. Mathematical Model

The mathematical model can be divided into many subclasses. Goal programming is one of these classes. Goal programming is a mathematical model approach where multiple goals are used to achieve at the same time. The model developed for the region under consideration is expressed as follows.

Minimize $z = d_1^+ + d_1^- + d_2^+$ (1)

Subject to

$\sum_j^J w_j \,.\, y_j = d_1^+ - d_1^-$ (2)

$\sum_j^J u_{jj}\, y_j = d_2^+ - d_2^-$ (3)

$\sum_j^J y_j = p$ (4)

$\sum_j^J u_{jj}\, y_j \geq SC$ (5)

$d_1^+, d_1^-, d_2^+, d_2^-, p, z \geq 0$ (6)

$y_j = (0,1)$ (7)

The j index used in the equation represents the fields. Equation 1 shows the deviation values from the goals. Equation 2 is the constraint to select a region with a high population. Equation 3 is the constraint to minimize the distance of the selected region. Equation 4 shows the total number of selected regions. Equation 5 is the set covering constraint. Equation 6 shows positive variables. Equation 7 shows the binary variable.

3. A NEW APPROACH FOR THE FINE KINNEY METHOD

Risk assessment is used for natural disasters. One of the methods used is the Fine Kinney risk assessment method. However, this method needs to be revised for natural disasters. The revised version of the Fine Kinney method developed by Kinney and Wiruth (1976) for natural disasters is as below in **Table 6, Table 7, Table 8,** and **Table 9**. **Table 6** depicts the

Table 6: Revised Likelihood of Hazardous Event.

Probability	Value	Revised Probability for Fire	Revised Probability for Earthquake	Revised Probability for Landslide	Revised Probability for Storm / Typhoon	Revised Probability for Flood
Might well be expected	10	1.level (the riskiest region)	1.level (the riskiest region)	1.level (the riskiest region)	1.level (the riskiest region)	1.level (the riskiest region)
Quite possible	6	2.level (potentially risky area)	2.level (potentially risky area)	2.level (potentially risky area)	2.level (potentially risky area)	2.level (potentially risky area)
Unusual but possible	3	3.level (unusual but possible)	3.level (unusual but possible)	3.level (unusual but possible)	3.level (unusual but possible)	3.level (unusual but possible)
Only remotely possible	1	4.level (only remotely possible)	4.level (only remotely possible)	4.level (only remotely possible)	4.level (only remotely possible)	4.level (only remotely possible)
Conceivable but very unlikely	0.5	5.level (Conceivable but very unlikely)	5.level (Conceivable but very unlikely)	5.level (Conceivable but very unlikely)	5.level (Conceivable but very unlikely)	5.level (Conceivable but very unlikely)
Practically impossible	0.2	6.level (practically impossible)	6.level (practically impossible)	6.level (practically impossible)	6.level (practically impossible)	6.level (practically impossible)
Virtually impossible	0.1	-	7.level (virtually impossible)	-	-	-

Table 7: Revised Exposure Factor.

Frequency	Value	Revised Frequency
Continuous	10	A natural disaster that occurs approximately every month
Frequent (daily)	6	A natural disaster that takes place approximately every two months
Occasional (weekly)	3	A natural disaster that takes place approximately three or four times a year
Unusual (monthly)	2	A natural disaster that occurs approximately twice a year
Rare (a few per year)	1	A natural disaster that occurs approximately once a year
Very rare (yearly)	0.5	Natural disaster less than once a year

Table 8: Revised Factors for Possible Consequences.

Severity	Value	Revised Severity
Catastrophe (many fatalities)	100	Deaths
Disaster (few fatalities)	40	Death or Destroyed Buildings
Very serious (fatality)	15	Injured
Serious (serious injury)	7	Damaged Buildings
Important (disability)	3	-
Noticeable (minor first aid accident)	1	No damage / No injured

Table 9: Revised Risk Score.

Fine Kinney Risk Score	Fine Kinney Risk Situation	Revised Fine Kinney Risk Value
> 400	Very high risk	5
200 – 400	High risk	4
70 – 200	Substantial risk	3
20 – 70	Possible risk	2
> 20	Risk; perhaps acceptable	1

probability values revised to cover the range for each natural disaster occurred in the region.

In **Table 7**, the incident frequencies that occurred in natural disasters are compared with the frequency values of the Fine Kinney method and revised frequency values are obtained.

In **Table 8**, the severity occurred in the natural disasters are created by comparing the severity values of the Fine Kinney method.

Table 9 depicts the revised Fine Kinney Risk scores. While the Fine Kinney Risk Score is depicted in Equation 8, in the revised Fine Kinney Risk Score it is depicted in Equation 9.

Fine Kinney Risk Score = Likelihood of Hazardous Event x Exposure Factor x Possible Consequences (8)

If (Fine Kinney Risk Situation > 400)
Revised Fine Kinney Risk Value = 5;
else If(200 < Fine Kinney Risk Situation < 400)
Revised Fine Kinney Risk Value = 4;
else If(70 < Fine Kinney Risk Situation < 200)
Revised Fine Kinney Risk Value = 3; (9)
else If(20 < Fine Kinney Risk Situation < 70)
Revised Fine Kinney Risk Value = 2;
else (Fine Kinney Risk Situation < 20)
Revised Fine Kinney Risk Value = 1;

4. APPLICATIONS AND RESULTS

4.1. Application and Result for The New Fine Kinney Method

This case is carried out in the Aegean region of Turkey. There are 8 provinces in the Aegean region. These provinces; Afyonkarahisar, Aydın, Denizli, İzmir, Kütahya, Manisa, Muğla, and Uşak are the provinces. The most common natural disasters in the Aegean region are taken into consideration. Fire, earthquake, landslide, storm/typhoon, and flood natural disasters are taken into consideration for each province. Frequency and Severity values are taken from the AFAD (Ministry of Interior Disaster and Emergency Management Presidency) page. Values are taken from 1990 to 2020. Probability values are taken by taking into consideration the regional risk level for each natural disaster. **Table 10, Table 11, Table 12, Table 13, Table 14, Table 15, Table 16, Table 17** show the values of the Fine Kinney and the revised Fine Kinney for each province.

4.2. Application and result for AHP based ELECTRE I

By the results depicted in the tables, the risk scores of some provinces are higher. However, a different method is recommended for the provinces with high scores since the difference between the risk scores is not high. AHP based ELECTRE I method is recommended for Muğla, Manisa, Denizli, and İzmir provinces with risk scores of 13, 14, 15, and 15. Studies are using the ELECTRE I method based on AHP

Table 10: Fine Kinney and Revised Fine Kinney Scores for Afyonkarahisar.

Hazards	Revised Probability for Natural Disasters	Revised Frequency	Revised Frequency	Deaths	Death or Destroyed Buildings	Injured	Damaged Buildings	Revised Severity	Fine Kinney Risk Score	Revised Fine Kinney Risk Value
Fire	10	11	0.5			6*15	4*7	(90+28) / 10 = 11.8	59	2
Earthquake	6	46	2	8*100	20*40	10*15	59269*7	7.03	84.36	3
Landslide	0.2	7	0.5				7*7	7	0.7	1
Storm/Typhoon	1	22	1				1*7	7	7	1
Flood	0.5	32	1				49*7	7	3.5	1
TOTAL Risk Score									154.56	8

Table 11: Fine Kinney and Revised Fine Kinney Scores for Aydın.

Hazards	Revised Probability for Natural Disasters	Revised Frequency	Revised Frequency	Deaths	Death or Destroyed Buildings	Injured	Damaged Buildings	Revised Severity	Fine Kinney Risk Score	Revised Fine Kinney Risk Value
Fire	10	127	4			4*15	8*7	(60+56) / 12 = 9.67	386.8	4
Earthquake	10	33	1					1	10	1
Landslide	0.2	45	2		5*40			40	16	1
Storm/Typhoon	3	23	1		1*40	2*15		23.33	69.99	2
Flood	0.5	16	0.5		6*40		120*7	8.57	2.1425	1
TOTAL Risk Score									484.9325	9

Table 12: Fine Kinney and Revised Fine Kinney Scores for Denizli.

Hazards	Revised Probability for Natural Disasters	Revised Frequency	Revised Frequency	Deaths	Death or Destroyed Buildings	Injured	Damaged Buildings	Revised Severity	Fine Kinney Risk Score	Revised Fine Kinney Risk Value
Fire	6	56	2	4*100	1*40	1*15	8*7	(400+40+15+56) / 14 = 36.5	438	5
Earthquake	10	52	2		100*40		100*7	23.5	470	5
Landslide	0.2	25	1				566*7	7	1.4	1
Storm/Typhoon	1	28	1	6*100		3*15		71.67	71.67	3
Flood	0.2	32	1	4*100		7*15	496*7	7.84	1.568	1
TOTAL Risk Score									982.638	15

Table 13: Fine Kinney and Revised Fine Kinney Scores for İzmir.

Hazards	Revised Probability for Natural Disasters	Revised Frequency	Revised Frequency	Deaths	Death or Destroyed Buildings	Injured	Damaged Buildings	Revised Severity	Fine Kinney Risk Score	Revised Fine Kinney Risk Value
Fire	10	194	6	4*100		6*15	27*7	(400+90+189) / 37 = 18.35	1101	5
Earthquake	10	115	3				2141*7	7	210	4
Landslide	0.2	36	1		2*40	1*15	32*7	9.11	1.822	1
Storm/Typhoon	3	59	2	6*100		10*15	3*7	40.58	243.48	4
Flood	0.5	21	1			4*15	101*7	7.3	3.65	1
TOTAL Risk Score									1559.952	15

Table 14: Fine Kinney and Revised Fine Kinney Scores for Kütahya.

Hazards	Revised Probability for Natural Disasters	Revised Frequency	Revised Frequency	Deaths	Death or Destroyed Buildings	Injured	Damaged Buildings	Revised Severity	Fine Kinney Risk Score	Revised Fine Kinney Risk Value
Fire	6	60	2		1*40	2*15	24*7	(40+30+168) / 27 = 8.81	105.72	3
Earthquake	6	85	3	2*100		50*15	1*7	18.06	325.06	4
Landslide	0.1	17	1					1	0.1	1
Storm/Typhoon	1	21	1	6*100		6*15		57.5	57.5	2
Flood	0.5	6	0.5				50*7	7	1.75	1
TOTAL Risk Score									490.13	11

Table 15: Fine Kinney and Revised Fine Kinney Scores for Manisa.

Hazards	Revised Probability for Natural Disasters	Revised Frequency	Revised Frequency	Deaths	Death or Destroyed Buildings	Injured	Damaged Buildings	Revised Severity	Fine Kinney Risk Score	Revised Fine Kinney Risk Value
Fire	10	82	3		1*40	2*15	9*7	(40+30+63) / 12 = 11.08	332.4	4
Earthquake	10	23	1		1*40			40	400	5
Landslide	0.2	41	1			2*15	29*7	7.52	1.504	1
Storm/Typhoon	3	37	1	11*100		7*15	1*7	63.79	191.37	3
Flood	0.2	17	1	6*100			430*7	8.28	1.656	1
TOTAL Risk Score									926.93	14

Table 16: Fine Kinney and Revised Fine Kinney Scores for Muğla.

Hazards	Revised Probability for Natural Disasters	Revised Frequency	Revised Frequency	Deaths	Death or Destroyed Buildings	Injured	Damaged Buildings	Revised Severity	Fine Kinney Risk Score	Revised Fine Kinney Risk Value
Fire	10	384	10	7*100		16*15	10*7	(700+240+70) / 33 = 30.61	3061	5
Earthquake	10	62	2			9*15	19*7	9.57	191.4	3
Landslide	0.2	18	1				9*7	7	1.4	1
Storm/Typhoon	1	70	2	5*100		1*15	1*7	74.57	149.14	3
Flood	0.5	19	1				28*7	7	3.5	1
TOTAL Risk Score									3406.44	13

Table 17: Fine Kinney and Revised Fine Kinney Scores for Uşak.

Hazards	Revised Probability for Natural Disasters	Revised Frequency	Revised Frequency	Deaths	Death or Destroyed Buildings	Injured	Damaged Buildings	Revised Severity	Fine Kinney Risk Score	Revised Fine Kinney Risk Value
Fire	10	21	1				11*7	77 / 11 = 7	70	3
Earthquake	6	0	0					1	0	1
Landslide	0.1	9	0.5					1	0.05	1
Storm/Typhoon	1	5	0.5		1*40	6*15		18.57	9.285	1
Flood	0.2	2	0.5				2200*7	7	0.7	1
TOTAL Risk Score									80.035	7

(Pang et al., 2011). There are also many studies using the ELECTRE I method (Almeida, 2005, Hatami-Marbini and Tavana, 2011). In this method, Muğla, Manisa, Denizli, and İzmir provinces are used as an alternative. The criteria are the Fine Kinney Risk Scores, the revised Fine Kinney Risk Scores, and provincial populations. The reason why the population is taken as a criterion is that the population is too high to be affected in the event of natural disasters.

Table 18 shows the weighting of criteria with AHP.

After the AHP weights are obtained, ELECTRE I steps are applied.

Step 1 – Constructing the Decision Matrix

In Table 19, a decision matrix is formed for alternatives and criteria. Alternatives represent the provinces in the revised Fine Kinney method. Criteria represent total the Fine Kinney risk score, the total revised Fine Kinney Risk Score, and population amount. The values in the total Fine Kinney Risk score are evaluated to take into account the difference between the values in the same situation.

Step 2 – Construction of the Normalized Decision Matrix

Table 20 depicts the normalization of the decision matrix.

Step 3 – Construction of the Weighted Normalized Decision Matrix

The Weighted Normalized Decision Matrix in Table 21 is formed by multiplying the criteria weights obtained by the AHP method with the normalized decision matrix obtained in Table 20.

Table 18: AHP Weight calculation.

The first part (scoring)	K1 (Fine Kinney Risk Score)	K2 (Revised Fine Kinney Risk Value)	K3 (Population amount)	Weight
K1 (Fine Kinney Risk Score)	1	1	3/1	0,43
K2 (Revised Fine Kinney Risk Value)	1	1	3/1	0,43
K3 (Population amount)	1/3	1/3	1	0,14

Table 19: Application of Step 1.

	K1 (Fine Kinney Risk Score)	K2 (Revised Fine Kinney Risk Value)	K3 (Population amount)
A1 (Denizli)	982.638	15	1037208
A2 (İzmir)	1559.952	15	4367251
A3 (Manisa)	926.93	14	1440611
A4 (Muğla)	3406.44	13	983142

Table 20: Application of Step 2.

	K1 (Fine Kinney Risk Score)	K2 (Revised Fine Kinney Risk Value)	K3 (Population amount)
A1 (Denizli)	0.25	0.53	0.22
A2 (İzmir)	0.39	0.53	0.91
A3 (Manisa)	0.23	0.49	0.3
A4 (Muğla)	0.86	0.46	0.2

Table 21: Application of Step 3.

	K1 (Fine Kinney Risk Score)	K2 (Revised Fine Kinney Risk Value)	K3 (Population amount)
A1 (Denizli)	0.1075	0.2279	0.0308
A2 (İzmir)	0.1677	0.53	0.1274
A3 (Manisa)	0.23	0.53	0.042
A4 (Muğla)	0.0989	0.1978	0.28

Step 4 / Step 5 – Determination of Concordance and Discordance Sets / Calculation of Differentiation Measures

The matrix V is used to determine the sets of concordance (C) and discordance (D).

Concordance Sets

In this set, two alternatives are compared and high-value ones are chosen. **Table 22** is obtained by applying the necessary procedures.

Table 22: Concordance Index Values.

	A1 (Denizli)	A2 (İzmir)	A3 (Manisa)	A4 (Muğla)
A1 (Denizli)	-	0	0	0.86
A2 (İzmir)	1	-	0.57	0.86
A3 (Manisa)	1	1	-	0.86
A4 (Muğla)	0.14	0.14	0.14	-

$C_{12} = \{\ \}$, $C_{13} = \{\ \}$, $C_{14} = \{1,2\}$, $C_{21} = \{1,2,3\}$, $C_{23} = \{2,3\}$, $C_{24} = \{1,2\}$, $C_{31} = \{1,2,3\}$, $C_{32} = \{1,2,3\}$, $C_{34} = \{1,2\}$, $C_{41} = \{3\}$, $C_{42} = \{3\}$, $C_{43} = \{3\}$

Discordance Sets

In this set, two alternatives are compared and low-value ones are chosen. **Table 23** is obtained by applying the necessary procedures.

Table 23: Discordance Index Values.

	A1 (Denizli)	A2 (İzmir)	A3 (Manisa)	A4 (Muğla)
A1 (Denizli)	-	1	1	1
A2 (İzmir)	0	-	0.73	0.46
A3 (Manisa)	0	0	-	0.72
A4 (Muğla)	0.12	1	1	-

$D_{12} = \{1,2,3\}$, $D_{13} = \{1,2,3\}$, $D_{14} = \{3\}$, $D_{21} = \{\ \}$, $D_{23} = \{1\}$, $D_{24} = \{3\}$, $D_{31} = \{\ \}$, $D_{32} = \{\ \}$, $D_{34} = \{3\}$, $D_{41} = \{1,2\}$, $D_{42} = \{1,2\}$, $D_{43} = \{1,2\}$

Step 6 – Superiority Comparison

The 0.5475 value obtained below is compared with **Table 22** and the larger values take the value "1" and the smaller values take the value "0". In this way, **Table 24** is formed.

Table 24: F Matrix (Concordance Superiority).

	A1 (Denizli)	A2 (İzmir)	A3 (Manisa)	A4 (Muğla)
A1 (Denizli)	-	0	0	1
A2 (İzmir)	1	-	1	1
A3 (Manisa)	1	1	-	1
A4 (Muğla)	0	0	0	-

$C = (1 / (m * (m – 1)))*\sum C_{kl}$

$C = (1 / (4* (4 – 1)))*(0.86+1+0.57+0.86+1+1+0.86+0.14+0.14+0.14) = 0.5475$

The 0.5858 value obtained below is compared with **Table 23** and the larger values take the value "1" and the smaller values take the value "0". In this way, **Table 25** is formed.

Table 25: G Matrix (Discordance Superiority).

	A1 (Denizli)	A2 (İzmir)	A3 (Manisa)	A4 (Muğla)
A1 (Denizli)	-	1	1	1
A2 (İzmir)	0	-	1	0
A3 (Manisa)	0	0	-	1
A4 (Muğla)	0	1	1	-

$D = (1 / (m * (m – 1)))*\sum D_{kl}$

$D = (1 / (4* (4 – 1)))*(1+1+1+0.73+0.46+0.72+0.12+1+1) = 0.5858$

Step 7 – Calculation of Net Concordance and Discordance Indices

Table 26 and **Table 25** values are applied and **Table 26** is obtained.

Table 26: Application of Step 7.

	A1 (Denizli)	A2 (İzmir)	A3 (Manisa)	A4 (Muğla)
A1 (Denizli)	-	0	0	1
A2 (İzmir)	0	-	1	0
A3 (Manisa)	0	0	-	1
A4 (Muğla)	0	0	0	-

AHP based ELECTRE I method results are as follows. A4 < A3 < A2 / A4 < A1. According to the results, A2 is the most critical region. For this reason, A2 information is used in goal programming.

4.3. Application and result for mathematical model

In this application, the A2 alternative province, which is obtained as the riskiest from AHP based ELECTRE I method, is discussed. The purpose of this case is to form a crisis center in the most suitable region in the riskiest region in case of a natural disaster. The appropriate crisis center location should be in a near and high-populated area that will increase the response rate.

A2 alternative is İzmir province. Districts in İzmir provinces are used as the j index. There are 30 districts in İzmir province. These districts are Aliağa, Balçova, Bayındır, Bayraklı, Bergama, Beydağ, Bornova, Buca, Çeşme, Çiğli, Dikili, Foça, Gaziemir, Güzelbahçe, Karabağlar, Karaburun, Karşıyaka, Kemalpaşa, Kınık, Kiraz, Konak, Menderes, Menemen, Narlıdere, Odemis, Seferihisar, Selcuk, Tire, Torbali and Urla. w_j values are entered into the system as population values (URL 1) and u_{jj} values as distances between districts (URL 2). Goals are to choose the district where the population is high and the distance to other regions is minimum. In the goal programming result, the most suitable district is obtained as the district of Karaburun. The p-value is 1.

5. CONCLUSIONS

Natural disasters consisting of earthquake, fire, landslide, storm/typhoon, flood, and many more. etc. are serious situations that pose a risk. When a risk analysis is performed in natural disasters for a region under consideration, one of the all-natural disasters is taken into account in general. However, more than one natural disaster can occur in an area and these situations need to be considered together. In this study, the provinces in the Aegean region of Turkey are taken into account. For the provinces in the Aegean region, the revised Fine Kinney method is used for natural disasters. Since the risk values resulting from the Fine Kinney method are near for more than one province, another method is needed. This method is the AHP based ELECTRE I method. In the AHP part of this method, the criteria are weighted. Then the criteria weighted by AHP are used as inputs in the ELECTRE I method. As a result of the ELECTRE I method, the riskiest province is seen as İzmir province. Since it is considered appropriate to establish a crisis center in İzmir province, a mathematical model is suggested for İzmir province. Goal programming is chosen as a mathematical model. In goal programming, determine the district/districts where the population is high and other districts are near. As a result of the study, the most suitable district in the riskiest city is chosen.

The original contribution of this study is the use of the Fine Kinney method with a new approach, the use of more than one method as an input, and a mathematical model. Besides, the most important part of the study is the consideration of many natural disasters that can occur in a wide area. For future studies, to expand the region and use the revised Fine Kinney method in new areas have been recommended.

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