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ASSESSMENT OF URBAN FLOOD RISKS OF THE CITIES USING ENTROPY-VIKOR METHODS IN TÜRKİYE

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Highlights

- Exposure, hazard, vulnerabilty are effective for urban flood risk.
- The risks of the areas should be evaluated by different methods.
- The study results are effective.

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ABSTRACT: In recent years, there is growing interest for evaluation of urban flood risks of cities over the past decade due to rapid urbanization and climate change. The optimal flood risk assessment is strategically achieved not only with classical risk modelling approaches but also with holistic and comprehensive framework. This paper focuses on a detailed flood assessment providing risk database for policymakers and urban planners to decide the flood prone areas in Turkey. In this context, the Entropy based VIKOR (VIseKriterijumska Optimizacija Kompromisno Resenje) was provided to evaluate a range of flood risk criteria named number of floods, population density and number of buildings, flood protection area which are under the concept of risk dimension including "hazard, exposure and vulnerability" aspects. Computational results demonstrate that the provinces of Şanlıurfa, Ordu, Zonguldak and Van are assigned with higher urban risk values, respectively and the ranking of the cities was presented with different q values. The findings should support practitioners and researchers for land use planning and risk reduction works as the detailed flood risk evaluation was presented in terms of the flood management.

Keywords: *Entropy-VIKOR, Exposure, Hazard, Urban flood risks, Vulnerability*

1. INTRODUCTION

The raising awareness of disaster management is of great significance to protect the earth, human health. Flooding is one of the most prominent disasters which bring about catastrophic effects [1]. Flood is defined as overflowing of water due to watercourses and the generation of storm water [2]. With increasing severity of the floods, more regions are affected by floods [3]. Given this, how can urban flood management deal with this crisis? As the disaster rates which threaten the sustainable world increase with the climate change, new management shifts are urgently required to overcome these disasters. This new shift is optimal urban flood management understanding the risks at the local level. It represents the shift from classical risk management models to holistic systems and visionary methods. Urban flood management is an integrated vision that requires multi-dimensional evaluation. With the growth of cities, urban flood risks have become increasing problems for regional and national government. The devastating impacts of flood are exacerbated in cities. In Mediterranean, large floodable regions highly destructive are generated and the population has affected due to intense population, wrong perception of risk, required short reaction time [4]. Turkey is a vulnerable country in which natural disasters cause large number of victims and affected people [5]. Accurate urban flood management models are required to reduce this mitigation and building resilience in regions. In the flood management of cities, first, cities with high risk should be identified. To determine the risk situations of cities, an evaluation including various parameters of the risk ensures the accuracy of the analysis. While most studies are evaluated based on vulnerability criteria, studies that include other criteria should be prioritized in the flood assessment. Vulnerability is considered as the low ability to cope with the environmental threats [6] and a tool for the severity and climate change [7]. The main contribution of this study is the integration of multi-criteria decision-making (MCDM) tools in urban flood risk assessment regarding hazard, exposure, and vulnerability dimensions of the risk. First, we identified the most important flood

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conditioning factors. Second, we ranked the cities to identify hazardous areas in a flood-prone city in Turkey. Although most papers have focused on flood management, there is a great gap of evaluation of cities and flood risk criteria at the national scale in Turkey.

This paper mainly uses the hierarchical analysis method to evaluate the cities to comprehensively assess the important influencing factors of flood management processes. Main contribution of this paper is to determine the weights of number of floods, population density and number of buildings, flood protection area and to evaluate them with the developed methodology in the context of flood management. Novelties of this study are presented as follows:

- Integrating Entropy and VIKOR method and various criteria were first incorporated to decide the importance weights of the criteria and ranking the cities in Turkey.
- Three basic components of risk; hazard, exposure, and vulnerability, are first considered for measuring urban flood risk. Flood disasters considering the hazard parameter, population density and the number of buildings discussed within the scope of exposure, flood protection area within the scope of vulnerability were incorporated into the study.
- Ranking the city's urban flood risks was validated with different q values and this ensures the comparison of the results.

2. LITERATURE REVIEW

Although few studies are available on flood risk evaluations in Turkey, not enough discussion has been presented at the national scale using MCDM methods. However, MCDM is widely used for the disaster studies [8] – [9]. Especially, TOPSIS has been applied for ranking the regions on flood risk assessments [10] – [12]. Sörensen et al. [13] identified regions which require improvements for urban flood management. They evaluated the water systems, reducing energy-usage, land usage, climate change effects, etc. Yang et al. [14] addressed the flood risk evaluation and prediction using fuzzy AHP. They predicted risk factors and presented the measures. Developed evaluation index could ensure more reasonable results for the flood risk management. Radmehr and Araghinejad [15] presented decisions for urban flood management with multi-criteria decision making and a geographic information system. Also, artificial neural network (ANN) model was used to weight the criteria of flood management strategies are discussed in Iran. Moghadas et al. [16] developed an index regarding social, economic, institutional, and environmental aspects using MCDM. The methodology integrates AHP and TOPSIS for ranking cities in Tahran. Data were mostly from the Statistical Center of Iran and Tehran Municipality's accessible data sources. The study resulted with most resilient districts. Sun et al. [17] presented a comprehensive analysis to decide the regional risk size. They used three MCDM methods to compare the units of Jiangsu Province and criteria including agriculture, population, drainage etc. Shah et al. [18] discussed the vulnerability to flood in Pakistan regions. They assigned weights to the criteria such as exposure, susceptibility using expert decisions. The results revealed the vulnerable and low resilience regions. Liu et al. [19] assessed the flood risks of regions of China using an index. The areas with high, moderate, and low levels of flood risk were obtained in the paper. Xu et al. [20] integrated an entropy weight method and analytic hierarchy process (AHP) method to weight the criteria. K-means cluster for flood risk map and TOPSIS for ranking were used to present the high-risk zones. Liu et al. [21] discussed the agricultural drought and flood disasters in the three provinces of Yangtze River. They used three MCDM methods and sensitivity analysis to decide the flood disaster. The results showed that the region was affected by drought and flooding. Danumah et al. [22] used MCDM to assess the flood risk in Abidjan. They evaluated the criteria, hazard, and vulnerability. Results of MCDM showed the areas under high and very high flood risk. Xie et al. [23] addressed the meteorological disasters to evaluate the provinces of China. They used a grey cluster model. They provided the serious and lighter grey classes. Camarasa-Belmonte and Soriano-García [4] assessed the flood risks in Spain. They evaluated the hazards and exposure and created a map that shows the floodable areas. Doorga et al. [24] proposed GIS based MCDM to model the flood risks. The vulnerable areas were identified based on the physical, social, and economical metrics. The regions highly vulnerable were considered to design the urban landscape. Garrote et al. [25] proposed a flood risk analysis regarding the relation of cultural heritage and the flow-prone areas. Developed risk matrix included hazard and vulnerability. Risk levels obtained showed the high flood risks to eliminate these risks. Souissi et al. [26] prepared a flood map with MCDM. They considered eight factors regarding their weights using AHP. The results showed the most prominent flood zones. Hadian et al. [27] analysed the flood risks using TOPSIS and Attributive Border Approximation Area Comparison (MABAC). They also developed a map showing distribution of high-risk regions.

3. MATERIAL AND METHODS

Climate changes reveal the risk of flooding in urban areas. In the study, urban flood risks are evaluated considering the "hazard, exposure and vulnerability" parameters. Real data for each parameter was used to assign the weights of the criteria. ENTROPY-based VIKOR method is applied to ranking the of the provinces in Turkey. In Figure 1, the risk parameters of natural events including combination of "hazard, exposure and vulnerability" are demonstrated in Figure 1.

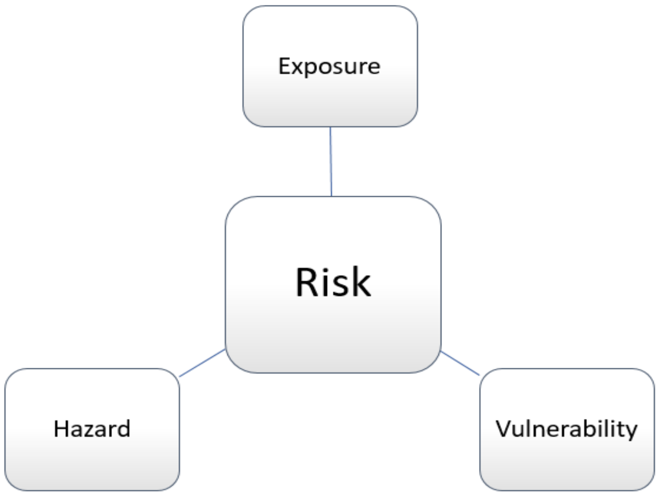

Figure 1. Conceptual framework of urban flood risk [28].

In the risk analysis, risk definition, measurement, evaluation and control stages are applied and probability and the effect are the basically used parameters to define the risk factors [29]. This paper deals with three risk factors including hazard indicates the frequency of the risks, vulnerability indicates the possibility of predicting risks before they occur, and exposure is the seriousness of the risk to the system.

This approach is derived from the FMEA (failure mode and effects analysis) method including occurrence, detectability, and severity parameters [30]. These FMEA parameters are part of the systematic method to examine the risks and reduce the highest risk factors [31] – [32].

3.1. Material

There are three basic components for measuring urban flood risk. In the study, these three components, hazard, exposure, and vulnerability, are considered. Flood risks were evaluated regarding number of floods, population density and number of buildings, flood protection area. In preliminary works, flood durations, depth-velocity were considered [33]; population, capacity, exposure [34]; only flood vulnerability [35]; mortality, economical and agricultural issues [36]; social and economical metrics [37], resilience [38].

Within the scope of hazard, flood disasters in Turkey in 2019, 2020 and 2021 are considered. In this context, distribution of Heavy Rain/Flood Disasters in Turkey in 2019 [39] by Meteorological Disasters

Assessment report of the T.C. Republic of Türkiye Ministry of Agriculture and Forestry, Distribution of Heavy Rain/Flood Disasters in Turkey in 2020 [40] by Meteorological Disasters Evaluation report of T.R. Ministry of Environment, Urbanization and Climate Change General Directorate of Meteorology, the Distribution of Heavy Rain/Flood Disasters in Turkey in 2021 [41] by Meteorological Disasters Assessment report of the Ministry of Environment, Urbanization and Climate Change General Directorate of Meteorology is taken into account. By evaluating the data published on the map, the average of the years 2019-2020-2021 was taken and in Table 1 is figured.

Table 1. Average values obtained by examining the maps for the years 2019-2020-2021

Provinces	Average values
Balıkesir	12.17
Bursa	12.5
İzmir	13
Antalya	11.33
Muğla	10.83
Ordu	9.33
Van	10.83
Giresun	11.83
Zonguldak	8
Manisa	9
Şanlıurfa*	5.33

*Taken into account due to severe flooding in 2023.

In the study, population density and the number of buildings are discussed within the scope of exposure. The data discussed contains the data in the “Annual growth rate of population and population density of provinces by years, 2007-2022” [42] and the “Households by provinces and ownership status of the dwelling 2021” [43] data shared by the Turkish Statistical Institute (TURKSTAT).

Table 2. Population density and number of households of provinces

Provinces	Population Density	Number of households by province
Balıkesir	88	456,193
Bursa	307	966,765
İzmir	371	1,053,086
Antalya	130	858,107
Muğla	82	362,287
Ordu	128	265,344
Van	58	241,504
Giresun	66	164,548
Zonguldak	178	199,841
Manisa	112	475,046
Şanlıurfa	116	411,421

Within the scope of Vulnerability, data of the year 2021 in the "Flood Protection Facilities by Province" shared by the General Directorate of State Hydraulic Works are used [44]. In this context, Flood Protection Facility Protection Area (ha) data are taken into consideration. In Table 3, protection area percentages are calculated by considering the area of the provinces and the 2021 Flood Protection Facility Protected Area data.

Table 3. Flood protection area percentages of provinces

Provinces	Surface Area of the Province (km2)	2021 Flood Protection Area (ha)	%Flood Protection Area
Balıkesir	14,583	39,932	2.738
Bursa	10,813	15,262	1.411
İzmir	11,891	55,733	4.687
Antalya	20,177	69,296	3.434
Muğla	12,654	31,543	2.493
Ordu	5,861	24	0.004
Van	20,921	290	0.014
Giresun	7,025	4,114	0.586
Zonguldak	3,342	647	0.194
Manisa	13,339	32,642	2.447
Şanlıurfa	19,242	5,615	0.292

3.2. Methods

Preliminary works evaluate the vulnerability of the regions to the flood using curve method [45] and probability [46]. In this study, MCDM methods were used due to potentially relevance to analyze the current data in Turkey. The presented study contains a new approach integrating Entropy and VIKOR methods. To the best of our knowledge, this integrating method named Entropy based VIKOR is first applied to decide the vulnerable cities to flood in the national scale.

3.2.1. ENTROPY method

Entropy method is one of the preferred MCDM methods although it is new for the flood assessment [47]. The method consists of 5 basic steps as follows:

Step 1: Creating the decision matrix

$$X = [x_{ij}]_{mxn} = \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ x_{m1} & x_{m2} & \dots & x_{mn} \end{bmatrix}; i = 1,2,\dots,m; j = 1,2 \dots n \tag{1}$$

Step 2: Performing normalization to eliminate measurement outliers

$$v_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \tag{2}$$

Step 3: Finding Entropy (E_j) values

$$e_j = -k\sum_{i=1}^{m} v_{ij} In\left(v_{ij}\right) = -\frac{1}{In(m)}\sum_{i=1}^{m} v_{ij}\, In(v_{ij}) \tag{3}$$

Step 4: Calculation of (D_j) and weight (W_j) values

$$D_j = 1 - e_j,\ j \in [1,\dots,n]$$

$$W_j = \frac{d_j}{\sum_{j=1}^{n} d_j} \tag{4}$$

3.2.2. VIKOR method

VIKOR method are less complex, ensuring accurate results, widely preferred [48]. The VIKOR method consists of 6 basic steps.

Step 1: Creating the decision matrix and determining the best/worst values

For each criterion, the best (fi^{+}) and worst (fi^{-})values are determined.

Step 2: Performing the normalization

Step 3: Weighting the normalized decision matrix

Step 4: Finding (S_i) and (R_i) values

$S_i = w_i \ ((fi^+ - f_{ij}) / (fi^+ - fi^-)$ (5)

$R_i = \max (w_i \ ((fi^+ - f_{ij}) / (fi^+ - fi^-)$ (6)

Step 5: Calculating (Q_i) values, v: weight of the strategy

$Q_i = v((S_i - Si^+)/S^- - Si^+) + (1 - v) ((R_i - Ri^+)/R^- - Ri^+)$ (7)

Step 6: Ranking the alternatives and examining the conditions

4. RESULTS and DISCUSSIONS

In Türkiye, many cities face flood disasters due to climate change and local authorities try to make great efforts to deal with this disaster. Therefore, it is critical to identify the cities where the risk of flooding is most intense and to take measures for the optimal land use planning. Evaluating this issue with a multidimensional approach enable a very important database for decision makers or stakeholders. In this context, this paper mainly presents the hierarchical analysis method to evaluate the cities to comprehensively assess the important influencing factors. The evaluation is based on the number of floods, population density and number of buildings, flood protection area. In addition, urban risks for each q levels (0, 0.25, 0.5, 0.75, 1) are presented in this section. This approach also enables the sensitivity analysis for the results.

4.1. Results of the ENTROPY method

Step 1: Creating the decision matrix

The criteria values for the 11 provinces discussed are demonstrated in Table 4.

Table 4. The decision matrix

Provinces	Number of floods	Population Density	Number of households by province	%Flood Protection Area
Balıkesir	12.17	88	456,193	2.738
Bursa	12.5	307	966,765	1.411
İzmir	13	371	1,053,086	4.687
Antalya	11.33	130	858,107	3.434
Muğla	10.83	82	362,287	2.493
Ordu	9.33	128	265,344	0.004
Van	10.83	58	241,504	0.014
Giresun	11.83	66	164,548	0.586
Zonguldak	8	178	199,841	0.194
Manisa	9	112	475,046	2.447
Şanlıurfa	5.33	116	411,421	0.292

Step 2: Performing normalization according to Benefit/Cost indices

Since the number of floods, population density and number of buildings will increase due to the investigation of the urban flood risk, and the low % protection area will increase the risk, the number of floods, population density and number of buildings are taken into consideration as max and % protection area as min.

Table 5. Calculation of Benefit/Cost criteria

Provinces	Number of floods	Population Density	Number of households by province	%Flood Protection Area
Balıkesir	0.936	0.237	0.433	0.001
Bursa	0.962	0.827	0.918	0.003
İzmir	1.000	1.000	1.000	0.001
Antalya	0.872	0.350	0.815	0.001
Muğla	0.833	0.221	0.344	0.002
Ordu	0.718	0.345	0.252	1.000
Van	0.833	0.156	0.229	0.286
Giresun	0.910	0.178	0.156	0.007
Zonguldak	0.615	0.480	0.190	0.021
Manisa	0.692	0.302	0.451	0.002
Şanlıurfa	0.410	0.313	0.391	0.014

Step 3: Performing normalization to eliminate measurement outliers
Table 6 shows the normalized decision matrix.

Table 6. Normalized decision matrix

Provinces	Number of floods	Population Density	Number of households by province	%Flood Protection Area
Balıkesir	0.107	0.054	0.084	0.001
Bursa	0.110	0.188	0.177	0.002
İzmir	0.114	0.227	0.193	0.001
Antalya	0.099	0.079	0.157	0.001
Muğla	0.095	0.050	0.066	0.001
Ordu	0.082	0.078	0.049	0.748
Van	0.095	0.035	0.044	0.214
Giresun	0.104	0.040	0.030	0.005
Zonguldak	0.070	0.109	0.037	0.015
Manisa	0.079	0.068	0.087	0.001
Şanlıurfa	0.047	0.071	0.075	0.010

Step 4: Finding Entropy (E_j) values
Step 5: Calculation of (D_j) and weight (W_j) values
Step 4 and Step 5 results are obtained as in Table 7.

Table 7. Calculation of (E_j), (D_j) and (W_j) values

Values	Number of floods	Population Density	Number of households by province	%Flood Protection Area
(E_j)	0.990	0.925	0.927	0.306
(D_j)	0.010	0.075	0.073	0.694
(W_j)	0.01182171	0.087633039	0.085918076	0.81462718

4.2. Results of the VIKOR method

Step 1: Creating the decision matrix and determining the best/worst values

At this stage, the description of Step 1 and Step 2 in the Application of the ENTROPY method section is handled similarly.

Step 2: Performing the normalization in Table 8.

Table 8. Normalization results.

Provinces	Number of floods	Population Density	Number of households by province	%Flood Protection Area
Balıkesir	0.108	0.904	0.672	0.584
Bursa	0.065	0.204	0.097	0.300
İzmir	0.000	0.000	0.000	1.000
Antalya	0.218	0.770	0.219	0.732
Muğla	0.283	0.923	0.777	0.531
Ordu	0.478	0.776	0.887	0.000
Van	0.283	1.000	0.913	0.002
Giresun	0.153	0.974	1.000	0.124
Zonguldak	0.652	0.617	0.960	0.041
Manisa	0.522	0.827	0.651	0.522
Şanlıurfa	1.000	0.815	0.722	0.061

Step 3: Weighting the normalized decision matrix

In this study, the weighting was done with the values obtained from the Entropy method results. Table 9 shows the weighted normalized matrix.

Table 9. Weighted normalized decision matrix

Provinces	Number of floods	2022 Population Density	Number of households by province	%Flood Protection Area
Balıkesir	0.001	0.079	0.058	0.476
Bursa	0.001	0.018	0.008	0.245
İzmir	0.000	0.000	0.000	0.815
Antalya	0.003	0.067	0.019	0.597
Muğla	0.003	0.081	0.067	0.433
Ordu	0.006	0.068	0.076	0.000
Van	0.003	0.088	0.078	0.002
Giresun	0.002	0.085	0.086	0.101
Zonguldak	0.008	0.054	0.083	0.033
Manisa	0.006	0.073	0.056	0.425
Şanlıurfa	0.012	0.071	0.062	0.050

Step 4: Finding S_i and R_i values

S_i values define row averages, R_i values define the max element in the row. Table 10 shows the values.

Table 10. Values of S_i and R_i

Provinces	S_i	R_i
Balıkesir	0.614	0.476
Bursa	0.272	0.245
İzmir	0.815	0.815
Antalya	0.686	0.597
Muğla	0.584	0.433
Ordu	0.150	0.076
Van	0.171	0.088
Giresun	0.274	0.101
Zonguldak	0.177	0.083
Manisa	0.560	0.425
Şanlıurfa	0.195	0.071

S*: 0.150; S-: 0.815; R*: 0.071; R-:0.815

Step 5: Calculating Q_i values

The q value represents the maximum group utility. In this study, q values were taken as (0; 0.25; 0.5; 0.75; 1). Table 10 shows the Q_i values.

Table 11. Q_i values

q **values**	**0**	**0.25**	**0.5**	**0.75**	**1**
Balıkesir	0.543835	0.582359	0.620882	0.659405	0.697928
Bursa	0.23325	0.220791	0.208332	0.19587	0.183414
İzmir	1	1	1	1	1
Antalya	0.706735	0.731514	0.756294	0.781073	0.805853
Muğla	0.486493	0.528147	0.569802	0.611456	0.653111
Ordu	0.006428	0.004821	0.003214	0.001607	0
Van	0.021849	0.024409	0.026969	0.029529	0.032088
Giresun	0.040158	0.076937	0.113716	0.150495	0.187274
Zonguldak	0.01495	0.02153	0.028111	0.034691	0.041272
Manisa	0.475727	0.510865	0.546003	0.581141	0.61628
Şanlıurfa	0	0.017111	0.034222	0.051332	0.068443

In this section, ranking of the cities were presented and all conditions were examined.

Step 6: Ranking the alternatives and examining the conditions

In Table 12, the alternatives are shown respectively. Table 13 shows the examination of the conditions.

Condition 1: Acceptable advantage condition and defined as Q (A2)- Q (A1) ≥ DQ (DQ = 1 / (number of alternatives -1)).

Condition 2: It is an acceptable stability condition, and the minimum values are the best alternative when the Qi values are ordered from smallest to largest, from smallest to largest, according to S and/or R values.

Table 12. Ranking of alternatives

q **values**	**0**	**0.25**	**0.5**	**0.75**	**1**
Balıkesir	9	9	9	9	9
Bursa	6	6	6	6	5
İzmir	11	11	11	11	11
Antalya	10	10	10	10	10
Muğla	8	8	8	8	8
Ordu	2	1	1	1	1
Van	4	4	2	2	2
Giresun	5	5	5	5	6
Zonguldak	3	3	3	3	3
Manisa	7	7	7	7	7
Şanlıurfa	1	2	4	4	4

Table 13. Examination of conditions

q **values**	**0**	**0.25**	**0.5**	**0.75**	**1**
Q(A2)	0.006428	0.017111	0.026969	0.029529	0.032088
Q(A1)	0	0.004821	0.003214	0.001607	0
Q(A2)-Q(A1)	0.006428	0.01229	0.023755	0.027922	0.032088
DQ	0.1	0.1	0.1	0.1	0.1
Condition 1	False	False	False	False	False
Condition 2	True	True	True	True	True

The q value should be selected when both conditions are met. However, since condition 1 is not met in the results, the relationship Q (A11) – Q (A1) < DQ is checked up to the upper limit value.

This examination was conducted again for each q in Table 14. According to the table, for q = 0, the provinces of Şanlıurfa, Ordu, Zonguldak, Van and Giresun, respectively, were assigned with more urban risks. For q = 0.25, the provinces of Ordu, Şanlıurfa, Zonguldak, Van and Giresun, respectively, were assigned with more urban risks. For q = 0.5, Ordu, Van, Zonguldak and Şanlıurfa provinces were assigned with more urban risks, respectively. For q = 0.75, Ordu, Van, Zonguldak and Şanlıurfa provinces were assigned with more urban risks, respectively. For q = 1, Ordu, Van, Zonguldak and Şanlıurfa provinces, respectively, were assigned with more urban risks.

Table 14. Alternatives according to q values

q **values**	**0**	**0.25**	**0.5**	**0.75**	**1**
Q(A2)-Q(A1)	0.006428	0.01229	0.023755	0.027922	0.032088
Q(A3)-Q(A1)	0.01495	0.01671	0.024897	0.033085	0.041272
Q(A4)-Q(A1)	0.021849	0.019588	0.031008	0.049726	0.068443
Q(A5)-Q(A1)	0.040158	0.072117	0.110502	0.148888	0.183414
Q(A6)-Q(A1)	0.23325	0.21597			
Provinces with Urban Flood Risk	Şanlıurfa, Ordu, Zonguldak, Van, Giresun	Ordu, Şanlıurfa, Zonguldak, Van, Giresun	Ordu, Van, Zonguldak, Şanlıurfa	Ordu, Van, Zonguldak, Şanlıurfa	Ordu, Van, Zonguldak, Şanlıurfa

Discussions of the study are presented in the following:

In this study, Entropy based VIKOR was used to define the flood risks although most papers have used geographic information system (GIS) [49] – [51], developed index method [52] – [53]. VIKOR was used for hazard, exposure, and vulnerability while risk mapping was addressed for the first time regarding both hazard and vulnerability [54].

Performance of developed Entropy based VIKOR was analyzed to compare the alternatives using q values.

This paper used the conceptual framework of urban flood risk dimensions including hazard, exposure, vulnerability [28] although some papers address the flood management based on PESTEL Analysis, SWOT Analysis [55].

5. CONCLUSION

The current cities are over consuming and overpopulated, and thus they are faced with enormous disasters environmentally damaging. All cities are facing this crisis and trying to control the disasters. Therefore, holistic strategies are required to transform existing cities to more sustainable. To understand the dynamics of the city in terms of the flood management concept, the presented paper provided various criteria to evaluate the cities. Integrated methodology involving the detailed evaluation of key strategies could ensure for long-term sustainability. In this article, flood risk is assessed using a combination of two decision-making methods. The data supporting the analysis consists of 11 flood points and various derived factors: number of floods, population density and number of buildings, flood protection area. Next, we used the VIKOR decision making method to analyse the urban flood risk vulnerability. The results showed that population density is the most critical factor in urban flood risk modelling. Given this, provinces with higher or very higher population density values have the most vulnerable flood risk. For each q value, the provinces with the highest urban flood risk were Ordu, Van, Zonguldak, and Şanlıurfa, respectively. In some q values, it was concluded that in addition to these provinces, Giresun province also has a high risk of urban flooding. The computational result showed that flood risk management provides recommendations to plan the flood risk management and urban disaster controlling. Some implications are presented for the cities which have high risks of urban flooding as follows:

- Flood warning system should be improved in these cities.
- Stakeholders should use a holistic approach for the land use planning.
- City planners should design the cities regarding water sensitive urban modeling systems or sponge city construction.
- City authorities raise the flood awareness providing information and risk maps.

The integrated approach provided in this study could be addressed as the first stage to manage flood risks in areas where there are no meteorological stations. The results could be evaluated by stakeholders and policy makers for guiding urban development, planning drainage systems, provide flood walls and other engineering structure, and protecting building. Urban floods cannot be only managed at the city scale but also with regarding political, economic, and environmental plans. Novel methods for urban flood management should be integrated among stakeholders and authorities that ensure resilience to climate change [13].

Declaration of Ethical Standards

Authors declare to comply with all ethical guidelines, including authorship, citation, data reporting, and original research publication.

Declaration of Competing Interest

There is no conflict of interest.

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Data Availability

Research data has not been made available in a repository.

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