MULTICRITERIA DECISION-MAKING UNDER HIGH-LEVEL UNCERTAINTY IN TOURISM: Z-NUMBERS BASED APPROACHES

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Abstract

The objective of this paper is to study the applicability and effectiveness of the decision-making models in the tourism sector under high-level uncertainty, formalized by Z-information. The topicality of this issue is significantly increased after the outbreak of the pandemic. Fuzzy multi-criteria decision-making (MCDM) models applied in the tourism area are partially solving this problem. But in these models, researchers are not paying due attention to the reliability of the information. One approach available for the formalization of such high-level uncertainty is the use of bi-component Z-number = (A, B). Components of the Z-numbers are expressed by perception-based fuzzy numbers. Part A defines the value of the uncertain variable and part B defines the confidence in this value. This approach allows considering the fuzzy-probabilistic nature of the information used for decision-making in tourism. In the paper, we are describing in detail the Z-numbers-based approach for the tourism destination selection task solution under high-level uncertainty. The model has been developed for the water sports tourism destination selection in Turkey. Initial information for model construction was derived via surveys. For the solution of this task, the Z-TOPSIS method is used. Results of the task solution illustrate the efficiency of the Z-numbers-based model for destination selection and the applicability of the approach for other MCDM tasks in tourism.

Keywords: destination selection, high-level uncertainty, Z-number, Z-TOPSIS, water sports tourism

INTRODUCTION

The leading role of tourism in the sustainable development of many countries, the expansion of the forms of tourism, and the increasing number of travelers are significantly changing the decision-making environment. Participants' differences, high level of their autonomy and complexity of the relationships between them, as well as distribution of the hospitality services between different actors, necessitate the use of multi-criteria decision-making (MCDM) models, taking into consideration imperfectness of the information and uncertainty. Destination selection is one of the most important tasks for both hospitality enterprises and travelers. The optimal solution of this task can be used for the formation of the tourist product, management of the consumers' motivation, and decision-making by travelers. The destination selection contributes the sustainability certification (confirmation), consumer support, public awareness. Also, relevant destination selection sets a common denominator for media to recognize destinations as sustainable and proposes to stakeholders the criteria for the formulation of requirements for the development of sustainable tourism.

The peculiarity and importance of the problem are also determined by the fact that a tourist destination, unlike a region, is defining not only by geographical, ethnic, cultural, and linguistic characteristics. It can be classified according to the principles of geography, seasonality, capacity, and level of demand. (Latypova, 2011)

Destination selection is a complex process for both tourists and other participants in tourism activities. The criteria and factors are vary depending on the type of tourism and the characteristics of the tourists themselves (Seyidov&Adomaitiene, 2016; Ouyang&Fang, 2018; Karl&Reintinger, 2017; Debski& Nasierowski, 2017; Ojo&Nerina, 2019). Most of the criteria for destination selection are quantitative and based on subjective opinions. In other words, the destination selection, regardless of the decision-makers - a tourist or a travel company manager, will often take place under conditions of high-level uncertainty. This may be due both to the lack of reliable statistical information and the inability to establish relationships between factors based on such information, as well as to the inaccuracy of the information itself. There may also be other factors that cause the imperfectness of information.

Considering the abovementioned circumstances, decision-making tasks in the tourism sector, such as destination selection, as well as service quality evaluation, location and supplier selection, strategy analysis and many other can best be described in many cases in linguistic terms and by Z-numbers. The axiomatic of Z-numbers allows expanding conventional multicriteria methods, such as TOPSIS, VICOR, PROMETHEE, SAW, ORESTE, and others, for Z-information use and decision-making under high-level uncertainty.

In the context of sustainable development, sports tourism can be noted among the important and currently developing types of tourism. (Li, 2017; Hodeck & Hovemann, 2015). Despite the pandemic, sports tourism became very popular and helps people in the satisfaction of the need for risk, in the avoidance of the daily routine, in the touching with nature, in the overcoming the usual behavior stereotypes (Liu & Chang, 2015; Humphreys, 2014; Vegara et al, 2020; Seryasat et al, 2014). Within the framework of sports tourism, water sports tourism takes a special place. There are many studies devoted to this type of activity (Hsiao-Ching, 2017; Lagarense & Walansendow, 2016; Derman & Yildiz, 2018). Despite the big potential, according to the results of Internet queries, at present Turkey is not a leading destination in water sports tourism. In our opinion, the selection of the most attractive destination can contribute to the further development of water-based sports tourism in Turkey and will support further recognition of the region in the world. Five regions that have been studied in the paper are popular for this type of tourism.

In our work, we studied the applicability of the Z-number-based MCDM approach for the selection of the destination for water sports tourism in Turkey.

MATERIALS AND METHODS

Z-number and operations with them

Definition 1. Z-number (Zadeh,2011).

Z-number is ordered pair $Z=(A,B)$ of fuzzy numbers determining the value of uncertain variable X. Most perception-based parts A and B of Z-number set the value of X and reliability of this value respectively. For example, the value of uncertain variable X= *Quality* can be expressed in the form of Z-number as *Quality = (very high, extremely likely)*

Definition 2. Arithmetic operations on Z-numbers (Aliev et al., 2015).

If Z_1 and Z_2 are two Z-numbers with parts A and B, expressed as (A_1, B_1) and (A_2, B_2), and * is one of the binary arithmetic operations (+, -, ˙ , /), then this operation on Z-numbers is defined by the formula

$$Z_{12}(A_{12}, B_{12}) = (A_1, B_1) * (A_2, B_2) \tag{1}$$

Part A of Z_{12} is calculated according to the rules of arithmetic operations with fuzzy numbers $A_{12}=A_1*A_2$.

The calculation of part B of the Z-number defining confidence degree is a more complex operation. To determine B_{12}, the methods based on the fundamental principles of operations on Z-numbers, related to fuzzy probabilities and probabilities of fuzzy events are used.

Definition 3. *Distance between Z-numbers.*

According to the (Aliev et al, 2017) the distance between two Z-numbers Z_1 and Z_2, whose parts expressed by trapezoidal fuzzy numbers $A_1 = (a_{11}, a_{12}, a_{13}, a_{14})$, $B_1=(b_{11},b_{12},b_{13},_{14})$, $A_2=(a_{21},a_{22},a_{23},a_{24})$, $B_2=(b_{21},b_{22},b_{23},_{24})$, are calculated according to the following formula

$$D(Z_1, Z_2) = 0.5 \cdot \left\{\sum_{i=1}^{4} |a_{1i} - a_{2i}| + \sum_{j=1}^{4} |b_{1j} - b_{2j}|\right\} \tag{2}$$

Z-number based TOPSIS

Applications of the classic and fuzzy TOPSIS are widely presented in research papers. Let us briefly outline the features of this method application, based on direct calculations with Z-numbers (Nuriyev, 2021).

Step 1. Defining a cost and benefit criteria.

Step 2. Construction of the initial decision matrix (*ZDMx*) with *m* rows (alternatives) and *n* columns (criteria). Each element of matrix is expressed by Z-number.

$$\text{ZDMx} = \begin{bmatrix} z_{11} & z_{12} & \cdots & z_{1n} \\ z_{21} & z_{22} & \cdots & z_{2n} \\ \cdots & \cdots & & \cdots \\ z_{i1} & z_{i2} & \cdots & z_{in} \\ \cdots & \cdots & & \cdots \\ z_{m1} & z_{m2} & \cdots & z_{mn} \end{bmatrix}$$

Step 3. Normalization of the decision matrix.

Step 4. Constructing of the Z-number-based weighted normalized decision matrix.

Step 5. Defining the Z-number-based positive ideal solution $Z_{pis} = (1,1)$ and Z-number-based negative-ideal solution $Z_{nis} = (0,0)$

Step 6. Calculation of the distance from each alternative to the ideal-positive and ideal-negative solution.

Distance between two Z-numbers is calculated as Z-number based on definition 3.

The distances of each *i-th* alternative from Z-number based positive-ideal solution (ZPIS) and Z-number based negative-ideal solution (ZNIS) are calculated as

$$d_i^+ = \sum_{j=1}^{N} d(Z_{ij}, Z_{pis}) \tag{3}$$

$$d_i^- = \sum_{j=1}^{N} d(Z_{ij}, Z_{nis}) \tag{4}$$

here N – number of criteria.

Step 7. Calculation of the relative closeness to the best alternative

$$Z_{cc_i} = \frac{d_i^-}{d_i^+ + d_i^-} \tag{5}$$

Step 8. Ranking of the alternatives with the relative closeness.

Candidate regions

Köprüçay is a river that originates in the Taurus Mountains flows through the Serik district of Antalya into the Mediterranean. Köprüçay is not only famous for its natural beauties and canyons, but also one of the most popular rivers for rafters. The 14-kilometer rafting track in Köprüçay can be taken in two and a half hours if there is no break; however, time gets longer when rafters play water games with each other as well as their struggle against the river.

The Çoruh River reaches the Black Sea by passing through these mountainous regions. The Çoruh River, with its rich flora and fauna, is one of the rivers that protect its natural characteristics. In the river, which is about 260 km by starting from Bayburt, following İspir and Yusufeli and going up to Artvin, there are 4 different rafting parkurs are done.

The Fırtına Stream, which is one of the rivers of Turkey located in the Eastern Black Sea Region, was formed by the merging of the creeks on the slopes of the Kaçkar Mountains facing the Black Sea. Tourists can reach Çamlıhemşin district at 22 km by following the highway going south from the Rize - Ardeşen highway.

Munzur Stream in the Munzur Valley, which has a beautiful view and takes on a different beauty in autumn, has become a frequent destination for rafting enthusiasts in all four seasons of the year with its track suitable for this sport. The Munzur Water, which originates from the foothills of the Ziyaret Hill on the Munzur Mountains in the north of Ovacık and joins with the Pulumur Stream in the central district, and pours into the Keban Dam Lake, runs a very long way within the provincial borders.

Dalaman Stream rises from the Yeşilgöl mountains in the south of Gölhisar county, draws the borders of Ortaca and Dalaman districts and pours into the Mediterranean. Rafting is done on the cay in an area of 26 km with a difficulty level of 3-4. Flowing in a narrow and deep valley, Dalaman Stream is one of the remarkable natural wonders in Turkey with its location that defines the borders of Ortaca and Dalaman districts.

Figure 1.

RESULTS

Defining fuzzy sets and linguistic values

For further calculations, it is necessary to define fuzzy sets using membership functions that determine linguistic variables (LV), expressing the values of the criteria and their weights. In this paper we are using trapezoidal membership functions (TMF). Values of the linguistic variables *Importance*, *Level*, *Values* and *Confidence* and their respective trapezoidal membership functions are presented in Tables 2 and 3.

Table 1. Trapezoidal membership functions and linguistic values of importance

Value of LV (importance)	Value of LV (Level)	Value of LV (Values)	TMF
Not important (NI)	Very Low (VL)	Very Low (VL)	(1 1 2 3)
Not very important (NVI)	Low (L)	Low (L)	(2 3 4 5)
Average (A)	Average (A)	Average (A)	(4 5 6 7)
Important (I)	High (H)	Good (G)	(6 7 8 9)
Very important (VI)	Very high (VH)	Very good (VG)	(8 9 10 10)

Table 2. Trapezoidal membership functions and linguistic values of confidence

Value of LV (Confidence)	TMF
Not sure (NS)	0.1 0.1 0.2 0.3
Not very sure (NVS)	0.2 0.3 0.4 0.5
Average (A)	0.4 0.5 0.6 0.7
Very sure (VS)	0.6 0.7 0.8 0.9
Extremely sure (ES)	0.8 0.9 1 1

Criteria for destination selection

Definition of criteria

Specifics of the tourist destination selection depend on its type because different destinations serve to meet different needs and goals of tourists. Certain attributes (attractions, amenities, accessibility, image, price, and human resources) make them suitable and accessible to travelers (Seyidov & Adomaitiene, 2016). In (Ouyang & Fang, 2018) distance, natural environment, resource conservation, regional culture, locality, shopping, and security were used as attributes of tourism destination selection. In (Karl & Reintinger, 2017) it is pointed out the idea that destinations with the same main attractive features (e.g., beach, sea, climate) can be interchanged. The comfort (and convenience), the attractiveness of the destination, good meal, as well as the acceptable price for shopping are the most important topic for young people considering decision-making about the destination (Debski & Nasierowski, 2017). The attractiveness of social/cultural and economic factors for international edu-tourists is shown in (Ojo & Nerina, 2019). In (Liu & Chang, 2015) among factors influencing the decision about sports tourism destination such factors, as sport tourist personality traits, motivation, experiences, and risk perception are considered. The importance of such factors for sports tourism, as to how the sport is embedded into the trip, value for money, total travel expenses, amenities and support facilities, accessibility of physical resources, reputation, and emotional rewards and benefits are noted in (Humphrey, 2014). Communication, staff, electronic word of mouth, destination image, satisfaction are influenced the future intentions of the sports tourist (Vegara et al,2020). Natural resources, infrastructure, human resources, and safety were pointed out as main factors for sports ecotourism in (Li, 2017). Conditions and value for money are very important factors for the destination selection of winter sports tourism (Hodeck & Hoveman, 2015). As for water sports tourism, in (Hsiao-Ching, 2017) such objective factors as safety, comfortable environment, climate factors, scenic spot and service, as well as subjective factors activity, excitement, and cultural experience are influencing the sports tourist decision about the destination. Favorable geographical conditions, attractions, accessibility, and human resources are noted as important factors in water tourism in [Seryasat, 2014; Lagarence & Walansendow, 2016; Derman & Yildiz, 2018). Climate, natural resources, ecology, prices, hotel, and sports infrastructure, investment are factors for the development of sports tourism in destinations (Panji Sekar Pambudi et al, 2020).

After literature analysis, for the initial discussion, the criteria such as accessibility, weather condition, financial affordability, entertainment activities, availability of the facility, destination image-branding, quality of service, safety & security were selected. After the next panel, such criteria as accessibility, weather condition, financial affordability, entertainment activities, availability of the facility, destination image-branding, quality of service, safety & security are selected for the destination selection task of the water sports tourism

Importance weights of criteria

Using the swing weights (Parnell & Trainor,2009) technique, extended for use with a Z-number-based evaluation, importance weights were determined. This is a multi-stage process.

At the first stage, existing criteria are placed in the corresponding cells of the matrix, according to their values of importance and confidence in these values. Z-number based swing matrix, constructed for our case, is shown in table 1.

Table 3. Z-number based swing weights matrix

Confidence \ Value of importance		Level of importance		
		Very high	High	Average
Level of confidence	Extremely sure	quality of service safety and security	availability of facility	
	Very sure	Accessibility financial affordability	entertainment activities	destination image-branding
	Sure			weather condition

At the next stage the assigned in the 1st stage weights should be normalized

$$Z_{Wnorm_i} = {Z_{wi}}\Big/{\sum_{i=1}^{number\ of\ criteria} Z_{w_i}} \quad (6)$$

After calculations according to the formula (6), the normalized Z-number based values of importance weighs are shown in table 4.

Table 4. Z-number-based importance weights

Criteria		Z-number based importance weight	
	Name	Part A	Part B
C1	Accessibility	0.111 0.132 0.167 0.192	0.286 0.418 0.627 0.796
C2	weather condition	0.056 0.074 0.1 0.135	0.367 0.504 0.698 0.814
C3	financial affordability	0.111 0.132 0.167 0.192	0.286 0.418 0.627 0.796
C4	entertainment activities	0.083 0.103 0.133 0.173	0.436 0.565 0.735 0.85
C5	availability of facility	0.083 0.103 0.133 0.173	0.444 0.567 0.772 0.888
C6	destination image-branding	0.056 0.074 0.1 0.135	0.504 0.65 0.825 0.916
C7	quality of service	0.111 0.132 0.167 0.192	0.37 0.505 0.753 0.876
C8	safety and security	0.111 0.132 0.167 0.192	0.37 0.505 0.753 0.876

Application of Z-number based TOPSIS

Step 1.

Construction of the Z-number based decison matrix (Table 5)

Table 5. Z-number-based decision matrix

Alternative / Criteria	**A1** Koprucay (Antalya)	**A2** Coruh River (Artvin)	**A3** Firtina River (Rize)	**A4** Munzur (Tunceli)	**A5** Dalaman (Mugla)
Accessibility	Very high, Extremely sure	High, Very sure	High, very sure	High, Sure	Very High, very sure
weather condition	Good, Very sure	Very good, Very sure	Average, sure	Very good, extremely good	Good, very sure
financial affordability	Very high, Extremely high	Average, very sure	Average, very sure	Average, very sure	Very High, very sure
entertainment activities	Very High, very sure	Average, very sure	Average, very sure	Average, very sure	Very high, extremely sure
availability of facility	Very High, very sure	Average, very sure	Average, very sure	Average, very sure	Very high, extremely sure
destination image-branding	Very high, Extremely sure	Average, sure	Average, very sure	Average, very sure	Very High, very sure
quality of service	Very high, very sure	High, very sure	High, sure	High, sure	Very high, Extremely sure
safety and security	high, Extremely sure	Very High, sure	Very High, very sure	High, sure	Very high, Very sure

Step 2

Normalization of the decision matrix and construction of the Z-number-based weighted normalized decision matrix (Table 6).

Table 6. Normalized weighted Z-number-based decision matrix

Alternative	Criteria	Part A				Part B			
A1	C1	0.089	0.119	0.167	0.192	0.229	0.376	0.627	0.796
	C2	0.034	0.052	0.08	0.122	0.415	0.538	0.697	0.818
	C3	0.089	0.119	0.167	0.192	0.257	0.376	0.627	0.796
	C4	0.066	0.093	0.133	0.173	0.462	0.581	0.721	0.841
	C5	0.066	0.093	0.133	0.173	0.464	0.582	0.732	0.856
	C6	0.045	0.067	0.1	0.135	0.499	0.654	0.855	0.93
	C7	0.089	0.119	0.167	0.192	0.222	0.354	0.616	0.802
	C8	0.089	0.119	0.167	0.192	0.222	0.354	0.616	0.802
A2	C1	0.067	0.092	0.134	0.173	0.255	0.38	0.585	0.76
	C2	0.045	0.067	0.1	0.135	0.313	0.447	0.637	0.787
	C3	0.044	0.066	0.1	0.134	0.222	0.307	0.502	0.716
	C4	0.033	0.051	0.08	0.121	0.278	0.4	0.608	0.786
	C5	0.033	0.051	0.08	0.121	0.283	0.401	0.635	0.815
	C6	0.022	0.037	0.06	0.095	0.378	0.52	0.629	0.728
	C7	0.067	0.092	0.134	0.173	0.324	0.457	0.689	0.834
	C8	0.089	0.119	0.167	0.192	0.148	0.252	0.479	0.653
A3	C1	0.067	0.092	0.134	0.173	0.255	0.38	0.585	0.76
	C2	0.022	0.037	0.06	0.095	0.321	0.45	0.613	0.71
	C3	0.044	0.066	0.1	0.134	0.222	0.307	0.502	0.716
	C4	0.033	0.051	0.08	0.121	0.278	0.4	0.608	0.786
	C5	0.033	0.051	0.08	0.121	0.283	0.401	0.635	0.815
	C6	0.022	0.037	0.06	0.095	0.522	0.673	0.764	0.867
	C7	0.067	0.092	0.134	0.173	0.306	0.413	0.61	0.749
	C8	0.089	0.119	0.167	0.192	0.222	0.354	0.616	0.802
A4	C1	0.067	0.092	0.134	0.173	0.253	0.35	0.534	0.689
	C2	0.045	0.067	0.1	0.135	0.404	0.536	0.749	0.846
	C3	0.044	0.066	0.1	0.134	0.222	0.307	0.502	0.716
	C4	0.033	0.051	0.08	0.121	0.278	0.4	0.608	0.786
	C5	0.033	0.051	0.08	0.121	0.283	0.401	0.635	0.815
	C6	0.022	0.037	0.06	0.095	0.522	0.673	0.764	0.867
	C7	0.067	0.092	0.134	0.173	0.306	0.413	0.61	0.749
	C8	0.067	0.092	0.134	0.173	0.306	0.413	0.61	0.749
A5	C1	0.089	0.119	0.167	0.192	0.172	0.293	0.502	0.725
	C2	0.034	0.052	0.08	0.122	0.415	0.538	0.697	0.818
	C3	0.089	0.119	0.167	0.192	0.172	0.293	0.502	0.725
	C4	0.066	0.093	0.133	0.173	0.582	0.703	0.868	0.926
	C5	0.066	0.093	0.133	0.173	0.586	0.704	0.887	0.944
	C6	0.045	0.067	0.1	0.135	0.383	0.534	0.737	0.87
	C7	0.089	0.119	0.167	0.192	0.296	0.454	0.753	0.876
	C8	0.089	0.119	0.167	0.192	0.222	0.354	0.616	0.802

Step 3.

Calculation of the distance from each alternative to the ideal-positive and ideal-negative solution according to the formulas (3) and (4), and calculation of the relative closeness to the best alternative according to the formula (5). We obtain next result (Table 7).

Table 7. Relative closeness of alternatives

Alternatives	Closeness
A1	0.352
A2	0.300
A3	0.309
A4	0.315
A5	0.356

Step 4. Ranking of the alternatives with the relative closeness.
The results are shown in table 8.

Table 8. Ranking of alternatives

Alternatives	Closeness
A1	2
A2	5
A3	4
A4	3
A5	1

Alternative **A1** is the best, followed by alternative **A5**. The remaining three alternatives are in the following order: **A4, A3, A2**.

DISCUSSION & CONCLUSION

In this paper, the task of destination selection for water sports tourism was solved by using the Z-number-based multi-criteria decision-making method Z-TOPSIS.

Complex structure of the tourism sector, variety and imperfectness of data used in decision making process, necessitate application of the Z-numbers for solution of the MCDM models in tourism industry. Use of such formalism for information with high-level uncertainty allows decision-making in condition of imperfectness of the available information. Experts assess criteria and alternatives values and reliability of these estimates in terms of natural language. Quantiative estimates of the linguistic terms are based on Z-numbers formalism. Importance weights of the criteria definerd by application of the Zextension of the swing method. Eight criteria are used for decision-making on selecting destination for water sports tourism in Turkey. According to these criteria and our calculations, Dalaman and Koprucay are determined as the preferable destinations. Other destinations - Coruh River, Firtina River and Munzur are less attractive due to weather conditions, entertainment activities, facilities, service quality.

Study has shown the successfulness of Z-number-based formalism for decision making in tourism sector in conditions of high-level uncertainty

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