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ABSTRACT

of the dissertation for the degree of Doctor of Philosophy

FUZZY APPROACH FOR MANAGERIAL DECISION-MAKING IN THE TOURISM SECTOR

Speciality: 3338.01 – Systems analysis, management, and information processing (management and decision making)

Field of science: Technical

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The work was performed at the research laboratory "Intelligent Control and Decision-Making Systems in Industry and Economics" of Azerbaijan State Oil and Industry University.

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GENERAL DESCRIPTION OF THE DISSERTATION

The actuality of the topic.

The importance of the tourism sector for the economy, and its growing impact on the image and sustainable development of many countries, give a serious impetus to the implementation of extensive research on the management of this area and determines the need for this research. Furthermore, the management of the tourism sector is characterized by presence of many actors, relationships and factors, changeable environment, information incompleteness, imperfectness, and high-level uncertainty.

The heterogeneity and incompleteness of data related to the tourism sector require a new approach to the mathematical description of data, which is characterized by a high degree of uncertainty. One of the possible approaches is based on Z-numbers. This approach has a wide range of possibilities, and the application of this approach to tourism management has great potential. Z-numbers allow considering the fuzzy-probabilistic nature of the information, used to make decisions in tourism.

The complexity of the tourism management tasks, the diversity (heterogeneity), and the imperfectness of the information used to solve the problems predetermine the urgency of developing methods and approaches to solving tourism management problems in the context of high levels of uncertainty. Therefore, the dissertation is devoted to the solution of these problems, and the abovementioned specifics determine the relevance of the dissertation.

Object and subject of research. The object of research is the management decision-making processes in the tourism sector. The subject of research is models, methods, and tools for making managerial decisions in an uncertain information environment.

Aims and objectives of the study. The aim is to develop models and methods, software platforms, and technologies for managerial decisions making in the tourism sector under uncertainty.

The following tasks are accomplished to achieve this aim:

1) system analysis-based identification of features of decision-making in tourism.

2) the use of Z-numbers for project risk assessment and analysis, formalization of the analysis process, and project approach-based generalization of tourism risks.

3) proposing a strategic planning model for the tourism sector in conditions of uncertainty.

4) applying multi-criteria decision-making (MCDM) methods in case of high uncertainty and studying its features, the extension of TOPSIS, PROMETHEE, and VIKOR methods for direct calculations with the values of criteria and weights expressed in Z-numbers.

5) development of approaches based on Z-extension of MCDM methods for selecting the hotel suppliers, tourism space, and tourism direction.

6) development of an approach based on Z-assessment to determine the quality of services provided in tourism.

7) development of software in Python for arithmetic operations with Z-numbers.

Research methods. To solve these problems in the dissertation: the theory of fuzzy sets, the theory of possibilities, the theory of decision-making in the conditions of imperfect information, system analysis methods, and methods of operations research are used. In addition, experimental research methods, mathematical modeling methods, and simulation were used to validate the results obtained.

Main highlights, brought forward for dissertation defense. The following provisions are submitted for defense in the dissertation:

- Proposing approaches to extending multi-criteria methods for managerial decision-making in the tourism sector under high levels of uncertainty.

- Development of approaches to the identification and analysis of tourism risks based on Z-information.

- Proposing fuzzy data-based approaches to multi-stage strategic analysis and strategic decision-making in the tourism sector.

- Development of Z-extension of the methodology for assessing the quality of services provided in the tourism sector and making decisions on its improvement.

Scientific novelty

The scientific novelty of the results of the work is as follows:

1) Proposal of a project approach to tourism trips, use of Z-numbers for analysis, assessment, and generalization of project risks, and development of the register of tourism risks.

2) Development of a model and an approach for strategic analysis of the tourism development (Z-IFE/EFE, Z-SPACE, Z-QSPM) based on a fuzzy approach using Z-information.

3) Development of the Z-assessment approach (Z-SERVQUAL, Z-IPA) to determine the quality of services provided by the tourism sector.

4) Extension of multi-criteria decision-making methods for direct calculations with Z-numbers (Z-TOPSIS, Z-VIKOR, Z-PROMETHEE). Solution of tourism management problems based on Z-extensions of MCDM methods.

The scientific value of the dissertation:

The scientific significance of the research lies in the development of managerial decision-making approaches based on fuzzy calculations and the development of tourism sector models, allowing to make well-informed decisions in conditions of imperfect information.

The practical value of the dissertation:

1. Assessment of the project risks using Z-numbers and description of the confidence in this assessment.

2. Development of threats and risk registers. The approach allows solving issues related to the analysis of threats for tourists, traveling in conditions of imperfect information.

3. The proposed approach to assessing the quality of services, provided in the tourism sector, allows conducting surveys, based on linguistic and quantitative assessments, and determining quality, based on the information obtained.

4. The proposed approach to conducting quantitative strategic analysis in a fuzzy information environment considers quantitative and linguistic information and allows for the effective use of expert assessment of factors.

5. Approaches based on Z-numbers allow the tourism sector to work with a high level of uncertainty in multi-criteria decision-making, such as the choice of suppliers, tourism site location, and tourism destination.

6. The extension of traditional MCDM methods for direct calculations with Z-numbers allows to solve problems directly.

7. The proposed Z-extension of the Swing Weighting method for criteria weights evaluation and the method of normalization of the decision matrix described by Z-numbers allows for expansion of the Z-estimates and applying these tools in other methods of MCDM.

8. The developed software allows to work with Z-numbers in a more accessible way and build Z-models.

Approbation of the dissertation. The main provisions and results of the dissertation were discussed at the seminars of the research laboratory and presented at the following international conferences:

1. 18th International Conference on Social Sciences - ICSS-XVIII, Lisbon, Portugal, 2019
2. 10th International Conference on Theory and Application of Soft Computing, Computing with Words and Perceptions- ICSCCW-2019, Prague, Czech Republic, 2019
3. 7th International Conference on Recent Social Studies and Research- ICSRS-2019, Rome, Italy, 2019
4. 14th International Conference on Theory and Application of Fuzzy Systems and Soft Computing - ICAFS-2020, Budva, Montenegro, 2020
5. 11th International Conference on Theory and Application of Soft Computing, Computing with Words and Perceptions and Artificial Intelligence - ICSCCW-2021, Antalya, Turkey, 2021
6. 7th International ZEUGMA Conference on Scientific Research, Gaziantep, Turkey, 2022

7. V-International European Conference on Interdisciplinary Scientific Research, Valencia, Spain, 2022

8. International Conference on Economics, Business, Tourism & Social Sciences - IIARP-2022, Malacca, Malaysia, 2022

Organization where the dissertation was realized: Azerbaijan State Oil and Industry University, Research laboratory “Intelligent Control and Decision-Making Systems in Industry and Economics”.

Structure of dissertation. The manuscript includes 181044 symbols, 42 tables, and 9 pictures. Introduction includes 10107 symbols, 1st chapter - 37442 symbols, 2nd chapter - 45672 symbols, 3d chapter - 27916 symbols, 4th chapter - 22158 symbols, 5th chapter - 34520 symbols, conclusion – 3229 symbols. The reference list has 224 sources.

Publications. The obtained dissertation results were published in 11 research works including 3 works in the SCOPUS database and 3 works in Conference Proceedings.

MAIN CONTENT OF THE DISSERTATION WORK

The **Introduction** substantiates the actuality of the research, forms the goals and objectives of the research, defines the research methods to be used, and the practical and theoretical significance of the research.

The **first chapter** analyzes the general characteristics of management decisions and the characteristics of the tourism sector in terms of decision-making. The chapter provides general information on risk analysis and decision-making, strategic analysis and decision-making, analysis of the quality of tourism services, and the selection of strategies for its improvement. The chapter also presents general information related to specifics of the hotel supplier selection, location of tourist facilities, and selection of tourist destination tasks.

The **second chapter** of the dissertation is devoted to the characteristics of information flows and uncertainty in managerial decision-making in tourism, the definition of Z-numbers as a formalism of high-level uncertainty, and operations with Z-numbers.

Management decisions are always forward-looking. Therefore, the decision-maker (DM) does not have irrefutable information about the development of events and changes in the situation. The high autonomy of tourism entities and the that this sector is a complex and large-size system determine the need for managerial decision-making under high-level uncertainty. Furthermore, the presence of many participants and relationships in the tourism sector significantly complicates the consideration of all the uncertainties within the system and in the environment. At the same time, it is impossible to formalize uncertainties only with a probabilistic approach.

At present, the fuzzy approach has become one of the essential tools for scientific research in tourism.

The dissertation examines the areas of higher uncertainty in management decision-making: the selection of development strategies; risk analysis; service quality analysis; selection of suppliers; selection of location and destination.

In tourism sector decision maker in the decision-making tasks in the most cases operates with information that can be characterized as imperfect.

For solution of such problems Zadeh proposed Z-numbers concept[1], allowing to describe imperfect information by expressions as close as possible to natural language. Z-numbers paradigm, unifying fuzzy and probabilistic approaches, allows to present information for decision making in natural language.

Operations on Z-numbers for decision-making.

Operations on Z-numbers have been described in accordance with principles proposed by Zadeh. Below are presented operations on Z-numbers and definitions used in the dissertation.

Definition 1. **Z-number**[2,3,4] - (continuous / discrete) is an ordered pair of fuzzy numbers $Z = (A, B)$. The first component is part A, represented by continuous/discrete fuzzy numbers. Component A is a constraint on the values that the indefinite variable X can take (on the axis of real numbers). Part B, expressed by a continuous/discrete fuzzy number, is a measure of reliability or confidence in A.

Definition 2. **Arithmetic operations on Z-numbers**[4]**.**

If $Z_1 = (A_1, B_1)$ and $Z_2 = (A_2, B_2)$ are two Z-numbers with parts A and B and * is one of the binary arithmetic operations (+, -, · /), then the operation on these Z-numbers is defined as:

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

The calculation of the A_{12} part of the number Z_{12} is carried out in accordance with the calculation operations on fuzzy numbers. $A_{12} = A_1 * A_2$.

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[1] Zadeh L.A. A note on Z-numbers. Information Sciences, 181(4), (2011), pp.2923-2932

[2] Zadeh L.A. A note on Z-numbers. Information Sciences, 181(4), (2011), pp.2923

[3] Aliev R.A. Uncertain computation-based decision theory, World Scientific, (2017)- p.127

[4] Aliev R.A. Uncertain computation-based decision theory, World Scientific, (2017)- pp.128-141

It is necessary to obtain B_{12}, which determines the reliability (confidence) of the A_{12} value. Supports of fuzzy numbers representing parts of B (support - supp) contain non-obvious (hidden) information about the probability distributions associated with A.

The probability of the fuzzy event[5] is a measure calculated according to:

$$P(A) = \int_A p_a(x)\mu_a(x) \tag{2}$$

Here $\mu_a(x)$ is a membership function of the A, $p_a(x)$ – probability distribution.

The values of $P(A_1)$ and $P(A_2)$ are known and are in the intervals defined by B_1 and B_2 *supp*, respectively. For additional calculations, it is necessary to restore (induce) the hidden distributions of $p_a(x)$ .To do this, *supp* B_1 və *supp* B_2 must be discretized and the corresponding values of $P_i(A_1)$ və $P_j(A_2)$ must be selected from these intervals.

This can be schematically illustrated as follows:

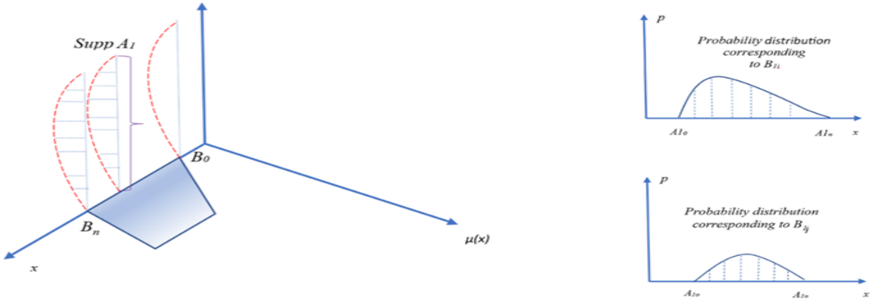

Figure 1. Hidden probability distributions

The restored probability distributions are used to calculate the B_{12} of the Z_{12} for subsequent convolution. Restoration (induction) of probability distribution is solved as an optimization problem.

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[5] Zadeh L.A. A note on Z-numbers. Information Sciences, 181(4), (2011), pp.2924

Definition 3. **Multiplying the scalar value by Z**.

The product of the scalar value λ and the Z number $Z = \lambda \cdot Z, \lambda \in R$, is determined by the following formula.

$$Z = (\lambda A_1, B_1) \tag{3}$$

Definition 4. **Z-information.**[6]

The expression *X* is equal to *(A, B)* is a Z-estimate. For example, *I am sure that the level of sanitation is average*. Here X is the level of sanitation and, respectively, A - *average, B - I'm sure*. The set of such estimates is called Z-information.

Definition 5. **Z-numbers ranking based on the principle of fuzzy Pareto optimality**[7]

Z-numbers are compared as alternatives with two attributes - one attribute determines the value of the variable, and the other determines the degree of confidence in this value. Z-numbers $Z_1=(A_1, B_1)$ and $Z_2=(A_2,B_2)$ are compared by calculating the degrees of optimality $do(Z_1)$ and $do(Z_2)$. The degree of optimality is calculated based on the number of components in which one Z-number predominates over another Z-number.

Step 1. Calculation of the functions $n_b(Z_i, Z_j)$, $n_e(Z_i, Z_j)$, $n_w(Z_i, Z_j)$.

These functions estimate how superior, equivalent, or inferior is one Z-number in comparison to another according to components A and B.

$$n_b(Z_i, Z_j) = P_b(\delta^{i}{}_{A}{}^{,j}) + P_b(\delta^{i}{}_{B}{}^{,j}) \tag{4}$$

$$n_e(Z_i, Z_j) = P_e(\delta^{i}{}_{A}{}^{,j}) + P_e(\delta^{i}{}_{B}{}^{,j}) \tag{5}$$

$$n_w(Z_i, Z_j) = P_w(\delta^{i}{}_{A}{}^{,j}) + P_w(\delta^{i}{}_{B}{}^{,j}) \tag{6}$$

here $\delta^{i}{}_{A}{}^{,j} = A_i - A_j$, $\delta^{i}{}_{B}{}^{,j} = B_i - B_j$

The conditions in formulas (4) - (6) are calculated as the weighted measures of the possibilities for components A and B, respectively.

Step 2. Normalization of parts A of Z-numbers.

If necessary, the values defining A_1 and A_2 should be normalized.

Step 3. Then the function d is calculated by the following formula

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[6] Zadeh L.A. A note on Z-numbers. Information Sciences, 181(4), (2011) p.2924

[7] Aliev, R., Huseynov, O., Serdaroglu, R. Ranking of Z-Numbers and Its Application in Decision Making. Int. Journal of Inf. Technology & Decision Making. 15, 1-17 (2016) – p.145

$$d(Z_i,Z_j) = \begin{cases} 0,\ if\ n_b(Z_i,Z_j) \le \frac{2-n_e\,(Z_i,Z_j)}{2} \\ \frac{2n_b\,(Z_i,Z_j)+n_b\,(Z_i,Z_j)-2}{n_b\,(Z_i,Z_j)} \end{cases} \tag{7}$$

If $d(Z_i,Z_j)=1$, then Z_i has Pareto-dominance over Z_j, if $d(Z_i,Z_j) = 0$, then Z_j does not have Pareto-dominance over Z_j. Based on the values of the function *d*, we can calculate the degree of optimality of the number Z_j using the following formula.

$$do\ (Z_i) = 1 - d(Z_i,Z_j) \tag{8}$$

$do\ (Z_i)$ shows how much one Z-number dominate other Z-number.

$Z_i > Z_j$, if $do\ (Z_i) > do\ (Z_j)$,

$Z_i < Z_j$, if $do\ (Z_i) < do\ (Z_j)$ *and* $Z_i = Z_j$, if $do\ (Z_i) = do\ (Z_j)$

Definition 6. **The distance between Z-numbers**[8,9].

When parts A and B are given by trapezoidal fuzzy numbers $A_1=(a_{11},a_{12},a_{13},a_{14})$, $B_1=(b_{11},b_{12},b_{13,14})$ *and* $A_2=(a_{21},a_{22},a_{23},a_{24})$, $B_2=(b_{21},b_{22},b_{23,24})$, distance (crisp value) between Z-numbers Z_1 and Z_2 is calculated by the following formula:

$$D(Z_1,Z_2) = 0.5 \cdot \left\{ \sum_{i=1}^{4} |a_{1i} - a_{2i}| + \sum_{j=1}^{4} |b_{1j} - b_{2j}| \right\} \tag{9}$$

Definition 7. **Degree of similarity**[10,11]

The degree of similarity of two fuzzy numbers is a real value from interval 0 to 1 and characterizes the similarity of fuzzy numbers in terms of shape and location.

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[8] Aliev, R.A. Approximate reasoning on a basis of Z-number valued If-then rules / R.A. Aliev, W. Pedrycz, O.H. Huseynov [et al.] // IEEE Transactions on Fuzzy Systems, - 2017, 25(6) – p.1591

[9] Nuriyev, A.M. Operations on Z-numbers in decision-making models with high-level uncertainty // Universum: technical sciences: electronical scien.jour. 2022. 2(95) – p.51

[10] Aliev, R.A. Approximate reasoning on a basis of Z-number valued If-then rules / R.A.Aliev, W.Pedrycz, O.H.Huseynov [et al.] // IEEE Transactions on Fuzzy Systems, - 2017, 25(6) – s.1591

[11] Nuriyev, A.M. Aggregation of Z-number based expert estimates. Proceedings Of Azerbaijan High Technical Educational Institutions, -2021, 23(6)- p. 40

If the Z-numbers are given as trapezoidal or triangular fuzzy numbers, it is suggested to use the following approach to calculate the similarity measure.

One approach is to calculate the Jaccard index. For Z-numbers, where parts A and B are trapezoidal or triangular numbers, the Jaccard index is calculated by the following formula[12]:

$$J\,(Z_1, Z_2) = \frac{1}{2}\,J(A_1, A_2) + \frac{1}{2}\,J(B_1, B_2) \tag{10}$$

Here $J(A_1, A_2)$ and $J(B_1, B_2)$ are calculated by formula[13] (11)

$$J\,(\dot{B}_1, \dot{B}_2) = \frac{\frac{1}{2}\sum_{i=1}^{8}(x_i * y_i)}{\sum_{i=1}^{8} x_i^2 + \sum_{i=1}^{8} y_i^2 - \sum_{i=1}^{8}(x_i * y_i)} + \frac{\frac{1}{2}\sum_{i=1}^{8}(x_i' * y_i')}{\sum_{i=1}^{8} x_i'^2 + \sum_{i=1}^{8} y_i'^2 - \sum_{i=1}^{8}(x_i' * y_i')} \tag{11}$$

To calculate the degree of similarity between the triangular and trapezoidal fuzzy numbers $\dot{B}_1 = (b_{11}, b_{12}, b_{13}, b_{14})$ and $\dot{B}_2 = (b_{21}, b_{22}, b_{23}, b_{24})$, we will use a formula that considers the mutual position of the numbers and the forms of membership functions. For fuzzy numbers given in the form of a trapezoid, the conditions $b_{11} \le b_{12} \le b_{13} \le b_{14} \le 1$ and $b_{21} \le b_{22} \le b_{23} \le b_{24} \le 1$ are satisfied.

When calculating the relative position of numbers, left and right extreme points

$l = \min\{b_{11}, b_{21}\}$ and $r = \max\{b_{14}, b_{24}\}$ are defined.

The first term determines the similarity with respect to l, and the second to r.

The measure of similarity between two Z-numbers is calculated as the inverse of the distance between them.

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[12] Aliev, R.A. Approximate reasoning on a basis of Z-number valued If-then rules / R.A. Aliev, W. Pedrycz, O.H. Huseynov [et al.] // IEEE Transactions on Fuzzy Systems, - 2017, 25(6) – p.1590

[13] Hwang C.-M., Yang M.-S. New Similarity Measures Between Generalized Trapezoidal Fuzzy Numbers Using the Jaccard Index. // International Journal of Uncertainty, Fuzziness and Knowledge-Based Systems. – 2014, 22 (6) – p.836

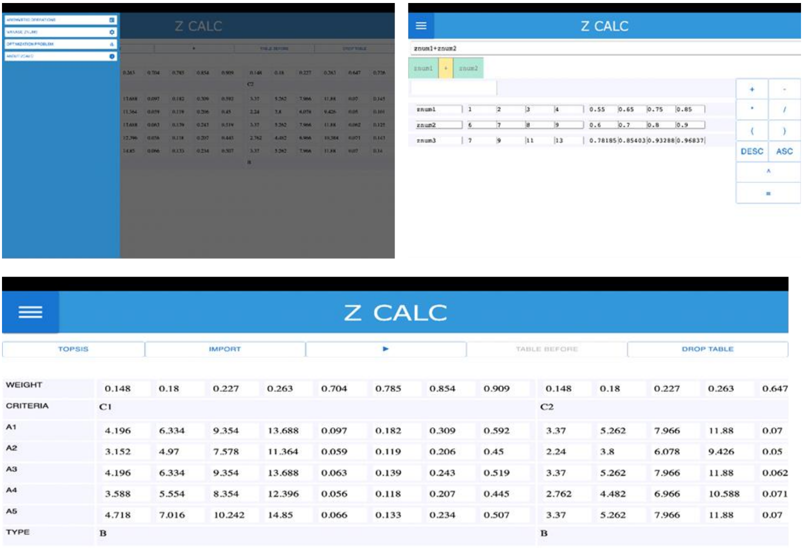
$$S\,(Z_1, Z_2) = \frac{1}{1 + D(Z_1, Z_2)} \tag{12}$$

The similarity measure can be used for determining the distance between the Z-numbers according to the formula (13).

$$D(Z_1, Z_2) = \frac{1}{S(Z_1, Z_2)} - 1 \tag{13}$$

Software for the direct calculations with Z-numbers

It is advisable to use appropriate software to apply models that consider high levels of uncertainty through Z-numbers. Such software has been created as part of the dissertation. Parts A and B of the Z-numbers are given in the form of a two-dimensional array represented by trapezoidal or triangular fuzzy numbers. Calculations with Z-numbers are based on Definition 2 and carried out according to existing approaches. The software was developed in Python using the SciPy platform.



znum1+znum2

znum1	1	2	3	4	0.55	0.65	0.75	0.85
znum2	6	7	8	9	0.6	0.7	0.8	0.9
znum3	7	9	11	13	0.78185	0.85403	0.93288	0.96837

WEIGHT	0.148	0.18	0.227	0.263	0.704	0.785	0.854	0.909	0.148	0.18	0.227	0.263	0.647
CRITERIA	C1								C2				
A1	4.196	6.334	9.354	13.688	0.097	0.182	0.309	0.592	3.37	5.262	7.966	11.88	0.07
A2	3.152	4.97	7.578	11.364	0.059	0.119	0.206	0.45	2.24	3.8	6.078	9.426	0.05
A3	4.196	6.334	9.354	13.688	0.063	0.139	0.243	0.519	3.37	5.262	7.966	11.88	0.062
A4	3.588	5.554	8.354	12.396	0.056	0.118	0.207	0.445	2.762	4.482	6.966	10.588	0.071
A5	4.718	7.016	10.242	14.85	0.066	0.133	0.234	0.507	3.37	5.262	7.966	11.88	0.07
TYPE	B								B				

Figure 2. Z-calc program segment

Aggregation of Z-number based expert estimates

An important step in managerial decision-making in the tourism sector is the study of expert opinions. Expert estimates can be obtained in a variety of ways.

If specialists have the same competencies, the aggregation of expert assessments is carried out by the following formula:

$$Z_{aver}\,(A_m, B_m) = \Sigma\, n_{im} \cdot Z_{im}/N_m \qquad (14)$$

Here n_{im} is the number of experts evaluating the criterion m by Z_{im} assessment, N_m is the total number of experts evaluating m criterion, and

$$n_{1m} + n_{2m} + \ldots + n_{im} = N_m$$

If the experts have different knowledge and skills, the respective terms in formula (14) are multiplied by importance weights.

In the **third chapter**, threats in the tourism sector were identified and studied, risk factors were identified, a register of risks was proposed, and methods for risk assessment and aggregation based on Z-numbers were proposed.

Risks in tourism can be conditionally divided into two groups: risks to the life/health of tourists and business risks. Because the tourism business is based on travel and the risks to life/health are very important, in this study the safety risks for travelers have been investigated.

A risk register has been compiled based on the study. The register includes 5 main risk factors related to tourist travel. These factors are associated with the destination country; natural environment; activities of tour firms; transportation; traveler’s individual features. Each risk factor consists of several sub-factors that characterize it (23 sub-factors in total).

There are always risks in all travel, and in this regard, the route with the lowest overall risk will be considered the safest.

Measuring tourism risks is a complex and voluminous task because the estimates of risk factors are uncertain and the information on the factors is incomplete.

Given the characteristics of the information related to the tourism sector, the use of Z-numbers is appropriate. The idea of using Z-numbers for project risk assessment has been supported by many researchers[14].

The aggregation of risks of different nature and origin is very important for their generalized assessment. Converting individual assessments into aggregated information allows for alternatives ranking. After aggregation, the information will be more complete than the information in individual sources, as it integrates individual assessments.

When analyzing travel risks, the weights of the affecting risk factors are essential. Since arithmetic operations on Z-numbers are defined, it is possible to calculate the weighted arithmetic mean of the Z-values. Calculation of the aggregated risk assessment is important for alternatives ranking (tourism destinations) according to the level of risk.

The aggregation of tourism risks described by Z-values can be described as follows[15].

In the first step, to calculate the value $Z_{a_{ij}}$of the N factor for the i-th alternative, it is necessary to divide the sum of the product of the values of the risk subfactors and the significance weights of the sub-factors by the sum of the weights of the relevant sub-factors.

$$Z_{a_{ij}} = \frac{\sum_{k}^{K_j} Z_{x_{ijk}} \cdot Z_{w_{jk}}}{\sum_{k}^{K_j} Z_{w_{jk}}} \qquad (15)$$

Z_{aij} – Z-value of the j-th risk factor for i-th alternative,

Z_{xijk} - Z-value of the k-th subfactor of the j-th factor for i-th alternative,

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[14] Nuriyev, A. Application of Z-Numbers Based Approach to Project Risks Assessment. European Journal of Interdisciplinary Studies, - 2020, 6(2), - p.36

[15] Nuriyev, A.M., Jabbarova, K. Z-Value Based Risk Assessment: The Case of Tourism Sector. Advances in Intelligent Systems and Computing, Vol.1095, Springer, Switzerland, 2020

Z_{wjk} - Z-weight of the k-sub-factor of the j-factor for i-th alternative.

To calculate the overall risk level of i-th alternative, the sum of the weighted factors is divided by the sum of the weights.

$$Z_{a_i} = \frac{\sum_1^n Z_{a_j} \cdot Z_{w_j}}{\sum_1^n Z_{w_j}} \qquad (16)$$

Z_{ai} – overall risk evaluation for i-th alternative,

Z_{aj}- Z-value of the j-th risk factor for i-th alternative,

Z_{wj} – Z-weight of the j-th factor significance for i-th alternative

The calculated risk values can then be compared in terms of the degree of dominance.

The **fourth chapter** of the dissertation offers approaches to strategic analysis and management, service quality analysis and management problems.

Z-Number Based Approach to Strategic Analysis in Tourism

Consider the use of Z-numbers for strategic decision-making in tourism[16]. Let`s assume that the strategy for developing the tourism sector should be defined.

Step 1. A group of experts identified factors influencing development of the tourism in the region and a SWOT matrix is compiled (matrix includes 6 strength, 4 weakness, 5 threat and 5 opportunities factors).

Step 2. IFE (internal factors evaluation) and EFE (external factors evaluation) matrices are compiled. The weight of each factor and its rating is determined by experts.

In the analysis Z-numbers with parts A and B described by triangular fuzzy numbers have been used.

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[16] Nuriyev, A. Z-Number Based Approach to Strategic Analysis in Tourism // Advances in Intelligent Systems and Computing, Vol.1306, Springer, Switzerland, 2021

Table 1. IFE matrix

Factor	Z-weights	Z-rating	Z-weighted score
S_1	About 0.17, VS	About 4, ES	(0.48,0.68,0.0) (0.43, 0.75,0,95)
. . .	. . .	. . .	. . .
W_1	About 0.1, ES	About 1, ES	(0, 0.1, 0.22) (0.63,0.98,1)
...	. . .	. . .	. . .

Here VS – very sure, ES – extremely sure

The following formula is used to calculate the Z-weighted values of internal factors.

$$Z_{int} = \sum_{k=1}^{K_i} ZW_k^s \cdot ZR_k^s + \sum_{n=1}^{N_i} ZW_n^W \cdot ZR_n^w \qquad (17)$$

Here ZW_k^s and ZR_k^s are the Z-weights and Z-ratings of the strengths, ZW_n^W və ZR_n^w are the Z-weights and Z-ratings of the weaknesses,

Depending on specifics of the analysis, experts can define weights or ratings as a scalar or Z-numbers.

Weighted aggregated Z-evaluation for internal factors:

$$Z_{int}=(1.96, 3.13, 4.5)(0, 0.04, 0.43).$$

The formula (18) is used to calculate the weighted Z-score of external factors.

$$Z_{ext} = \sum_{k=1}^{K_e} ZW_k^t \cdot ZR_k^t + \sum_{n=1}^{N_e} ZW_n^o \cdot ZR_n^o \qquad (18)$$

Here ZW_k^t is the Z-weight of the threats and ZR_k^t the Z rating, ZW is the Z-weight of opportunities and ZR_n^o is the Z rating.

Weighted aggregated Z-evaluation for external factors:

$$Z_{ext}=(1.66, 2.89,4.27)(0.01, 0.21, 0.82).$$

Table 2. EFE matrix

Factor	Z-weights	Z-rating	Z-weighted score
T_1	About 0.08, VS	About 4, ES	(0.21,0.32,0.45) (0.46, 0.74,1)
…	…	…	…
O_1	About 0.15, VS	About 1, VS	(0, 0.15,0.32) (0.3, 0.63,1)
…	…	…	…

Here VS – very sure, ES – extremely sure

Step 3. The results are used in the Z-SPACE matrix to determine the type of strategies.

In the case of Z-values, the maximum values of internal and external factors $Z_{max\text{-}int}$ and $Z_{max\text{-}ext}$ are used. You can use the lowest value of the Z-rating to determine the origin of the coordinates or set another appropriate value, for example, $Z_{\min}=(0, 1, 2),(0.25, 0.5, 0.75)$. Quadrants (Figure 3) can be defined, based on $Z_{aver\text{-}int}$ and $Z_{aver\text{-}ext}$ or other Z-values.

$Z_{aver\text{-}int}$=(1.5,2.5,3.5),(0.25,0.5,0.75) and
$Z_{aver\text{-}ext}$ =(1.5,2.5,3.5),(0.25,0.5,0.75)

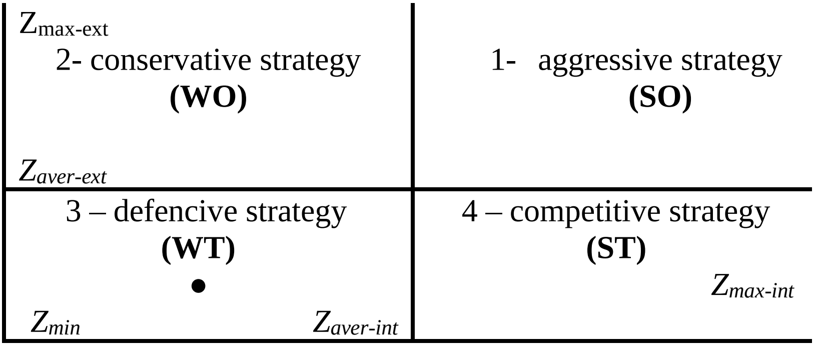

Figure 3. Z-SPACE matrix

$Z_{int} > Z_{aver\text{-}int}$ and $Z_{ext} > Z_{aver\text{-}ext}$ means the aggressive strategy; $Z_{int} < Z_{aver\text{-}int}$ and $Z_{ext} > Z_{aver\text{-}ext}$ - conservative strategy; $Z_{int} < Z_{aver\text{-}int}$ and $Z_{ext} < Z_{aver\text{-}ext}$ – defencive strategy; $Z_{int} > Z_{aver\text{-}int}$ and $Z_{ext} < Z_{aver\text{-}ext}$ – competitive strategy. Then calculated Z_{ext} and Z_{int} are compared with $Z_{aver\text{-}ext}$, $Z_{aver\text{-}int}$

$do\ (Z_{ext}, Z_{aver\text{-}ext}) = 0.82$, $do\ (Z_{aver\text{-}ext}, Z_{ext}) = 1$ and

$do\ (Z_{int}, Z_{aver\text{-}int}) = 0.6$, $do\ (Z_{aver\text{-}int}, Z_{int}) = 1$

In this case, the results fall into the 3rd quadrant, and therefore the defense strategy is more appropriate.

Step 4. After defining type of the strategy, we are building a QSPM matrix with two strategies (1 - development of tourist entertainment infrastructure, 2 - creation of a positive image as a place of rest). Experts rate the Z-score of attractiveness (AS) for each factor. Strategic analysis uses exact numbers for weights to show the possibility of using Z-values and crisp numbers together.

The overall attractiveness of each strategy is calculated as follows

$$Z = \sum_{s=1}^{n1} W_s \cdot Sas_s + \sum_{w=1}^{n2} W_w \cdot Sas_w + \sum_{t=1}^{n3} W_t \cdot Sas_t + \sum_{o=1}^{n4} W_o \cdot Sas_o \tag{19}$$

Here W_s, W_w, W_t, W_o are weights of factors, - Sas_s, Sas_w, Sas_t, Sas_o - Z-values of AS, n_1, n_2, n_3, n_4 - the number of factors that have certain AS (Attractiveness) values.

The overall attractiveness of the strategy N_1 is expressed by Z_1 = (3.24, 4.88, 6.52) (0.03,0.29.1) and for the strategy N_2 by $\underline{Z_2}$ = (3.61.5.25.6.79) (0.02.0.27, 0.93).

Comparing the values of Z_1 and Z_2 we get degrees of dominance $do(Z_1, Z_2)$ = 0.91 and $do(Z_1, Z_2)$ = 1, so the 2nd strategy is more preferred.

Z-numbers-based approach to Hotel Service Quality Assessment

Analysis of the service quality is based on subjective perceptions and feelings and implies the use of adequate formalism. The application of traditional SERVQUAL and IPA methods, based on subjective assessments, using both crisp and fuzzy estimates, does not consider the respondent's level of confidence in their assessments. In this regard, Z-numbers provide an opportunity to adequately reflect consumer feedback and assessments in quality analysis.

In the example of one of the hotels, let us consider the use of Z-numbers to evaluate the quality of service[17].

Step 1. After analysis and expert interviews, a questionnaire consisting of 38 questions covering 21 items of SERVQUAL was prepared. In the questionnaire, guests assess their expectations and perceptions using Z-numbers.

The summative assessment for each question is calculated as the average of all Z-assessments on service expectations and perceptions.

$$Z_{aver} = n_1 * Z_1/N + n_2 * Z_2/N + \ldots + n_m * Z_m/N \qquad (20)$$

Here n_m is the number of respondents who give the value Z_m

N is the total number of respondents and $N = \sum_1^m n_m$

To calculate the Z_{aver}, the operations of Z-numbers multiplication by scalar and adding the Z-numbers are used. The choice of arithmetic mean is because the opinion of each guest of the hotel is equally important.

Service expectations and service perceptions for each question are calculated with a Z-score.

Step 2. The gap must be calculated for each item.

The table of Z-assessment obtained for the 1st item is as follows.

Table 3. Z-assessment of 1st item of SERVQUAL

Sub items	Expectation	Perception	Importance weights
1.1	(3.25 4.25 4.99) (0.4 0.67 0.86)	(3 4 5) (0.5 0.75 1)	0.2
1.2	(3.1 4.1 4.8) (0.18 0.4 0.67)	(3.12 4.16 4.98) (0.41 0.7 0.86)	0.4
1.3	(2.84 3.88 4.66) (0.03 0.18 0.41)	(3.19 4.82 4.98) (0.39 0.67 0.88)	0.4

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[17] Nuriyev, A., Baysal, B. Z-numbers based approach to hotel service quality assessment// Lecture Notes in Networks and Systems, Vol.362, Springer,2022

here 1.1. - Modern and comfortable furniture; 1.2 - Modern air-conditioning system, lightening; 1.3 - Conveniences for people with disabilities.

Gap is calculated according to:

$$Z_{gapj} = \sum w_i * (Z_{pi} - Z_{ei}) \qquad (21)$$

$i=1, m$, here m is number of questions in j-th item of SERVQUAL

w_i –relative weight of the i-th question within the j-th item.

When the item consists of one question, the formula (21) will be in the following form

$$Z_{gapj} = Z_{pi} - Z_{ei} \qquad (22)$$

In (21) and (22) j = 1, 2, ..., 21 is total number of items.

Based on (21) gap is calculated

$$Z_{gap1} = (-1.65\ 0.35\ 1.95)\ (0.01\ 0.08\ 0.29)$$

It should be noted that $\sum w_i * Z_{pi}$ and $\sum w_i * Z_{ei}$ are Z-estimates of expectations and perceptions for each item, respectively.

In the same way, the Z-values of the expectation, perception and the gap are calculated for each indicator.

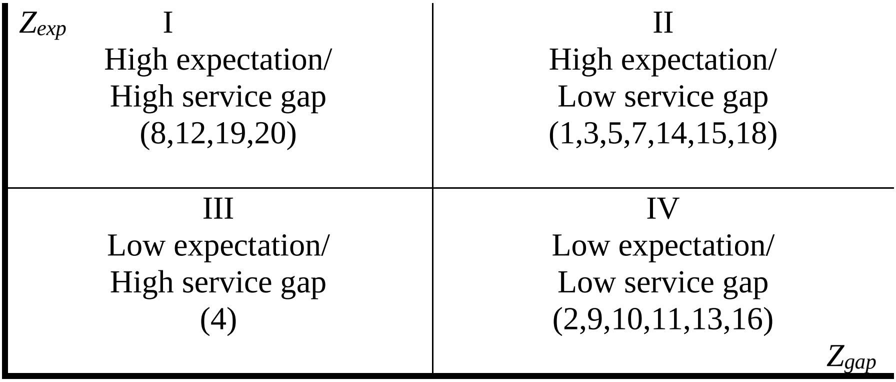
The next step is ranking of the $Z_{expectation}$ and Z_{gap}. The result is the following Z-SERVQUAL table.

Table 4. Z-SERVQUAL results

Item	Z-expectation	Z_{exp} rank	Z-perception	Z-gaps	Z_{gap} rank
1	(3.03 4.04 4.78) (0.01 0.11 0.34)	4	(3.12 4.39 4.98) (0.16 0.49 0.78)	(-1.65 0.35 1.95) (0.01 0.08 0.29)	8
2	(1.6 2.7 3.8) (0.12 0.21 0.5)	19	(1.75 2.75 3.75) (0.18 0.44 0.75)	(-1.36 0.64 2.64) (0.04 0.18 0.43)	6
...	...	...	...	...	...
21	(2.01 3.01 4.02) (0.17 0.5 0.73)	14	(2 3.01 4.02) (0.17 0.5 0.73)	No gap	10-17

Step 3. After ranking, Importance-Performance Analysis is performed to measure the quality of the service and to identify indicators that need to be considered to improve quality. Typically, the averages of expectations and differences are determined to construct quadrants.

As a result, we get the following Z-IPA model.



Z_{exp} I High expectation/ High service gap (8,12,19,20)	II High expectation/ Low service gap (1,3,5,7,14,15,18)
III Low expectation/ High service gap (4)	IV Low expectation/ Low service gap (2,9,10,11,13,16) Z_{gap}

Figure 4. Z-IPA model

Step 4. After setting up the Z-IPA model, we identify problematic indicators requiring improvement of the service quality.

The **fifth chapter** examines the application of the Z-approach to multi-criteria decision-making in the context of high levels of uncertainty. For example, tasks related to the Turkish and Azerbaijani tourism sectors have been resolved.

The specifics of the tourism sector determine the appropriateness of the use of multi-criteria decision-making (MCDM) models. At the same time, the need to process imperfect information in tourism management decisions necessitates the use of Z-information. The use of Z-information in MCDM models has several aspects. Let's look at them separately.

Z-number-based Swing Weight Method

Appropriate calculation methods should be used in the MCDM models as the values of the criteria and significance weights are expressed in Z-numbers.

In the dissertation, the Z-number-based extension of the Swing Weighting Method[18] was suggested to determine the weights. It is proposed that the weights of the criteria be determined based on the significance levels of the criteria and the confidence values of these rates.

The implementation of this approach consists of several stages.

Step 1. The Swing matrix is constructed for weights expressed in Z-numbers (Table 5). The most important and most reliable criterion for decision-making is placed in the upper left corner of the matrix (the cell marked with A). The criterion of the least importance and degree of certainty is placed in the lower right corner of the matrix (cell E).

Step 2. Consistency rules. As with the traditional Swing Weight Matrix, appropriate rules have been established to ensure the consistency of the weights based on the Z-numbers.

Step 3. Criteria are placed in the cells of the matrix according to significance values and confidence levels.

Step 4. Weights are normalized according to the following formula

$$Z_{Wnorm_i} = {Z_{wi}} \Big/ {\sum_{i=1}^{number\ of\ criteria} Z_{w_i}} \qquad (23)$$

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[18] Parnell, G. and Trainor, T., “Using the Swing Weight Matrix to Weight Multiple Objectives.” Proceedings of the INCOSE International Symposium, Singapore, July 19-23, 2009, pp. 283-298

Table 5. Swing matrix for the Z-numbers based weights

Value / Confidence	High	Medium	Low
High	*A*	B_2	C_3
Medium	B_1	C_2	D_2
Low	*C1*	D_1	*E*

Z-extension of the MCDM and direct calculations with Z-numbers

There are many methods for determining the optimal solutions in tourism. The dissertation studies Z-extensions of TOPSIS, VIKOR and PROMETHEE methods and proposes approaches based on direct calculations.

In all approaches, the initial version of the decision matrix ZDMx consisting of m rows (alternatives) and n columns (criteria) is constructed. Each element of the matrix is described by a Z-number.

In the following stages, direct calculations with Z-numbers are performed as follows.

Z-TOPSIS

Step 1. Normalization of the decision matrix.

TOPSIS has a variety of approaches to normalize the decision matrix. The linear transformation of part A is applied to normalize the decision matrix expressed by Z-numbers. For example, if part A is expressed as a triangular fuzzy number, then

$$A_{ij}^{norm} = \left(\frac{l_{ij}}{r_j^*}, \frac{m_{ij}}{r_j^*}, \frac{r_{ij}}{r_j^*}\right),\ j \in \mathrm{B}\ (\textit{benefit criteria}), \qquad r_j^* = \max\nolimits_{\mathrm{i}} c_{ij} \text{ if } j \in \mathrm{B} \tag{24}$$

$$A_{ij}^{norm} = \left(\frac{l_j^-}{r_{ij}}, \frac{l_j^-}{m_{ij}}, \frac{l_j^-}{l_{ij}}\right),\ j \in \mathrm{C}\ (\textit{cost criteria}), \qquad l_j^- = \min\nolimits_{\mathrm{i}} c_{ij} \quad \text{if } j \in \mathrm{C} \tag{25}$$

For Z_{ij}, $B_{ij}^{norm} = B_{ij}$

Step 2. Construction of a weighted normalized solution matrix with Z-numbers. To do this, multiply the values of the normalized decision matrix by the weights of the corresponding values.

Step 3. Determination of the positive ideal solution and the negative ideal solution given by Z-numbers. $Z_{pis} = (1,1)$ is used as a positive ideal solution for the Z-extension of the TOPSIS method, and $Z_{nis} = (0,0)$ is used as a negative ideal solution.

Step 4. Calculation of the distance from each alternative to the ideal positive and ideal negative solutions.

The distance between two Z-numbers is calculated based on formula (9).

The distances between each i-alternate and the positive ideal solution (Z-PIS) described by the number Z and the negative ideal solution (Z-NIS) described by the number Z can be calculated as follows.

$$d_i^+ = \sum_{j=1}^{N} d(Z_{ij}, Z_{pis}) \tag{26}$$

$$d_i^- = \sum_{j=1}^{N} d(Z_{ij}, Z_{nis}) \tag{27}$$

where N is the number of criteria.

Step 5. Calculation of the relative closeness to the best alternative

$$Z_{cc_i} = \frac{d_i^-}{d_i^+ + d_i^-} \tag{28}$$

Step 6. Ranking of the alternatives by relative closeness.

Z-PROMETHEE

Step 1. Normalization of the decision matrix.

Normalization is performed in the same way as for Z-TOPSIS.

Step 2. Determination of the weights of the Z_{CWi} criteria expressed in Z-numbers.

Step 3. Calculation of the differences between the alternatives in terms of the degree of optimality (dominance).

Step 4. Calculation of the preference function

$$P_j(Z_{ij}, Z_{ji})=0 \text{ if } do(Z_{ij},Z_{ji}) \leq do(Z_{ji}, Z_{ij})$$
$$P_j(Z_{ij}, Z_{ji})= do(Z_{ij},Z_{ji})-do(Z_{ji}, Z_{ij}) \text{ if } do(Z_{ij},Z_{ji}) \leq do(Z_{ji}, Z_{ij}) \qquad (29)$$

Step 5. Calculation of the weighted preference function given by Z.

$$Z_{\pi w}(Z_{ij}, Z_{ji}) = P_j(Z_{ij}\ , Z_{ji}) \cdot\ Z_{CW_i} \qquad (30)$$

Step 6. Calculation of the preference inflow in and outflow (direct and reverse preference) for each alternative.

$$\Phi^{+}_{Z_j}\ (a)\ = \sum\ Z_{\pi w}\ (\,a, b) \qquad (31)$$

$$\Phi^{-}_{Z_j}\ (a)\ = \sum\ Z_{\pi w}\ (\,b, a) \qquad (32)$$

The direct preference factor Φ^+ indicates how "good" the object is compared to other objects in the sample. And the Φ^- factor − how "bad" this object is compared to other objects in the sample.

Step 7. For a complete ranking, the net flow of preferences $\Phi_{Z_j}\ (a)$ is used.

The flow of positive and negative preference is aggregated into the final preference flow.

$$\Phi_{Z_j}\ (a)\ = \Phi^{+}_{Z_j}\ (a)\ -\ \Phi^{-}_{Z_j}\ (a) \qquad (33)$$

Z-VIKOR

Step 1. Definition of the positive ideal point (Z-PIP) and negative ideal point (Z-NIP) based on Z-numbers as follows

a^+= (0,99 0,993 0,996 0,999) (0,975 0,981 0,986 0,991) və a^- = (0,001 0,002 0,004 0,005) (0,95 0,96 0,97 0,98).

Step 2. Calculation of the measure of regret for each alternative (regret measure based on Z-number)

$$R_{ij,i\in 1,3} = max\ \left(w^{z}_{j\,crit}\,\frac{\left(a^{+}_{i} - a_{ij}\right)}{\left(a^{+} -\ a^{-}\right)}\right) \qquad (34)$$

The expression in parentheses indicates the regret degree of *i*-th alternative with respect to *j*-th criterion.

Step 3. Calculation of the utility S_i for each alternative

$$S_{i,i\in 1,n} = \sum_{j=1}^{number\ of\ criteria} \left(w_j \, {(a_i^+ - a_{ij})} \Big/ {(a^+ - a^-)} \right) \qquad (35)$$

Step 4. Calculation of the Qi index for all alternatives:

$$Q_{i,i\in 1,3} = v\frac{(S_i - S^-)}{(S^+ - S^-)} + (1 - v)\frac{(R_i - R^-)}{(R^+ - R^-)} \qquad (36)$$

$S^- = min\ S_i$; $S^+ = max\ S_i$; $R^- = min\ R_i$; $R^+ = max\ R_i$

Minimum and maximum values of weights R and S for strategy *v* - "most of criteria" (or "maximum group utility") are calculated according to the minimum and maximum values of the R and S.

Step 5. Ranking of the S, R and Q.

Step 6. The ranking results are analyzed according to the conditions C_1 (Satisfactory advantage) and C_2 (Satisfactory stability in decision making)

Two approaches are possible to assess the differences between Q_1 and Q_2 values. The first approach calculates the difference between the degrees of optimality. The second approach involves calculating the measure of similarity between the Z-numbers with the Jacquard index - formula (10) and (11).

According to the VIKOR method, considering the values of alternatives, it is necessary to determine how much the alternative with the minimum value of Q is superior to the next alternative with the higher value of Q. It is necessary to determine the difference between an alternative with a minimum Q value and an alternative with the next Q value, as well as alternatives with subsequent Q values.

The condition Q (a ') - Q (a *) ≥ DQ = 1 / (N-1) must be satisfied, where N is the number of alternatives.

Z-number-based fuzzy approach for selection of the hotel supplier. The *task of choosing a hotel supplier* has been solved for small and medium-sized hotels in Azerbaijan and Turkey (Izmir).

Supplier selection is based on the following criteria: *price, service quality, in time delivery, flexibility, profile and rating, capacity, long-term relationships*.

Z-VIKOR procedures include calculation of the regret measure $R_{ij,i\in 1,3}$ according to formula (34), calculation the utility according to formula (35), and using formula (36) for calculation of Qi for all alternatives.

The values of S, R and Q are ranked according to the degree of optimality. The alternative A_1 has the best rating in S and R.

The rating results are analyzed and then the difference between Q_1 and Q_2 is determined. Based on the degree of optimality, the difference between do (Q_1) and do (Q_2) is 0.04, according to the Jacquard index the distance between Q_1 and Q_2 is 0.12. In both cases, the results are less than DQ = 0.5.

Thus, it can be concluded that the alternative A_1 is the best option.

Z-number-based fuzzy approach for tourism location selection. The solution of the *problem of tourism facilities location* for the regions of Azerbaijan was considered.

In this example, five regions of the country are considered as attractive locations for the tourism development. Six criteria were selected by Delphi analysis: *Economical criterion, Recreation and tourism resource availability, Accessibility, Ecological and environmental attractiveness, Infrastructure and utilities availability, Human resources.*

After compiling a table of normalized weighted decision matrix, according to the Z-TOPSIS approach the distance from each alternative to the ideal positive and ideal negative solutions is calculated and the relative closeness to the best alternative (ideal solution) is calculated.

By sorting the alternatives according to the relative closeness to the ideal solution, we obtain the following sequence of alternatives: A_1 (closeness to ideal solution -0.147), A_4 (0.142), A_5 (0.142), A_3 (0.128), A_2 (0.123). Alternative A_1 has a higher priority.

The solution of the problem of tourism facilities location by Z-PROMETHEE method was also considered. Once a decision matrix has been developed, the search for the best alternative is implemented as a multi-step process.

The differences between the alternatives are determined and the preference function is calculated based on the Z-values. The values of the criteria for each alternative are compared in pairs according to the degree of optimality. Then the preference function is calculated based on the degree of optimality (formula 29).

Weighted preferences expressed in Z-numbers (formula 30) are calculated as the product of the corresponding values of the preference function and the weights of the criteria given in Z-numbers.

The entering and leaving flows are calculated for each alternative, and then the net (final) flows are calculated.

Table 8. **Net flows of preference**

Alter-natives	**Z-value of net flow**	
	Part A	**Part B**
A_1	0.235 0.355 0.507 0.662	0.0000001 0.0000029 0.0000662 0.0010787
A_2	-1.206 -0.96 -0.73 -0.568	0.0005868 0.0023007 0.0082631 0.0271535
A_3	-0.34 -0.139 0.054 0.249	0.0001737 0.0004808 0.0007893 0.0027116
A_4	0.152 0.297 0.492 0.714	0.0000804 0.0003813 0.0017818 0.0052415
A_5	0.04 0.173 0.326 0.476	0.0000161 0.0001472 0.0011994 0.0072920

The alternatives are ranked according to the Z-values of the net flow. By ranking the alternatives according to the dominance value, we obtain the following priority order of alternatives: A_1, A_4, A_5, A_3, A_2. Both approaches-*Z-TOPSIS* and *Z-PROMETHEE* obtained the same results.

Fuzzy approach for selection of the tourist destination.

Selection a tourist destination is one of the essential tasks for participants in the tourism business and travelers. Therefore, selecting a tourist destination (direction) has been resolved within the study of the potential of water sports tourism in Turkey.

Significance of the criteria (*accessibility, weather conditions, financial opportunities, entertainment activities, availability of the necessary infrastructure, image of the destination, quality of service, security*) was determined using the method of the maximum deviations.

Z-numbers based TOPSIS was used and respective decision matrix was composed. According to Z-TOPSIS method calculations the following results were obtained: A_1 - 0.352, A_2 - 0.300, A_3 - 0.309, A_4 - 0.315, A_5- 0.356

Alternative A_5 is the best, next one is the alternative A_1. The other three alternatives are ranked in the following order: A_4, A_3, A_2.

CONCLUSION

A detailed analysis of the information considered in managerial decision-making for the tourism sector is carried out. It was found that the information used in tourism management decision-making is imperfect and has a high level of uncertainty.

The need to use fuzzy models considering high-level uncertainty in management decision-making in the tourism sector was justified and new appropriate approaches were proposed.

It was suggested to use the concept of Z-numbers to describe and process fuzzy-probabilistic data for managerial decisions. Z-numbers allow more adequately present experts and other stakeholders knowledge and opinions in the decision-making methods widely used in tourism.

Risks and threats affecting the safety of tourists during the trip were identified. A generalized register of tourism risks and threats has been developed, combining risks of different nature and origin. The risk register allows determining the input information required for analysis, regardless of the country under study and the availability of statistics. Z-numbers were used to determine the level of various risks affecting tourists. To assess the tourist destination from the security point of view, a method of risk aggregation has been proposed.

An approach based on multi-stage fuzzy analysis has been proposed for quantitative strategic analysis in the tourism sector. The problem of determining the values and weights of the factors was considered. To solve this problem, it is proposed to use Z-numbers to adequately express expert knowledge and assessments during strategic analysis. Procedures for constructing Z-IFE, Z-EFE matrices have been identified, as well as approaches to building strategic position and performance assessment (Z-SPACE) matrix and quantitative strategic planning matrix (Z-QSPM). The proposed approaches can be applied in the tourism sector and other areas of activity.

A Z-extension of the SERVQUAL methodology has been proposed to assess the quality of services provided in the tourism sector and decision-making on quality improvement. The proposed Z-SERVQUAL model allows to more accurately describe the expectations and perceptions of the quality of service provided and to determine the difference between expectations and perceptions. The proposed approach was used for assessing the quality of service in small and medium-sized hotels in Turkey and Azerbaijan and confirmed its appropriateness.

New approaches to Z-extensions have been proposed for the multi-criteria decision-making methods used in the tourist sector under a high degree of uncertainty. These MCDMs are based on different principles. Based on the proposed approaches and using Z-VIKOR, Z-TOPSIS, and Z-PROMETHEE methods, problems such as selection of optimal alternatives for hotel suppliers, water-sports tourism destinations, and location of tourism facilities were solved.

For the construction of fuzzy models, based on Z-information, and problem solutions, appropriate software (Z-calc) was developed in the Python programming language.

The proposed approaches and developed models provide opportunities for making good management decisions in the tourism sector.

The main content of the dissertation is published in the following works

1. Nuriyev, A.M. Jabbarova K. Z-Value Based Risk Assessment: The Case of Tourism Sector. Advances in Intelligent Systems and Computing, Vol.1095, Springer, Switzerland, 2020, pp.205-213, doi.org: 10.1007/978-3-030-35249-3_26
2. Nuriyev, A. Application of Z-Numbers Based Approach to Project Risks Assessment. European Journal of Interdisciplinary Studies, 2020, 6 (2), 30–40. doi.org:10.26417/ejis-2019.v5i2-287.
3. Nuriyev, A. M. Identification of the Tourism Risks for Z-Value Based Risk Assessment. European Journal of Formal Sciences and Engineering, 2021, 4(2), 80–94. doi.org:10.26417/ejef.v3i3.p47-55.
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5. Nuriyev A. Application of Z-numbers for evaluation and aggregation of the travel threats in the post-pandemic era. European Journal of Social Science Education and Research, 2021, Vol. 8 No. 2, pp. 129-149.
6. Nuriyev, A.M. Aggregation of Z-number based expert estimates. News of Azerbaijan High Technical Educational Institutions. – 2021, Vol 23(6), pp 37-44 (Recommended by the High Attestation Commission of Azerbaijan Republic)
7. Nuriyev, A & Baysal, B. Z-numbers based approach to hotel service quality assessment. Lecture Notes in Networks and Systems, Vol. 362, Springer, Switzerland, 2022, pp. 85-94
8. Nuriyev A.M. Operations on Z-numbers in decision-making models with high-level uncertainty// 7Universum: technical sciences: scientific electronical journal, 2022, 2(95). doi.org:10.32743/UniTech.2022.95.2.13141 (Recommended by the High Attestation Commission of Uzbekistan Republic)

9. Nuriyev A., Baysal A.B. Multicriteria decision-making under high-level uncertainty in tourism: Z-number-based approaches. Proceedings of 7th International Zeugma Conference on Scientific Research January 21-23, 2022, Gaziantep, Turkey, pp. 350-358
10. Nuriyev A., Baysal A.B. Selection of the hotel suppliers under high-level uncertainty. Proceedings of 5th International European Conference on Interdisciplinary Scientific Research, January 28-29, 2022, Valencia, Spain, pp. 259-272
11. Nuriyev A. (2022). Fuzzy MCDM Models for Selection of the Tourism Development Site: Case of Azerbaijan. Proceedings of IIARP International Conference on Economics, Business, Tourism & Social Sciences, February 18, 2022, Malacca, Malaysia. doi.org:10.7490/f1000research.1118922.1

Personal contribution of the applicant in the works published in co-authorship.

[1]- problem statement, mathematical modeling, and analysis of results.

[7,9,10]- problem statement, mathematical modeling, computer simulation and analysis of results.

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The defense will be held on September 23, 2022, at 1 PM at the meeting of the Dissertation council ED 2.02 of Supreme Attestation Commission under the President of the Republic of Azerbaijan operating at the Azerbaijan State Oil and Industry University.

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