SELECTION OF THE HOTEL SUPPLIERS UNDER HIGH-LEVEL UNCERTAINTY

Aziz NURIYEV
Azerbaijan State Oil and Industry University, Khazar University

Ahmet Bahadir BAYSAL
Khazar University

ABSTRACT

The objective of this paper is to develop a model for supplier selection under high-level uncertainty in the decision-making environment. The pandemic seriously affected the economic well-being of the hospitality industry, decreased travel and tourists` numbers, undermined hospitality service delivery systems and their financial stability. Business structures and relationships, developed in the industry during several decades of stability, have been destroyed fully or partially, and service quality is deteriorating. One of the consequences of the pandemic is supply chains disruptions, caused by the inabilities of suppliers to provide services according to customer requirements. Given that, it is necessary to solve the problem of supplier selection for the tourism sector taking into consideration specifics of the pandemic and post-pandemic conditions. During pandemic and post-pandemic recovery, internal and external environments of the business tasks are characterized by the high-level of uncertainty, insufficiency, and subjectivity of the available information. Supply chain management task is a classic example of such tasks, and it is necessary to develop an approach that can operate with uncertainties and subjectivity of various nature, inherent to this decision-making problem. In such circumstances, traditional probabilistic or fuzzy methods may not always be relevant for formalizing uncertainties, and the use of perception-based dual-natured (fuzzy & probabilistic) Z-numbers may be more appropriate. Z-number-based multi-criteria decision-making (MCDM) method Z-VIKOR was used to select alternatives (suppliers) for the hotels. The criteria for the supplier selection were determined by Delphi analysis. The supplier selection task is solved on the example of hotels in Turkey and Azerbaijan. Results of the research illustrate the applicability of the approach for solving MCDM problems in the tourism sector under conditions of high-level uncertainty.

Keywords: hotel supplier selection, uncertainty, selection criteria, Z-number, Z-VIKOR

INTRODUCTION

During pandemic and post-pandemic period, service providers in the tourism industry are forced to select new suppliers because several actors suspended their activity and left the market due to the difficulties caused by lockdowns. Internal and external environment of the supply chain related decisions has significantly changed, and these changes enforce decision makers to revise and re-evaluate decision-making process. High level uncertainty, inherent to supplier selection task, should be considered in model development and problem solution approaches. Hotel supplier selection is a MCDM task and in the problem statement special attention should be paid to identifying multiple potential alternatives and criteria selection. Preliminary study of the problem revealed fuzzy nature of the criteria and evaluations of their importance, alternatives descriptions and evaluations, and priorities of decision makers. In this paper, criteria for supplier selection have been determined based on the literature review and Delphi analysis.

There is not reliable and representative statistical data for supplier selection in case of high-level uncertainties and changes. In the absence of statistical data for model development and alternatives evaluations, estimates provided by experts in the linguistic form are the only source of information for modelling and problem solution. Experts are using various numbers of linguistic terms for describing alternatives, variables, and criteria. As a rule, three or five terms allow expert to cover domain of judgements related to single variable. For example, the value of criteria can be expressed in the linguistic form as "High", "Medium" or "Low". The importance of criteria is also can be expressed in linguistic forms such as “Very important”, “Important” or “Not very important”. Formalization of such information can be done by use of the fuzzy logics. Linguistic evaluations of criteria and alternatives have subjective nature and usually they do not reflect the degree of the respondents` confidence in information that they are providing. Remedy of this deficiency can be done by applying of the Z-numbers (Zadeh, 2011), which provide opportunity to take into consideration imperfection or incompleteness of knowledge, provided by experts. Application of this approach allows to formalize imperfectness and incompleteness of the information about the suppliers and terms of supply in the supplier selection model. The responsible person can express an assessment of the product quality and the reliability of this assessment through bi-modal Z-evaluation, for example (“Very high, Likely”). For the tasks with high level uncertainty Z-numbers based approach is preferable. In this case problem statement and solution are based on fuzzy evaluations and reliability of these evaluations.

In our work, for solution of the supplier selection problem, Z-numbers based MCDM model and Z-extension of the VIKOR method are applied. Operations on Z-numbers are carried out according to Zadeh's ideas with the technique presented in (Aliev et al,2015). The results of the problem solution show the efficiency of using Z-numbers for suppler selection in conditions of imperfect information.

The rest of the paper is organized as follows: section 2 presents review of the approaches used in suppler selection, section 3 describes methodology, section 4 presents the results, and in final section are presented discussion and conclusions.

Literature review

Supplier selection is the task of finding the best supplier for the given set of criteria and alternatives. Depending on decision-making environment, various multi-criteria decision-making techniques have been applied for this problem solution. Key points in the problem solution are identifying multiple alternatives, selecting a set of criteria, prioritizing the criteria according to their importance, selecting the solution method and problem solution. The supplier selection task has been studied in various publications.

The process of relevant criteria selection is one of three important steps such as identifying the criteria, determining their weights, and multi-criteria decision-making (Taherdoost & Brard, 2019). In review (Stevic, 2017), devoted to supplier selection, such criteria as quality, delivery-time, financial parameters were pointed out as main criteria, and communication, reliability, capacity, flexibility, reputation, speed of response were mentioned as very important criteria. For the hospitality industry in (Onder&Kabadayi, 2015) 7 criteria (reliability, quality, price-cost, communication and relations, sustainability, service quality, technology) and 37 sub-criteria were used. In (Chowdhury et al.,2019) facilities, inventory, transportation, information, sourcing, pricing, and quality are positioned as supply chain drivers which predetermine the efficiency of supply chain management in the hospitality industry. In other work (Biljanoska & Martinoska, 2010), the questionnaire used in the survey is consisted of 20 supplier selection criteria, whereas, as the most important criteria are mentioned accuracy in filling orders, consistent quality level, on-time delivery. In (Şimşek et al., 2015) price, quality, delivery, relationship, and service as main criteria were analyzed to determine the most suitable supplier for the hotel business. In review (Ristono et al., 2018) the techniques used on the different stages (criteria determination, the relation between criteria, prioritizing of criteria) of supplier selection were analyzed and Delphi and ANOVA methods were suggested for selection of the criteria. In (İnan&Yüncü, 2018) the set of criteria for selecting the hotel supplier is determined by the use of the Delphi method.

Since the 90s (Lu et al., 2021), fuzzy logics based approaches are widely used for supplier evaluation, defining criteria, and weights. This overview of fuzzy methods applications in supply chain management pointed out the idea that fuzzy MCDM techniques have been applied widely, and a significant part of the research was dedicated to the assessment of suppliers. Transformation of the available information into a fuzzy model decreases both the subjectivity of each responsible person in group decision-making and the errors, caused by the problems of mathematical calculations (Petrovic et al., 2019). Fuzzy MCDM methods allow using numerical and linguistic data. The fuzzy approach also was used for tourism supply chain management (SCM). Due to the complexity of tourism supply chain management (Sasrawan&Citra, 2019), the activity of actors was analyzed by the application of fuzzy logic that provides a simple way to describe inference of the definite conclusions from ambiguous, vague, or incorrect information.

In recent years several papers were published that used Z-numbers in the statement of the supplier selection problem. But in most cases, these works are not strictly following the procedures of the decision-making, based on Z-information. In most of these publications, the authors are using the conversion of the Z-numbers (higher level of uncertainty) to fuzzy numbers (lower level of uncertainty). The stated goal of this conversion is to simplify computations. Simplifying computation is a reasonable argument, but not in this case because such conversion contradicts Zadeh's conceptual work (Zadeh, 2011). If we do not want to lose information in case of higher uncertainty, all computations should be carried out in accordance with Z-numbers axiomatics. The utilizations of Z-numbers without any conversion for the supplier selection problem solution were shown in (Agakishiyev, 2016; Jabbarova, 2018). An acceptable approach to the use of Z-information was applied in this work (Wang & Mao, 2019).

MATERIALS AND METHOD

Z-numbers and operations with them

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

Z-number is ordered pair $Z=(A,B)$ of perception-based fuzzy numbers determining the value of uncertain variable X. Part A sets the value of X, and part B sets the reliability of A. For example, value of uncertain variable X= *Accessability* can be expressed in the form of Z-number as *Accessibility=(high, very 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

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

Part A of Z_{12} is computed under the rules of arithmetic operations on fuzzy numbers $A_{12}=A_1*A_2$. The calculation of part B of the Z-number is a more complex task since this part defines the degree of confidence, which is expressed in terms of the theory of probability. To calculate B_{12}, the method described in (Aliev & Salimov, 2017) is used. This method is based on the fundamental principles of operations on Z-numbers, related to fuzzy probabilities and probabilities of fuzzy events.

Definition 3. Comparison of Z-numbers on the base of fuzzy Pareto optimality (FPO) principle (Aliev et al,2015).

According to this principle, two Z-numbers $Z_1=(A_1,B_1)$ and $Z_2=(A_2,B_2)$ are compared by calculation of the functions n_b, n_e,n_w, which evaluate how much one of the Z-numbers is better, equivalent or worse than the other with respect to the first and the second component A and B. Degree of optimality *(do)* of Z-numbers are calculated based on computed $n_b(Z_i,Z_j)$ $n_e(Z_i, Z_j)$ $n_w(Z_i, Z_j)$. If $do(Z_1) > do(Z_2)$, then $Z_1 > Z_2$, if $do(Z_1) < do(Z_2)$, then $Z_1 < Z_2$ and $Z_1 = Z_2$ otherwise.

Definition 4. Jaccard index-based similarity measure

Similarity measure is a real number from 0 to 1, which characterizes the similarity of fuzzy numbers in terms of their shape and location. If two fuzzy numbers are identical, then the similarity measure is 1.

The Jaccard index can be used to calculate the similarity measure (Aliev et al, 2017). The Jaccard index for Z-numbers, with parts A and B represented by triangular or trapezoidal fuzzy numbers, can be calculated using the following formula:

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

where $J(A_1, A_2)$ и $J(B_1, B_2)$ are calculated according to formula

$$J(\tilde{X}, \tilde{Y}) = \frac{\frac{1}{2}\sum_{i=1}^{8}(x_i * y_i)}{\sum_{i=1}^{8} x_i^2 + \sum_{i=1}^{8} y_i^2 - \sum_{i=1}^{8}(x_i * y_i)} + \frac{\frac{1}{2}\sum_{i=1}^{8}(x_i' * y_i')}{\sum_{i=1}^{8} x_i'^2 + \sum_{i=1}^{8} y_i'^2 - \sum_{i=1}^{8}(x_i' * y_i')} \quad (3)$$

For calculation of the similarity measure between triangular or trapezoidal fuzzy numbers, for example, $\dot{B}_1 = (b_{11}, b_{12}, b_{13}, b_{14})$ и $\dot{B}_2 = (b_{21}, b_{22}, b_{23}, b_{24})$, where $b_{11} \le b_{12} \le b_{13} \le b_{14} \le 1$ and $b_{21} \le b_{22} \le b_{23} \le b_{24} \le 1$, formula (3) considers the relative position of numbers and the forms of membership functions (Hwang&Yang, 2014).

To consider the relative position of numbers in the calculations, the so-called extreme left and right points $l = min\{b_{11}, b_{21}\}$ and $r = max\{b_{14}, b_{24}\}$ are defined. The first addend in formula (3) determines the similarity with respect to l, the second with respect to r.

Arguments for the formula are calculated according to the rules shown in Table 1.

Table 1. Arguments for calculating the measure of similarity

x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8
$b_{11}-l$	$b_{12}-l$	$b_{13}-l$	$b_{14}-l$	1	$b_{12}-b_{11}$	$b_{13}-b_{12}$	$b_{14}-b_{13}$
y_1	y_2	y_3	y_4	y_5	y_6	y_7	y_8
$b_{21}-l$	$b_{22}-l$	$b_{23}-l$	$a_{24}-l$	1	$b_{22}-b_{21}$	$b_{23}-b_{22}$	$b_{24}-b_{23}$
x'_1	x'_2	x'_3	x'_4	x'_5	x'_6	x'_7	x'_8
$r-x_4$	$r-x_3$	$r-x_2$	$r-x_1$	1	x_6	x_7	x_8
y'_1	y'_2	y'_3	y'_4	y'_5	y'_6	y'_7	y'_8
$r-y_4$	$r-y_3$	$r-y_2$	$r-x_1$	1	y_6	y_7	y_8

The similarity measure between two numbers is calculated as a value, inversely proportional to the distance

$$S(Z_1, Z_2) = \frac{1}{1 + D(Z_1, Z_2)} \quad (4)$$

Then distance is calculated according to the formula

$$D(Z_1, Z_2) = \frac{1}{S(Z_1, Z_2)} - 1 \quad (5)$$

Determining the criteria and their importance

Panels of Delphi analysis were carried out for small and medium-sized hotels in Turkey (Izmir region) and Azerbaijan to define the hotel supplier selection criteria. Each of them was attended by 7 experts. After analyzing the literature and conducting a survey, the initial 12 criteria for supplier selection were presented in the first round. In the second round of panels, the experts from both countries settled on 8 criteria.

Further, the weights for each criterion were determined separately for the hotels in Turkey and Azerbaijan. For this purpose, each expert had assigned a degree of importance expressed in linguistic form for each criterion. Due to the fact, that the expert groups included the experienced staff from hotels with a long presence in the tourism sector, it made sense to consider them equally competent. For each criterion, the importance weights expressed by Z-number-based values were determined. The application of the Z-number methodology allowed for a consensus in the expert group, and the decision-maker (expert panel moderator) was able to find an acceptable group rating.

After determining the criteria and their importance weights, the supplier selection model was built. Supplier selection for hotels was performed by using Z-number-based VIKOR multi-criteria decision-making approach (Z-VIKOR). As shown in (Mardani et al,2016; Lu, 2021), the VIKOR method is widely and effectively used for supplier selection. Z-extension is significantly increased descriptive power of the method and range of tasks that successfully can be solved by applying this method.

Z-number based VIKOR

Step 1. 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 2. At the first stage we are determining Z-number-based positive-ideal point (Z-PIP) and negative-ideal point (Z-NIP) as a^+= (0.99 0.993 0.996 0.999) (0.975 0.981 0.986 0.991) and a^- = (0.001 0.002 0.004 0.005) (0.95 0.96 0.97 0.98).

Step 3. Calculation of Z-number-based regret measure for each alternative according to the formula

$$R_{ij,i\in 1,3} = max\left(w_{j\,crit}^{z}\frac{(a_i^+ - a_{ij})}{(a^+ - a^-)}\right) \quad (6)$$

The expression in brackets is expressing the regret measure of j-th criteria of i-th alternative.

Step 4. The values of utility measures Si of each alternative are calculated according to the formula

$$S_{i,i\in 1,3} = \sum_{j=1}^{number\ of\ criteria} \left(w_j \left(a_i^+ - a_{ij}\right) \Big/ \left(a^+ - a^-\right) \right) \qquad (7)$$

Step 5. Index Q_i for all alternatives is calculated according to the formula :

$$Q_{i,i\in 1,3} = v\frac{(S_i - S^-)}{(S^+ - S^-)} + (1-v)\frac{(R_i - R^-)}{(R^+ - R^-)} \qquad (8)$$

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

v- weight of the strategy of ''the majority of criteria'' (or ''the maximum group utility''), *min* and *max* values of R and S are determined according to the Definition 3.

Step 6. The values S, R and Q are ordered according to degree of optimality.

Step 7. The results of ordering are analyzed according to conditions C1 and C2 (Opricovic & Tzeng, 2004).

For evaluation of the differences between Z-number-based values of Q_1 and Q_2 two approaches are possible. According to first approach the subtraction of optimality degrees is calculated. Second approach is related to calculation of the Jaccard index-based similarity measure between Z-numbers, according to the Jaccard index (Definition 4). According to VIKOR method (Opricovic & Tzeng, 2004), it is necessary to identify how much the alternative with less value Q is superior in comparison with alternative Q with the next value, with respect to all alternatives. That is, condition $Q(a^')- Q(a^*) \geq DQ=1/(N-1)$ must be satisfied, where N- is number of alternatives.

RESULTS

Problem solution is the multistage process and can be described as follows:

Step 1. Determination of the criteria and their importance weights

After literature analysis and initial survey of experts, at the first round of Delphi panel the following criteria for supplier selection were chosen - *support, cost, technology, on-time delivery, flexibility, profile and rating influence, supplier location, capacity, long-term relationships, force major and crisis situations, reliability, payment method.*

After second round 8 criteria: *C_1- cost, C_2-service quality, C_3-on-time delivery, C_4-flexibility, C_5-profile and rating, C_6-location, C_7-capacity, C_8-long-time relations* were selected. The values of 5 criteria are expressed linguistically and values of 3 criteria *(Cost, Location, Long time relation)* can be both the crisp numbers and linguistic evaluations according to available information.

To determine the importance of criteria, experts assigned values from term-set T_{im} = {"not important" (NI), "not very important"(NVI), "average"(A), "important"(I), "very important"(VI) } and T_{conf} = { Not sure (NS), not very sure (NVS), Sure (S), Very sure (VS), Extremely sure (ES)}.

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, and Confidence and their respective trapezoidal membership functions are presented in Table 2.

Table 2. Trapezoidal membership functions and linguistic values

Value of LV (Importance)	**Value of LV (Level)**	**Value of LV (Confidence)**	**TMF**
Not important (NI)	Very Low (VL)	Not sure (NS)	0.3, 0.3, 0.3, 0.4
Not very important (NVI)	Low (L)	Not very sure (NVS)	0.3,0.4, 0.5, 0.6
Average (A)	Average (A)	Average (A)	0.5 0.6 0.7 0.8
Important (I)	High (H)	Very sure (VS)	0.7 0.8, 0.9, 1
Very important (VI)	Very high (VH)	Extremely sure (ES)	0.9 1 1 1

After defining the criteria, group opinions of the experts on importance of the criteria, expressed by Z-numbers, are presented in Table 3.

Table 3. Importance of criteria for Izmir region hotels

Criteria	Name	Z-number based values of importance	Z-value expressed by TFN
C_1	cost	H,VS	(0.7 0.8 0.9 1) (0.7 0.8 0.9 1)
C_2	service quality	VH,ES	(0.9 1 1 1) (0.9 1 1 1)
C_3	on-time delivery	VH,ES	(0.9 1 1 1) (0.9 1 1 1)
C_4	flexibility	A,VS	(0.5 0.6 0.7 0.8) (0.7 0.8 0.9 1)
C_5	profile and rating	H, S	(0.7 0.8 0.9 1) (0.5 0.6 0.7 0.8)
C_6	location	A,S	(0.5 0.6 0.7 0.8) (0.5 0.6 0.7 0.8)
C_7	capacity	A,S	(0.5 0.6 0.7 0.8) (0.5 0.6 0.7 0.8)
C_8	long-time relations	H,VS	(0.7 0.8 0.9 1) (0.7 0.8 0.9 1)

Step 2. Supplier evaluation by criteria**.**

We have three alternatives for hotel suppliers. Information about suppliers according to criteria is shown in Table 4.

Table 4. Information about suppliers

Criteria	S_1	S_2	S_3
C_1	3.45 TL	3.4 TL	3.35 TL
C_2	VH, ES	H,ES	H, ES
C_3	EL,ES	VL, VS	EL,VS
C_4	VH, VS	VH, ES	H, ES
C_5	VH,ES	VH, VS	H,VS
C_6	4 km	6 km	8 km
C_7	VH, VS	VH,ES	H,VS
C_8	10	6	8

For decision-making about supplier, the information expressed both in crisp and fuzzy forms can be used (cost, location, long-time relations). The information about suppliers shown in Table 4 should be presented in form of Z- numbers. The values of criteria expressed by crisp numbers can easily be converted in the fuzzy form without information lost. For example, crisp number 10 can be expressed by Z-number "About 10, Extremely sure" with membership function (9.8, 10, 10, 10.2) (0.9, 1, 1, 1).

Then Z-number based normalized decision matrix is built.

For bringing criteria in comparable form and dimensionless quantities, the normalization should be performed. For part A of Z-numbers the linear scale transformation (Chen,2000) is applied. Part B is not transformed and B_{ij}^{norm} of Z_{ij} = B_{ij} of Z_i

Criterion C_1 is Cost-criteria, others are beneficial. Despite the expression of criterion C_6 *(location)* values with crisp numbers, according to the expert opinion, the linguistic evaluations such as "nearly", "far away" are used, usually, during the decision-making in the hotel industry. On this basis, for a fuzzy evaluation of the "Location" criterion, the numbers, inverse to the distance values, were used.

The Z-number-based normalized decision matrix is shown in table 5.

Table 5. Normalized decision matrix

Criteria	Alternatives	Z-number based values	
		Part A	Part B
C1	A1	0.915 0.942 0.942 0.97	0.9 1 1 1
	A2	0.929 0.956 0.956 0.985	0.9 1 1 1
	A3	0.942 0.97 0.97 1	0.9 1 1 1
C2	A1	0.9 1 1 1	0.9 1 1 1
	A2	0.7 0.8 0.9 1	0.9 1 1 1
	A3	0.7 0.8 0.9 1	0.7 0.8 0.9 1
C3	A1	0.9 1 1 1	0.9 1 1 1
	A2	0.7 0.8 0.9 1	0.7 0.8 0.9 1
	A3	0.9 1 1 1	0.7 0.8 0.9 1
C4	A1	0.9 1 1 1	0.7 0.8 0.9 1
	A2	0.9 1 1 1	0.9 1 1 1
	A3	0.7 0.8 0.9 1	0.9 1 1 1
C5	A1	0.9 1 1 1	0.9 1 1 1
	A2	0.9 1 1 1	0.7 0.8 0.9 1
	A3	0.7 0.8 0.9 1	0.7 0.8 0.9 1
C6	A1	0.9 1 1 1	0.9 1 1 1
	A2	0.7 0.8 0.9 1	0.9 1 1 1
	A3	0.5 0.6 0.7 0.8	0.9 1 1 1
C7	A1	0.9 1 1 1	0.7 0.8 0.9 1
	A2	0.9 1 1 1	0.9 1 1 1
	A3	0.7 1 1 1	0.7 0.8 0.9 1
C8	A1	0.9 1 1 1	0.9 1 1 1

	A2	0.5 0.6 0.7 0.8	0.9 1 1 1
	A3	0.7 0.8 0.9 1	0.9 1 1 1

Step 3. Supplier selection by Z-VIKOR

Calculations of Z-VIKOR method are a multistage process.

At the first stage the regret measures are calculated according to the formula (6)

For example, the Z-number-based regret measure of 1st criteria for 1st alternative is calculated as below

$$R_{11} = \frac{\big((0.99\ 0.993\ 0.996\ 0.999)(0.975\ 0.981\ 0.986\ 0.991) - (0.915\ 0.942\ 0.942\ 0.97)(0.9\ 1\ 1\ 1)\big)}{(0.99\ 0.993\ 0.996\ 0.999)(0.975\ 0.981\ 0.986\ 0.991) - (0.001\ 0.002\ 0.004\ 0.005)(0.95\ 0.96\ 0.97\ 0.98)} * (0.7\ 0.8\ 0.9\ 1)(0.7\ 0.8\ 0.9\ 1)$$

R_{11}= (0.014 0.041 0.049 0.086) (0.662 0.757 0.856 0.966)

Arithmetic operations are performed according (Aliev et al,2015) without any conversion. The *max* in formula (6) is determined according to the Definition 3. For the 1st alternative

R_1= *max*[(0.014 0.041 0.049 0.086)(0.662 0.757 0.856 0.966); (-0.01 0.003 0.006 0.099) (0.768 0.922 0.936 0.95); (-0.01 0.003 0.006 0.099)(0.768 0.922 0.936 0.95); (-0.008 0.002 0.004 0.08)(0.624 0.734 0.851 0.975); (-0.01 0.002 0.005 0.099)(0.684 0.82 0.893 0.967); (-0.012 0.002 0.004 0.081) (0.79 0.906 0.943 0.98); (-0.008 0.002 0.004 0.08)(0.624 0.734 0.851 0.975);(-0.015 0.003 0.004 0.1)(0.855 0.95 0.96 0.969)]= (0.014 0.041 0.049 0.086)(0.662 0.757 0.856 0.966)

Similarly, are calculated the values of R_2 and R_3 :

R_2= (-0.015 0.072 0.177 0.303) (0.569 0.73 0.838 0.96)

R_3=(-0.008 0.056 0.139 0.244)(0.614 0.777 0.879 0.991)

At the next stage, the values of utility measures S_i of each alternative are calculated according to the formula (7)

For the 1st alternative the calculated Z-number-based utility is

S_1= (0.014 0.041 0.049 0.086)(0.662 0.757 0.856 0.966) + (-0.01 0.003 0.006 0.099) (0.768 0.922 0.936 0.95) + (-0.01 0.003 0.006 0.099)(0.768 0.922 0.936 0.95) + (-0.008 0.002 0.004 0.08)(0.624 0.734 0.851 0.975) + (-0.01 0.002 0.005 0.099)(0.684 0.82 0.893 0.967) + (-0.012 0.002 0.004 0.081) (0.79 0.906 0.943 0.98) + (-0.008 0.002 0.004 0.08)(0.624 0.734 0.851 0.975) + (-0.015 0.003 0.004 0.1)(0.855 0.95 0.96 0.969) = (-0.059 0.058 0.082 0.724)(0.035 0.224 0.336 0.705)

Values of S_2 and S_3 are calculated similarly.

S_2= (-0.065 0.348 0.755 1.478) (0.037 0.157 0.355 0.76)

S_3= (-0.079 0.375 0.86 1.785) (0.029 0.29 0.331 0.758)

At the third stage index Q_i for all alternatives is calculated according to the formula (8). *min* and *max* values of R and S are determined according to the Definition 3.

R^-= (0.014 0.041 0.049 0.086) (0.662 0.757 0.856 0.966)

R^+=(-0.015 0.072 0.177 0.303) (0.569 0.73 0.838 0.96)

S^-=(-0.059 0.058 0.082 0.724)(0.035 0.224 0.336 0.705)

S^+=(-0.079 0.375 0.86 1.785) (0.029 0.29 0.331 0.758)

The calculated Z-number-based values of Q indexes are

Q_1= (-23.882 -0.43 0.43 20.232) (0 0.002 0.009 0.237)

Q_2=(-60.403 0.501 8.292 25.841) (0 0.001 0.007 0.245)

Q_3= (-65.078 0.534 8.65 26.054) (0.019 0.057 0.1 0.298)

On the next step the values S, R and Q are sorted according to degree of optimality. The results are shown in table 6

Table 6. Ranking of R, S and Q

Alternative	R	S	Q
A1	1	1	1
A2	3	2	2
A3	2	3	3

Then the results of ordering are analyzed. In case of optimality degree-based approach, the subtraction between do(Q1) and do (Q2) is 0.04.

In case of similarity measure, according to the formulas (2), (3) and (5), the Jaccard index-based similarity measure is 0.89, distance between Q_1 and Q_2 is 0.12

In both cases the results are less than DQ=0.5.

Alternative A1 has the best rank according to *S* and *R*.

So, we can conclude that the alternative A1 is the best option.

Analogiusly calculations was performed for Azerbaijan hotels. For this case initial information about suppliers is shown in table 7.

Table 7. Information about suppliers

Criteria	S_1	S_2	S_3
C_1	180 AZN	200 AZN	220 AZN
C_2	H	A	VH
C_3	VL	VL	EL
C_4	VL	VL	EL
C_5	H	A	VH
C_6	20 km	125 km	135 km
C_7	H	VH	VH
C_8	2	3	2

Importance weights of criteria expressed by Z-numbers are shown in table 8.

Table 8. Importance weights of criteria

Criteria	Azerbaijan Hotels
	Z-value of IW
C_1	(0.25 0.5 0.75) (0.5 0.75 1)
C_2	(0.5 0.75 1) (0.5 0.75 1)
C_3	(0.5 0.75 1) (0.75, 0.99, 1)
C_4	(0.25 0.5 0.75) (0.5 0.75 1)
C_5	(0.5 0.75 1) (0.5 0.75 1)
C_6	0.25 0.5 0.75) (0.5 0.75 1)
C_7	(0.25 0.5 0.75) (0.5 0.75 1)
C_8	(0.5 0.75 1) (0.5 0.75 1)

After calculation according to abovementioned technique we obtain the next preferability ranks (Table 9)

Table 9. Ranking of suppliers

Supplier	Rank
S_1	1
S_2	3
S_3	2

DISCUSSION&CONCLUSIONS

The research results show the applicability of the Z-numbers-based approach for supplier selection in case of high-level uncertainty of the information. In such cases, Z-numbers-based formalism can be used for the description of the alternative attributes, evaluation of the criteria importance, and evaluation of the alternatives with respect to criteria.

Given that criteria are playing a decisive role in MCDM models, especially in case of high-level uncertainty and information imperfectness, special attention was paid to criteria identification for the supplier selection task. Criteria for selecting suppliers for hotels were identified and proposed. The proposed criteria were used to solve the supplier selection problems for hotels in Turkey (Izmir region) and Azerbaijan.

For the solution of the task, the VIKOR method is used. The proposed Z-number-based extension of the VIKOR method is based on the use of direct calculations with Z-numbers without transforming them into fuzzy or crisp numbers. A certain complexity of the calculations is fully compensated by the relevant solution of the problem, according to the initial conditions and without any simplifications in the solution process. The study showed the importance of such criteria as service quality, on-time delivery as well as profile and rating in hotel supplier selection. The results obtained illustrate the great potential of using the Z-numbers paradigm as a higher-level uncertainty formalism for decision-making in supply chain management and other areas under conditions of imperfect information.

REFERENCES

Agakishiyev, E. (2016). Supplier selection problem under Z-information. Procedia Computer Science, 102, 418–425. https://doi.org/10.1016/j.procs.2016.09.421

Aliev, R. & Salimov, V. (2017). Software for Z-arithmetic. Procedia Computer Science. 120. 290-295. 10.1016/j.procs.2017.11.241.

Aliev, R. et al. (2015). The Arithmetic of Z-Numbers: Theory and Applications. World

Aliev, R.A., Pedrycz, W., Huseynov, O.H., Eyupoglu, S.Z. (2017).Approximate reasoning on a basis of Z-number-valued if–then rules. IEEE Trans. Fuzzy Syst. 25(6), 1589–1600

Biljanoska, J., Martinoska, S. (2010). Supplier selection criteria as a critic point in the menu quality. Tourism & Hospitality Management, Conference Proceedings. pp. 266-272

Chen, C.-T. (2000). Extensions of the TOPSIS for group decision-making under fuzzy environment. Fuzzy Sets and Systems. 114. 1-9. 10.1016/S0165-0114(97)00377-1.

Chowdhury, M., M., Ziauddin, A., Das, T. & Hasan, K.(2019). Drivers of Supply Chain Performance Analysis in Hospitality and Tourism Industry. The Proceedings of the 2nd International Conference on Business and Management (ICBM 2019) Dhaka, Bangladesh ISBN 978-984-344-3540

Hwang, C.-M. & Yang, M.-S. (2014). New Similarity Measures Between Generalized Trapezoidal Fuzzy Numbers Using the Jaccard Index. International Journal of Uncertainty, Fuzziness and Knowledge-Based Systems. 22. 831-844. 10.1142/S0218488514500445.

İnan, H. E., & Yüncü, H. R. (2018). Determining Prior Factor of Supply Chain on Hotel Industry: Case Study in Eskisehir. GSI Journals Serie A: Advancements in Tourism, Recreation and Sports Sciences, 1(1), 53–60.

Jabbarova, A. I. (2017). Application of Z-number concept to supplier selection problem. Procedia Computer Science, 120, 473–477. 10.1016/j.procs.2017.11.266

Lu, K., Liao, H., & Kazimieras Zavadskas, E. (2021). An overview of fuzzy techniques in supply chain management: Bibliometrics, methodologies, applications and future directions. Technological and Economic Development of Economy, 27(2), 402–458. https://doi.org/10.3846/tede.2021.14433

Mardani, A., Zavadskas, E.K., Govindan, K., Amat Senin, A., Jusoh, A.(2016). VIKOR Technique: A Systematic Review of the State of the Art Literature on Methodologies and Applications. Sustainability, 8, 37. https://doi.org/10.3390/su8010037

Önder, E. & Kabadayi, N. (2015). Supplier Selection in Hospitality Industry Using ANP. International Journal of Academic Research in Business and Social Sciences. 5.

Opricovic, S. & Tzeng, G.-H. (2004). Compromise solution by MCDM methods: a comparative analysis of VIKOR and TOPSIS. European Journal of Operational Research. 156. 445-455. 10.1016/S0377-2217(03)00020-1.

Petrović, G., Mihajlović, J., Cojbasic, Z., Madić, M. & Marinkovic, D. (2019). Comparison of three fuzzy MCDM methods for solving the supplier selection problem. *Facta Universitatis,* Series: Mechanical Engineering. 17. 455.

Ristono, A., Pratikto, Santoso, P. B., & Tama, I. P. (2018). A literature review of criteria selection in supplier. Journal of Industrial Engineering and Management, 11(4), 680. https://doi.org/10.3926/jiem.2203

Sasrawan M. & Citra D. (2019).Analysis of Tourism Supply Chain Management after The Eruption of Mount Agung, Bali. Proceedings of the 3rd International Seminar on Tourism (ISOT 2018).Atlantis Press.pp.162-165, ISSN-2352-5398.

Scientific

Şimşek, A., Çatir, O. & Ömürbek, N. (2015).Vendor Choice with TOPSIS and MOORA Methods: A Practice in Tourism Sector. Balıkesir University The Journal of Social Sciences Institute Vol(18) No 33. Pp.133-163. Retrieved from http://sbe.balikesir.edu.tr/dergi/edergi/c18s33/133-161.pdf.

Stević, Željko. (2017). Criteria for supplier selection: A literature review. International Journal of Engineering, Business and Enterprise Applications. 1. 23-27

Taherdoost, H., & Brard, A. (2019). Analyzing the process of supplier selection criteria and methods. Procedia Manufacturing, 32, 1024–1034. 10.1016/j.promfg.2019.02.317

Wang, F., & Mao, J. (2019). Approach to multicriteria group decision making with Z-numbers based on TOPSIS and power aggregation operators. Mathematical Problems in Engineering, 2019, 1–18. https://doi.org/10.1155/2019/3014387

Zadeh, L. A. (2011). A note on Z-numbers. Information Sciences, 181(14), 2923–2932. https://doi.org/10.1016/j.ins.2011.02.022