



Application of Z-Numbers for Evaluation and Aggregation of the Travel Threats in the Post-Pandemic Era

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Abstract

The purpose of this paper is a study of the applicability and efficiency of the Z-numbers (Zadeh, 2011) for estimation of the various travel risk factors, aggregation, and evaluation of the overall risks of the different destinations. At present, travel risk analysis is mainly carried out by using the available statistical data about target country. Therefore, the possibilities of analysing the risks of travelling to a country/region, with insufficient or unreliable information remain questionable. Moreover, the sharp decline of the number of tourists travels due to the COVID-19 pandemic could lead to a decrease of the amount of necessary statistic data. To improve quality of the risk assessment, especial in post-pandemic era, the procedures of the Z-numbers based risks identification, assessment and risks aggregation are suggested. Expert's predictions of the risks are formalized as Z-number-based evaluations. This approach allows considering reliability of the information. For aggregation of the tourist threats of different nature, the method for calculation of Z-weighted arithmetic means was proposed, the overall risk was determined by aggregating factors and a riskier direction was identified. Suggested approach provided an opportunity to go beyond the country-specific statistic-based risk assessment. Tourism risks assessment by using of Z-numbers as well as the proposed method of risks aggregation allows to conduct a comparative analysis of the risks, travelling to different destinations, even in conditions of large uncertainty.

Keywords: travel threats, risk factors, Z-number-based evaluation, risk aggregation, Z-weighted arithmetic means

Introduction

The pandemic of COVID-19 significantly impacted on world tourism, as well as on other spheres of human activity. The pandemic had a significant impact on risk perception and trip intentions of people (Perić, Dramićanin & Conić, 2021). On the other hand, even though pandemics periodically occur at intervals of a decade (World Health Organization/Europe n.d.), the travels have become an important human need. So according to the statistics for 1950-2000 (Akdağ & Oter 2011) the number of trips grew from year to year. Moreover, World Bank (The World Bank, 2018) data on international tourism from 1996 to 2018 also showed an overall upward trend in travel, despite a slight drop in travel numbers in 2003 and 2009. The encouraging media information on COVID-19 vaccines provide an opportunity to predict the recovery of the tourism sector in the future.

Alongside the growth of international tourist arrivals worldwide, we are witnessing the increase in various types of tourism as well (atomic, Antarctic etc.). Obviously, any tourist trip is a risky activity because it is an activity of staying outside of a regular environment (World Tourism Organization, 1995). Tourists may face the hazards of different nature and types.

Many publications devoted to risk analysis in the tourism sector are associated both with risks for the activities of travel agencies and with risks for tourists in certain countries and regions. However, relatively fewer publications are devoted to risk analysis from the point of view of the traveller's safety, as well as comparative risk analysis of the safety of certain destinations. In our opinion, more attention should be paid to these issues since single travel is becoming increasingly popular in the world, especially such as extreme leisure, etc. Regardless of the way travel is organized, risk analysis, especially for security, will always be relevant. Decision-makers (manager, traveller etc.) desire to clearly structure possible problems of tourist activities.

Tourism risk assessment utilizes many tools for the formalization of the uncertainties such as probability theory, fuzzy approach, interval computation etc. Tourism activities occur in more uncertain environments than other human activities. This is due to the involvement in tourist activities of many actors (international, public, private), the distribution of services among different suppliers, the influence of many factors (political, natural, economic, cultural, etc.), the existence of complex linkages between participants, the necessity to process a large amount of poorly structured information. Although national tourism authorities and private agencies publish statistical information and it deserves close attention, it is more aimed at promoting national and corporate interests in tourism.

In addition, statistical data (data for the years of the pandemic, before and after) can be with larger deviance of many indicators than usually. According to Richter (2021) after an annual increase in 2012-2019, the number of tourist arrivals declined from 1.5 billion to 1 billion in 2020. The level of tourism returned to the values of the 90s.

Therefore, when the availability and the certainty of statistical data are questionable the quantitative data and expert's judgement should be considered.

All these aspects necessitate the use of such formalism for describing and handling uncertainty that also allows to consider the reliability of information.

In this work we have studied the threats to tourists, showed the suitability of the bi-component (value of uncertain variable and the reliability if this value) Z-numbers for evaluation and aggregation of the tourism risks of different nature and origin.

Literature review

Tourism risks

Studies are being conducted to examine the risks to tourists and those to tourism participants. While the two areas of research are interlinked, our work analyses the risks to tourism safety. To identify risk factors, it is important to examine what constitutes a threat to the lives and safety of tourists.

In tourism, the concept of risk has been introduced since the 1970s (Osland et al, 2017). In (Beirman, 2016) the key risks to tourism and tourism enterprises are indicated. In (Zhilenko & Pan, 2015) the main risk factors are analysed and improper insurance package are mentioned as a tourist safety risk factor.

According to the World Tourism Organization (1996), risks for tourism safety and security originated from four source areas - human and institutional environment; the tourism and related commercial sectors; the individual traveller risks; physical or environmental risks. In (Tsaour et al, 1997) the tourist risks are divided on physical risks (problems related to health, weather, hygiene, law, and order) and equipment risks (telecommunication, transportation, etc.). In (Sönmez and Graefe 1998) ten types of risk (equipment, financial, health, physical, political instability, psychological, satisfaction, social, terrorism, time) are used. In (Faraji Sabokbar et al, 2016) the political, environmental-health, social-cultural, economic, technological, functional, safety and security risks are pointed out. According to (Cui & Fangnan et al. 2016) tourism security is evaluated through tourism risk perception which include subjective feelings, objective evaluation, and cognition of the negative impact. A review of literature devoted to the travel risk perception (Hasan, Ismail & Islam, 2017) highlights important aspects of risk perception and its impact on travel decision-making and points out that the methods of risk evaluation are not well defined.

Threats for tourists according to their causes can be divided into several basic classes: natural, technogenic, anthropogenic, and social (Maizura 2018). Many works have been devoted to these threats (Korstanje & Clayton, 2012; Kurez & Prevolšek, 2015; Mataković & Cunjak Mataković, 2019). Real dangers for tourists in airports and train stations are also periodically reported in the media.

Climatic and weather conditions affect the state of human activity (Sharafi et al, 2013; Horanont et al, 2013). The changeable weather at tourism destinations can significantly affect the comfort of tourists and their travel decisions (Franzoni & Pelizzari, 2016). Tourists decide about places and time to visit according to the climate of a destination, especially its temperature and rainfall (Hughes et al, 2018).

In addition, the behaviour of the tourists themselves may pose a threat to them. Uriely & Belhassen (2006) mentioned that the tourists are ready to voluntarily engage in risks avoided in everyday life. The wrong attitude of tourists to the local population and local laws which led to conflict situations are widely covered in the media. Therefore, cultural, and mental differences should be considered as risk factors. Moreover, uncontrolled, and dangerous behaviour of tourists negatively affects their safety. Dangers can increase when driving a car in countries with low road safety - Africa and South-East Asia countries (World Health Organization, 2018).

Based on the literature review, it is possible to conclude that there are different approaches to categorizing tourism risks. Therefore, a well-thought-out method of risk formalization and analysis is required.

Tourism risk assessment methods

The statistical methods based on the processing of data collected through various questionnaires and interviews are mainly used to assess tourism risks (Sönmez & Graefe, 1998; Liu-Lastres et al, 2013; Osland et al, 2017; Karl, 2017; Hasan, Ismail & Islam, 2017). Hypotheses/propositions about destination safety/risks are evaluated using the probability theory, data analysis techniques with collected quantitative and qualitative data. However, the assessment of tourism risks is not based solely on statistical methods.

Another tool that successfully deals with uncertainty is Fuzzy Sets theory that is pointed in (Gil et al, 2018) as Mathematics of Uncertain. In (Guo & Ai, 2013) it is shown that Shinohara in 1976 first pointed the utilization of fuzzy set theory to the risk assessment and decision-making. As the use of fuzzy risk analysis has been expanded, since the 1990s (Tsaur et al., 1997) this approach has been applied in tourism.

At present, more and more papers devoted to the using of fuzzy set theory and fuzzy logic for evaluating the uncertainty and risk analysis in the tourism sector (Hsu & Lin, 2005; Faraji Sabokbar, 2016). In (Hsu & Lin, 2014) fuzzy sets are used to represent the uncertainty of risks and then authors compare the risk perceptions associated with 12 factors by using fuzzy PROMETHEE method. The interdependencies of risks

of the conference tourism service supply chain are analysed by Fuzzy Interpretive Structural Modelling in (Karadayi-Usta, 2020).

In last years, for risk analysis in cases of greater uncertainty, the more complex fuzzy sets (type-2) introduced by Zadeh with membership grades measured with linguistic terms are used (Zadeh, 1975). The utilization of fuzzy sets and fuzzy logic type-2 for risk analysis is shown in (Zivkovich et al, 2018; Jana et al, 2019) and utilization for tourism is applied in (Dincer & Yüksel, 2019; Shukla & Muhuri, 2019).

Methodology

Risk measurement

As it was mentioned above, research on tourism risks focuses on perceived risk for tourists who have visited or are visiting a particular country (object of study). It is possible when researchers carry out the analysis about their own country or they can study the tourists who have visited target country.

But how to assess the risks of traveling to a country located on another continent? How to conduct research if the flow of tourists to the country of interest is very small or not exists? Very often in practice, it is necessary to assess the risk of traveling to the particular country based on insufficient information (on Internet data, impressions of individual tourists, etc.). The pandemic of COVID-19 has adjusted statistical data. In the future, using 2019-2021 data, these circumstances should be considered.

As it is shown below, the number of tourism threats is quite large, and this issue is seriously complicating analysis and appropriate decision making. Therefore, like project risks, the effective way is the compilation of the tourism risk register with highlighting risks and sub-risks for further evaluation and aggregation.

Risk is always presented in all travels. In fact, the risk should be accepted and a decision with a lower level of risk should be chosen. Multi-Criteria Decision Analysis (MCDA) methods are used to assess risks during evaluation of several alternatives.

To conduct the analysis, the risk should be measured and the level and possibility of danger (threat) from a particular source for an object (person, group) are determined. The literature describes several approaches to measuring risk. One of them is so called engineering and it is focused on the quantitative calculation of the probability of accidents, failures, and other undesirable events (Bilir Mahcicek & Gurcanli, 2018; Aven, 2009). The second approach involves modelling processes with unacceptable consequences (Minucci et al, 2016; Garlick, 2007). The third approach to measuring risks is related to expert evaluations (Yildiz, Dikmen & Birgonul, 2014; Beronius & Ågerstrand 2017). Experts are exclusive sources of information in a situation of lack of statistical data or insufficient reliability of the statistical data, as well as in case of poor structured information. Another approach used for risk analysis is based on the use of sociological information - measuring the perception (Nyre & Jaatun, 2013;

Gaskell, Hohl & Gerber, 2016) of a particular risk by the population (groups). In most cases considering sociological information in risk assessment is very significant.

Tourism risks measurement is a complex and voluminous task because the values of risk factors are uncertain and information on factors is incomplete. Incompleteness and uncertainty are associated with the fact that adequate and exact data are not always available to researchers. For example, if geographical information (climate, terrain, coastline, environment etc.) is relatively accessible to researchers, information about the activities of tour operators is inaccessible or very limited. In the same way, we can say that information about the situation in the country of destination is also not sufficiently accessible. In such circumstances, expert judgment should be used to measure risks. Tourism experts study a large amount of information related to tourism activities, analyse the reports of national and international tourism organizations, they are interested in the activities of tourism operators, get acquainted and process the data indicated on the websites of international campaigns (organizations) and government agencies around the world.

The heterogeneity and incompleteness of data associated with the tourism sector require a new approach to the mathematical description of information, characterized by a high degree of uncertainty. One of these possible approaches is based on the use of Z-numbers. The positive results can be expected from the application of Z-numbers that allow to take into consideration the fuzzy-probabilistic nature of the information used for decision-making in the tourism sphere.

Risk assessment was indicated by (Zadeh et al, 2014) as one of the main areas of application of Z-numbers. The utilization of Z-numbers for risk analysis applied in (Abiyev et al, 2018; Das, Dhalmahapatra & Maiti, 2020)

Using of Z-numbers for tourism risk assessment

Preliminaries

Definition 1. Z-number (continuous/discrete) is an ordered pair (A, B) of fuzzy numbers, the first component A (continuous/ discrete fuzzy number) is restriction on the values which a real-valued uncertain variable X , can take. The part B (continuous/discrete fuzzy number) is measure of reliability or certainty of A .

Example: (about 5, sure), (approximately 10, very sure)

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

Let $Z_1 = (A_1, B_1)$ and $Z_2 = (A_2, B_2)$ are two Z-numbers and $*$ let be a binary arithmetic operations $(+, -, \cdot, /)$. Then these operations on Z-numbers are defined by following expression

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

Computation of $A_{12}=A_1*A_2$ is defined in accordance with arithmetic operations on fuzzy numbers.

Computing with B_1 and B_2 to construct B_{12} is a more complex operation. Briefly computation procedures can be described in the following way:

Step 1. B_1 and B_2 are restrictions on the probability measure of A. Real probability distributions are not known. So, it is necessary from the fuzzy estimates (fuzzy numbers B_1 and B_2) restore sets of probability distributions (Table 1) for A_1 and A_2 . For example, if B_1 is expressed by fuzzy number of “about 0.2” with values of membership function (MF) - 0.1/0, 0.2/1, 0.3/1, and B_2 - “about 0.5” with values of membership function - 0.4/0, 0.5/1, 0.6/1, then the appropriate probability distributions for further computations should be constructed according to A_1 and A_2

Table 1. Distributions of probability

P ₁			P ₂		
0,10	0,20	0,30	0,4	0,50	0,6
0,45	0,40	0,35	0,3	0,25	0,2
0,10	0,20	0,30	0,4	0,50	0,6
0,45	0,40	0,35	0,3	0,25	0,2

Each distribution is relevant to appropriate value of $supp B_1$ [0.1, 0.3] and B_2 [0.4, 0.6] respectively (in our example left, middle and right parts of support are used).

Step 2. Distributions table construction by convolution operation.

Table 2. Value of A_{12} (according to arithmetic operations), MF values of A_{12} and distribution of probabilities

A_{12}	μ_{A1} 2	P ₁₁	P ₁₂	P ₁₃	P ₂₁	P ₂₂	P ₂₃	P ₃₁	P ₃₂	P ₃₃
A_{12} ₁	0,0	0,13 5	0,11 3	0,0 9	0,1 2	0,1 0	0,0 8	0,10 5	0,08 8	0,0 7
A_{12} ₂	0,0	0,21 0	0,25 0	0,2 9	0,2 2	0,2 5	0,2 8	0,23 0	0,25 0	0,2 7
...	1,0	0,31 0	0,27 5	0,2 4	0,3 2	0,3 0	0,2 8	0,33 0	0,32 5	0,3 2
...	0,0	0,21 0	0,25 0	0,2 9	0,2 2	0,2 5	0,2 8	0,23 0	0,25 0	0,2 7
A_{12} _n	0,0	0,13 5	0,11 2	0,0 9	0,1 2	0,1 0	0,0 8	0,10 5	0,08 7	0,0 7

Step 3. By multiplying the values from $P_{11} \dots P_{33}$ columns and corresponding values of the A_{12} membership function, the left and right parts of $\text{supp } B_{12}$ [0.31,0.33] are defined.

Step 4. The membership function of B_{12} calculation by maxmin operation over values of membership functions of B_1 and B_2 $B_{12} = (0.31/0, 0.32/1, 0.33/0)$

Definition 3. Z-information (Zadeh, 2011). The statement X is (A, B) is considered as Z-valuation. Using Z-numbers, experts evaluate risk factors and sub-factors, as well as their importance, and then develop the set of Z-number-based evaluation X is $Z(A, B)$. For example – Level of sanitation is medium likely. Here the **X**- Level of sanitation and **A** - medium, **B**- likely, respectively. A collection of such valuations referred to as Z-information.

Aggregation of Z-number based information on travel risks

It is well known that in case of large numbers of alternatives and risk factors, analysis and decision-making is quite complicated task. This issue becomes more complicated when we are working with uncertain and subjective information formalized via the set of Z-number-based evaluations. In such circumstances, it is necessary to aggregate the information. Aggregation of risks of various nature and origin is very important for their generalized assessment. Convolution (aggregation) of partial assessments into a generalized assessment lets us to effectively rank the alternatives. After convolution, the information should be richer in quality than the original (source).

Topicality of the effective aggregation of information obtained from various sources for deriving of the reliable solution is unquestionable. Aggregation of fuzzy information was the subject of many research (Mardani et al, 2018).

In general, the function of integration (aggregation) combines several input variables into generalized output value. Usually, for obtaining a global estimate the sum of indicators or average value of indicators are used. The process of the multi-criteria decision making involves comparison of two or more alternatives, each of which is evaluated by applying several criteria. To take into consideration, the importance of the criteria, weights are assigned to each criterion. Usually, it is assumed that the criteria are independent of each other. However, this assumption does not always reflect the reality and there are many situations where the criteria complement each other or correlate with each other. In this case, the interaction between them cannot be expressed by assigning weights (importance) to each criterion. To consider mutual influence between attributes, the concepts of fuzzy measures (Murofushi & Sugeno, 1991; Yuan & Klir, 1996) are used in the calculation of aggregation functions. The convolution operator should allow for interactions of the criteria. The fuzzy integral combines subjective information about the value of the source information (criterion), quantitatively expressed by using a fuzzy measure, with objective information.

Therefore, the stage of compilation of the risk register (list of risk factors and sub-factors) is very important. Only a scrupulous study of the subject area and identification of risks allows selection of the correct convolution (aggregation) operators. Using many risks for travel decision-making does not always lead to a comprehensive solution but always complicates the problem solution. The number and diversity of risk factors should be relevant to the task and problem-solving technique.

In the case of aggregation of risk factors, the following should be noted. An integrated risk is calculated by summing (integrating) the values of risk factors. In the context of identifying risks, the risk analyst seeks to create a catalogue of risks and risks that would allow the calculation of the integral risk assessment for each alternative. Risk identification reveals the influence of any factors on the overall level of risk. As a rule, the mutual influence of risks in most cases is not considered in risk factors evaluation.

Although the use of fuzzy measure theory for risk analysis is described in the literature (Rey, García-Fronti & Casparri, 2005; Li & Ma, 2013; Li, Han & Zhang, 2018), the calculation of the Choquet integral itself is a simple action, but the identification of a fuzzy measure is complex and voluminous task (Grabisch, 1995). It is quite difficult or practically impossible to relevantly evaluate the relationship between risk factors.

In the analysis of travel risks, the weights of the influencing risk factors are important. When we have information about the importance of the criteria or we can make some judgments about this, we can assume that the aggregation function will be additive, and weighted arithmetic mean (WAM) can be used for calculations.

After the formation of Z-evaluations of the risk factors for each alternative, the next step is integrated risk assessment for each alternative. Since arithmetical operations on Z-numbers as are defined (Aliev et al, 2015), the calculation of Z-weighted arithmetic means becomes possible. Calculation of an integrated risk assessment is important for alternatives ranking (tourism travel destinations) by risk level.

Since its introduction, the concept of Z-numbers has been successfully used in the analysis of uncertain and complex systems.

Results

Common threats of travel and tourism risks register

Based on subject area analysis the following threats for tourism travel were identified:

threats at the planning stage of a tourist trip such as force majeure circumstances, financial and other problems of the tour operator, visa refusal, restriction of entry threats during the journey such as criminal, sanitary, ecological situation in the host country as well as culture differences, unfavourable climatic and weather conditions,

possibility of natural disasters threats associated with inappropriate activities of tourism service providers (overbooking, improper catering, improper insurance package services, etc.)

threats related to the incorrect tourist behaviour or non-compliance with safety rules (violation of personal hygiene, bad habits, age/chronic diseases, etc.)

transport threats when traveling to / returning from the country of destination (Improper service, limited time for a change of transport, etc.)

Compilation of the risk register

To compile the risk register, a Delphi analysis was conducted involving of local (Azerbaijan) and foreign (Turkey, Georgia, EU) experts. During the rounds of the Delphi analysis, threats with low probability of occurrence were excluded from the list of threats. Also excluded are threats analysis of which is impractical for one or another reason. For example, when analysing the risks of a tourist trip, the risks associated with transport accidents/accidents are not of practical importance. This area belongs to the competence of the management of transport companies. In addition, the risks, occurrence of which bear a pronounced country-oriented specificity, were excluded (for example, radiation risk - since it is not very relevant for most tourist routes) from further consideration.

The resulting risk register can be used to assess the safety of a trip to a specific country, as well as for selection of the safe trip among several alternatives. It should be noted that the question of whether it is safe to travel to a particular country should be classified more as a psychological issue, because, for example, for adventure seekers, a high level of risk is not decisive for a route selection decision.

The prepared risk register includes 5 main risk factors associated with a tourist trip:

- destination country's risks
- natural environment's risks
- travel firm (tour operator's) risks
- transportation risks
- traveller's risks.

Each risk factor consists of sub-factors characterizing it. For example, risk factors related to the conditions of the environment in the country of destination consists of sub-factors related to the possibility of disasters, the characteristics of natural and weather conditions, flora, and fauna.

The indicated risk factors are independent of each other. The sub-factors of each factor are also independent.

Z-number based approach to tourism risk evaluation and aggregation

As it was mentioned above, each risk (threat) factor or sub-factor can be evaluated by an expert, based on his own intuition, experience, available information etc., using linguistic terms such as “high”, “average”. Moreover, during the assessment an expert can express the degree of belief (confidence). All of this is formalized with bi-component Z-number which consists of two parts: value of the uncertain variable - part A and degree of value confidence – part B. Since A and B are linguistically expressed fuzzy numbers, their codebook should be defined. The example of such a codebook is shown in Table 3.

Table 3. Codebook of part A (uncertain variable) and part B (degree of confidence)

A		B	
Linguistic term	Value of membership function (trapezoidal or triangle)	Linguistic term	Value of membership function (trapezoidal or triangle)
Average	0/2, 1/3, 0/4 or 0/2, 1/ 2.7, 1/3.3, 0/4	Sure	0/0.25, 1/0.5, 0/0.75 or 0/0.25, 1/0.4, 1/0.6, 0/0.75
High	0/3, 1/ 4, 0/5 or 0/3, 1/3.7, 1/ 4.3, 0/5	Very Sure	0/0.5, 1/0.75, 0/1 or 0/0.5, 1/0.7, 1/0.8, 0/1

Z-information on risk factors based on experts’ opinions is shown in the Table 4:

Table 4. Values of risk factors and their weights expressed by Z-numbers

Risk factor & subfactors	Alternative N 1 (Country A1)		Alternative N 2 (Country A2)	
	Value	Weight	Value	Weight
Risk factor 1		(Average, Very Sure)		(Average, Sure)
Subfactor1	(Average, Not Sure)	(High, Very Sure)	(High, Very Sure)	(Very high, Sure)
Subfactor2	(High, Very Sure)	(Average, Sure)	(Average, Sure)	(Very high, Sure)
.....
Risk factor N		(H, VS)		(H, VS)
Subfactor1	(H, VS)	(VH, S)	(A, VS)	(VH, S)
Subfactor2	(VH, NS)	(A, S)	(H, VS)	(VH, NS)

The general scheme of Z-value based risks aggregation can be described as follows.

At first stage for calculation of the value of risk factor N for i-th alternative Z_{ai} , the sum of multiplications of risk sub-factors values and corresponding importance weights of the sub-factors should be divided on the sum of importance weights of the sub-factors according to the formula:

$$Z_{a_{ij}} = \frac{\sum_k^{K_j} Z_{x_{ijk}} \cdot Z_{w_{jk}}}{\sum_k^{K_j} Z_{w_{jk}}}$$

$Z_{a_{ij}}$ is Z-valued evaluation of j-th risk factor for i-th alternative.

$Z_{x_{ijk}}$ is Z-valued evaluation of k-th sub-factor of j-th factor for i-th alternative.

$Z_{w_{jk}}$ is Z-valued importance weight of k-th sub-factor of j-th factor for i-th alternative.

For calculation of the i-th alternative total risk, the sum of weighted factors is divided to sum of weights:

$$Z_{a_i} = \frac{\sum_1^n Z_{a_j} \cdot Z_{w_j}}{\sum_1^n Z_{w_j}}$$

Z_{a_i} is Z-valued total risk for i-th alternative.

Z_{a_j} is Z-valued evaluation of j-th risk factor for i-th alternative

Z_{w_j} is Z-valued importance weight of j-th factor for i-th alternative.

Calculated risk evaluations then can be compared based on degree of dominance (Aliev et al, 2015).

Table 5. Example of tourism risk register

Number of risk and subrisk	Risks /subrisks
1	destination country's risk
1.1.	Terrorism activity
1.2.	Level of criminality
1.3.	Poor sanitation
2	natural environment's risk
2.1.	Erratic Weather
2.2.	dangerous animals and insects
2.3.	Ecological

3	Personal risk
3.1.	Person's age
3.2	Bad habits

Example

Let's suppose that we have to analyse the risks of travel to the countries A1 and A2 in the summer for a middle-aged citizen of a Northern country. After compiling of the risk register, shown in Table 5 (fewer risks and sub-risks are listed for brevity), based on the codebook (Table 6), experts carry out Z-evaluation of sub-factors for each risk factors, i.e., using the Z-numbers experts assess both level and weight (importance) of each threat.

Table 6. Codebook of A and B

A		B	
Linguistic term	Value of triangle membership function	Linguistic term	Value of triangle membership function
Very low	1/0, 1/1,0/2	Very not sure	1/0.05, 1 /0.05, 0/0.25
Low	0/1, 1/2, 0/3	Not Sure	0/0.05, 1 /0.25, 0 /0.5
Average	0/2, 1/3, 0/4	Sure	0/0.25, 1 / 0.5, 0 /0.75
High	0/3, 1/4, 0/5	Very Sure	0 /0.5, 1 / 0.75, 0 /1
Very high	0/4, 1/5, 1/5	Extremely Sure	0 /0.75, 1 /1, 1 / 1

Table 7. Z-information about tourism risks for countries A1 and A2

Number of risk and subrisk	Country A1		Country A2	
	Threat	Importance weight	Threat	Importance weight
1		0.3		0.4
1.1.	(H, VS)	(H, VS)	(M, VS)	(H, VS)
1.2.	(H, ES)	(H, VS)	(A, VS)	(H, VS)
1.3.	(H, VS)	(H, VS)	(L, VS)	(H, VS)
2		0.5		0.3
2.1.	(H, VS)	(H, VS)	(L, VS)	(H, H)
2.2.	(M, VS)	(H, VS)	(L, VS)	(L, H)
2.3.	(M, VS)	(H, VS)	(L, VS)	(L, H)

3		0.2		0.3
3.1.	(L, VS)	(H, VS)	(L, VS)	(A, S)
3.2	(L, VS)	(A, S)	(L, VS)	(A, S)

On the first stage, each of the three risks for these countries is calculated, that is, the sub-factors of each risk are aggregated. For example, the destination risk for country A1 (1st risk factor for 1st alternative) is calculated based on value and weights of three sub-factors (terrorism activity, level of criminality, sanitation) according to the following formula:

$$Z_{a11} = \frac{\sum_1^3 Z_{x_{11k}} \cdot Z_{w_{1k}}}{\sum_1^3 Z_{w_{1k}}}$$

$$Z_{a11} = \frac{(H, H) * (H, H) + (H, VH) * (H, H) + (H, H) * (H, H)}{(H, H) + (H, H) + (H, H)}$$

$$Z_{a11} = \frac{(3,4,5)(0.5,0.75,1) \cdot (3,4,5)(0.5,0.75,1)}{(3,4,5), (0.5, 0.75, 1) + (3,4,5), (0.5, 0.75, 1) + (3,4,5), (0.5, 0.75, 1)}$$

$$+ \frac{(3,4,5) (0.75,1,1) \cdot (3,4,5) (0.5,0.75,1) + (3,4,5), (0.5, 0.75, 1) \cdot (3,4,5), (0.5,0.75,1)}{(3,4,5), (0.5, 0.75, 1) + (3,4,5), (0.5, 0.75, 1) + (3,4,5), (0.5, 0.75, 1)}$$

$$Z_{a11} = (1.8, 4, 8.38), (0.13, 0.42, 0.91)$$

Similarly, other risk factors are calculated for each country and the resulting risk table 8 is composed:

Table 8. Tourism risks for countries A1 and A2

N	Risks / subrisks	Country A1		Country A2	
		Z-evaluation of threat	Importance weight	Z-evaluation of threat	Importance weight
1	Destination country's risk	(1.8, 4, 8.33) (0.13,0.42, 0.91)	0.3	(1, 2.67, 6.11) (0.12,0.39, 0.89)	0.5
2	Natural environmental risk	(1.4, 3.33,7.22) (0.11,0.38, 0.9)	0.5	(0.5, 2, 6) (0.19,0.31, 0.63)	0.3
3	Personal risk	(0.56, 2, 5.4) (0.12,0.31, 0.61)	0.2	(0.4, 2, 6) (0.1,0.23, 0.52)	0.2

It should be noted that for risk weights description both crisp and Z-numbers can be used. Crisp number was taken to demonstrate the universality of suggested approach. Weights of different risks may vary from country to country, i.e. country have stable political situation, low criminal activity and unstable weather conditions and vice versa. Also, the significance of personal risk factors of a traveller may vary from destination to destination.

By multiplying the Z-evaluation of each risk by its weight and adding the products, we get the total risk estimates for each country.

For country A1 the Z-evaluation of generalized risk is = (1.35, 3.27, 7.19), (0.02, 0.12, 0.57) and for country A2 the Z-evaluation of generalized risk is = (0.73, 2.34, 6.05), (0.02, 0.08, 0.39)

For determining a safer destination, we compare (rank) the Z-number-based generalized country-specific risks in accordance with an approach described in (Aliev et al. 2015) by calculation the degree of Z-number domination.

The result of ranking is shown below

Country II vs. Country I:

$$do(Z_{a1}, Z_{a2})=1, do(Z_{a2}, Z_{a1})=0.69$$

Thus, the Country II is the best, more secure and safe for travel.

Discussion

This study demonstrates the effective usability of Z-numbers for tourism risk assessment. Calculations were done based on the method shown in the (Aliev & Salimov, 2017).

Z-numbers based approach, fuzzy and statistical methods are formalizing uncertainties of different levels, nature, and origin. It is necessary to note that experts often express evaluations like this one “likely that value of threat is high” or “very likely that this variable is important”. An expert is more correctly answering questions of a qualitative nature than quantitative.

Z-numbers formalize the uncertainty of higher level and complexity. Z-numbers give the opportunity for the risk analysts to deal with fuzzy and probabilistic information that reflects the values of factors and defines the reliability of information about factor values. Two-component Z-number integrates the fuzzy value of a linguistic variable and its fuzzy probability. Both parts of Z-number are perception-based and linguistically expressed fuzzy numbers. Due to these specifics, direct comparison of our research results and results that can be obtained based on other methods is not entirely correct.

In our study we did not consider the issue of construction of Z-numbers. There are no limitations and all relevant methods of construction of fuzzy numbers and their

membership functions can be used. While working with experts, risk analysts are free to set the codebooks. This does not affect the risk analysis process.

Conclusion and Further Research

Potential risks of traveling to various countries have been studied and based on the analysis most common risks that travellers can encounter (almost in all countries, in any season, on any means of travel, etc.) are identified.

Tourist trips considered as a project and travel risks viewed as risks of project. These risks have been identified and a generalized risk register was developed. Identified risk factors are independent of the data processing tools (statistical, expert opinion study, fuzzy approach, etc.) and can be used for the comparative analysis of the trip risks in various countries.

The use of expert judgment to the evaluation of the threats and Z-value based risk assessment allows developing a more universal methodology for assessing tourism risks. The proposed approach allows for a more flexible formalization of the experts' risk judgments, as well as for the degree of their confidence in assessments.

Such assessment methods are not dependent on the country being studied. Application of the approach allows establishing more general risk factors for a tourist trip, which are independent of the country and the amount of statistical information. In some cases, in addition, comparative analysis can be carried out and, based on the results of the study, country-specific factors can be added.

The suggested aggregation (convolution) mechanism of the risks with different nature and origin provides better information for overall risk assessment and for further decision-making process. Aggregation of Z-information into an integrated assessment lets us to rank the alternatives (tourism travel destinations) by risk level and to make proper decisions. Using the Z-value based approach provides more efficient comparison by using perception-based predictions of risk experts.

Available Z-software allows for computing with Zadeh numbers, including risk assessment calculations. Further studies include software enhancement and implementation of operations with Z-numbers in the form of subroutines and functions.

The obtained results create necessary prerequisites for the use of the Z-number in future not only for tourism risks assessment but also for the other research of tourism.

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