



## INTELLECTUAL-ANALYTICAL PLATFORM FOR ASSESSING THE SECURITY RISK OF TOURIST TRAVEL

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**Abstract.** *The main goal of this study is to develop an intellectual and analytical platform for assessing the safety risk of a tourist trip. The intellectual and analytical platform for determining the safety risk of a tourist trip consists of three analytical modules: individual level of safety of a tourist trip, regional level of safety of a tourist trip, and national level of safety of a tourist trip. The essence of the intellectual and analytical platform is that, based on the assessments of participants in the tourist movement regarding their sense of their safety in the selected region, the predictability of a repeat visit and expert assessment of the level of safety of regional tourist systems, it forms both quantitative and linguistic indicators of the risk of travel safety. For the first time, an information module has been developed for assessing the level of safety of a tourist trip, covering 17 criteria for assessing one's safety at the destination. Also, three analytical modules have been developed for the first time, covering levels from individual to national: a module for term assessment of the risk of one's safety of a tourist trip; a module for assessing the level of the sense of safety of the region; a module for assessing the risk of travel safety. The input data is presented in the form of linguistic variables that reflect the impressions of the participants of the tourist movement after visiting the region and the level of their concern about their safety at the destination. The modules are based on the principles of fuzzy logic and multidimensional membership functions. Data is aggregated on the generalized safety risk of a tourist trip and the forecast of repeat visits to the region. Expert assessments of the safety of regional tourist systems are combined with the subjective level of feeling of safety among tourists. The result is both a quantitative and linguistic assessment of the safety risk of a tourist trip. The intellectual and analytical platform was verified and tested on real data of 327 respondents from Zakarpattia, Lviv, and Ivano-Frankivsk regions, and an example of its practical application for assessing.*

**Key words:** *information technology, linguistic variables, fuzzy logic, decision support, risks, regional tourism.*

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### 1. INTRODUCTION

In the current conditions of globalization, as the world becomes increasingly open to travel, and tourism industry is rapidly developing and involving ever-wider segments of the population, the issue of tourist safety has emerged as a priority in the tourism sector, state policy, and international cooperation. A tourist trip, despite its many positive aspects—such as memorable experiences, cultural enrichment, relaxation, and the opportunity to explore something new—may also involve a range of potential threats. These risks are diverse in nature, ranging from social and political (e.g., increased crime rates, social conflicts, terrorist acts) to natural (earthquakes, floods, hurricanes), infrastructural (transportation accidents, insufficient medical services), and informational (lack of reliable information about the real safety situation in the region).

Under such conditions, there is a growing need not only for the development of risk management systems but also for the formation of new approaches to monitoring and forecasting situations that may pose a threat to tourists. Taking into account and timely assessing such risks is a key condition for building an effective system to

protect the interests of tourists, preserve their health and lives, as well as enhance the overall competitiveness of tourist destinations and improve the quality of tourist services.

However, it is important to note that traditional approaches to risk analysis are usually based on statistical data, formal factors, and historical retrospectives, and often fail to consider such important aspects as tourists' subjective perception of danger, the emotional state of travelers, and the level of trust in local infrastructure or personnel. These approaches also lack sufficient flexibility in conditions of dynamic change—for instance, sudden shifts in epidemiological situations, political instability, or natural disasters occurring in real-time. This gives rise to the need for modern tools that combine artificial intelligence methods, expert assessments, and analytical models.

The intelligent-analytical platform for assessing the safety risk of a tourist trip consists of three analytical modules: the individual level of tourist trip safety; the regional level of tourist trip safety; the national level of tourist trip safety. The essence of the intelligent-analytical platform lies in the fact that, based on the evaluations of participants in the tourism movement regarding their personal sense of safety in a given region, their likelihood of returning, and expert assessments of the safety level of regional tourism systems, it generates both quantitative and linguistic indicators of travel safety risk. This approach enables a comprehensive analysis of a territory from the standpoint of tourism safety, taking into account the specific features of local tourism systems. In turn, this contributes to a deeper understanding of tourist consumer behavior and the identification of current trends in regional tourism development.

Over the past decade, there has been a steady trend towards intensifying scientific research aimed at analyzing and assessing risks in the tourism sector using modern intellectual and analytical approaches. The growing complexity of the global tourism environment and the influence of external factors—such as climate change, pandemics, and social conflicts—create a demand for innovative tools to ensure tourist safety. In this context, researchers are increasingly applying decision support systems (DSS), artificial neural networks, fuzzy logic mechanisms, multi-criteria analysis methods, as well as geographic information systems (GIS) for modeling, forecasting, and visualizing the safety levels of tourist routes and regions [1–3]. These methods allow for both retrospective and predictive risk assessments, taking into account various factors that influence the tourist attractiveness of territories [4–5].

In the works of foreign authors, special attention is given to the use of cutting-edge digital technologies such as Big Data, artificial intelligence, social networks, open data from official sources, and mobile applications, which serve as powerful tools for the rapid collection and analysis of information on potential threats. Among the objects of analysis are natural disasters, crime rates, political stability, epidemiological situations, and more. Interactive risk maps are being developed with real-time data integration capabilities, enabling tourists to access up-to-date information both during trip planning and while traveling [6–8].

At the same time, Ukrainian and other domestic researchers are focusing on a more personalized approach to assessing the safety of tourist travel. The use of expert evaluations, linguistic variables, subjective impressions of tourists, and multi-level criteria models for analyzing perceived safety is gaining particular relevance. Tools of fuzzy logic and mathematical modeling are being used to combine qualitative and quantitative indicators into a unified analytical platform. These approaches make it possible to adapt risk assessments to the specifics of individual regions, taking into account local conditions and tourist behavior patterns [9–11].

Despite the growing scientific activity in this area, there is still a lack of comprehensive solutions that would provide a multi-level safety assessment taking into account both individual factors (such as tourist behavior, anxiety levels, readiness to respond) and regional and national characteristics of tourism infrastructure. Issues related to the integration of intelligent modules into general decision support systems (DSS) remain relevant, as such integration would allow for adaptive management of tourist flows depending on the level of risk. Thus, there is an urgent need to create next-generation intelligent-analytical platforms that combine modern data analysis technologies with flexible decision-making mechanisms based on aggregated sources of information [12–14].

The main goal of this study is to develop an intelligent-analytical platform for assessing the safety risk of tourist travel, which can be used to support decision-making in the tourism sector, as well as to inform potential travelers about the safety levels in various regions.

## 2. MATERIALS AND METHODS

To assess the level of risk associated with the safety of a tourist trip, a specific region, denoted as  $R$ , is considered. The set of individuals participating in tourism activities is denoted as  $E = \{e_1; e_2; \dots; e_n\}$ . These participants have already visited the designated region and have provided their subjective evaluations regarding their overall impression, level of concern, and sense of threat in terms of their personal safety. The assessment is carried out according to a set of risk criteria, which are grouped into categories  $G_1; G_2; \dots; G_l$ , each reflecting a particular aspect of the safety of the tourist environment.

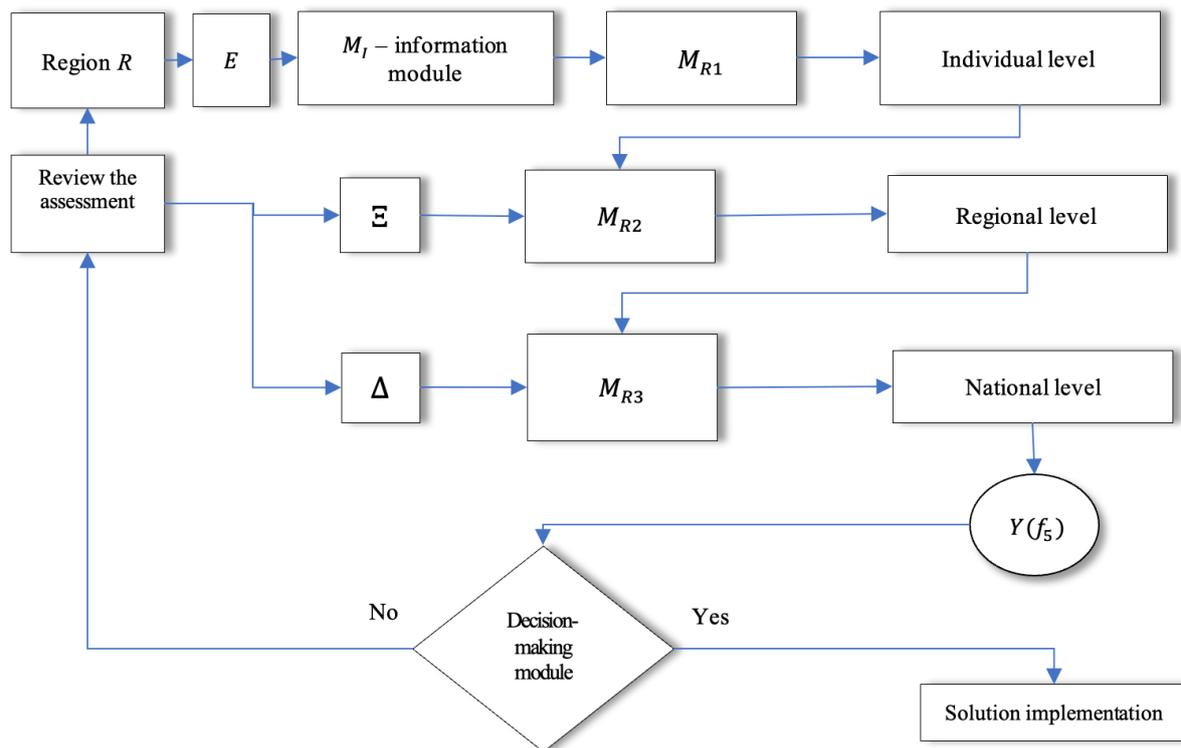
The intelligent-analytical platform for assessing the safety risk of a tourist trip is formally represented in the form of an operator:

$$T_5(R, E, \Xi, \Delta, M_I, M_{R1}, M_{R2}, M_{R3})|Y(f_5). \quad (1)$$

where  $T_5$  – is an operator that, based on the input data  $R, E, \Xi, \Delta, M_I, M_{R1}, M_{R2}, M_{R3}$  produces an output evaluation  $Y(f_5) = \{\mu_R, T_R\}$  which includes: a quantitative assessment of the safety risk of the tourist trip ( $\mu_R$ ) a linguistic (verbal) assessment of the safety risk of the tourist trip ( $T_R$ ). The input parameters are as follows:  $\Xi$  – is the predicted level of repeat visits to the region by participants in the tourist flow;  $\Delta$  – is the expert-assessed level of safety of regional tourism systems;  $M_I$  – information module for assessing the level of tourist trip safety;  $M_{R1}$  – module for determining the term-based risk assessment of personal travel safety (individual level);  $M_{R2}$  – module for assessing the level of regional sense of safety (regional level);  $M_{R3}$  – module for assessing the safety risk of a tourist trip (national level).

The intelligent-analytical platform is represented as a structural diagram (see Fig. 1).

Figure 1 illustrates the structural diagram of the intelligent-analytical platform for assessing the safety risks of a tourist trip. Based on the input data regarding the evaluation region and the participants in the tourist flow, calculations are performed in the information module for assessing the safety level of the tourist trip, i.e.  $M_I$ . The processed data are then directed to  $M_{R1}$  – the module for determining the thermal (term) risk assessment of personal travel safety, which represents the individual level. Next  $\Xi$  – the predicted level of repeat visits to the region by participants in tourist activities – is introduced, and the data are transferred to  $M_{R2}$  – the module for assessing the regional sense of safety (regional level). After that,  $\Delta$  – the expert level of safety of regional tourism systems – is used to process data in  $M_{R3}$  – the module for assessing the safety risk of a tourist trip (national level). The output data  $Y(f_5)$  are then sent to the decision-making module. If the assessed level of travel safety risk across regions does not satisfy the decision-maker (DM), there is an option to revise the evaluation by adjusting the platform's parameters.



**Figure 1.** Structural diagram of the intelligent-analytical platform for assessing the safety risks of a tourist trip

Next, we will consider all the modules of the intelligent-analytical platform for assessing the safety risks of a tourist trip.

$M_I$  – is an information module for assessing the safety level of a tourist trip.

We consider a set of criteria for evaluating personal safety at the destination, denoted as  $K = \{K_i; i = \overline{1, m}\}$ . These criteria are structured into  $l$  logical groups, denoted as  $G_1; G_2; \dots; G_l$ , each covering a specific aspect of safety. Each participant in the tourist flow provides evaluations for each criterion using a set of linguistic variables  $L = \{l_1; l_2; l_3; l_4; l_5\}$ , which reflect the participant's subjective perception of safety and expectations regarding conditions in the tourist region. It is proposed to interpret the linguistic variables as follows:  $L = \{l_1 - \text{«Strongly disagree»}; l_2 - \text{«Disagree»}; l_3 - \text{«Neither agree nor disagree»}; l_4 - \text{«Agree»}; l_5 - \text{«Strongly agree»}\}$ .

The set of criteria covers key aspects of participants' perception of personal safety, including their impressions, level of concern, and degree of anxiety regarding conditions and risks at the destination. These criteria also take into account tourists' expectations regarding the quality of a safe environment.

For a clearer structure of the information module, all criteria are grouped into several logically justified assessment groups, each reflecting a particular aspect of tourist trip safety. The proposed classification is as follows:

$G_1$  – Group of infrastructure safety risks at the destination;

$K_{11}$  – The information on signs was insufficiently clear or ambiguous for me;

$K_{12}$  – In my opinion, the region lacks infrastructure or authorities responsible for tourist safety;

$K_{13}$  – I felt concerned about chaotic traffic and potential road safety risks;

$K_{14}$  – I was concerned about the safety of the accommodation during my trip;

$K_{15}$  – While traveling by car, I felt fear or anxiety about the possibility of a traffic accident;

$G_2$  – Group of social and environmental safety risks in tourism;

$K_{21}$  – I was concerned about severe environmental pollution at the tourist site;

$K_{22}$  – Due to fear of theft by local vendors, I preferred shopping in supermarkets or specialized stores;

$K_{23}$  – I felt fear or discomfort due to large crowds in popular tourist locations;

$K_{24}$  – I was worried about unfriendly or disrespectful behavior of local workers toward tourists;

$K_{25}$  – I felt anxiety due to hostile or unfriendly attitudes of locals toward tourists;

$K_{26}$  – I was concerned about accidentally violating local traditions, cultural norms, or unwritten rules;

$K_{27}$  – I was worried that locals are reluctant to welcome tourists into their communities;

$G_3$  – Group of medical safety risks during the tourist trip;

$K_{31}$  – I was concerned about the state of infrastructure as it could pose a health risk;

$K_{32}$  – I felt that the surrounding natural environment could be a health hazard;

$K_{33}$  – I was worried about the likelihood of contracting viral infections during the trip;

$K_{34}$  – I was concerned about threats to my health while at the destination;

$K_{35}$  – I was concerned about the quality and safety of local food products.

Of course, the group of criteria is open, and the information module does not depend on the number of groups or criteria.

$M_{R1}$  – Module for determining the term-evaluation of the tourist trip's personal safety risk (individual level)

Based on tourists' evaluations of the visited region, their concerns about personal safety, and their expectations at the destination, a set of input linguistic variables is formed. In the first stage, using membership rules and a knowledge base, a generalized term-evaluation  $T_g$  is determined for each group of risk criteria. In the second stage, using the obtained  $T_g$ , evaluations, an aggregated travel safety risk assessment is calculated for each tourist  $e$ .

To transit from linguistic evaluations to numerical values, each variable is assigned a corresponding score  $\tau$ :  $l_1 - \tau_1=1$ ;  $l_2 - \tau_2=2$ ;  $l_3 - \tau_3=3$ ;  $l_4 - \tau_4=4$ ;  $l_5 - \tau_5=5$ . The value of the quantitative assessment  $\tau$  increases with the growing level of tourist satisfaction with accommodation facilities.

Next, within the group of risk criteria, the sum of the quantitative assessment values is calculated for a given expert  $e$ :

$$\theta_g = \sum_{i=1}^{m_g} \tau_{gi}, \quad g = \overline{1, l}. \quad (2)$$

$m_g$  – the number of criteria on group  $g$ .

To calculate the final term-based assessment for each group of risk criteria, the corresponding characteristic function is applied:

$$T_g = \begin{cases} l_1 & \text{if } \theta_g < m_g, \\ l_2 & \text{if } m_g \leq \theta_g < 2m_g, \\ l_3 & \text{if } 2m_g \leq \theta_g < 3m_g, \\ l_4 & \text{if } 3m_g \leq \theta_g < 4m_g, \\ l_5 & \text{if } \theta_g \geq 4m_g. \end{cases} \quad (3)$$

Next, the aggregated assessment of the personal travel safety risk is determined. For this purpose, let us consider an object with  $g$  inputs and one output:

$$r^*(e) = \lambda(T_1, T_2, \dots, T_l). \quad (4)$$

where:  $r^*$  – the resulting output term-based assessment for the group of risk criteria  $g$ ;  $T_1, T_2, \dots, T_l$  – the input linguistic evaluations provided by the expert  $e$ , respectively;

$\lambda$  – an operator that assigns the resulting output term-based assessment  $r^*$ , at input variables  $T_1, T_2, \dots, T_l$  (logical inference rule). Let the following term set of linguistic variables for personal travel safety risk be proposed:  $R = \{L; BA; A; AA; H\}$ ,  $r^* \in R$ , L – «low risk»; BA – «below average risk»; A – «average risk»; AA – «above average risk»; H – «high risk».

The next step is to construct membership rules for the resulting terms. These rules are formulated as logical constructs of the «If–Then–Else» type, which establish a connection between the terms of the input  $T_1, T_2, \dots, T_l$  and one of the possible values of the output variable  $R$ . To do this, well-known approaches can be used, specifically fuzzy logic methods, including the use of membership functions and operations on them. In particular, as the main tools, techniques such as the Mamdani or Jiang methods can be applied, which allow the creation of rules reflecting complex dependencies between input variables and outcomes based on fuzzy sets [1, 4]. This makes it possible to model the uncertainty and fuzziness that are present in real systems.

For example, the membership rules for aggregating the assessment of personal safety risk in a tourist trip are defined as follows:

1) If the number of resulting term-assessments by groups of criteria is at least: one with term  $T_5$  and two with term  $T_4$ , then aggregation gives L – «low risk».

2) If the number of resulting term-assessments by groups of criteria is at least: one with term  $T_5$ , one with term  $T_4$ , and one with term  $T_3$ , then the risk is defined as BA – «below average risk».

3) If the number of resulting term-assessments by groups of criteria is at least: one with term  $T_4$ , one with term  $T_3$ , and one with term  $T_2$ , then aggregation gives A – «average risk».

4) If the number of resulting term-assessments by groups of criteria is at least: two with term  $T_3$  and one with term  $T_2$ , then the risk assessment will be AA – «above average risk».

5) For all lower cases, the result is H – «high risk».

Thus, at the output of module –  $M_{R1}$  an aggregated term-assessment  $r^*(e)$  of the personal safety risk of a tourist trip is produced for expert  $e$  in the visited region  $R$ .

$M_{R2}$  – module for assessing the level of the region's perceived safety (regional level).

Thus, based on the previous module, for each expert an aggregated term-assessment of the personal safety risk of the tourist trip is obtained:  $r^*(e_1), r^*(e_2), \dots, r^*(e_n)$ .

First, the overall value of the safety risk of the tourist trip in the studied region  $R$  is calculated. All participants in the tourist activity involved in the study are considered equivalent. If necessary, the decision-maker (DM) may differentiate them by level of competence by introducing weighting coefficients.

The aggregated term-assessment of risk is usually determined using a percentage scale (0–100%), where each possible value is assigned a range within a certain interval  $[a; b]$ , for example: L –  $[0; 15]$ , BA –  $[15; 30]$ , A –  $[30; 50]$ , AA –  $[50; 80]$ , H –  $[80; 100]$ .

Next, the following value is introduced for further analysis:

$$\delta(R) = \frac{1}{n} \sum_{j=1}^n \chi(e_j), \text{ where } \chi(e_j) = \begin{cases} 15 & \text{if } r^*(e) = L, \\ 30 & \text{if } r^*(e) = BA, \\ 50 & \text{if } r^*(e) = A, \\ 80 & \text{if } r^*(e) = AA, \\ 100 & \text{if } r^*(e) = H. \end{cases} \quad (5)$$

$n$  – the number of participants in tourist activities in region  $R$ , where  $j = \overline{1, n}$ . The generalized value  $\delta(R) \in [15; 100]$  of the safety risk of a tourist trip, obtained for a specific region, reflects the assessment of the safety level in that region from the perspective of the participants in tourist activities. The higher this value, the greater the safety risk of the tourist trip, and accordingly, the lower the level of safety in the region. This relationship can be viewed as an uncertainty of

the «small quantity» type, which is expressed through Z-shaped membership functions. For example, a quadratic Z-spline for this task will have the following form:

$$\phi(R) = \begin{cases} 1, & \delta(R) \leq 60; \\ 1 - \frac{(\delta(R) - 60)^2}{800}, & 60 < \delta(R) \leq 80; \\ \frac{(100 - \delta(R))^2}{800}, & 80 < \delta(R) < 100, \\ 0, & \delta(R) \geq 100. \end{cases} \quad (6)$$

The obtained value  $\phi(R) \in [0; 1]$ , represents a normalized generalized value of the safety risk of a tourist trip. When the value of  $\phi(R)$  approaches 1, the risk of the tourist trip in the studied region is minimal.

Let there be a predicted level for the studied region  $R$  regarding the likelihood of repeat visits by participants in tourist activities ( $\Xi \in [0; 1]$ ). The value of this level determines the potential possibility of revisiting the region and/or attracting new consumers of tourist services [15]. The greater the value of  $\Xi(R)$ , the higher the level of tourists' desire to return to the region. Within the framework of our study, it is assumed that when participants in tourist activities intend to revisit a region, this indicates their satisfaction with the previous trip and their sense of safety in the region.

To determine the level of perceived safety of the region by participants in tourist activities, it is proposed to apply intelligent knowledge analysis using multidimensional membership functions. Since the values  $\phi(R); \Xi(R)$  in the evaluation space  $[0; 1]$  are characterized by «average value» type uncertainty, conical or pyramidal membership functions can be used. For example, a conical membership function with its base at the point (1;1) and scaling by the coordinates (2;2) will have the following form:

$$m_s(R) = 1 - \frac{1}{2} \cdot \sqrt{(\phi(R) - 1)^2 + (\Xi(R) - 1)^2}. \quad (7)$$

The obtained value is normalized and characterizes the level of the region's perceived safety from the perspective of participants in tourist activities.

$M_{R3}$  – module for assessing the safety risk of a tourist trip (national level).

Let us consider that, in the context of this study, a regional tourism system is defined as a complex system formed at the regional level under the influence of tourist flows, with its primary goal being the innovative and sustainable development of the region's tourism sector. At the present stage, the main focus in tourism development is ensuring tourism safety. In this regard,  $\Delta$  – the expert level of safety of regional tourism systems is introduced, representing a nationally comparative assessment within the region. To establish this level, the decision-maker (DM) analyzes the region in terms of innovative and sustainable development under the influence of tourist flows, and then formulates conclusions in the form of linguistic variables from the corresponding term set:  $\Delta = \{\Delta_1; \Delta_2; \Delta_3; \Delta_4; \Delta_5\}$ , where:  $\Delta_1 = \{\text{Low level of safety of regional tourist systems}\}$ ;  $\Delta_2 = \{\text{Below average level of safety of regional tourist systems}\}$ ;  $\Delta_3 = \{\text{Average level of safety of regional tourist systems}\}$ ;  $\Delta_4 = \{\text{Above average level of safety of regional tourist systems}\}$ ;  $\Delta_5 = \{\text{High level of safety of regional tourist systems}\}$ .

In the first step, the fuzzification operation of the input hybrid data is performed. For this purpose, each input value ( $m_s(R); \Delta(R)$ ) is assigned a corresponding membership function value  $\mu_R(R)$ . To achieve this, it is necessary to construct membership rules to obtain a normalized assessment of the input data. Let the term set of linguistic variables  $\Delta$  be represented on a numerical interval, with the terms separated as follows:  $\Delta_1 \in [a_1; a_2]$ ,  $\Delta_2 \in [a_2; a_3]$ ,  $\Delta_3 \in$

$[a_3; a_4]$ ,  $\Delta_4 \in [a_4; a_5]$ ,  $\Delta_5 \in [a_5; a_6]$ . The interval boundaries can be adjusted and modified based on real data. Next, using the characteristic function, the corresponding quantitative values  $\omega$  are calculated:

$$\omega(R) = \begin{cases} a_2 \cdot m_S(R), & \text{if } \Delta(R) \in \Delta_1; \\ a_3 \cdot m_S(R), & \text{if } \Delta(R) \in \Delta_2; \\ a_4 \cdot m_S(R), & \text{if } \Delta(R) \in \Delta_3; \\ a_5 \cdot m_S(R), & \text{if } \Delta(R) \in \Delta_4; \\ a_6 \cdot m_S(R), & \text{if } \Delta(R) \in \Delta_5. \end{cases} \quad (8)$$

This will allow combining quantitative assessments with the opinions of tourism safety experts (TSE). As a result, an objective evaluation  $\omega(R)$  of the safety of a tourist trip in the region is obtained, which will lead to well-founded decision-making.

For a correct interpretation of the relationship between the perceived level of regional safety—formed by participants in the tourist flow—and the expert assessments of TSE regarding the safety of regional tourism systems, it is necessary to normalize the obtained values. To enable comparison of these data, it is appropriate to use a membership rule represented as an S-shaped membership function:

$$\mu_R(R) = \begin{cases} 0, & \omega(R) \leq a_1 \\ 2 \left( \frac{\omega(R) - a_1}{a_6 - a_1} \right)^2, & a_1 < \omega(R) \leq \frac{a_1 + a_6}{2} \\ 1 - 2 \left( \frac{a_6 - \omega(R)}{a_6 - a_1} \right)^2, & \frac{a_1 + a_6}{2} < \omega(R) < a_6 \\ 1, & \omega(R) \geq a_6 \end{cases}. \quad (9)$$

The membership function, constructed in this way, reflects that the value  $\mu_R(R)$  approaches 1 in the case of a minimal tourist trip safety risk. This approach allows for the consideration of subjective expert assessments and facilitates the transition from fuzzy linguistic and quantitative judgments to normalized, comparable indicators.

Next, based on the obtained normalized tourist trip safety risk assessment, a linguistic interpretation is provided using the term set  $T_R$  as follows:  $\mu_R(R) \in [0; 0,2) - R_1$ : very high tourist trip risk;  $\mu_R(R) \in [0,2; 0,4) - R_2$ : high tourist trip risk;  $\mu_R(R) \in [0,4; 0,6) - R_3$ : average tourist trip risk;  $\mu_R(R) \in [0,6; 0,8) - R_4$ : low tourist trip risk;  $\mu_R(R) \in [0,8; 1] - R_5$ : very low tourist trip risk.

The decision-making levels can be adjusted by the systems analyst to account for current data on participants in the tourist flow and the specific characteristics of regional tourism in a particular country. This approach allows the model to be adapted to real-world conditions, ensuring more accurate and relevant support for management decision-making.

### 3. RESULTS AND THEIR DISCUSSION

The study underwent a verification and validation process based on real empirical data collected between October and December 2023 among 327 respondents from the Zakarpattia, Lviv, and Ivano-Frankivsk regions [16]. Participants completed a specially designed questionnaire that covered various aspects of their tourist experiences across different destinations and contexts. The structure of the questionnaire consisted of 16 thematic sections containing a total of 320 questions. The sample included respondents of different age groups, education levels, genders, and other demographic characteristics, ensuring the representativeness of the results. The obtained dataset meets the main requirements of statistical reliability, covering all key demographic and substantive parameters necessary for a comprehensive analysis of the studied topic.

Based on the collected information, a series of experimental assessments of risks associated with the safety of tourist trips was conducted. Detailed data for each region are presented in [16], and examples of input linguistic expert data are provided in Table 1.

Table 1

Input expert data

Group	Criteria	$R_1$ – Zakarpattia region ( $e_1$ )	$R_2$ – Ivano-Frankivsk region ( $e_{210}$ )	$R_3$ – Lviv region ( $e_{251}$ )
$G_1$	$K_{11}$	$l_5$	$l_4$	$l_1$
	$K_{12}$	$l_5$	$l_2$	$l_1$
	$K_{13}$	$l_1$	$l_2$	$l_2$
	$K_{14}$	$l_1$	$l_2$	$l_1$
	$K_{15}$	$l_1$	$l_2$	$l_2$
$G_2$	$K_{21}$	$l_1$	$l_2$	$l_1$
	$K_{22}$	$l_1$	$l_2$	$l_1$
	$K_{23}$	$l_1$	$l_3$	$l_2$
	$K_{24}$	$l_1$	$l_2$	$l_1$
	$K_{25}$	$l_1$	$l_3$	$l_2$
	$K_{26}$	$l_1$	$l_2$	$l_3$
	$K_{27}$	$l_1$	$l_1$	$l_3$
$G_3$	$K_{31}$	$l_2$	$l_2$	$l_1$
	$K_{32}$	$l_2$	$l_3$	$l_2$
	$K_{33}$	$l_2$	$l_3$	$l_4$
	$K_{34}$	$l_1$	$l_4$	$l_2$
	$K_{35}$	$l_1$	$l_5$	$l_3$

At the first stage, the linguistic evaluations provided by experts for each individual criterion are converted into a single generalized term-based assessment within the corresponding groups of risk criteria. Each linguistic variable corresponds to a specific numerical value. Next, these quantitative assessments are summed within each group according to formula (2). To form the final term-based evaluation for the groups of risk criteria, a characteristic function presented in formula (3) is applied. The obtained results are as follows:  $e_1: T_3; T_2; T_2; e_{210}: T_3; T_3; T_4; e_{251}: T_2; T_2; T_3$ .

The next step involves determining the aggregated assessment of the personal safety risk during the tourist trip. To achieve this, membership rules are applied to derive the personal safety risk assessment for the tourist trip:  $r^*(e_1) = AA; r^*(e_{210}) = A; r^*(e_{251}) = AA$ .

After conducting the analysis at the individual level of the participants in the tourist flow, the regional-level calculations are performed. At this stage, the aggregated data of the generalized value of the tourist trip safety risk and the predicted level of repeat visits to the region are processed separately for each region:  $R_1$  – based on data from 209 experts;  $R_2$  – based on data from 41 experts;  $R_3$  – based on data from 77 experts.

First, a single generalized value of the tourist trip safety risk is calculated for the studied regions. To do this, an aggregated safety risk value is derived using a weighted sum, according to formula (5):  $\delta(R_1) = 79,54; \delta(R_2) = 69,73; \delta(R_3) = 87,89$ . Afterward, to enable data comparison, the membership function (formula (6)) is applied:  $\phi(R_1) = 0,5; \phi(R_2) = 0,88; \phi(R_3) = 0,13$ .

Let the predicted level of repeat visits to the studied regions be as follows [15]:  $\Xi(R_1) = 0,85; \Xi(R_2) = 0,78; \Xi(R_3) = 0,88$ .

Next, according to formula (7), the level of perceived regional safety from the perspective of participants in the tourist flow is determined as follows:  $m_S(R_1) = 0,74$ ;  $m_S(R_2) = 0,875$ ;  $m_S(R_3) = 0,56$ .

In the third module, the degree of tourist trip safety risk is derived, taking into account both the regional sense of safety among tourists  $m_S(R)$  and the expert-assessed level of safety of regional tourism systems  $\Delta$ .

Let us assume that the decision-makers (DMs) for each region have their own evaluations of the safety of regional tourism systems:  $\Delta_5(R_1) = \{ \text{High level of safety of regional tourism systems} \}$ ;  $\Delta_4(R_2) = \{ \text{Above-average level of safety of regional tourism systems} \}$ ;  $\Delta_4(R_3) = \{ \text{Above-average level of safety of regional tourism systems} \}$ .

Let the term set of linguistic variables  $\Delta$  be represented on a certain numerical interval  $[0; 100]$ , divided as follows:  $\Delta_1 \in [0; 20]$ ,  $\Delta_2 \in [20; 40]$ ,  $\Delta_3 \in [40; 60]$ ,  $\Delta_4 \in [60; 80]$ ,  $\Delta_5 \in [80; 100]$ . Then, using the characteristic function (8), the quantitative assessments and DMs' opinions are combined to yield:  $\omega(R_1) = 74$ ;  $\omega(R_2) = 70$ ;  $\omega(R_3) = 44,8$ .

Subsequently, the S-shaped membership function (9) is applied, giving:  $\mu_R(R_1) = 0,86$ ;  $\mu_R(R_2) = 0,82$ ;  $\mu_R(R_3) = 0,41$ .

Based on the obtained normalized safety risk assessment, the linguistic interpretation is as follows:  $\mu_R(R_1) = 0,86 \in [0,8; 1] - R_5$ : very low tourist trip risk;  $\mu_R(R_2) = 0,82 \in [0,8; 1] - R_5$ : very low tourist trip risk;  $\mu_R(R_3) = 0,41 \in [0,4; 0,6] - R_3$ : average tourist trip risk.

Overall, the developed intelligent-analytical platform for assessing the safety risks of tourist trips demonstrates a high level of formalization in the processes of analysis and decision-making in the field of tourism safety. Its modular structure, adaptability to various levels of data, and the use of fuzzy evaluations create favorable conditions for its implementation in modern tourism management systems, particularly in the context of smart regions and digital monitoring of tourist flows.

#### 4. CONCLUSIONS

The main objective of the conducted study is the development of an intelligent-analytical platform for assessing the safety risk of tourist trips, which has yielded the following scientific results.

For the first time, an information module has been developed to evaluate the level of safety during a tourist trip, encompassing 17 criteria for assessing personal safety at the destination. These criteria are grouped into three main categories. The module makes it possible to account for the subjectivity of expert judgments and ensures a transition from fuzzy linguistic evaluations to normalized and comparable values.

Additionally, for the first time, three analytical modules have been designed to cover different levels, i.e. from individual to national: the module for term-based assessment of personal safety risk during a tourist trip, the module for assessing the perceived safety level of a region, and the module for evaluating the overall safety risk of a tourist trip. The input data are represented in the form of linguistic variables, reflecting the impressions of tourists after visiting a region and their level of concern for personal safety at the destination. These modules are based on the principles of fuzzy logic and multidimensional membership functions. The system performs data aggregation to produce a generalized assessment of the safety risk of a tourist trip and to forecast the likelihood of repeat visits to the region. Furthermore, the model integrates expert assessments of regional tourism system safety with the subjective sense of safety among tourists. The result is both a quantitative and a linguistic (qualitative) evaluation of the safety risk of a tourist trip.

The intelligent-analytical platform has been verified and validated using real data from 327 respondents from the Zakarpattia, Lviv, and Ivano-Frankivsk regions, and an example of its practical application for risk assessment has been demonstrated.

Future research will focus on developing a web-oriented software application for the intelligent-analytical platform for assessing tourist trip safety risks. This will enable the practical implementation of the developed tool by both businesses and government authorities.

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# ІНТЕЛЕКТУАЛЬНО-АНАЛІТИЧНА ПЛАТФОРМА ОЦІНЮВАННЯ РИЗИКУ БЕЗПЕКИ ТУРИСТИЧНОЇ ПОДОРОЖІ

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*Резюме.* Основною метою дослідження є розроблення інтелектуально-аналітичної платформи оцінювання ризику безпеки туристичної подорожі. Інтелектуально-аналітична платформа оцінювання ризику безпеки туристичної подорожі складається з трьох аналітичних модулів: індивідуальний рівень безпеки туристичної подорожі; регіональний рівень безпеки туристичної подорожі; національний рівень

безпеки туристичної подорожі. Суть інтелектуально-аналітичної платформи полягає в тому, що вона, спираючись на оцінювання учасників туристичного руху щодо відчуття власної безпеки у вибраному регіоні, передбачуваність повторного візиту та експертне оцінювання рівня безпеки регіональних туристичних систем, формує як кількісні, так і лінгвістичні індикатори ризику безпечності подорожі. Вперше розроблено інформаційний модуль для оцінювання рівня безпеки туристичної подорожі, що охоплює 17 критеріїв оцінювання власної безпеки у місці призначення. Також вперше розроблено три аналітичні модулі, що охоплюють рівні від індивідуального до національного: модуль терм-оцінювання ризику власної безпеки туристичної подорожі; модуль оцінювання рівня почуття безпеки регіону; модуль оцінювання ризику безпеки туристичної подорожі. Вхідні дані представлені у вигляді лінгвістичних змінних, що відображають враження учасників туристичного руху після відвідування регіону та рівень їхньої стурбованості щодо власної безпеки у місці призначення. Модулі базуються на принципах нечіткої логіки та багатовимірних функцій належності. Здійснюється агрегування даних щодо узагальненого ризику безпеки туристичної подорожі та прогнозу повторного відвідування регіону. Поєднуються оцінювання безпеки регіональних туристичних систем від експертів із суб'єктивним рівнем почуття безпеки серед туристів. Результатом є як кількісна, так і лінгвістична оцінка ризику безпеки туристичної подорожі. Інтелектуально-аналітичну платформу верифіковано та апробовано на реальних даних 327 респондентів із Закарпатської, Львівської та Івано-Франківської областей, а також проілюстровано приклад її практичного застосування для оцінювання.

**Ключові слова:** інформаційні технології, лінгвістичні змінні, нечітка логіка, підтримання прийняття рішень, ризику, регіональний туризм.