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Knowledge management in tourism: Leveraging Fuzzy modelling to understand and predict tourist behaviour in the V4 countries

JEL Classification: *C02; B55; Z33; Z38*

Keywords: *knowledge management; consumer behaviour; tourism industry; fuzzy modelling; decision-making*

Abstract

Research background: Although knowledge management has become one of the most discussed concepts in management, its application in tourism—both at the organizational and destination levels—remains limited. Existing literature highlights potential benefits of knowledge management for improving tourist experiences, yet empirical evidence in the tourism sector is scarce compared to other industries.
Purpose of the article: The main goal of this study is to develop a fuzzy assessment model and derive the level of the possibility of repeated visits to the region by participants of the tourist movement in the Visegrad Group countries (the Czech Republic, Hungary, Poland, Slovakia).

Methods: A fuzzy sets and fuzzy logic-based model was applied to evaluate tourist satisfaction, regional infrastructure, and digital popularity, which allowed deriving quantitative and linguistic predictions of repeated visits.
Findings & value added: The research provides a novel, data-driven method for evaluating tourism performance from the perspective of tourist satisfaction and regional attractiveness. It highlights the interplay between infrastructure, accessibility, and digital visibility in shaping repeated visit behaviour. This approach offers actionable insights for policymakers, destination managers, and tourism organizations seeking to optimize strategies for sustainable tourism growth. The study contributes to the broader knowledge management discourse by demonstrating how fuzzy logic models can capture complex human perceptions and decision-making processes in tourism.

Introduction

Knowledge management (KM) represents the strategies and processes that enable the recognition, capture, and effective use of knowledge to increase the competitiveness of sectors and enterprises. This scientific discipline has been developed for more than three decades, and thus, it affects many economic dimensions: business, management, trade, information systems, and information. In recent years, the development of information dimensions, media penetration, public health, public policy, environmental policy, and other fields is evident. From a procedural point of view, a comprehensive systematic approach to strategic, operational, and crisis management of tangible and intangible assets, financial flows, organization, and human resources management is apparent in KM.

To increase the level of satisfaction of tourists as subjects of consumer behaviour, it is necessary to pay attention to the following factors: safety, emotions, the hospitality of residents, ecology, tourist infrastructure, quality of service, logistics, availability and completeness of tourist information, pricing and others. It is also important to consider the emergence of a new paying young generation of consumers who have the following consumer preferences: recreation and visiting popular attractions; visiting natural places; main expenses for entertainment, food, and accommodation; high interest in ecotourism. In addition, today, there is a trend that decisions about the place of rest and travel are made based on information from the Internet and pages on social networks.

In tourism, the greater the gap between the expected and real properties of the trip (of the tourist product), the greater the consumer's dissatisfaction, which affects his further behaviour, regarding repeated visits to the region.

Despite the growing number of studies on tourist satisfaction, regional infrastructure, and digital engagement, a systematic analysis that integrates these dimensions into predictive models for repeated visits is limited. Recent research (Kovačić & Barkiđija Sotošek, 2025; Li *et al*., 2022) often emphasizes isolated aspects, such as service quality or online reviews, but fails to combine them with fuzzy or linguistic evaluations to capture subjective perceptions comprehensively. Moreover, most existing studies focus on local or national contexts, which limits their generalizability for international audiences.

Research gap: Although knowledge management has been widely discussed in the literature, empirical research and practical applications in tourism remain limited. Few studies integrate tourists' satisfaction, regional infrastructure and accessibility, and digital popularity of regions into a comprehensive predictive model for repeated visits. Additionally, conventional models rarely combine quantitative and linguistic evaluations or employ fuzzy logic for forecasting tourist behaviour.

Research questions:

Q1: *How can tourists' satisfaction with various aspects of regional tourism, including infrastructure, accessibility, and online popularity, be systematically quantified to predict the likelihood of repeated visits?*

Q2: *How can the integration of tourists' satisfaction, regional infrastructure, and digital information about the region enhance the predictive accuracy of a fuzzy model for repeated visits?*

This study focuses on the Visegrad Group countries (the Czech Republic, Hungary, Poland, and Slovakia), which are culturally rich and rapidly developing tourism destinations in Central Europe. For international audiences, including travellers from Asia and the Americas, these regions offer unique insights into tourist behaviour in emerging European destinations, highlighting both opportunities and challenges for regional tourism promotion.

Our research is aimed at deriving the predicted level of repeated visits to the region by participants of the tourist movement, taking into account: the attitude of tourists to various aspects of selected areas related to tourism; the level of tourist movement in relation to infrastructure and accessibility in the regions; expert level of popularity of the region in the infor-

mation space (Internet, social networks). A mathematical model based on the theory of fuzzy sets and fuzzy logic is presented to formalize such a forecast.

At the first stage of the model, according to the selected groups of criteria of tourist aspects, the level of travel satisfaction is evaluated about the expected and real experience of the participants of the tourist movement.

At the second stage, the data on the level of satisfaction with various aspects of tourism and the assessment of the level of tourist movement about infrastructure and accessibility in the regions are aggregated.

In the final—third stage, the predicted level of repeated visits to the region by participants of the tourist movement is derived, considering the expert level of popularization of regional tourism in the information space. The essence of the model will be that, based on the satisfaction of tourists, as subjects of consumer behaviour, quantitative and linguistic levels are derived from visiting the region, which indicates the potential for repeated visits to the region and/or the attraction of new consumers of tourist services. This will allow analysing the region from the point of view of satisfaction of tourists as consumers of tourism services, considering the region's level in terms of infrastructure and accessibility, as well as its popularization of the region in the information space. This study contributes to understanding consumer behaviour and tourist loyalty in regional tourism. Tourist loyalty remains a key issue in tourist management because repeated visitors represent significant trade opportunities for destinations and are a source of competitive advantage.

In response to the above considerations, it was decided to conduct a scientific study, the main objective of which is to develop a fuzzy evaluation model and derive a level regarding the possibility of repeated visits to the region by participants of the tourism movement, using the example of the countries of the Visegrad Group (Czech Republic, Hungary, Poland, Slovakia).

This article consists of the following parts. Part 2 provides an overview of domestic and foreign research studies on this issue. Part 3 is devoted to describing the formal formulation of the problem and the fuzzy mathematical model for estimating the predicted level of repeated visits to the region by participants of the tourist movement. In Part 4, the fuzzy model is verified and tested. An example of the model's functioning on real data is also given here. Part 5 discusses the results of the research. Part 6 concludes the research, presenting the scientific results obtained for the first time. It also

identifies ideas for future work, namely the development of comprehensive information technology and tools in the form of web-based software, which will allow the promotion of regional tourism through the understanding of consumer behaviour.

Literature review

The main goal of KM in tourism is to create the strategies and the processes to effectively use the knowledge that enables increasing competitiveness. Tourist loyalty related to repeated visits to hotels and destinations is a key strategic element and a significant determinant of competitiveness. There has been a strong interest in researching tourist satisfaction in the recent period, while more attention should be paid to researching tourist loyalty.

Significant sectoral differentiation is visible in the research studies examining KM principles and strategies (Xiao, 2006). Many authors justify this by the different characteristics of the sectors that negatively impact the adaptation of new approaches, strategic development processes, and models.

Some studies report the fact that the tourism sector has insufficient prerequisites and potential for an application of the KM approaches and strategies and for KM-based innovations (Ruhanen & Cooper, 2004; Ruhanen, 2008; Yiu & Law, 2014; Czernek, 2017). This may be due to the perception of long-term strong discrepancies between knowledge stocks in tourism on the one hand and their use on the other (Pyo, 2012; Hudson, 2013; Lopes *et al*., 2017). From the available research studies, it is also possible to identify potential barriers to the introduction of effective KM processes, such as business type, ownership specification, tourism products fragmentation, as well as the incorrect processes in human resource management related to part-time employment, seasonality of work, turnover of employees, low qualification of employees, and so on for instance. (Weidenfeld *et al*., 2009). Czernek (2017) mentions regional characteristics versus local characteristics of tourism as a barrier.

There are clear trends established from monitoring the development of the KM concept in tourism. For the growth of KM in tourism, the communication of the KM concepts and benefits will be essential because, according to many authors, KM concepts in this sector need to be understood (Bouncken & Pyo, 2002; Zhang *et al*. 2021). It is necessary to investigate the

relations between the innovations within KM and maintaining a competitive advantage in tourism, to look for ways to use the employees' creativity, to reveal the continuous processes of product and service improvement. The issues of knowledge security, intellectual property of knowledge workers, and understanding social processes and their relation to business processes have come into focus, too (Kantabutra, 2021; Chen, 2021; Ilvonen *et al*., 2019). In the future, the destinations are expected to become learning organizations to be competitive and overcome the risks associated with constant change (Schianetz *et al*., 2007; Baggio *et al*., 2020).

Also, the role of stakeholders in tourism, including tourists-visitors, as well as the entities in the supply chain in the process of a KM application, will continue to grow. This is also due to the increasingly strong pressures in destination management to link knowledge more effectively with the decision-making processes (Del Chiappa & Baggio, 2015; Trunfio & Campana, 2019). KM will make it possible to create a competitive, innovative, and sustainable tourism sector.

The tourism sector responds to the KM strategies in its management, planning, and development practices very slowly and thus, resulting in the need for more research activities in this area in the recent period (Xiao, 2006). Evidence is emerging in the literature on how tourism can benefit from KM in organizations as well as destinations, although the tourism sector has adapted to the KM strategies so far considerably slowly (Cooper, 2015; Cavusqil *et al*. 2003). The significant benefits of KM strategies can also be obtained within the networked tourism organizations and destinations. This also supported the emergence of several models for tourism and KM (Cooper, 2015).

Although the indirect links between tourists' satisfaction, their loyalty, and the KM processes are recorded in the research studies, their explicit investigation enabling the development of new tools and means for setting up successful KM strategies is absent (Chen, 2021). The studies, which investigate tourist loyalty and the determinants of repeated visits, provide a suitable platform to create the innovative tools and to reveal new determinants of tourist loyalty to destination as well as to tourism institutions.

Given the above, next is a review of modern research to identify gaps in knowledge management in tourism to predict repeated visits to the region by participants in the tourism movement. To review modern research, work was carried out in the following areas: the importance of KM in the tourism sector; tourists' loyalty as a determinant of KM; and fuzzy models

in KM. These areas were chosen to consider the extensive experience of the authors, the multidisciplinary of the research, and the innovativeness of the application of fuzzy mathematics to the tourism industry through the prism of knowledge management.

Importance of KM in the tourism sector

Currently, KM in tourism is beginning to be the subject of research interest for many researchers. Even though the theoretical platform of KM and its application in tourism, including benefits, seems to be well mapped, the need for more level of its implementation and the missing effects force researchers to explore the deeper associations and relationships within the tourism sector.

Martínez-Martínez *et al*. (2023) emphasise the importance of KM in tourism. The authors explain the strong relations between KM and tourism sustainability understood in the context of environmental, social, and economic development. The principles of sustainable tourism support better strategies. Thus, they initiate education and knowledge management, cocreation of values, building corporate social responsibility and trust, and pro-environmental behaviour in tourism. Cooper (2015) criticizes the missing approaches to KM in tourism compared to the other sectors, even though the benefits of knowledge management in tourism are clear, and the creation of policies linked to KM possesses significant benefits for tourism. Here, KM enables the use of knowledge to gain a competitive advantage for the destination and entities operating in tourism. Moreover, KM enables improvement of the business processes, faster innovation development, organizational learning, better access to markets, decision-making process improvement, and more efficient activities. KM in tourism also supports individual education and employee loyalty as well. KM models have an interdisciplinary approach.

Some studies report that tourism needs more prerequisites for KM implementation and KM-based innovations (Ruhanen & Cooper, 2004; Czernek, 2017). Nevertheless, some studies declare discrepancies between the knowledge pool in tourism on the one hand and their use on the other hand (Hudson, 2013; Lopes *et al*., 2017).

From some studies, it is possible to identify the potential barriers to effective KM processes, which include the type of business, fragmentation of the tourism products, as well as incorrect processes in human resource

management related to part-time employment, seasonal work, employee turnover, low employee qualifications, and so on for instance (Weidenfeld *et al*., 2009; Hallin & Marnburg, 2008; Hsieh *et al*., 2020; Gössling, 2018). It is necessary to investigate the relations between innovations within KM and maintaining a competitive advantage in tourism, to look for ways to use the creativity of employees, to reveal the continuous processes of improvement of products and services. Knowledge security issues, the intellectual property of knowledge workers, and the understanding of social processes and their connection to business processes are also receiving attention in the present time (Tzortzaki & Mihiotis, 2014).

Weidenfeld *et al*. (2010) confirm that product and market similarity and spatial proximity facilitate knowledge transfer and innovation transfer at the local and regional level. It has been proven that the effects of product similarity and spatial proximity are closely related. Many research studies state that the construction of destination networks (Xiao & Smith, 2007; Baggio & Cooper, 2010; Mistilis & Sheldon, 2006) as well as policy networks (Dredge, 2006a, 2006b; Van der Zee & Vanneste, 2015) is necessary for the effective transfer of innovations within KM *et al*., 2015). Clark and Scott (2006) see a critical place in the KM principles application in tourism planning processes. According to the authors, no tools would still enable KM implementation in planning initiatives.

Valeri and Baggio (2022) draw attention to the preferential use of KM applications for individual organizations rather than for destinations and networks of destination management organizations. According to the authors, if KM is an effective tool in tourism innovation, it will be necessary to involve governments, ministries, and other organizations in this process.

The insufficient use of KM in tourism represents a loss of strategic potential for the industry. Knowledge that could contribute to innovation, sustainability and strengthening tourist loyalty remains either unrecognised or unused. Hence, the success of tourism will depend on the ability of destinations to transform information into knowledge and knowledge into value, that is, on the implementation of effective KM.

Tourists' loyalty of as a determinant of KM

Tourist loyalty can be an important determinant of KM. From a process perspective, it expresses the relation between visitor behaviour and the destination ability to learn, to innovate, and to improve its services. Alt-

hough there is much research on loyalty and its relationship with various marketing strategies (Cossio-Silva *et al*. 2019), only a few research studies have analysed loyalty to tourist destinations as well as approaches that integrate several destinations visited by tourists (Zhang *et al*. 2022). From a behavioural perspective (Oliver, 1999), loyalty is usually quantified through the number of product purchases or visits to a destination (Anantamongkolkul *et al*. 2019). Tourist destinations compete for repeated visits of tourists. Hence, from a behavioural perspective, the more times a tourist visits a destination, the more loyal he or she will be considered.

Keshavarz and Jamshidi (2018) mention that loyalty is the most important strategic goal in the hotel industry. Caber *et al*. (2020) state that it is very important to examine the tourism behaviour and attitudes of future generations because their demand structure will shape the development of the tourism industry in the future. The value perception of young tourists may be different from older tourists. Yolal *et al*. (2017) investigated the loyalty of first-time and repeated visitors at all-inclusive resorts. The authors point out that there are differences between these groups of visitors. Tourists who value cognitive attributes for the first time will rely more on cognitive evaluations.

Tourist loyalty (behavioural, emotional, value-based, and so on) generates feedback, experiences, and knowledge that are key inputs into the knowledge management system in tourism (Chen, 2025). This means that a loyal tourist is not only a repeat customer, but also a source of knowledge for the destination.

Meleddu *et al*. (2015) examine a multidisciplinary framework with different definitions of loyalty to express loyalty. According to the authors, past loyalty determines tourists' future behaviour. Chi (2012) investigated the differences between first-time and repeated visitors' loyalty. Repeated visitors were dominated by a higher level of intentions than first visitors. Satisfaction was more important for first-time visitors than for repeated visitors. Gursoy *et al*. (2014) looked for determinants that directly and indirectly influenced the formation of loyalty. They proposed the framework of destination loyalty formation. Relationship to place and a level of involvement was identified as the second most influential factor. The most influential driver of building loyalty is previous experience. Sharma and Nayak (2019) criticize claims that tourist satisfaction is the most significant factor affecting destination performance. Their findings confirmed the importance of memorable tourism experiences for forming behavioural inten-

tions. Prayag *et al*. (2019) mention by examining numerous sources for the period 2000–2016 that the positive effects of tourist satisfaction on loyalty, behavioural intentions, and switching costs are well known, but further research is needed.

Li *et al*. (2008) investigated the relationship between destination knowledge (destination awareness) and tourist destination loyalty (regarding affective and behavioural loyalty). The authors found a close relationship between destination knowledge and destination loyalty. Tourists may have different motivations to share knowledge. This is also demonstrated by the study by Lee and Hyun (2018), which the authors examined the influence of altruism, expected reciprocal benefits, reputation, and trust as important motivational factors in shaping online community loyalty in. Tacit knowledge can also help develop loyalty.

Pereira *et al*. (2021) developed a model that highlights the importance of tacit knowledge in developing loyalty in rural tourism accommodation facilities, emphasising its cognitive, technical, and social dimensions. Tacit knowledge improves employee performance in creating effective customer relationships. Muniz *et al*. (2021) investigated how customer KM (CKM) can help organisations to manage tourism experiences intelligently and contribute to creating smart solutions and promoting smart tourism destinations. Tourism experiences are customer knowledge and thus, they are essential for improving and innovating tourism products and services.

Measuring KM processes can be methodologically quite comprehensive. This is also related to the range of dimensions that it can include. For instance, Phuong and Le (2022) measure KM through seven dimensions: knowledge acquisition, knowledge sharing, knowledge maintenance, knowledge codification, personalisation, and social networks. Knowledge of the relationships between them will reveal the importance of individual processes and their contribution to building or increasing tourist loyalty (Anand *et al*., 2023).

Within KM, some authors also examine environmental knowledge. Yusof *et al*. (2016) found that the impact of resort environmental practices on tourist loyalty is greater for tourists, who have a higher level of concern for the environment and who directly or indirectly behave more environmentally friendly.

Several research studies have attempted to define models based on the relationship between loyalty and the factors that lead to it, but few studies have integrated these models with the mathematical approaches. Talaee

Malmiri *et al*. (2021) developed a probabilistic model of tourist loyalty, identifying the image of the tourist environment, natural versus historical attractions and the image of the infrastructure as the most influential factors at a lower level in the analysis process. Almeida-Santana and Moreno-Gil (2018) recommend to analyse horizontal loyalty (consumer loyalty divided between several destinations) in relation to the underlying factors that influence this loyalty (for instance, cognitive, affective, as well as overall destination image, motivation, conative loyalty, previous behaviour, as well as sociodemographic characteristics). This position is opposed by the study by Cossio-Silva *et al*. (2019), which the authors suggest a synthetic indicator for a simpler measurement of loyalty in. The authors identified the four groups of tourists according to their level of loyalty and profitability applying the number of overnight stays during a visit to a destination. A simpler measurement of loyalty can also support the creation of appropriate marketing strategies. Nevertheless, each measurement tool works with several methodological and data limitations. Cong (2021) perceives the complexity of the relationship between satisfaction and loyalty. Hence, they test the combined role of perceived risk and destination knowledge in the relationship between satisfaction and loyalty intention. The outcomes of their study confirmed the direct effects of perceived risk on destination satisfaction and loyalty intentions.

Although many research studies examine the selected aspects of KM in relation to achieving tourist loyalty, they miss the complexity that would enable the aggregation of the processes and their relations defined for achieving, maintaining, and increasing tourist loyalty. The available research shows that the quantification of the impact of tourist loyalty on destination competitiveness through KM is limited as it is for the prediction of the dynamics of tourism development and its sustainability. Creating tourist loyalty supported by KM suggests the creation of a knowledge cycle and its feedback (Mohamad *et al*., 2023). This cycle would go through phases such as knowledge generation, retention, sharing, service innovation, and loyalty reinforcement. The use of a knowledge feedback loop is a clear instance of how loyalty becomes a determinant as well as an outcome of effective KM.

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Fuzzy models in KM

In recent years, there have been studies looking for optimal KM implementation strategies through fuzzy approaches, but a direct link with the tourism sector appears in them only very sporadically. For example, Wu and Lee (2007) suggest using multicriteria methods for choosing the right KM strategy and its subsequent implementation. Chen *et al*. (2023) investigated the linking mechanisms between customer knowledge management competencies and the Balanced Scorecard. The authors used an index system based on the BSC and KM processes, an analytical hierarchy process, and fuzzy evaluations at different levels. Ziyadin *et al*. (2019) proposed an economic and mathematical model of sustainable tourism based on the application of fuzzy algebra. The developed fuzzy model combined the

results of economic benefits with environmental and social indicators. Haskova *et al*. (2023) demonstrated the applicability of a fuzzy evaluation model in assessing manufacturing machinery from a sustainable business perspective, which supports the broader use of fuzzy logic approaches in evaluating complex systems, such as tourism.

The area of fuzzy decision-making and applications in KM has begun to develop more intensively in recent decades due to the reactions to the complex requirements of the information society. From the content point of view, the overlap of fuzzy decision-making processes and applications in the various areas of business management is visible, such as the planning of strategic activities of companies, the selection of target locations, the selection of optimal suppliers in the supply chain, the evaluation of performance, safety, and risks (Zhang, 2019). Atsalakis *et al*. (2018) use neuro-fuzzy techniques to predict the success of a new tourism service. The authors developed the Adaptive Neuro-Fuzzy Inference System (ANFIS). Mazroui Nasrabadi (2023) identified critical health tourism supply chain resilience factors through Fuzzy Cognitive Map Approach. Zahmatkesh Saredorahi *et al*. (2022) also used the Fuzzy Cognitive Map Approach to identify factors influencing the development of geriatric health tourism. This tool enabled the creation of strategic scenarios. Musulin *et al*. (2011) draw attention to the need to distinguish between formal and professional education, with the most important being the need for continuous education in KM. The KM strategy is essential for its successful implementation. Khadivar *et al*. (2022) proposed a fuzzy expert system to select an appropriate KM strategy regarding the factors affecting the KM strategy. Pourdarab *et al*. (2012) had the same ambition to design a Fuzzy Expert System to select the appropriate effective variables while choosing the optimal KM strategy. Akhavan *et al*. (2017) developed a KM strategy model after the defuzzification of experts' opinions. The authors considered the organization's maturity level and effective knowledge of the management strategy. Also, Taghizadeh and Soltani Fesghandis (2022) applied the model based on fuzzy set theory to identify the KM score of an organization. Aghashahi *et al*. (2020) proposed a fuzzy logic system to determine a suitable KM implementation strategy by prioritizing the KM processes. According to the authors, this method will enable a more precise determination of KM priorities and processes and find the optimal strategy for KM implementation in the company. Mardani *et al*. (2017), unlike the previous authors, employed the integration of the fuzzy set theory with the qualitative and quantitative

approaches to evaluate the most important KM practices in enterprises. The information technology infrastructure from a technological point of view was identified as the first most important factor, and human resource management as the second from an organizational point of view.

Fuzzy techniques can also be applied to identify and to prioritise the KM influence factors in tourism. Gheibdoust and Homayounfar (2024) identified the KM influence factors in tourism through fuzzy SWARA, finding that knowledge obtaining is the first criterion and knowledge evaluation is located on the last position. Knowledge of the most important KM influence criteria in tourism can help to create innovations and to increase competitive advantages. Dejprayoon *et al*. (2025) applied fuzzy logic to model customer behaviour under uncertainty through seven determinants of sustainable purchase intention, while satisfaction is the most influential factor. This reasons the importance of knowledge sharing through customer involvement in creating sustainability-oriented strategies.

Sedaghat *et al*. (2018) focused on identifying loyal tourists through the DFR model as loyal tourists can reduce spending and support tourism development. New models based on data mining techniques can generate new knowledge that is an important process within the KM system. Some techniques can also predict the improvement of service quality in tourism. For instance, according to the application of a fuzzy cognitive map employed by Xu and Lu (2020), it was found that the key factors, which influence the quality of online tourism services, are complex types of services, provision of true, comprehensive, and accurate information, updates, payment security, data and information security, protection of customer rights and interests, service friendliness and evaluation processing. The listed studies clearly declare the significant position of fuzzy approaches and methods in the KM processes, not only in generating knowledge, but also in its storage, sharing, and support for the creation of strategies for service innovation that lead to strengthening loyalty.

According to the outcomes of the research studies, the scientific hypothesis was formulated: If, in the selected region, the participants of the tourist movement have a high level of satisfaction with the trip in relation to various tourist aspects, a high level of tourist movement in the region in relation to infrastructure and accessibility, a high expert level of popularization of regional tourism in the information space, then it can be argued about a high predicted assessment of repeated visits to the region by the partici-

pants of the tourist movement, obtained based on the constructed fuzzy model.

Methods

Let it be considered $R = \{R_1; R_2; \dots; R_n\}$—a set of regions for evaluation and derivation of the level regarding the possibility of repeated visits to the region by participants of the tourist movement. Let the participants of the tourist movement (tourists)$E = \{e_1; e_2; \dots; e_m\}$ visited the destination and evaluate the level of satisfaction with the trip about various tourism aspects $G_1; G_2; \dots; G_l$. Each of the tourist aspects $G_1; G_2; \dots; G_l$ is a group of evaluation criteria. M_{LT}—a fuzzy method of evaluating the level of travel satisfaction relative to the expected and real experience of the participants of the tourist movement. M_{AS}—a fuzzy method of aggregating satisfaction level assessments of various aspects of tourism and tourist movement about infrastructure and accessibility in the region. M_{PL}—a fuzzy method of estimating the predicted level of repeated visits to the region by participants of the tourist movement.

Thus, the fuzzy model of the predicted behaviour of tourist movement participants in relation to repeated visits to the region is formally presented in the form of an operator:

$$\delta(R, E, G, M_{LT}, M_{AS}, M_{PL}) \to f(m_{RV}, L_{RV}). \quad (1)$$

Here we have: δ—a statement that outputs the output values f, with input variables $R, E, G, M_{LT}, M_{AS}, M_{PL}$; m_{RV}—quantitative / L_{RV}—linguistic levels indicating the potential for repeated visits to the region and/or attracting new consumers of tourism services.

The fuzzy evaluation model is based on expert conclusions and knowledge, in this connection, the following management subjects are introduced: participants of the tourist movement—respondents (experts) of the research questionnaire, who expressed their satisfaction with the trip about various tourist aspects in the destination; a system analyst—is a person who adjusts assessment processes according to a mathematical model; a decision maker (DM)—is a person who makes decisions about regional tourism policies through the prism of tourist consumption behaviour.

At the first stage of the model, the level of travel satisfaction is evaluated about the expected and real experience of the participants of the tourist movement, using the following fuzzy method—M_{LT}.

Necessary to adequately build a system of evaluation criteria and approaches to processing input data. For the system of indicators to evaluate a level of satisfaction of tourists with the trip, a set of criteria for tourist aspects is proposed, divided into groups $G_1; G_2; \ldots; G_l$. Each group of criteria consists of certain indicators: $G_1 = \left(K_{11}; K_{12}; \ldots; K_{1g_1}\right), G_2 = \left(K_{21}; K_{22}; \ldots; K_{2g_2}\right), \ldots, G_l = \left(K_{l1}; K_{l2}; \ldots; K_{lg_l}\right)$.

Each group of criteria represents some side of tourist aspects. Each criterion is some question about the expected and real experience, based on which the expert gives one of the judgments $L_h = \{L_{h1};\ L_{h2};\ L_{h3};\ L_{h4}\}$ regarding positive and negative tourist aspects in the destination. The questions and answers of experts for this task are as follows:

1. What POSITIVE aspects did you EXPECT/ASSUMED to experience in terms of some aspects of tourism?

Reply—L_{h1} ={Unexpected; Expected}.

2. What POSITIVE aspects did you EXPERIENCE in terms of some aspects of tourism?

Reply—L_{h2} ={Haven't experienced; Experienced}.

3. What NEGATIVE aspects did you EXPECT to experience in terms of some aspects of tourism?

Reply—L_{h3} ={Unexpected; Expected}.

4. What NEGATIVE aspects did you EXPERIENCE in terms of some aspects of tourism?

Reply—L_{h4} ={Haven't experienced; Experienced}.

The evaluation procedure assumes that the expert answers the questions on the proposed evaluation criteria in the context of the expected and positive and negative aspects of the trip, choosing the option closest to the truth.

To obtain a single estimate of the level of travel satisfaction relative to the expected and real experience of the participants in the tourist movement, it is necessary to carry out a fuzzy logical conclusion. For this purpose, it is proposed to use the intellectual analysis of knowledge, considering the logic of the psychological properties of an individual's behaviour. We see the logic in the fact that anticipation increases the motivational potential of an individual, which leads to an increase in purchasing power and helps to understand the consumer behaviour of regional tourism. And

vice versa, the discrepancy between expectations and real experience leads to a decrease in the desire to visit the destination again, the spread of negative reviews in the information space, and a decrease in the attraction of new consumers of tourist services.

All expert judgments are considered Boolean variables:

$$\lambda_{h1} = \{1\ if\ L_{h1} = \{Expected\}; 0\ if\ L_{h1} = \{Unexpected\}\};$$

$$\lambda_{h2} = \{1\ if\ L_{h2} = \{Experienced\}; 0\ if\ L_{h2} = \{Haven't\ experienced\}\};$$

$$\lambda_{h3} = \{1\ if\ L_{h3} = \{Expected\}; 0\ if\ L_{h3} = \{Unexpected\}\};$$

$$\lambda_{h4} = \{1\ if\ L_{h4} = \{Experienced\}; 0\ if\ L_{h4} = \{Haven't\ experienced\}\}.$$

Where is the score for the positive aspects relative to the expected experience—λ_{h1}, a λ_{h2} for real experience. The other two scores are for negative aspects, regarding expected experience and real experience, respectively $\lambda_{h3}, \lambda_{h4}$.

Next, the sum of the scored points is calculated separately by groups of criteria $G_1; G_2; \ldots; G_l$ according to the following formula:

$$Z_{hk} = \sum_{p=1}^{g_h} (\lambda_{hk})_{hp},\ h = \underline{1, l};\ k = \underline{1,4}. \quad (2)$$

Let levels be considered α, β, allowing us to consider the expected and real travel experience, considering positive and negative aspects.

The model was verified based on real data, which made it possible to formalize the determination of α, and β levels. For this, a system of logical statements is used—"If, Then, Else" with the values of the input variables $Z_{hk}, h = \underline{1, l};\ k = \underline{1,4}$, and one of the possible values of the α, and β levels, respectively. Moreover, significant discrepancies between the desired and have a negative effect on the possibility of repeated visits to the region by participants of the tourist movement. Based on the psychology of tourism consumers, we come to the following conclusion: differences in positive aspects give a higher initial assessment, and in negative aspects, on the contrary, they decrease. Further, we formalize this conclusion by building rules of belonging, based on experiments conducted on real data of evaluation of 2,343 respondents (Data from 2,343 participants, 2023b).

Therefore, for positive aspects, the α level is determined as follows:

$$\text{IF } Z_{h1} = Z_{h2} \text{ THEN } \alpha = 1, \text{ ELSE}$$

$$\text{IF } Z_{h1} < Z_{h2} \text{ THEN } \alpha \textit{ must be} < 1, \text{ ELSE}$$

$$\text{IF } Z_{h1} > Z_{h2} \textit{ THEN } \alpha \textit{ must be} > 1.$$

For negative aspects, the β level is determined as follows:

$$\text{IF } Z_{h3} = Z_{h4} \text{ THEN } \beta = 1, \text{ ELSE}$$

$$\text{IF } Z_{h3} < Z_{h4} \text{ THEN } \beta \textit{ should be much more 1,} \text{ ELSE}$$

$$\text{IF } Z_{h3} > Z_{h4} \text{ THEN } \beta \textit{ should be a little more 1.}$$

The coefficient β is always ≥1; its magnitude above 1 reflects a level of impact of negative aspects on the overall evaluation, with larger differences leading to higher β values. In contrast, α can be <1, =1, or >1, depending on the comparison of positive aspects.

Next, based on real experience regarding the satisfaction of the trip, considering the psychology of human reasoning, initial estimates are derived regarding the expected and actual. At the same time, the following logic is used. A participant in the tourist movement receives more disappointment from the trip if the real experience does not meet expectations in positive aspects. To derive a quantitative normalized assessment, within the criteria group, the following membership function is considered, considering the real experience of the participants of the tourist movement, and changing the direction of the goal for negative aspects:

$$\mu_h = \frac{1}{2} * \left(\left(\frac{Z_{h2}}{g_h} \right)^{\alpha} + \left(1 - \left(\frac{Z_{h4}}{g_h} \right)^{\beta} \right) \right). \quad (3)$$

Let DM know or be able to set weighting factors for each group of criteria $G_1; G_2; \ldots; G_l$ tourist aspects. The importance of the groups of criteria is explained by the fact that each of the tourist aspects has a different effect on predicting the behaviour of the participants of the tourist movement re-

garding the repeated visit to the region. The weighting coefficients are indicated $\{w_1; w_2; \ldots; w_l\}$, and they are normalized $[0, 1]$.

In the next step, to obtain the same level of travel satisfaction concerning various tourist aspects, a membership function is constructed as one of the proposed convolutions, for example, the average convolution will look like:

$$m_{3LT}(R) = \sum_{h=1}^{l} \quad w_h \cdot \mu_h; \tag{4}$$

As a result, a single level of travel satisfaction concerning various tourist aspects from the interval [0, 1] for some experts e in the region R. This assessment procedure is repeated for all participants of the tourist movement who visited the region R. As a result, based on a fuzzy method of evaluating the level of travel satisfaction relative to the expected and real experience of the participants of the tourist movement—M_{LT}, for region R, a set of satisfaction levels across all participants is obtained: $m_{LT}(R(e_1)), m_{LT}(R(e_2)), \ldots, m_{LT}\big(R(e_m)\big)$.

At the final step, one generalized value is calculated, based on the satisfaction levels of all participants of the tourist movement in the researched region R:

$$m_{SC}(R_j) = \frac{1}{m(R_j)} \sum_{i=1}^{m(R_j)} \quad m_{LT}(R(e_i)), j = \underline{1, n}. \tag{5}$$

Where $m(R_j)$—the number of participants in the tourist movement in a certain region R_j. The generalized value within the region $m_{SC}(R_j) \in [0, 1]$, characterizes the level of satisfaction with travel about various tourist aspects for all participants of the tourist movement in the studied region.

At the second stage of the model, the following fuzzy method is proposed for aggregating data on the level of satisfaction with various aspects of tourism and evaluating the level of tourist movement regarding infrastructure and accessibility M_{AS}.

Let some selected region R_j, $j = \underline{1, n}$ there is an expert level of tourist movement in terms of infrastructure and accessibility. This level value is indicated $m_{RC}(R_j) \in [0, 1]$, it determines the level of travel satisfaction with the expected and real experience about the infrastructure and availability of tourist movement in the region R_j. The greater the value of the assessment, the better the infrastructure, and external and internal accessibility, from the point of view of the participants of the tourist movement. Also,

this assessment can be evaluated through linguistic levels $L = \{H; AA; A; L; VL\}$ of tourist movement to infrastructure and accessibility, for example: high level—H (let's assume that $m_{RC}(R) \in (0.7, 1]$); above average level—AA ($m_{RC}(R) \in (0.5, 0.7]$); average level—A ($m_{RC}(R) \in (0.4, 0.5]$); low level—L ($m_{RC}(R) \in (0.2, 0.4]$); very low level—VL ($m_{RC}(R) \in [0, 0.2]$).

To aggregate data to each input value $(m_{SC}(R_j); m_{RC}(R_j)), j = \underline{1,n}$ is matched to the value of the membership function. For this, the following approach of intellectual analysis of knowledge based on multidimensional membership functions is used. Magnitudes $m_{SC}(R_j); m_{RC}(R_j),\ j = \underline{1,n}$ are characterized by the uncertainty of the "average value" type in the space of estimates [0. 1]. For this purpose, it is proposed to use a cone-shaped or pyramidal membership function in two-dimensional space. For example, a cone-shaped membership function will have the form:

$$m_{LT}(R_j) = \{1 - \lambda_j\ 0, otherwise., if\ \lambda_j < 1, \tag{6}$$

where $\lambda_j = \frac{1}{2} \cdot \sqrt{\left(m_{SC}(R_j) - 1\right)^2 + \left(m_{RC}(R_j) - 1\right)^2}$, and the center of the base of the cone is the unit vector (1;1), and we set the scaling according to the coordinates $(2; 2)$.

It is noted that the choice of the cone-shaped membership function, this approach was adopted as it enables two-dimensional modelling of interdependent criteria (infrastructure and accessibility), where both variables contribute simultaneously to the outcome. In contrast to more common triangular or Gaussian membership functions, typically applied in one-dimensional contexts, the cone-shaped function offers a geometrically intuitive representation of the "average value" in multidimensional space. Comparative experiments demonstrated that the cone-shaped function provides smoother aggregation and reduces distortions at boundary values, particularly when balancing infrastructure quality with accessibility.

At the final third stage, the predicted level of repeated visits to the region by participants of the tourist movement is derived, considering the expert level of popularization of regional tourism in the information space.

Designed for this M_{PL}—a fuzzy method of estimating the predicted level of repeated visits to the region by participants of the tourist movement.

Let DM, based on its knowledge and reasoning, establish the level of popularization of regional tourism in the information space, separately by R_j regions. For this, it is suggested to apply the following term-set of lin-

guistic variables, for example: $T = \{t_1;\ t_2; \ldots;\ t_f\}$. This set is presented in the form of triangular membership functions, which are divided into the numerical interval [0, 1]. To illustrate the algorithm, let us present three linguistic conclusions of DM regarding the level of popularization of regional tourism in the information space: t_1—low, t_2—average, t_3—high. Then the breakdown of linguistic variables on the numerical interval [0, 1] is as follows: $t_1 \in [0, a_2]$, $t_2 \in [a_1, a_3]$, $t_3 \in [a_2, 1]$. Let the variable be entered Δ_j, which makes it possible to adjust the assessment $m_{LT}(R_j)$ and the conclusion of the DM:

$$\Delta_j = (T_j; m_{LT}(R_j)) = \begin{cases} a_1 \cdot m_{LT}(R_j) & if \quad R_j \in t_1; \\ a_2 \cdot m_{LT}(R_j) & if \quad R_j \in t_2;, j = \overline{1, n}. \\ a_3 \cdot m_{LT}(R_j) & if \quad R_j \in t_3; \end{cases} \quad (7)$$

Therefore, the linguistic variables t_1, t_2, and t_3 represent low, average, and high levels of popularization, respectively. Their numerical intervals may partially overlap due to the use of triangular membership functions, allowing smooth transitions between levels and reflecting the fuzzy nature of the assessment.

In this case, the analytical form of the triangular membership functions will look like this:

$$\mu_j^{t_1} = \begin{cases} 0, & if \quad \Delta_j \leq 0, \\ \frac{\Delta_j}{a_1}, & if \quad 0 < \Delta_j \leq a_1, \\ \frac{a_2 - \Delta_j}{a_2 - a_1}, & if \quad a_1 < \Delta_j < a_2, \\ 0, & if \quad \Delta_j \geq a_2. \end{cases}; \quad (8)$$

$$\mu_j^{t_2} = \begin{cases} 0, & if \quad \Delta_j \leq a_1, \\ \frac{\Delta_j - a_1}{a_2 - a_1}, & if \quad a_1 < \Delta_j \leq a_2, \\ \frac{a_3 - \Delta_j}{a_3 - a_2}, & if \quad a_2 < \Delta_j < a_3, \\ 0, & if \quad \Delta_j \geq a_3. \end{cases}; \quad (9)$$

$$\mu_j^{t_3} = \begin{cases} 0, & if \quad \Delta_j \leq a_2, \\ \frac{\Delta_j - a_2}{a_3 - a_2}, & if \quad a_2 < \Delta_j \leq a_3, \\ \frac{1-\Delta_j}{1-a_3}, & if \quad a_3 < \Delta_j < 1, \\ 1, & if \quad \Delta_j \geq 1. \end{cases}; \tag{10}$$

Then the quantitative level, which indicates the potential opportunity to repeated visits the region and/or attract new consumers of tourist services, is the following:

$$m_{RV}(R_j) = \begin{cases} \mu_j^{t_1} & if \quad R_j \in t_1; \\ \mu_j^{t_2} & if \quad R_j \in t_2; \\ \mu_j^{t_3} & if \quad R_j \in t_3; \end{cases} \qquad j = \overline{1,n} \tag{11}$$

Next, the L_{RV} linguistic level is determined, which indicates the potential for repeated visits to the region and/or the attraction of new consumers of tourist services. For this, the received value $m_{RV}(R_j) \in [0,1]$ from the formula (11) is mapped to one term-set variable $L_{RV} = \{lrv_1, lrv_2, \ldots, lrv_5\}$ according to the following content: $m_{RV} \in (0.8, 1]$ – lrv_1 = "high potential possibility of repeated visits to the region by participants of the tourist movement"; $m_{RV} \in (0.6, 0.8]$ – lrv_2 = "the potential possibility of repeated visits to the region by participants of the tourist movement is above average"; $m_{RV} \in (0.4, 0.6]$ – lrv_3 = "the average potential possibility of repeated visits to the region by participants of the tourist movement"; $m_{RV} \in (0.2, 0.4]$ – lrv_4 = "low potential possibility of repeated visits to the region by participants of the tourist movement"; $m_{RV} \in [0, 0.2]$ – lrv_5 = "very low potential possibility of repeated visits to the region by participants of the tourist movement".

The presented fuzzy model of evaluation and derivation of the level regarding the possibility of repeated visits to the region by the participants of the tourist movement is developed in such a way that it does not depend on the number of evaluation criteria and regions. Finally, quantitative and linguistic levels are obtained, which indicate the potential possibility of repeated visits to the region and/or the attraction of new consumers of tourist services, based on which the consumer behaviour of regional tourism is predicted.

Results

Verification of the Fuzzy Model

The fuzzy model of assessment and level derivation regarding the possibility of repeated visits to the region by participants of the tourist movement was verified and tested on real data in the countries of the Visegrad Group (Czech Republic, Hungary, Poland, Slovakia) (Data from 2,343 participants, 2023a). For this, a research questionnaire containing 132 questions was created, which are aimed at studying attitudes towards selected areas related to tourism. The procedure for implementing data collection became possible thanks to the cooperation of various organizations. Data were collected from March to December 2021 from 2,343 respondents of the tourist movement from 2017 to 2021. The obtained data m*eet al*l the requirements for forming a sample of statistical data. The respondents covered the full set of elements of the studied issues and corresponded to the demographic characteristics.

Data and questionnaire characteristics

To provide a clearer understanding of the sample, descriptive statistics were calculated for the 2,343 respondents from the Visegrad Group countries. The dataset included a balanced representation of tourists across age, gender, and countries, with 51% female and 49% male participants. The respondents' ages ranged from 18 to 75 years, with a mean of 39.4 years (SD = 12.6). The distribution of respondents across countries was as follows: the Czech Republic—31.36%, Hungary—16.94%, Poland—10.88%, Slovakia—40.82%. The 132-question survey was grouped into 16 criterion clusters, with each cluster containing 5–10 indicators, providing both expected and real experience assessments. The descriptive statistics for key criteria groups (G_1—environment, nature, and weather; G_2—areas of shopping and business services at the destination; G_3—destination pricing) revealed that mean scores for positive experiences ranged from 0.81 to 0.95, while negative experiences were generally below 0.15. These statistics illustrate the overall trends in tourist satisfaction and serve as input for the fuzzy evaluation and level derivation models. The dataset is publicly available at (Data from 2,343 participants, 2023a).

Experiments were conducted based on the entire data set, using the developed fuzzy model of evaluation and level derivation of the possibility of repeated visits to the region by the participants of the tourist movement. The manuscript provides an example of the estimation of data fragments.

Step 1: Evaluation of Travel Satisfaction

The research questionnaire contained 132 questions, which were divided into 16 groups of criteria. An example of evaluating the predicted level of repeated visits to the region by participants of the tourist movement is given on three groups of criteria: G_1 – environment, nature, and weather; G_2—areas of shopping and business services at the destination; G_3—destination pricing.

Group of criteria G_1—these are tourist aspects regarding the environment, nature, and weather. It consists of the following indicators:

K_{11} – the landscape at the destination;

K_{12} – the level of crowding at the destination;
K_{13} – noise level at the destination;

K_{14} – the level of the natural environment, or vice versa, excessive development or commercialization in the destination;

K_{15} – favorable climate, weather, ambient temperature;

K_{16} – barrier-free level of visiting places.

The second group of criteria G_2—these are the tourism aspects of shopping and business services at the destination. This group of criteria includes the following:

K_{21} – the number of shops with souvenirs and gifts;

K_{22} – availability of shopping centers and department stores;

K_{23} – the frequency level of stores;

K_{24} – accessibility (barriers) to shops.

The third group of criteria G_3—are tourism aspects regarding destination pricing. This group of criteria includes the following items:

K_{31} – level of food price-quality ratio;

K_{32} – level of ratio of price and quality of housing;

K_{33} – level of price-quality ratio of services.

The expert needs to answer the question about the expected and real experience, about the positive and negative tourist aspects of the destination, choose the option that is close to the truth, and give one of the judgments $L_h = \{L_{h1};\ L_{h2};\ L_{h3};\ L_{h4}\}$.

For example, to illustrate the model, we will present the input data for some expert e_2 after traveling in 2020, the Karlovy Vary region of the Czech Republic (Data from 2,343 participants, 2023a), table 1.

At the first stage of the model, the level of travel satisfaction is evaluated to the expected and real experience of the participants of the tourist movement, using the proposed fuzzy method—M_{LT}.

Intellectual analysis of knowledge is employed and the logic of the psychological properties of an individual's behaviour is considered. We will consider all expert considerations in the form of Boolean variables. Next, the sum of scored points is calculated separately by groups of criteria according to the formula (2). The calculated results are given in the table 2.

Successively, a quantitative normalized assessment is derived within the criteria group, considering the real experience of the participants of the tourist movement using the membership functions according to formula (3). Let DM determine the value of the levels α, β as follows:

$$\text{IF } Z_{h1} = Z_{h2} \text{ THEN } \alpha = 1, \text{ ELSE}$$

$$\text{IF } Z_{h1} < Z_{h2} \text{ THEN } \alpha = \frac{3}{5}, \text{ ELSE}$$

$$\text{IF } Z_{h1} > Z_{h2}\ THEN\ \alpha = \frac{6}{5}.$$

$$\text{IF } Z_{h3} = Z_{h4} \text{ THEN } \beta = 1, \text{ ELSE}$$

$$\text{IF } Z_{h3} < Z_{h4} \text{ THEN } \beta = \frac{8}{5}, \text{ ELSE}$$

$$\text{IF } Z_{h3} > Z_{h4}\, THEN\, \beta = \frac{7}{5}.$$

$f_1(Z_{12}) = \frac{6}{6} = 1;\ f_1(Z_{12}) = \left(\frac{0}{6}\right)^{8/5} = 0;\ \mu_1 = \frac{1}{2} * \big(1 + (1-0)\big) = 1;\ f_2(Z_{22}) = \left(\frac{3}{4}\right)^{3/5} = 0.841;\ f_2(Z_{22}) = \left(\frac{1}{4}\right)^{8/5} = 0.109;\ \mu_2 = \frac{1}{2} * \big(0.841 + (1-0.109)\big) = 0.866;\ f_3(Z_{32}) = \left(\frac{3}{3}\right)^{3/5} = 1;\ f_3(Z_{32}) = \left(\frac{0}{3}\right)^{1} = 0;\ \mu_2 = \frac{1}{2} * \big(1 + (1-0)\big) = 1.$

Next, the decision-maker set the weighting coefficients for each group of criteria $G_1; G_2; G_3$ of tourist aspects as follows: $w_1 = 0.27$; $w_2 = 0.38$; $w_3 = 0.35$. These weights were assigned based on the DM's expertise and professional judgment regarding the relative importance of each group, reflecting their contribution to the overall travel satisfaction.

To obtain the same level of travel satisfaction concerning various tourist aspects, a membership function is built, for example, the DM chooses the average according to the formula (4): $m_{3LT}(R) = 0.27 \cdot 1 + 0.38 \cdot 0.866 + 0.35 \cdot 1 = 0.949$.

As a result, based on a fuzzy method of evaluating the level of travel satisfaction relative to the expected and real experience of the participants of the tourist movement—M_{LT}, for the Karlovy Vary region, we get a set of satisfaction levels for all participants. We will illustrate the result in the form of a column chart, fig.1.

In the final step, one generalized value is calculated based on the satisfaction levels for all 53 participants of the tourist movement in the Karlovy Vary region, according to the formula (5): $m_{SC}(Karlovy\ Vary) = 0.806$.

Step 2: Aggregation of Satisfaction and Tourist Movement

At the second stage of the model for aggregating data on the level of satisfaction with various aspects of tourism and evaluating the level of tourist movement regarding infrastructure and accessibility, we consider a fuzzy method M_{AS}.

For the Karlovy Vary region, we have an expert level of tourist movement in terms of infrastructure and accessibility $m_{RC}(Karlovy\ Vary) = 0.845$ from (Data from 2,343 participants, 2023b). The linguistic level of tourist

movement to infrastructure and accessibility is high ($m_{RC}(Karlovy\ Vary) \in (0.7, 1]$).

Next, to aggregate data on the level of satisfaction with various aspects of tourism and to evaluate the level of tourist movement to infrastructure and accessibility, the input value $(m_{SC}(Karlovy\ Vary); m_{RC}(Karlovy\ Vary))$ corresponds to the value of the two-dimensional cone-shaped membership function according to the formula (6): $m_{LT}(Karlovy\ Vary) = 1 - \frac{1}{2} \cdot \sqrt{(0.806-1)^2 + (0.845-1)^2} = 0.875$.

Step 3: Predicted level of repeated visits

In the final third stage, the predicted level of repeated visits to the region by participants of the tourist movement is derived, considering the expert level of popularization of regional tourism in the information space using a fuzzy method—M_{PL}.

Let DM, who are the authors of the article, based on their knowledge and reasoning, establish the level of popularization of regional tourism in the information space, as t_2 – average. Breakdown of linguistic variables on a numerical interval $[0, 1]$ the DM offers the following: $t_1 \in [0, 0.4]$, $t_2 \in [0.4, 0.8]$, $t_3 \in [0.6, 1]$. In the first step, the variable is calculated Δ according to formula (7), which will make it possible to adjust the estimate relative to the confidence of the DM regarding its assignment: $\Delta = \left(t_2; m_{LT}(Karlovy\ Vary)\right) = 0.6 \cdot 0.875 = 0.525$.

Then the quantitative level indicating the potential possibility of repeated visits to the region and/or attracting new consumers of tourist services is determined by the formula (11): $m_{RV}(Karlovy\ Vary) = 0.625$.

Next, the linguistic level is determined L_{RV}, which indicates the potential for repeated visits to the region and/or attraction of new consumers of tourism services: $m_{RV} \in (0.6, 0.8]$ – lrv_2 = "the potential possibility of repeated visits to the region by participants of the tourist movement is above average".

Similarly, it is possible to establish the possibility of repeated visits the region by participants of the tourist movement in all regions from the research questionnaire.

Discussion

Tourism has changed significantly during the COVID-19 pandemic, affecting repeated visits by tourists. Restrictions on international travel have led to an increase in the popularity of local tourism. The COVID-19 pandemic has had a significant impact on value added in national economies (Kostiuk, 2021; Okunola & Fakunle, 2021). Many people have given up long-distance travel and are choosing to vacation within their region, which in turn affects transport companies (Periokaite, 2021). Hotels, restaurants, and other establishments in the tourism industry are paying more attention to safety and hygiene standards to ensure the safety of tourists. Virtual tourism, which allows people to visit places through virtual tours and excursions without a physical presence, is growing in popularity. This raises the issue of implementing various labour activities remotely (Strakšienė, 2021). All this also affects the repeated visit of tourists to the destination.

In work, a fuzzy model of assessment and level derivation of the possibility of repeated visits to the region by participants of the tourist movement, using the example of the V4 countries, is developed. To this end, the following was developed: a fuzzy method of evaluating the level of travel satisfaction relative to the expected and actual experience of the participants of the tourist movement; a fuzzy method of aggregating satisfaction level assessments of various aspects of tourism and tourist movement about infrastructure and accessibility in the region; a fuzzy method of estimating the predicted level of repeated visits to the region by participants of the tourist movement; the research results were tested, and the developed model was verified on real data from 2,343 participants of the tourist movement for the regions of the V4 countries; an example of evaluation is illustrated on data fragments of the Karlovy Vary region on three groups of criteria — the environment, nature, and weather, areas of shopping and business services at the destination, pricing at the destination.

The study is based on the modern theory of fuzzy sets and fuzzy logic, which increases a level of validity of the final management decisions. The value of the model is that it takes into account expert assessments of positive and negative tourist aspects in the destination relative to the expected and real experience of the participants of the tourist movement; expert level of tourist movement regarding infrastructure and accessibility; expert level of popularization of regional tourism in the information space; all model settings are tested and verified on real data. The model based on the

satisfaction of tourists, as subjects of consumer behaviour, from the visitation of the region, a quantitative and linguistic level is derived, indicating the potential possibility of repeated visits to the region and/or the attraction of new consumers of tourist services, based on which the consumer behaviour of regional tourism is predicted.

The advantages of the fuzzy model stem from the fact that: the sets and groups of criteria of tourist aspects are open, the model does not depend on their number, so it is possible to study various problems of regional tourism development; the model makes it possible to understand the consumer behaviour of tourists through the prism of the level of satisfaction with the trip, the level of infrastructure and accessibility, the level of popularization of regional tourism in the information space; the model reveals the uncertainty of input expert evaluations using the fuzzy logic of psychological properties of an individual based on levels α, β, which allows taking into account the expected and real travel experience, taking into account positive and negative aspects; carries out the aggregation of data on the level of satisfaction of various aspects of tourism and the assessment of the level of tourist movement to infrastructure and accessibility; to derive the predicted level of repeated visits to the region by participants of the tourist movement, the model takes into account the expert level of popularization of regional tourism in the information space; all model settings are implemented and tested on real data; initial evaluations enable the DM to make informed decisions about regional tourism policies through the lens of tourists' consumer behaviour.

Comparative analysis showed that traditional statistical approaches (logistic regression, SEM) can identify only general trends, whereas the developed fuzzy model more effectively captures nonlinear discrepancies between expected and actual tourist experiences, providing higher interpretability and predictive stability across diverse respondent groups. Future research is planned to expand this analysis through systematic comparisons with other statistical and machine learning methods to quantitatively assess the incremental predictive value of the fuzzy approach.

To address the concern regarding the justification of fractional values assigned to the parameters α and β, we clarify that the choice of such ratios (e.g., 3/5, 6/5, 7/5, 8/5) is not arbitrary but results from a combination of empirical testing and calibration on the dataset of 2,343 respondents. These values emerged during the verification process as the most stable in reflecting discrepancies between expected and real tourist experiences. Specifical-

ly, sensitivity analysis was performed on alternative fractional values, and the reported ones demonstrated the best balance between model accuracy and interpretability. While the model is based on fuzzy logic principles, the fractional coefficients serve as normalization factors that adjust the impact of positive and negative mismatches in perception. Nonetheless, we recognize that a more rigorous psychometric validation, for instance through standardized satisfaction or expectation–confirmation scales, would further enhance the robustness of this step. Future research will therefore focus on extending the calibration procedure by including validated psychological measurement instruments and conducting additional cross-regional testing to refine these coefficients.

This study is subject to several important limitations. Although the dataset of 2,343 respondents is statistically sufficient, issues of representativeness remain, as the sample may not fully capture the heterogeneity of the tourist population across the V4 countries. In addition, the results presented are illustrated mainly for selected regions, which restricts the generalizability of the conclusions to the entire Visegrad Group.

These limitations are often mentioned in many research studies investigating process relationships in the tourism ecosystem, which geographical and socio-economic aspects also influence other types of limitations in, such as limited access to data, methodological, as well as comparative limitations (for instance, Antolini & Grassini, 2020; e Silva *et al*., 2018; Campos-Soria *et al*., 2021; Yang *et al*., 2018).

Another limitation concerns the use of different types of membership functions of one and many variables and their convolution in processing the results, which may introduce ambiguity in interpretation. Furthermore, the model's sensitivity to the weights assigned by the decision maker has not yet been systematically examined, potentially affecting the robustness of the predictions. Finally, while managerial implications for destination managers are acknowledged, they are not yet fully developed into concrete, practice-oriented recommendations. These limitations underline the need for future research to incorporate more diverse and representative cross-regional datasets, conduct sensitivity analyses, extend testing to other countries, and deepen the practical dimension of the findings.

Concerning managerial implications, the study highlights that the fuzzy model can serve as a decision-support tool for destination managers by enabling them to better understand discrepancies between tourists' expectations and actual experiences. Understanding these differences can in-

crease managers' knowledge and support the creation of innovation strategies and effective decision-making processes (Opewal *et al*., 2015). Insufficient innovation strategies lead to weaker innovation performance, which is a consequence of the insufficient use of KM. Similarly, duplicate and inefficient decisions, missing flexibility in responding to changing tourist needs (Jiang *et al*., 2019), as well as the loss of competitive advantage compared to smart destinations represent serious consequences of the insufficient use of KM (Mariani *et al*., 2021).

This knowledge can be applied to prioritize investments in infrastructure, service quality, and marketing strategies aimed at enhancing tourist satisfaction and loyalty. However, it should be acknowledged that the discussion of practical implications remains preliminary, and future research should translate the model's outputs into more detailed, practice-oriented guidelines tailored for destination management. This will enable creating destination knowledge platforms (shared databases, big data), supporting employee education in data literacy and digital intelligence, and preparing a collaborative culture within the tourism ecosystem (Liu *et al*., 2022) and for KM development.

The rationality of the obtained initial estimates m_{RV}, L_{RV} for making a decision on regional tourism policies through the prism of tourists' consumer behaviour proves the developed model's advantages. The reliability of the obtained results is ensured by the justified use of the theory of fuzzy sets and fuzzy logic.

In this way, the findings of this study provide answers to both research questions. Regarding the first question, tourists' satisfaction with infrastructure, accessibility, and online popularity can be systematically quantified through a fuzzy evaluation framework that integrates quantitative indicators with linguistic assessments, thus capturing both objective measures and subjective perceptions. Regarding the second question, the integration of satisfaction data, regional infrastructure, and digital visibility into a single fuzzy model has enhanced the predictive accuracy of repeated visits by better reflecting the complexity of tourist decision-making. Overall, the proposed approach advances knowledge management applications in tourism and provides practical value for regional tourism planning and destination competitiveness.

Conclusions

The implementation of smart tourism is a significant step in the development of information and communication technologies and brings new, high-level aspects to tourism systems. The emergence of this phenomenon relates to the digital revolution and constant innovation. Tourism has suffered from a lack of innovation for a long time. Destination revisit decisions offer scope for successful application of fuzzy approaches.

Fuzzy mathematics enables effective modelling of uncertainty in expert knowledge, which is often imprecise and expressed in natural language. It allows linguistic concepts to be mathematically represented, facilitating analysis and creating flexible, adaptive models. This demonstrates the effectiveness and necessity of using fuzzy mathematics in research based on expert knowledge.

This study involves a complex assessment system that cannot be addressed by conventional single-class approaches. The fuzzy model integrates multiple methods, using expert evaluation, fuzzy set theory, fuzzy logic, and intellectual analysis of knowledge to process respondents' data through membership functions.

KM has become one of the most discussed management concepts in the recent period, but empirical research and applications have yet to be recorded in tourism at the same level as in other sectors. This restricted insight into the dynamics of the KM processes in tourism and its determinants. There still needs to be more information on the specific knowledge required for effective management of tourism in the context of globalization, knowledge necessary for forecasting the business changes, the sector's effective management and its entities, and ensuring its sustainability and competitiveness.

The main goal of this research was to develop a fuzzy assessment model to estimate the likelihood of repeated visits to regions by participants of the tourist movement, exemplified by the V4 countries. The scientific hypothesis was confirmed, and the following key results were obtained: (1) a fuzzy method to aggregate satisfaction levels across tourism aspects using multidimensional membership functions; (2) a method to estimate predicted repeated visits, incorporating the DM's evaluation of regional tourism promotion; (3) a method to evaluate travel satisfaction relative to expected and actual experiences, verified on real data and formalized through α and β levels; (4) a fuzzy model predicting tourist behaviour regarding repeated

visits, tested on data from 2,343 respondents, with an example for the Karlovy Vary region based on three criteria groups: environment, services, and pricing.

Further research of the problem can be seen in the continuation of the development of other fuzzy models and methods of assessing the level of tourism in selected regions through the psychology of consumers, which will contribute to understanding the consumer behaviour of regional tourism. For the practical use of these mathematical approaches, all interested persons will develop web-based software, including tourists, businesses, and public authorities.

The study outcomes will be very beneficial for managers of destinations, local governments, creators of regional and national strategic development plans, and policymakers for creating effective KM strategies in the tourism industry. The effects of these KM strategies will be visible mainly in formulating active policies in the tourism industry, constructing effective private and public development marketing strategies, and forecasting tourism development in various destinations and time horizons.

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Compliance with ethical standards

This article does not contain any studies with human participants or animals performed by the authors. Extracting and inspecting publicly accessible files (scholarly sources) as evidence, before the research began no institutional ethics approval was required.

Data availability statement

All data generated or analyzed are included in the published article. The raw data supporting the conclusion of this article will be made available by the authors, without undue reservation. The raw anonymized data can be provided by emailing the primary author.

Author contributions

All listed authors have made a substantial, direct and intellectual contribution to the work, and approved it for publication. The authors take full responsibility for the accuracy and the integrity of the source analysis.

Conflict of interest statement

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Annex

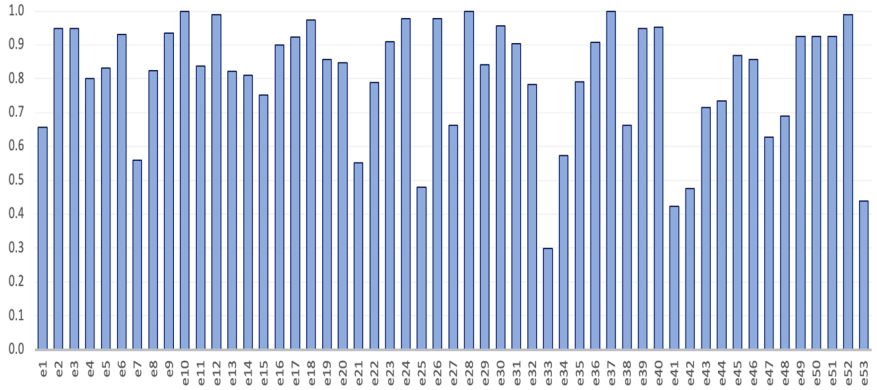
Table 1. Input expert data from the respondent e_2

Group of criteria	Criteria	Positive aspects		Negative aspects	
		Expected experience	**Real experience**	**Expected experience**	**Real experience**
G_1 – environment, nature, and weather	K_{11}	Expected	Experienced	Unexpected	Haven't experienced
	K_{12}	Expected	Experienced	Expected	Haven't experienced
	K_{13}	Expected	Experienced	Unexpected	Haven't experienced
	K_{14}	Expected	Experienced	Expected	Haven't experienced
	K_{15}	Expected	Experienced	Unexpected	Haven't experienced
	K_{16}	Expected	Experienced	Unexpected	Haven't experienced
G_2 – areas of shopping and business services at the destination	K_{21}	Expected	Experienced	Unexpected	Haven't experienced
	K_{22}	Unexpected	Haven't experienced	Unexpected	Experienced
	K_{23}	Unexpected	Experienced	Unexpected	Haven't experienced
	K_{24}	Expected	Experienced	Unexpected	Haven't experienced
G_l – destination pricing	K_{31}	Unexpected	Experienced	Unexpected	Haven't experienced
	K_{32}	Expected	Experienced	Unexpected	Haven't experienced
	K_{33}	Expected	Experienced	Unexpected	Haven't experienced

Table 2. The output of the sum of scored points

The amount of scored points	Positive aspects		Negative aspects	
	Expected experience	**Real experience**	**Expected experience**	**Real experience**
Z_1	6	6	2	0
Z_2	2	3	0	1
Z_3	2	3	0	0

Figure 1. A set of travel satisfaction levels relative to the expected and real experience for 53 participants of the tourist movement in the Karlovy Vary region



Appendix

Data availability

Data from 2,343 participants of the tourist movement to evaluate the predicted behavior of tourist movement participants in relation to repeated visits to the region in the countries Visegrad Group. 2023. https://docs.google.com/spreadsheets/d/1U6cqQvCj04XiZP_4m3pq-OL1BWnbBPIj/edit?usp=share_link&ouid=111497346858387909549&rtpof=true&sd=true (28.07.2025).

Data from 2,343 participants of the tourist movement to evaluation of the level of tourist movement to infrastructure and accessibility in the countries of the Visegrad Group. 2023. https://docs.google.com/spreadsheets/d/1_KMoYC5rzg2v4LcU3vi5F0_rs2cb-A7M/edit?usp=share_link&ouid=111497346858387909549&rtpof=true&sd=true (28.07.2025).