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FUZZY LOGIC APPROACH IN THE MODELING OF SUSTAINABLE TOURISM DEVELOPMENT MANAGEMENT

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Abstract: The paper proposes an economic and mathematics models of sustainable tourism development strategic management based on application of fuzzy algebra mathematical apparatus. The conducted research is built, starting from the formulation of strategic management of sustainable tourism development concept and ending with the creation of economic and mathematics models of decision support. A mathematical model that supports decision making in the evaluation of sustainable development of tourist and recreational areas was developed based on the use of mathematical apparatus of fuzzy inference. The model is built in Fuzzy Logic Toolbox environment of MATLAB and allows selecting strategic reference points for sustainable tourism development with the combination of the results of economic benefits with environmental and social indicators.

Key words: fuzzy algebra, sustainability, social indicators, tourism industry, fuzzy inference

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Introduction

Among the latest world trends in tourism development, the concept of sustainable tourism development occupies a special place. The need for the transition of the tourist sphere to the principles of sustainable development in the current conditions of globalization and the informatization of society is obvious. Practice shows that the uncontrolled growth of tourism, aiming at rapid profit making, often has negative consequences, as it damages the environment, to the local community and destroys the very foundation on which the functioning and successful development of tourism is maintained. The above listed data determine the growing relevance and relevance of modeling the management of sustainable development of the tourism industry.

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The problems of sustainable development are now at the center of attention of many foreign and domestic researchers. Sabden and Turginbayeva (2017) note that in the context of globalization of world markets for goods and services, when interdependence and interaction between various spheres of public life and activity increase, innovation is the basis for the qualitative transformation of production potential and sustainable development. Shaikh et al. (2017), in their research, consider the sustainable development of the financial system, according to which "*the sustainable development of the financial system*" means cooperation to promote the principles and reasonable methods of ensuring financial stability through the development of well-functioning financial systems and market discipline. The study of the sustainability of the development of tourist territories in general and the management of sustainable development of the tourism industry in particular, is considered in the works of Lordkipanidze et al. (2005), Fortuny et al. (2008), Buckley (2012), Angelevska-Najdeska and Rakicevik (2012), Logar (2010), Northcote and Macbeth (2006). Badulescu and Badulescu, (2017), in their study, consider the sustainable development of rural tourism through cross-border cooperation. Gretzel and Hardy (2019) consider the role of digital nomadism in the sustainable development of tourism and the promotion of innovation in technology services and tourism products. However, despite a large number of studies on this issue, currently there is no economically justified model for managing the sustainable development of the tourism industry, and the methodology for assessing the effectiveness of sustainable development of the industry has not been sufficiently studied. In this regard, there is a serious need to develop an economically efficient model for managing the sustainable development of the tourism industry. This study examines some comparative indicators for measuring the sustainable development of tourism using fuzzy sets. Accordingly, the aim of this study is, using fuzzy sets, to reduce the possibility of incorrect decisions that could be caused by inexact measurement of indicator or by impossibility to determine the indicator itself and to reduce the impact of subjectivity that exists in evaluation of comparative indicators. The proposed approach allows a more economical way, in comparison with other tools, to substantiate effective options for managing the sustainable development of tourism industry. However, it should be noted that the reasons for such a wide dissemination of these concepts are due not so much to their universality, as to the lack of a clear and unambiguous interpretation of their content, not to the development of sustainable concepts and the mechanism for quantitative measurement of the degree of sustainability of development. Modern economic science cannot yet determine the full impact of the integration processes at the global level. This is not due to the complexity of calculating the results of the integration and plurality eff ects in time and space (Ziyadin and Kabasheva, 2018).

Management in the tourism industry is a system of activities, the elements of which are various types of activities carried out by managing entities. International organizations propose different approaches to assessing the sustainable development of tourism. Let us dwell on some of them. In accordance with the recommendations of UNWTO (2004), universal indicators and indicators for special territories are proposed for the assessment of the sustainable development of tourist destinations. The indicators developed by the European Environment Agency in the work "Sustainable Tourism as a Cohesion Factor in the European Region" (CoR, 2018) are aimed at assessing the impact of the tourism sector and other key issues. The European Commission has established its own European Tourism Indicator System (ETIS), which is a tool for managing the sustainability of destinations and initially includes 27 basic and 40 additional indicators, combined into four blocks: management; social and cultural influence; economic value; impact on the environment (EC, 2018).

Results Discussion

Although extensive studies of fuzzy sets have been conducted In the past, less attention has been paid to its application in tourism. Because of its inherent advantages, recent tourism research is increasingly using fuzzy sets. Benitez et al. (2007) analyzed the quality of service of three hotels based on triangular fuzzy numbers. Hsu and Lin (2006) presented a fuzzy multi-criteria approach for measuring consumer perceived travel risk. Sanna et al. (2008) presented a ranking procedure based on qualitative and quantitative variables expressed as fuzzy numbers among various conservation projects that can be defined for an archaeological site in order to improve its cultural and tourist competitiveness. In order to determine the factors that influence tourists ' choice of destination, and to assess the preferences of tourists at destination, Hsu et al. (2009) proposed to convert descriptions and judgments expressed in linguistic terms into triangular fuzzy numbers before adopting the order preference method by similarity to the ideal solution (TOPSIS). The fuzzy multi-criteria decision-making model (FMCDM) for the selection of hotel locations by international tourists, in which language values are converted to triangular fuzzy numbers, was developed by Chou et al. (2008).

Methodology

Identify a comprehensive indicator of sustainable tourism development using the theory of desirability (Harrington functions)

The transition to sustainable development in its classical sense is possible provided that economic, social and environmental goals are met, and socio-economic systems of different rank are in accordance with three key criteria: 1) economic efficiency (cost recovery of incomes); 2) environmental sustainability (ensuring long-term viability of ecosystems); 3) social well-being (meeting equally cultural, material and spiritual needs of society). These criteria are very relevant for tourism, the development of which uses a large number of different types of resources; there is a significant impact on the territory and direct interaction with the local population.

The proposed comparative indicators for assessing the sustainability of the development of tourist destinations were made for the integration of economic, environmental, social and cultural factors, as well as assessing the satisfaction of tourists with the services offered. These factors were decisive in grouping indicators that measure sustainability (the intensity of sustainable development) of tourist destination. Based on this, comparable indicators for assessing the sustainability of tourism destination are divided into the following groups:

1. Group of indicators for evaluation of the economic state: shows the intensity of the economic impact of tourism business in the tourist place, destination or area.
2. Group of indicators for evaluation of social component: reflects the social integrity of the local community in terms of subjective well-being and benefits that tourism brings to local population.
3. Group of indicators for evaluation of the impact on cultural identity: express the level of preservation of cultural identity of local community under the influence of visitors who carry different cultural integrity.
4. Group of indicators for evaluation of environmental conditions: identify environmental conditions under the influence of tourism activities in the monitored area.
5. Group of indicators for measuring satisfaction of tourists: identify level of satisfaction of tourists that visit the destination as well as comments about the attractiveness of the destination (Jovicic, 2014).

Given that the selected indicators will have different dimensions and physical content, it is advisable to transform them into a dimensionless scale and identify a comprehensive indicator of sustainable tourism development using the theory of desirability (Harrington functions). The desirability scale has an interval from 0 to 1 and is conditionally divided into five intervals characterizing the dimensionless size of the indicators under study. The value of $d_t = 0$ corresponds to the absolutely unacceptable level of this property, and the value of $d_t = 1$ corresponds to the best value of the property.

Single key indicators of sustainable tourism development are grouped according to the spheres of their influence. Further, the reference values of single indicators are determined, and the closer the indicator to the reference value is, the higher will be the level of sustainable development of tourism. The reference values are determined for each indicator separately. This can be either normative values or values determined with the help of experts.

The assessment of the level of individual indicators of the socio-economic development of an enterprise in accordance with the theory of desirability is carried out by calculating the desirability indicators (d_i) using the formulas:

$$d_i = exp\ (-\ exp(-\ y_i)), \quad (1)$$

$$y_i = a_0 + a_1 P \quad (2)$$

where: d_i is the value of the i-th unit indicator on the desirability scale; y_i is an auxiliary indicator that reflects the dimensionless value of the i-th single indicator; x_i - the natural (calculated) value of the i-th indicator; a_0 and a_1 are coefficients that depend on the reference values of the indicator x_i, and are calculated separately for each y_i.
To calculate complex indicators for each sphere, it is necessary to determine the significance of each individual indicator in the complex on a scale from 0 to 1. Complex indicators of a separate component are determined by the formula:

$$I = \sum_{i=1}^{n} d_i \, a_i \quad (3)$$

where: I is a complex indicator of a separate sphere of influence; a_i - the weight of a single indicator.
To determine the complex indicator of the level of sustainable development of tourism, it is necessary to determine the significance of each component, which in sum should be one. An integrated indicator of sustainable tourism development is defined as the sum of components multiplied by the corresponding weight coefficients.

From Comparative Indicators to Fuzzy Number

A fuzzy set is defined by a function that assigns a membership degree to each unit. Membership degree indicates how much the unit is close, similar, or compatible with the concept expressed by the fuzzy set. Fuzzy numbers are convex and normalized fuzzy sets with a piecewise continuous membership function defined in R. In other words, the membership function that characterizes a fuzzy number is continuous, it maps an interval [a; b] to [0; 1], and it monotonically increases (D'Urso et al., 2016).
LR fuzzy number is general class of fuzzy number can be defined in a matrix form as follows (Dubois and Prade, 1998):

$$\tilde{X} = \{\tilde{x}_{ik} = (m_{ik}, l_{ik}, r_{ik})_{LR} : i = 1, \ldots, N;\ k = 1, \ldots, K\}, \quad (4)$$

where: $\tilde{x}_{ik} = (m_{ik}, l_{ik}, r_{ik})_{LR}$ denotes the LR fuzzy variable k observed on the ith unit; m_{ik} indicates the center, i.e. the "core" of the fuzzy number; l_{ik} and r_{ik} represent the left and right spread, i.e. the vagueness of the observation. A common LR fuzzy number is the triangular one, with the following membership function:

$$\mu_{\tilde{x}_{ik}}(u_{ik}) = \begin{cases} 1 - \frac{m_{ik} - u_{ik}}{l_{ik}} & u_{ik} \le m_{ik}\ (l_{ik} > 0) \\ & k \\ & l \\ 1 - \frac{u_{ik} - m_{ik}}{r_{ik}} & u_{ik} > m_{ik}\ (r_{ik} > 0) \end{cases} \quad (5)$$

Alternatively, a fuzzy number can be expressed as $(m_{ik} - l_{ik}, m_{ik}, m_{ik} + r_{ik})$, where $m_{ik} - l_{ik}$ and $m_{ik} + r_{ik}$ are the lower and upper bounds of the fuzzy number, respectively.
Notice that elicitation and specification of the membership functions are two important issues connected with the representation of natural language by means of fuzzy numbers. Following the subjectivistic approach to probability, also the

choice of the membership functions is subjective (Coppi et al., 2006). When dealing simultaneously with K variables, two approaches for the specification of the membership functions can be used: (a) the conjunctive approach and (b) the disjunctive approach. In this work we follow the disjunctive approach in which the interest focuses upon the "juxtaposition" of the K variables observed as a whole in the group of N objects. In this case, K membership functions are considered and the investigation of the links among the K fuzzy variables is carried out directly on the matrix of fuzzy data concerning the NK-variate observations (Coppi, 2003).

The Empirical Study

Let's say that we are considering a set of sustainable tourism development core indicators $In = \{In_1, In_2, In_3\}$, evaluated by the indicators system $F = \{F_1, F_2, \ldots, F_n\}$, some components of which $F_i \in F$, and perhaps all, are of a qualitative nature because of lack of knowledge. Fuzzy knowledge about these indicators are described by means of linguistic variables $< F_i, T(F_i), U_i, \mu_{F_i}$, where F_i is the name of the linguistic variable, $T(F_i) = \{A_1^i, A_2^i, \ldots, A_\alpha^i\}$ is a term set of the F_i variable represented by a set of fuzzy variables A_j^i, $i = \overline{1, \alpha}$ in the form of words describing the qualitative characteristics in the composition of a linguistic variable represents a fuzzy set; U_i is the universe containing all possible values of a fuzzy variable A_j^i; $\mu_{F_i} = \left\{\mu_{A_j^i}^{F_i}\right\}_{i=1}^{\alpha}$ is the set of membership functions $\mu_{A_j^i}^{F_i} : U_i \rightarrow [0, 1]$, which puts a real number $\mu_{A_j^i}^{F_i}(u) \in [0, 1]$ in correspondence to each element $u \in U_i$ and represents the semantics of fuzzy sets (Dyakonov et al., 2006). The terms $A_\varepsilon^i \in T(F_i)$, $i = \overline{1, k}$, $\varepsilon = \overline{1, \alpha}$, playing the role of qualitative characteristics of sustainable development, represent the fuzzy sets. When specifying the term set $T(F_i) = \{A_j^i\}_{j=1}^{\alpha}$ the following, atomic terms can be used: $T(F_i) =$ {Low, Medium, High}, where $A_1^i =$ «Low», $A_2^i =$ «Medium», $A_3^i =$ «High», or $T(F_j) =$ {«Does not match», «Not fully consistent», «Fully consistent»}, where $A_1^i =$ «Does not match», $A_2^i =$ «Not fully consistent», $A_3^i =$ «Fully consistent», etc.

Membership function $\mu_{A_j^i} : U_i \rightarrow [0,1]$ is assumed to specify explicitly in the form of functional dependencies. Analytical representation of functions $\mu_{A_j^i}$ is justified by the fact that, first, it greatly simplifies calculations when implementing

the fuzzy logic algorithm and second, these functions are implemented in many tools.
The evaluation of sustainable tourist and recreational areas development on the basis of qualitative indicators $F=\{F_1,F_2,...,F_k\}$, which are described by fuzzy sets $T(F_i)=\{A_1^i,A_2^i,...,A_\alpha^i\}$, is accomplished through the use of mathematical apparatus of fuzzy logic, involving the preparation of production rules set of fuzzy inference of the following form (Streltsova et al., 2016):

$$P_\Omega : if \ F_\varepsilon \ is \ A_i^\varepsilon \ and \ F_\varphi \ is \ A_j^\varphi \ then \ F_\beta is \ A_r^\beta . \quad (6)$$

The set of rules $\Omega=\overline{1,z}$ is determined by the problem to be solved. The result of fuzzy inference is the clear value of a variable F_β^ω based on the specified clear values of the variables $F_\varepsilon, F_\varphi, F_\lambda$. The logical inference mechanism consists of three stages: fuzzification (fuzzy assignment), the implementation of fuzzy inference production rules and defuzzification (conversion to HD).

Results and Discussion

The indicators set $\{F_i\}_{i=1}^k$ is decomposed into subsets of indicators of economic state influence; indicators of evaluation of tourism influence on social component; indicators of evaluation of influence on cultural identity; indicators of environment's condition; indicator of tourists' satisfaction. It is obvious that components of the indicators set are semi structured; therefore, they are described by linguistic variables. So, formally, F_1 is described by a linguistic variable $< F_1, T(F_1), U_1, \mu_{F_1} >$, $\mu_{F_1}=\left\{\mu_{A_i^1}\right\}_{i=1}^1$, $T(F_1)=A_1^1,A_2^1,...,A_3^1$, where A_i^1, $i=\overline{1,3}$, represent the terminal values. At the same, the atomic term A_1^1 means "does not match", A_2^1 means "not fully consistent", A_3^1 means "fully consistent".
The indicator F_2 is described by the linguistic variable $< F_2, T(F_2), U_2, \mu_{F_2} >$, $\mu_{F_2}=\left\{\mu_{A_i^2}\right\}_{i=1}^2$, where the term set $T(F_2)=A_1^2,A_2^2,...,A_3^2$, comprises the atomic terms, evaluating the level of tourism influence on social component in the following way: A_1^2 = "Low", A_2^2 = "Medium", A_3^2 = "High".
The indicator F_3 is formally described by a linguistic variable $< F_3, T(F_3), U_3, \mu_{F_3} >$, $\mu_{F_3}=\left\{\mu_{A_i^3}\right\}_{i=1}^3$. Its terminal set of atomic terms $T(F_3)=A_1^3,A_2^3,...,A_3^3$ consists of quality characteristics, evaluating the level of tourism influence on cultural identity as follows: A_1^3 = "Low", A_2^3 = "Medium", A_3^3 = "High".
The indicator F_4 is formally described by a linguistic variable $< F_4, T(F_4), U_4, \mu_{F_4} >$, $\mu_{F_4}=\left\{\mu_{A_i^4}\right\}_{i=1}^4$. Its terminal set of atomic terms $T(F_4)=$

$A_1^4, A_2^4, \dots, A_3^4$ consists of quality characteristics, evaluating the level of tourism influence on cultural identity as follows: $A_1^4 =$ "Low", $A_2^4 =$ "Medium", $A_3^4 =$ "High".

The indicator F_5 is formally described by a linguistic variable $< F_5, T(F_5), U_5, \mu_{F_5} >$, $\mu_{F_5} = \left\{\mu_{A_i^5}\right\}_{i=1}^{5}$. Its terminal set of atomic terms $T(F_5) = A_1^5, A_2^5, \dots, A_3^5$ consists of quality characteristics, evaluating the level of tourists' satisfaction as follows: $A_1^5 =$ "Low", $A_2^5 =$ "Medium", $A_3^5 =$ "High".

The level of sustainable tourism development $In_\delta \in In$ is also formally described by the linguistic variable $< sust, T(sust), U_{sust}, \mu_{F_{sust}} >$, $\mu_{F_{sust}} = \left\{\mu_{A_i^{sust}}\right\}_{i=1}^{3}$, where $T(F_{sust}) = A_1^{sust}, A_2^{sust}, A_3^{sust}$. The atomic terms $A_1^{sust}, A_2^{sust}, A_3^{sust}$ set the following levels of appeal in the terminal set $T(F_{sust})$: $A_1^{sust} =$ «Low», $A_2^{sust} =$ «Medium», $A_3^{sust} =$ «High».

According to limit values indicated in the Jovicic et al. (2014) research work, we can construct the fuzzy logic rules. Each input F_1, F_2, F_3, F_4, F_5 and output $priv$ variable complies with the membership function. $Sust$ is determined by fuzzy sets' results $F_1 \times F_2 \times F_3 \times F_4 \times F_5$.

$$\begin{aligned} Sust &= \{(S_oS_nS_a) \times (K_nK_pK_o) \times (L_nL_z)\} \times \{(U_mU_v) \times (T_nT_pT_o)\} \\ &\times \{(N_nN_pN_o) \times (R_nR_pR_o)\} \times \{(Q_nQ_pQ_o) \times (M_nM_pM_o) \times (B_nB_pB_o)\} \times \{(Z_nZ_aZ_v)\} \\ &= \left\{\begin{matrix} S_oK_nL_n, S_oK_pL_n, S_oK_oL_n, S_oK_nL_z, S_oK_pL_z, S_oK_oL_z, S_nK_nL_n, S_nK_pL_n, S_nK_oL_n, S_nK_nL_z, \\ S_nK_pL_z, S_nK_oL_z, S_aK_nL_n, S_aK_pL_n, S_aK_oL_n, S_aK_nL_z, S_aK_pL_z, S_aK_oL_z \end{matrix}\right\} \\ &\times \{T_nU_m, T_nU_v, T_pU_m, T_pU_v, T_oU_m, T_oU_v\} \\ &\times \{N_nR_n, N_nR_p, N_nR_o, N_pR_n, N_pR_p, N_pR_o, N_oR_n, N_oR_p, N_oR_o\} \\ &\times \left\{\begin{matrix} Q_nM_nB_n, Q_nM_pB_n, Q_nM_oB_n, Q_nM_nB_p, Q_nM_pB_p, Q_nM_oB_p, Q_nM_nB_o, Q_nM_pB_o, Q_nM_oB_o, \\ Q_pM_nB_n, Q_pM_pB_n, Q_pM_oB_n, Q_pM_nB_p, Q_pM_pB_p, Q_pM_oB_p, Q_pM_nB_o, Q_pM_pB_o, Q_pM_oB_o, \\ Q_oM_nB_n, Q_oM_pB_n, Q_oM_oB_n, Q_oM_nB_p, Q_oM_pB_p, Q_oM_oB_p, Q_oM_nB_o, Q_oM_pB_o, Q_oM_oB_o \end{matrix}\right\} \\ &\times \{Z_nZ_aZ_v\} \end{aligned} \quad (7)$$

In order to establish certain criteria according to which the condition will be described by an appropriate attribute representing an indistinct number, we use the fact that each attribute of the evaluated indicator describes the condition for the influence of the estimated indicator denoted by the fuzzy number (Table 1).

Therefore, for each of these attributes, we can join the function that characterizes it. A specific function for each attribute a_i:

$$\varphi: a_i \to \varphi(a_i) \in \begin{cases} 1, & positive\ condition\ of\ indicator \\ 0, & improved\ condition\ of\ indicator \\ -1 & negative\ condition\ of\ indicator \end{cases} \quad (8)$$

Table 1. Attributes of description of indicators' conditions that determine intensity of indicators effect of sustainable tourism development

Effects	Attribute / Evaluation indicator	Symbol	Possible condition of attribute $\varphi(a_i)$	Fuzzy logic rules	Characteristic attribute function $\varphi(a_i)$
Economic effects of tourism development (F_1)	Visit seasonality	S	S_o	0,5< (50 %<)	1
			S_p	0,4 - 0,5 (40 % - 50 %)	0
			S_n	<0,4 (<40 %)	-1
	Relation between number of tourist's overnights and accommodation facilities	K	K_o	0,43<	1
			K_p	0,33 - 0,43 (33 % - 43 %)	0
			K_n	<0,33	-1
	Coefficient of local tourist gain	L	L_z	has significant influence	1
			L_n	does not have any significant participation	-1
Social (F_2)	Participation of tourism in local people's employment	U	U_v	large	1
			U_m	small	-1
	The percentage of tourists that came without mediation of tourist agency	T	T_o	70%<	1
			T_p	50% - 70%	0
			T_n	<50%	-1
Cultural (F_3)	Relationship between accommodation capacity and number of local population	N	N_o	0,9<	1
			N_p	0,6 - 0,9	0
			N_n	<0,6	-1
	Intensity of tourism expressed in proportion of number of overnights and number of local population	R	R_o	0,9<	1
			R_p	0,6 - 0,9	0
			R_n	<0,6	-1
Environment condition (F_4)	Control of tourists' visits to protected area	Q	Q_o	20%<	1
			Q_p	10% - 20%	0
			Q_n	<10%	-1
	Intensity of realization of spatial plan for the needs of tourism development	M	M_o	20%<	1
			M_p	10% - 20%	0
			M_n	<10%	-1
	Management of PA's forest ecosystem	B	B_o	40%<	1
			B_p	30% - 40%	0
			B_n	<30%	-1
Tourist satisfaction (F_5)	Destination attractiveness	Z	Z_o	40%<	1
			Z_p	30% - 40%	0
			Z_n	<30%	-1

Let us define a function which will assign a value to each condition s from $S(sust)$, depending of individual value of attributes describing that very condition

s. Let us refer to that function as a "severity influence function" and denote it by $\tau(s)$. It is equal to sum of individual attributes that make observed condition:

$$\tau(s) = \sum_{i=1}^{n} \varphi(a_i) \quad (9)$$

where $\varphi(a_i)$ is a function of influence of individual attributes' condition, s is condition of influence of evaluated indicators, $s = (a_1, a_2, \ldots a_n)$ and ai are individual attributes (i = 1, 2, ..., n).

Studies of uncertainty in the management of tourism are beneficial and there are several reasons for this:

- Fuzzy sets ideally describe subject activity.
- Fuzzy numbers (kind of fuzzy sets) are ideal for planning factors in time when their future estimate is difficult (blurred, does not have sufficient probabilistic bases).
- It is possible within a single model to formalize both the features of a tourist object and the cognitive features of the manager and analyst subjects associated with this object.
- It is possible to return probabilistic descriptions to your scientific use, as probabilistic distributions with fuzzy parameters.

Conclusions

Tourism is a part of the region's economy. Depending on the region, special qualities of tourism can be the main source of income. Tourism has organized many jobs, improved regional infrastructure and the popularity of the region (Ziyadin et al., 2018). Measuring sustainable tourism development in comparative indicators, the classical method contains many inaccuracies caused by uncertainty within individual indicators, and solutions are the result of assessing the impact of individual indicators in a traditional way. The proposed model allows us to measure tourism in the field of sustainable development, which we can not use for accurate values of comparative indicators. New approach to the selection of strategic installations in the functioning of the tourism industry, that differs from the existing by the indicators set that integrate processes such as evolutionary and revolutionary development has been created. The problem of economic-mathematical modeling of in conditions of uncertainty caused by the qualitative nature of the values of the input and output parameters has been formally described. The economic-mathematical assessment model of sustainable development management strategy of the tourism industry, which describes verbally expressed expert knowledge of professionals when using the characteristics of a qualitative nature has been created, based on the application of fuzzy logic mathematical apparatus. A software performance of the economic-mathematical model created has been implemented by means of the Fuzzy Logic Toolbox block of the MATLAB system. In total, it can be said that tourism management is a combination of methods, principles, methods, managerial techniques, forms and means that contribute to the effective management of the tourism industry and personnel employed in the service sector of tourism activities. The main objectives of management in tourism are to achieve high efficiency in its fields, the best use of natural potential and quality and productive leadership of the sphere, which will bring a positive economic effect.

To conclude, it can be said in such a way that fuzzy logic methods can help in the management of tourism. In view of the above, the following conclusions can be drawn:

- Fuzzy management turns out to be particularly useful when technological processes in the management of the tourism industry are too complex to analyze using conventional quantitative methods, or when available sources of information are interpreted qualitatively, inaccurately, indefinitely.
- It is experimentally shown that fuzzy control gives better results than those obtained with conventional control algorithms. Fuzzy logic, on which fuzzy control is based, is closer in spirit to human thinking and natural languages than traditional logical systems. Fuzzy logic basically provides an efficient means of displaying the uncertainties and inaccuracies of the real world.

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PODEJŚCIE ROZMYTE W MODELOWANIU ZARZĄDZANIA ROZWOJEM ZRÓWNOWAŻONEJ TURYSTYKI

Streszczenie: W artykule zaproponowano ekonomiczne i matematyczne modele strategicznego zarządzania rozwojem zrównoważonej turystyki oparte na zastosowaniu aparatu matematycznego algebry rozmytej. Przeprowadzone badania zbudowane zostały począwszy od sformułowania strategicznego zarządzania koncepcją zrównoważonego rozwoju turystyki, a skończywszy na tworzeniu ekonomicznych i matematycznych modeli wspomagania decyzji. Opracowano model matematyczny wspierający podejmowanie decyzji w zakresie oceny zrównoważonego rozwoju terenów turystycznych i rekreacyjnych w oparciu o zastosowanie aparatu matematycznego wnioskowania rozmytego. Model został zbudowany w środowisku Fuzzy Logic Toolbox w MATLAB i pozwala na wybór strategicznych punktów odniesienia dla zrównoważonego rozwoju turystyki dzięki

połączeniu wyników korzyści ekonomicznych ze wskaźnikami środowiskowymi i społecznymi.
Słowa kluczowe: algebra rozmyta, trwałość, wskaźniki społeczne, przemysł turystyczny, wnioskowanie rozmyte

可持续旅游开发管理模型的模糊逻辑方法

摘要：数学代数数学装置。在经济发展领域进行研究和开发。模糊推理的数学模型。该模型建立在MATLAB的Fuzzy Logic Toolbox环境中。
关键词：模糊代数，可持续性，社会指标，旅游业，模糊推理。