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Multi-Criteria Decision Framework to Support Managerial Choices in IT-Enabled Waste Reduction and Sustainability in Tourism

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Abstract

Sustainable tourism is a necessity to preserve natural habitats, thus presenting a vital part of achieving sustainable development. This work aims to address a business decision problem related to the conservation of natural resources and the protection of habitats through waste management and IT applications in the hotel sector in Serbia. Tourism in Serbia presents a sensitive issue regarding the balance between the economy and ecology. Thus, the multi-criteria optimisation method of Analytic Hierarchy Process (AHP) and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), can help to tackle this problem. To achieve this goal, a hierarchical model was developed that considers nine criteria and four alternatives. The alternatives considered are: service user satisfaction, service cost, waste minimisation, and service quality. The developed model was analysed to select the best alternative using AHP and TOPSIS as a hybrid approach. The analysis shows that (environmental) waste prevention ranks first among all considered alternatives and plays an important role in the development of sustainable tourism in Serbia.

Keywords: AHP method; IT tools; multi-criteria analysis; TOPSIS method; sustainable tourism

1. Introduction

Tourism, one of the largest employers in the world, is considered the largest and fastest-growing branch. Further, due to climate change, pollution, and the increasing amount of waste, tourism has experienced a significant change in recent years [1]. Undoubtedly, the economy benefits from tourism. However, it can now be seen as a double-edged sword in terms of its deteriorating impact on the natural resources that cannot be quickly renewed [2]. Serbia, as a candidate for EU membership, is obligated to adhere to guidelines related to sustainable development. First and foremost, there is the EU Sustainable Development Strategy, developed by the European Council, which is a key document. Within this document, guidelines are provided for the development of policies and practices aimed at sustainability and EU integration. Also, some of the most relevant documents for sustainable tourism include the Eco-Tourism Declaration (2002), the Declaration on Climate Change and Tourism (Davos Declaration), and the Agenda for Sustainable and Competitive European Tourism (2007) [3]. To achieve set goals, Serbia needs to adjust policies and management in the tourism sector towards sustainable tourism. Sustainable tourism, as opposed to mass tourism, minimizes the negative effects of a growing industry [4]. Sustainable hospitality counters the benefits of hospitality in economic and environmental aspects. Also, satisfaction in regard to sustainability in tourism services includes local and environmentally preferable purchasing, energy conservation,

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water conservation, greenhouse gas emissions control, transportation minimization, harmful substances, pollution minimization, biodiversity conservation, and local food [5]. Therefore, the dynamic development implies the inclusion of tourism under this concept of Circular Economy (CE) and Bioeconomy (BE), and Technological innovations (TI). Linked with consumption, production, and transportation sectors, tourism leads to the unregulated growth of solid waste and CO2 footprint, focusing on the causal linkages to natural resource rent. Priorities of BE are to decrease food waste and to achieve efficient biomass conversion. It has been noticed that with tourists' arrivals, there is a significant increase in CO2 emissions, a serious environmental pollutant (CO2) proven negative effects on tourism itself. In the long run and in the short run, a 1% increase in tourism influence increases CO2 emissions metric tons per capita by 0.26% and 0.045% respectively [6]. Ecological footprint affects sustainable development by a more inclusive measure than CO2 emissions for targeting the influence of climate change and biodiversity productivity loss [7,8]. Sharing the same objectives, decrees of CO2 emission, although with different approaches, BE and CE aim to replace fossil carbon with renewable biomass. Therefore, one can conclude that BE goes beyond the general objectives of the circular economy. Also, there is a strong link between environmental protection and Information technologies. The inevitable Industry 4.0, considered as one of the major trends in sustainability, automatically merges monitoring of environmental degradation. For instance, among plethora of tools offered by Industry 4.0, automation and big data has been used to control water, air and soil quality [9], industrial sharing linked to environmental innovations [10]. Therefore Industry 4.0 provides a environmental sustainability, while policies and regulation of sustainability can be seen as a backbone of Industry 4.0 [11]. That is to say, there is no progress in BE and CE application without IND 4, 0 support to overcome the obstacles on this path to sustainability. The new concept of tourism in the EU includes sustainable development, ecotourism, and digitalization (Table 1).

Table 1. Concept of tourism.

	Selected countries			
	Croatia and Greece	Croatia, Germany, Austria, and Slovenia	Ireland, Finland and Portugal	Western Balkans
Sustainable tourism	✓	✓	✓	✓
Ecotourism/green tourism		✓	✓	
Policy and Governance Excellence	✓			
Application of IT in tourism (digitalization)		✓		✓

The EU has a clear path to sustainability. Sustainability is an imperative to achieve well-being, bring changes in all sectors of the economy and society. One of many areas that undergoes transition is tourism. Sustainable innovations involve reducing reliance on raw materials and optimizing energy and resource consumption in terms of green innovation, environmental innovation, and eco innovation [12]. Further, digital technologies play a crucial role in driving change within the tourism and hospitality industry, improving their accessibility and sustainability [13]. These transitions include forward-looking tourism ecosystem capacity to get greener and more digital [14]. The members of the Tourism Advisory Board [15] are tasked with identifying best practices in tourism across the 27 EU Member States. Contribution to European Green Deal strategies and climate targets includes benchmarks such as green and digital transitions, resilience, and skill development within tourism trends and policies [15]. Thus, Croatia and Greece are recognized as members with Policy and Governance Excellence. Ireland, Finland, and Portugal stand out for their successful green transition. Also, these countries are leaders in Skills Development and Transition Support. Digitalisation, although introduced in almost all member states, Croatia and Germany stand out.

Strengthening resilience refers to economic, ecological, and sociocultural changes that are effectively evaluated for feedback and converted into adaptive responses. Further, digitalisation is an asset in Strengthening Resilience in tourism. These improvements, which lead to sustainable tourism, are highly visible in Austria and Slovenia [15]. A good example of sustainable tourism is Geopark Karawanken (Austria / Slovenia). The Geopark region is known for a sustainable cross-border network and mobile app known as the 'Geopark Guide', with trilingual animation clips and a collaborative tourist web. The Western Balkan Tourism Industry undergoes a transition towards sustainable tourism, but at a slower pace compared to EU countries. The City of Trebinje is encouraging investors to invest in sports and congress infrastructure, which has successfully reduced the number of tourists in the summer months. Additionally, projects with the UNDP and USAID have contributed to the development of new domestic tourism products, aiming to stimulate the bioeconomy and sustainable tourism in Bosnia and Herzegovina [16]. However, we cannot talk about digitalisation or ecotourism in full capacity. The Western Balkans region, which includes countries such as Albania, Bosnia and Herzegovina, Croatia, Kosovo, Montenegro, North Macedonia, and Serbia, are characterized by natural beauty and cultural heritage. Thus, it can be seen as a place for sustainable tourism. However, due to the economic situation, the main obstacle to achieving sustainability is a balance between economic development and environmental protection [17]. Although the idea of sustainable tourism development cannot be completely applied in practice, green orientation in tourism is present in National strategies adopted by each country [18].

Learned from the COVID-19 pandemic, information technology has been a key driver in education, the economy, production, and the environmental field, among others. As an efficient tool, IT provides benefits in everyday life, including online teaching, work, shopping, passenger screening, and enhancing customer experiences [19]. Moreover, from 2019 to 2022, due to Covid 19 pandemic, the world experienced the greatest hit on the global economy and social life, repetitive lockdowns, travel bans, uncertainty, and challenges to decision makers in every industrial sector [20,21]. This period brought technological innovations, environmental protection, ecosystem preservation, and sustainable tourism [22]. The application of new technologies in tourism has enabled the emergence of the concept of smart tourism. Modern travel booking and planning platforms, such as Booking.com, Expedia, TripAdvisor, and Airbnb [23,24] have transformed the way tourists organize their trips. Global Distribution Systems (GDS) provide travel agencies with access to a large amount of data about available services. Pan (2023) [25], in an encyclopedic article from the Encyclopedia of Tourism (Springer), describes in detail the evolution of GDS systems: from CRS systems in the 1960s, through the emergence of Sabre, Galileo, Amadeus, and through development through the Internet into a special category of digital platforms, which made them the standard in the tourism industry. Customer relationship management (CRM) systems allow travel companies to analyze consumer behavior, personalize offerings, and create targeted marketing campaigns.

Big data analytics and predictive modeling applications in marketing and operational strategies have been proven in several studies [26,27]. Augmented (AR) and virtual reality (VR) technologies allow potential tourists to experience a destination before they travel, increasing the likelihood of a visit. [28]. The Internet of Things (IoT) is being used in hotels, airports, and smart cities, improving the comfort, safety, and efficiency of tourism services [29].

In the context of sustainable development, IT technologies enable the collection and analysis of data on energy consumption, waste, and CO_2 emissions, thereby encouraging environmental awareness and responsible behavior of tourists. [30]. The use of artificial intelligence (AI), machine learning (ML), and blockchain technology offers personalization, service automation (e.g., via chatbots), and review analysis [31]. Cloud computing provides a flexible and efficient IT infrastructure for tourism organizations, while systems such as the Tourism Cloud Management System (TCMS) represent a concrete application in smart tourism. Blockchain technology is being explored as a means to ensure transparent transactions, luggage tracking, and identity verification. [32].

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Modern concepts of integrated systems, such as a smart tourism ecosystem that combines IoT, AI, and Big Data [33], represent the future in the development of smart tourism destinations. The frameworks of such destinations include platforms that enable personalized, sustainable, and technologically advanced tourism experiences [29].

The integration of these technologies not only enhances the tourist experience but also supports the development of efficient, responsible, and inclusive tourism in accordance with the principles of sustainability. This study presents a framework to evaluate and prioritize key criteria(influence) on sustainable tourism within a tourism sector in Serbia, integrating the Analytic Hierarchy Process (AHP) method and TOPSIS, a multi-criteria decision-making method. The research provides a comprehensive approach essential to green tourism management planning.

2. Materials and Methods

In this study, a decision-making approach combining the Analytic Hierarchy Process (AHP) and the TOPSIS method was applied in order to ensure a comprehensive and reliable evaluation of the considered alternatives. The AHP method is used to determine the relative weights of the criteria, as it enables the integration of quantitative and qualitative parameters through a hierarchical structure and pairwise comparisons. Subsequently, the TOPSIS method is applied to rank the alternatives. The combined application of the AHP and TOPSIS methods enables a more reliable and transparent decision-making process.

The respondents in the paper represent users of hotel services with diverse demographic and educational characteristics, which ensured a heterogeneous sample. Data were collected using a questionnaire that included information on the socio-demographic characteristics of the respondents, their attitudes toward the application of information technologies in the hotel industry, as well as their perceptions of the importance of environmental protection and waste management. Although the sample size is adequate for conducting multi-criteria analysis, the obtained results should be interpreted within the regional context of Serbia and the Western Balkans.

2.1. AHP (Analytic Hierarchy Process) METHOD

The Analytic Hierarchy Process (AHP) is a mathematical method that was developed in the 1970s and is one of the best-known methods of scenario analysis and decision-making through the consistent evaluation of hierarchies. The method is based on the principles of multi-criteria decision making, in which the most favorable alternative is selected from an available group of alternatives on the basis of the decision criteria. The conceptual and mathematical framework of the AHP was created by Thomas Saaty. A hierarchically structured decision model generally consists of objectives, criteria, sub-criteria, and alternatives. The objective is at the top and is not comparable with any of the other elements. At the first level, there are n criteria, which are compared in pairs with each other in relation to the immediately superior element at a higher level. The AHP method is carried out in several steps.

The first step involves defining a matrix of comparison pairs. Data generation implies that the decision maker assigns relative scores to attribute pairs at all levels of the hierarchy except zero (the target is not compared). The well-known nine-point scale (Saaty scale) is used [34].

Table 2. Saaty Scale of Relative Importance.

Scale of Importance for Pairwise Comparisons	Numeric Rating
Extreme Importance	9
Very Strong Importance	7
Strong Importance	5
Moderate Importance	3
Equal Importance	1

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The results of the comparison of elements at a certain hierarchy level are entered in the corresponding comparison matrices A= $[a_{ij}]_{nxn}$. The reciprocal value of the comparison result is placed in the corresponding position, $a_{ji} = 1/a_{ij}$ To maintain the consistency of the argumentation. The weights of the criteria and/or alternatives are to be determined by evaluating their coefficients. The relative importance matrix A is formed from these relative importance coefficients.

$$A = [a_{ij}] = \begin{bmatrix} 1 & a_{12} & \dots a_{1n} \\ 1/a_{12} & 1 & \dots a_{2n} \\ \vdots & \vdots & \\ 1/a_{1n} & 1/a_{2n} & \dots 1 \end{bmatrix} \quad (1)$$

The second step consists of the matrix normalization of the comparison pairs. It is necessary to calculate the weights of the criteria by the geometric mean of the elements of each row of the matrix and thus normalize the matrix of comparison pairs.

$$\bar{a}_{ij} = \frac{a_{ij}}{\sum_i a_{ij}} \quad (2)$$

$$w_i = \left(\Pi_{j=1}^{n} \bar{a}_{ij}\right)^{\frac{1}{n}} \quad (3)$$

In the third step, we develop the value λ_{max}. If the matrix A contains inconsistent estimates (in practical examples this is almost always the case), it is necessary to calculate the value λ_{max}, which should be equal to the number of factors in the comparison n to achieve complete consistency.

$$\lambda_{max} = \sum_{i=1}^{n}\left(\sum_{i=1}^{n} a_{ij}\right) w_j \quad (4)$$

In the fourth step the consistency index, as a measure of deviation n from λ_{max}., has been calculated.

$$CI = \frac{\lambda_{max} - n}{n-1}, \quad (5)$$

Then, the next step includes the degree of consistency, calculated as the quotient of the consistency index and the random index, RI, (Random Index):

$$CR = \frac{CI}{RI} < 0.1 \sim 10\%. \quad (6)$$

The random index (RI) depends on the row of the matrix, as can be seen in Table 3, where the first row represents the row of the comparison matrix, and the second the random indices.

Table 3. Random Index.

No. of Criteria	1	2	3	4	5	6	7	8	9
R. I.	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45

The random index (RI) depends on the order of the matrix. If the degree of consistency (CR) is less than 0.10, the result is sufficiently accurate and no corrections are necessary when comparing and repeating calculations. If the degree of consistency is greater than 0.10, the results should be analysed again and the reasons for the inconsistency determined.

2.2. TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) METHOD

TOPSIS is a multi-criteria decision-making method/technique first developed by Ching – Lai Hwang and Kwangsun Yoon [35]. In this method, the alternatives are determined according to their distance from the ideal solution. In the literature, the TOPSIS method is often defined as: "The basic principle according to which the selected alternative should have the smallest distance from the positive ideal solution and the greatest distance from the negative ideal solution" [36]. It is a method/technique for ranking preferences according to their similarity to the ideal solution.

TOPSIS is a compensatory method. Such methods enable a compromise between different criteria, whereby a poor result for one criterion can be compensated for by a good result for another criterion. The TOPSIS method assumes that each criterion has either a monotonically increasing or decreasing advantage [37]. Due to the possibility of modeling criteria, compensatory methods, especially TOPSIS, are widely used in various areas of multi-criteria decision making [38–40].

The TOPSIS algorithm/procedure consists of five steps [G]. Firstly, it should be the initial matrix created. A matrixA_{ij}, is according to form (7), where the columns of the matrix n represent the criteria (C), and the rows of the matrix m alternatives (A).

$$A_{ij} = \begin{bmatrix} a_{11} & a_{12} & \dots a_{1n} \\ a_{21} & a_{22} & \dots a_{2n} \\ \vdots & \vdots & \vdots \\ a_{m1} & a_{m2} & \dots a_{mn} \end{bmatrix} \quad (7)$$

The second, the normalized matrix is created, with the matrix elements A_{ij} according to equation (8).

$$r_{ij} = \frac{a_{ij}}{\sqrt{\sum_{i=1}^{m} a_{ij}^2}} \quad (8)$$

$$R_{ij} = \begin{bmatrix} r_{11} & r_{12} & \dots r_{1n} \\ r_{21} & r_{22} & \dots r_{2n} \\ \vdots & \vdots & \vdots \\ r_{m1} & r_{m2} & \dots r_{mn} \end{bmatrix} \quad (9)$$

The third step is creation of a normalized weight matrix. The weight-normalized decision matrix is defined using equation (10).

$$v_{ij} = w_{ij} \cdot r_{ij} \quad (10)$$

In the fourth step positive and negative ideal solutions are determined. The value of the positive ideal solution (A^{+}) and the value of the negative ideal solution (A^{-}) is determined using the value of the normalized weight matrix v_{ij}. A^{+} shows a better result than A^{-}. The value of the positive ideal solution (A^{+}) and the value of the negative ideal solution (A^{-}) are determined according to patterns (11) and (12).

$$A^{+} = \{v_i^{+}, \dots, v_n^{+}\} = \left\{\left(\max_i v_{ij}, j \in j\right)\left(\min_i v_{ij}, j \in j'\right)\right\} \quad (11)$$

$$A^{-} = \{v_i^{-}, \dots, v_n^{-}\} = \left\{\left(\min_i v_{ij}, j \in j\right)\left(\max_i v_{ij}, j \in j'\right)\right\} \quad (12)$$

In the previous forms (11) and (12), j belongs to the criteria that are maximized, i.e., it refers to the utility criterion, and j' belongs to the criteria that is minimized, that is, it is related to the cost criterion.

Step five determines the distance of the alternatives from the positive ideal solution and the negative ideal solution. The distance from the positive ideal solution (S_i^{+}) and the distance from the negative ideal solution (S_i^{-}) for each alternative according to the given criterion is determined according to equations (13) and (14).

$$S_i^{+} = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^{+}\right)^2} \quad (13)$$

$$S_i^{-} = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^{-}\right)^2} \quad (14)$$

Finally, the coefficient of relative closeness to the ideal solution is determined. The coefficient of relative closeness (RC_i^{+}) to the positive ideal solution can be calculated using equation (15).

$$RC_i^{+} = \frac{S_i^{-}}{S_i^{+} + S_i^{-}} \quad (15)$$

The index value RC_i^{+} is between 0 and 1. The higher the value of the index, the better the performance of the alternative.

3. Results and Discussion

This research aims to identify the criteria with the biggest influence on sustainable tourism, thus improving hotel services, and the best transition path to green marketing in Serbia. The ranking of alternatives that significantly affect services and marketing in the hotel industry is shown in Table 4.

Table 4. Alternatives to hotel services and hotel marketing.

No	Alternatives
A1	Quality of services
A2	Cost of services
A3	Waste minimisation

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A4	Satisfaction of service users

9 criteria and 27 sub-criteria were included in the analysis of the choice of the most favorable alternative, and the influential criteria are listed in Table 5.

Table 5. Criteria of hotel services and hotel marketing.

No.	Criteria
C1	Gender
C2	Age
C3	Professional qualification
C4	Costs for the use of IT in the hotel industry
	Attitude towards the use of IT in the hotel industry
C6	Business costs of using IT to secure hotel operations
C7	Relationship IT applications in the hotel industry—waste management
C8	The importance of IT in protecting the environment
	Reducing the carbon footprint through the use of IT

For each of the 9 criteria listed, Table 6 lists the sub-criterion that was considered in the impact of IT implementation in the provision of hotel services and hotel marketing in Serbia.

Table 6. Sub-criteria of hotel services and hotel marketing.

Criterion	Sub-criterion	Designation
C1	Male	M
C1	Female	F
C2	20-30	A
C2	31-45	B
C2	46-50	C
C2	>50	D
C3	SSS	1
C3	VSS	2
C3	MAS	3
C4	<100	€
C4	101-500	€
C4	501-1000	€
C4	1001-2000	€
C4	>2000	€
C5	I do not agree at all	I
C5	I partially disagree	II
C5	I have no opinion	III
C5	I partly agree	IV
C5	I completely agree	V
C6	Yes	
C6	No	
C7	Yes	
C7	No	
C8	Yes	
C8	No	
C9	Yes	
C9	No	

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The data available for the creation of the optimization model were collected on the basis of a questionnaire comprising 109 respondents from the Western Balkans. Part of the questionnaire for 5 respondents is shown in Table 7.

Table 7. Questionnaire with the criteria of the optimization model.

C1	C2	C3	C4	C5	C6	C7	C8	C9
M	B	2	1001-2000	V	Yes	No	Yes	No
F	B	3	<100	V	No	No	Yes	No
F	B	1	1001-2000	V	Yes	No	Yes	No
F	B	2	1001-2000	IV	Yes	Yes	Yes	No
F	A	3	501-1000	IV	Yes	Yes	Yes	No

For the data analysis, a matrix of the relative importance of the criteria that make up the optimization model was created. The data analysis was carried out using the AHP method, i.e. the values in Table 8 were determined using the AHP model by comparing the criteria in pairs and scoring them according to the Satie scale.

Table 8. Matrix of relative importance of hotel services and hotel marketing criteria.

Criteria	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**
C1	1.000	0.333	0.167	0.111	0.111	0.500	0.125	0.167	0.500
C2	3.000	1.000	0.500	0.333	0.333	2.000	0.500	0.500	2.000
C3	6.000	2.000	1.000	1.000	1.000	2.000	1.000	1.000	2.000
C4	9.000	3.000	1.000	1.000	1.000	2.000	1.000	1.000	4.000
C5	9.000	3.000	1.000	1.000	1.000	3.000	1.000	2.000	4.000
C6	2.000	0.500	0.500	0.500	0.333	1.000	0.333	0.500	1.000
C7	8.000	2.000	1.000	1.000	1.000	3.000	1.000	1.000	4.000
C8	6.000	2.000	1.000	1.000	0.500	2.000	1.000	1.000	3.000
C9	2.000	0.500	0.500	0.250	0.250	1.000	0.250	0.333	1.000

Expert Choice was used as a decision-making tool for the implementation and processing of survey data. The importance attached to the individual criteria is shown in Table 9.

Table 9. Weighting of the criteria for hotel service and hotel marketing.

Criteria	**Weight**
C1: Gender (M/F)	0.023
C2: Age (years)	0.076
C3: Professional qualification (SSS, VSS, MAS)	0.141
C4: Costs of IT application (€) in the hotel industry	0.167
C5: Attitude towards the use of IT in the hotel industry	0.188
C6: Business costs due to the use of IT to secure hotel operations	0.058
C7: Relationship between IT applications in the hotel industry and waste management	0.163
C8: Importance of IT in preserving the environment	0.136
C9: Carbon reduction through the use of IT	0.048
Total	1.000

The greatest importance is attributed to criterion C5, which is rated at 18.8%, Attitude towards the use of IT in the hotel industry, which inevitably reflects the belief in the necessity of using IT when it comes to the marketing of hotels in Serbia and the provision of hotel services. Criterion C7 was rated at 16.3%, indicating the increasing importance attached to waste management and environmental protection in general. Such a connection is certainly also present in the provision of

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hotel services. The ratings for criteria C4, C8 and C3 are listed below. The weighting coefficient of criterion C4 is 16.7% and shows that the use of IT in the hotel industry, however necessary and compliant it may be for the provision of services, is associated with significant costs that cannot be ignored. Criterion C8 is weighted at 13.6% and this criterion relates to the importance of IT for the preservation of the environment. These scores for the above criteria simply show that it is difficult to separate the inevitability/importance of IT use in the hotel industry from the importance of waste management in the provision of this type of service. Criterion C3, which refers to the level of professional training of hotel service users, was rated at 14.1%. It is interesting to note that users of hotel services recognize the importance and the level of costs associated with such services, but users with a higher level of education attach greater importance to waste management than users with a lower level of education. Criteria C2, C6, C9 and C1 are a group of criteria to which slightly less importance is attached. Criterion C2 refers to the age of users of hotel services. This criterion is determined by 4 sub-criteria, from 20-30, 31-45, 46-50 and > 50 years. In this way, the generationally differentiated population that uses hotel services is largely covered. The weighting coefficient for criterion C2 is 7.6%. Criterion C6 was assigned a weighting coefficient of 5.8%. This criterion is relatively less important, but shows above all that the use of IT in hotel security, camera surveillance, audio and video surveillance is unavoidable under today's conditions. Criterion C9, with a weighting of 4.8%, shows the connection between the use of IT and environmental protection through the content of carbon as a by-product. This weighting was not set high, as the carbon content cannot be reduced through the use of IT to the same extent as is possible with other forms of waste avoidance and environmental protection. Criterion C1, which relates to gender, was assigned the lowest weighting coefficient, namely 2.3%. Logically, this criterion has the least influence on the importance of hotel marketing or the use of hotel services. There is no significant gender-specific differences either in the importance of the use of IT in the hotel industry or in the importance of waste management and environmental protection. The question of gender was only taken into account to the extent that it is actually apparent that these services are used equally by men and women.

After processing the data using the Expert Choice software, the ranks of the alternatives according to the individual criteria and the rank of the alternatives for the model as a whole were determined. The ranking of the alternatives according to the criteria from C1 to C9 is shown in Table 10.

Table 10. Ranking of the alternatives according to the criteria hotel services & hotel marketing.

Rank	C1	C2	C3	C4	C5	C6	C7	C8	C9
1	A1	A3	A3	A3	A4	A3	A3	A3	A3
2	A4	A4	A1	A4	A2	A2	A2	A4	A4
3	A3	A1	A2	A2	A3	A4	A4	A1	A2
4	A2	A2	A4	A1	A1	A1	A1	A2	A1

If the ranks of the alternatives are averaged according to the individual criteria and reduced to a model, i.e. to determine the importance and role of IT in the provision of hotel services and sustainable tourism in Serbia, the order of the alternatives is as follows: A3 → A4 → A2 → A1. The results of the ranking of the alternatives of the optimization model are shown in Table 11.

Table 11. Ranking of the alternatives of the optimization model.

Rank	Alternative	Rating
4	A1 Quality of service	20.4%
3	A2 Cost of the service	21.9%
1	A3 Waste minimisation	35.4%

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2	A4 Satisfaction of service users	22.3%
Total		100%

The resulting solution has an inconsistency index of 0.01, so that the solution, i.e. the best-ranked alternative, which in this case refers to waste reduction, can be considered a high-quality solution and an example of a good practical solution to the problem.

As for the analysis of the results based on the TOPSIS technique, Table 12 shows the initial data of the observed decision problem.

Table 12. Output matrix.

Alternatives	**Criteria**								
C/A	C1	C2	C3	C4	C5	C6	C7	C8	C9
A1	100.0	62.1	83.4	50.0	58.7	60.4	47.8	66.7	68.4
A2	60.5	65.1	92.3	50.0	81.5	75.0	68.4	66.7	68.4
A3	85.1	85.3	79.4	100.0	60.9	75.0	79.4	100.0	100.0
A4	100.0	86.7	68.7	50.0	82.1	60.4	56.0	66.7	70.5

The parameters required for matrix normalization are listed in Table 13.

Table 13. Parameters for the normalization of the initial matrix.

Criter.	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**
Square sum	30902.3	20090.2	14691.6	17500.0	20537.2	18546.3	16403.8	23346.7	24327.4
SQRT	175.79	141.74	120.84	132.29	143.31	136.19	128.08	152.80	155.97

Based on the matrix normalization parameters, a normalized matrix is obtained, which is shown in Table 14.

Table 14. Normalized matrix.

Alternatives	**Criteria**								
C/A	C1	C2	C3	C4	C5	C6	C7	C8	C9
A1	0,569	0,438	0,402	0,378	0,410	0,444	0,373	0,437	0,439
A2	0,344	0,459	0,486	0,378	0,569	0,551	0,534	0,437	0,439
A3	0,484	0,602	0,650	0,756	0,425	0,551	0,620	0,654	0,641
A4	0,569	0,485	0,425	0,378	0,573	0,444	0,437	0,437	0,452

Using form (10), the normalized weight matrix shown in Table 15 was created.

Table 15. Normalized weight matrix.

Alternatives	**Criteria**								
A/C	C1	C2	C3	C4	C5	C6	C7	C8	C9
A1	0,013	0,033	0,057	0,063	0,077	0,026	0,061	0,060	0,021
A2	0,008	0,035	0,069	0,063	0,107	0,032	0,087	0,060	0,021
A3	0,011	0,046	0,092	0,126	0,080	0,032	0,101	0,089	0,031

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A4	0,013	0,037	0,060	0,063	0,108	0,026	0,071	0,060	0,022
Criter. weight. coefficients	0.023	0.076	0.141	0.167	0.188	0.058	0.163	0.136	0.048

The values of the positive ideal solution (A^+) and the values of the negative ideal solution (A^-) are determined based on the value of the normalized weight matrix v_{ij}, where A^+ has a better performance result than A^-, and the results are shown in Table 16.

Table 16. Values of the positive ideal solution and the negative ideal solution.

Criteria	C1	C2	C3	C4	C5	C6	C7	C8	C9
A^+	0,013	0,046	0,092	0,126	0,108	0,032	0,101	0,089	0,031
A^-	0,008	0,033	0,057	0,063	0,077	0,026	0,061	0,060	0,021

The distance from the positive ideal solution (S_i^+) and the distance from the negative ideal solution (S_i^-) for each alternative according to the given criterion is determined according to equations (13) and (14), and the relative proximity coefficient (RC_i^+) to a positive ideal solution, which determines the ranking of the alternatives and thus the decision results obtained by the TOPSIS technique, can be calculated according to equation (15). The results of the ranking of the alternatives are shown in Table 17.

Table 17. Ranking of the alternatives with Topsis method.

Alternatives	S_i^+	S_i^-	RC_i^+	Rank
A1	0,0944	0,0051	0,051	4
A2	0,0763	0,0420	0,355	2
A3	0,0279	0,0894	0,762	1
A4	0,0833	0,0332	0,285	3

The results based on the TOPSIS technique show that the alternative A3: Waste minimisation has the highest score, which suggests the importance of environmental awareness in tourism and in general. A2: Service costs are the second most relevant alternative based on the analyzed questionnaire, followed by A4: Service quality and A1: Service users' satisfaction. Both methods, AHP and TOPSIS, show that the dominant impact in sustainable tourism is primarily related to environmental waste reduction.

The application of multi-criteria analysis enables the systematic identification of key factors that influence the development of information and communication technologies in tourism. Through an iterative and cumulative approach, this method supports the incremental development of digital systems and creates a multi-layered architecture of complex information systems. In this case, the base layer consists of analytical tools or methods, the middle layer includes automated digital processes (e.g. IoT, cloud, ML) and the top layer consists of intelligent systems based on artificial intelligence [41], which are able to learn autonomously and make decisions in real time. Multi-criteria analysis, which integrates qualitative and quantitative parameters, can be implemented in human resources management software systems and enables real-time monitoring, employee classification and optimisation of human resources strategies. Although MCDM methods are effective in structuring decisions, challenges remain in the areas of emotional interpretation and empathy — particularly in human resource management and with service users. Due to the complexity of human psychology, it is necessary to use a heterogeneous approach by integrating multiple methods. For example, the integration of the multi-criteria approach and other methods with artificial intelligence,

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including machine learning and affective computing, enriches the precision and realism of decision models. [42]

AI enables the automatic processing of "big data" before subjective and emotional aspects of user behaviour are recognised through socio-digital signals (textual, visual, audio). The application of artificial intelligence can qualitatively improve the existing process of personnel management. [43–45]

For example, methods such as fuzzy AHP [46] and sentimental MCDM models [47–49] have proven their worth in tourism decision-making — including the selection of hotels and restaurants — by combining structured criteria with the analysis of user reviews.

This paper confirms the hypothesis that a series of small, iterative steps through a multi-criteria assessment allows not only a deeper understanding of individual cases, but also the quantification and accumulation of knowledge. This scientifically sound framework becomes the basis for the development of intelligent decision-making systems that combine systematically structured decisions with the adaptive autonomy of AI systems. In this way, multi-criteria analysis takes on the role of a generative input for advanced AI models for decision-making in tourism and management. Of course, due to the great complexity of the given area, it is necessary to develop the organisation of the development process, i.e. the methods themselves, i.e., the way they are applied in time and space within the given development process as a supporting framework. The impact of a modern development platform that integrates development methods, Industry 4.0 concepts, i.e. key ICT systems [50], and environmental practices, is directly reflected in the development of tourism and the economy as a whole.

4. Conclusions and Perspectives of Further Research

This paper offers an empirically oriented and analytical insight into the importance of integrating information technology for the development of sustainable tourism in Serbia. By applying the comparative AHP and TOPSIS methodology, the key factors influencing environmental sustainability in the hospitality sector are the use of IT tools and effective environmental management. The research results show that users with a higher level of education and a strong ecological awareness attach the greatest importance to waste management and environmental protection. The most important criterion in the AHP analysis was the users' attitude towards the use of IT in the hotel industry, indicating the need for continuous digital education on the importance of sustainability in tourism. In both models applied, the alternative "waste minimisation" (A3) was given the highest priority, further confirming the key role of ecology in modern tourism. Also, IoT, big data, cloud, and AI not only improve efficiency but also enable the development of "smart" and sustainable destinations. In this context, multi-criteria decision-making methods (MCDM) such as AHP and TOPSIS are one of the foundations for the development of management processes, i.e., strategies. The application of these methods in research confirms their practical applicability in Serbia and also opens up possibilities for their application in other regions of the Western Balkans. Research results show that IT-enabled waste management is the most significant factor in the development of sustainable tourism, with a strong influence of digital literacy, environmental awareness, and cost structure. Future research needs to integrate advanced MCDM techniques, AI-supported user behavior analytics, and IoT resource management systems to develop comprehensive models for digital and environmentally responsible management of the tourism industry. Also, recognized principles of the circular economy and bioeconomy, combined with technological innovation through the implementation of key Industry 4.0 technologies, provide a roadmap for achieving long-term sustainability in the tourism industry. This transformation requires the integration of sustainable practices and the application of ICT tools to optimise resource use, thus reducing carbon emissions and preserving natural ecosystems. The future success of the tourism industry will depend on its ability to adapt to the changing challenges by relying on synergy effects, human resources management processes, and the application of advanced information technologies, with environmental responsibility and sustainable management practices. By taking this direction,

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tourism businesses can improve their strategic decision-making, strengthen their market position, and contribute to the broader goals of sustainable development.

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