Journal of Scientific & Industrial Research
Vol. 84, February 2025, pp. 183-195
DOI: 10.56042/jsir.v84i02.8163

# MCDM Approach Combining DEA and AHP Methods in Sustainable Tourism: Case of Serbia

Zlatko Langović[1], Brankica Pažun[2]*, Željko Grujčić[2], Magdalena Nikolić[2], Ana Langović Milićević[3] & Dragan Ugrinov[4]

[1]Faculty of Hotel Management and Tourism, Vrnjačka Banja, University of Kragujevac, Serbia
[2]Faculty of Engineering Management, Belgrade, University Union Nikola Tesla, Serbia
[3]Faculty of Geography, Belgrade, University in Belgrade, Serbia
[4]Faculty of Europe "Kallos", University Business Academy in Novi Sad, Serbia

*Received 20 January 2024; revised 29 August 2024; accepted 16 December 2024*

This paper focuses on the workforce capable of implementing new trends through the application of environmental tourism and IT knowledge. Multi-criteria optimization methods such as Data Envelopment Analysis (DEA) and Analytical Hierarchy Process (AHP) were used to solve a particular and sensitive business decision problem. A unique questionnaire on five global trends - renewable energy growth, pollution, electrification, cloudification, data boom and smartization - was developed to assess the capabilities of potential candidates in relation to environmental issues in tourism and to determine whether they are able to solve tasks in a sustainable way. This paper proposes an approach for the selection of candidates for sustainable and green tourism. From 200 candidates, data collected in a northern region of Serbia in the fall of 2023, the model resulted in the 5 best alternatives under 5 criteria. The final solution was the alternative/candidate B with the consistency index 0.03. The intention was that by combining AHP and DEA methods to evaluate efficiency, the subjectivity of decision making in the selection of candidates would be minimized. The new value of this work could be that advanced technologies are integrated into sustainable tourism in a practical and scalable way, and that methods for evaluating and implementing the technologies in question are developed. This could form the basis for future research and practical applications.

**Keywords:** AHP method, DEA method, IT tools, Multi-criteria analysis, Sustainable tourism

## Introduction

In this day and age of being more competitive, being better than others and achieving the best possible results, leaders must be aware of today's issues and strive to hire the right people. These employees, with their shared values, form a synergy that allows their knowledge and experience to create a competitive advantage. This is particularly pronounced in the tourism and hotel sector because it is the only thing that cannot be copied and because, on the other hand, the strength of the sector consists of the people who come into contact with tourists, who represent their company and who, together with their values, strengthen the organizational culture that makes an organization better than others. In this regard, managers who are looking for the right staff will try to select employees who already have a developed awareness of ecology, environmental protection and sustainability, in addition to a number of other elements they need. All of this has an impact on the company's image and creates a form of socially responsible management that is more than necessary and desirable in today's society.

To improve transparency in decision making and the necessary analytics, it is necessary to use methods that support the decision-making process.[1–3] A large body of research emphasizes Multi-Criteria Decision Analysis (MCDA) or Multi-Criteria Decision Making (MCDM), which was developed in the 1970s.[4–11] Since then, this analysis has inspired a large number of scientific papers and projects in various fields such as medicine, engineering, finance, business, and education.[12,13]

The use of certain methods of multi-criteria analysis, such as DEA and AHP, can further improve personnel selection processes and identify managers with development potential through specific projects. These methods can be used in different areas of industry or business when the aim is to optimize a specific decision at an operational, tactical and strategic level. These methods can enable the

*Author for Correspondence
E-mail: brankica.pazun@fim.rs

evaluation of managers based on several criteria (such as environmental awareness, technological knowledge and long-term impact of projects), which increases the accuracy of the evaluation and contributes to the sustainable development of projects.[14,15] Their application already exists and the given methods are also used in other business processes of the tourism system, e.g. in the process of offer definition, then in decision making related to the management of the so-called green hotels.[16] Or, for example, in improving the implementation of tourism policy.[17] It can be said that these methods provide algorithms that are implemented in a modern business environment using modern technologies, starting with 5G systems, then IoT systems, smartphones, cloud, big data, machine learning, i.e. artificial intelligence, and which converge into a powerful tool, i.e. a complex information system. Again, information technology is an important driver in all processes, e.g. environmental, educational, economic, production, etc.[18]

In line with sustainability, the instruments of environmental protection can be understood as a force for sustainability. In this direction, green tourism combines the three pillars of environment, economy and society.[19] Thus, sustainable tourism includes measures that prevent the depletion of natural resources.[20] Furthermore, the terms “green” or “sustainable” in tourism refer to all measures from eight areas of tourism that do not have a harmful impact on the environment.[19] Therefore, trained employees in environmental tourism bring the core competencies required to promote sustainability with pleasant hospitality.[21] Mínguez *et al*. (2021)[(22)] examine the vulnerabilities in tourism during the COVID-19 pandemic in Spain.

The participants were both students and teachers, because knowledge and innovation are needed in crises and challenging situations. Sustainable tourism pedagogy as a framework showed a solid but insufficient understanding of sustainable and green tourism. Therefore, it was recommended to close the knowledge gaps in the areas of pollution and biodiversity protection in the future.[23] In general, environmental science knowledge is needed in the tourism sector to monitor, identify and make recommendations to prevent pollution.[24,23] Therefore, the tourism sector should consider candidates that have proven to be environmentally friendly. Good candidates must be consistent with new, sustainable goals and objectives. In other words, each candidate must demonstrate a fundamental understanding of the European Union's new approach to the green transition, critical and proactive thinking and, above all, an understanding of the impact of everyday actions and decisions on the environment and sustainable development.[25] To be able to perform all tasks related to the provision of sustainable services, future employees must answer basic questions about their contribution to sustainability, the importance of preserving cultural heritage and traditions, and the protection of local resources and ecosystems.[26] The main problem in developing countries is behavior. Thus, slow changes in people's behavior due to their perception of environmental protection and not a lack of knowledge can be identified as a major obstacle to sustainability practice.[27] The selection of employees is a multi-criteria decision problem. The use of multicriteria analysis in ecotourism has found its place through the well-known methodology used in environmental planning to resolve inconsistencies between stakeholder objectives over scarce natural resources.[28] To reduce the negative impacts of tourism on the environment, multicriteria analysis has been widely used.[29–31]

The study presents an example of multi-criteria optimization in the selection of a candidate in the field of tourism and ecology for a position in the tourism sector. The decision making was carried out using two methods, the DEA and the AHP method, taking into account that decision making is inherently sensitive, with an emphasis on maximum objectivity in decision making. The specificity of this study lies in the following aspects:

- defining the candidate selection model for a job in green and sustainable tourism;
- identifying the appropriate inputs and outputs of the model;
- creation of the questionnaire to assess the candidates' attitude towards five global trends of today's society: growth of renewable energy, electrification, cloudification, data boom and smartization;
- selection of MCDM methods for choosing the optimal alternative;
- qualitative and quantitative prediction of the future scientific contribution in this field.

## Materials and Methods

The methodological framework in this paper was designed with the intention of providing an aggregate assessment of the efficiency of the decision making units (DMUs) considered. The data were collected in the area of the 6 largest cities in the Autonomous Province of Vojvodina, Republic of Serbia (Novi Sad, Subotica, Pančevo, Zrenjanin, Sombor, Sremska Mitrovica). At the time of the survey, the source of the data set consisted of 200 interested candidates from the above-mentioned cities. The survey was conducted in the period September-December 2023. The first step was to define the concepts and objectives of the analysis. In the next step, the efficient DMUs were extracted using the DEA method and finally ranked using the AHP method. In this sense, a questionnaire was created and used to select candidates for selection in sustainable tourism.

The criteria used to evaluate the candidates are identical for the DEA and AHP methods. The intention was that by combining these methods to evaluate efficiency, the subjectivity of decision making in the selection of candidates to work in sustainable tourism would be minimized. At the beginning of the analysis, the DEA method was used to evaluate the efficiency of the selected DMUs, mainly because this method can identify inefficient DMUs very quickly. The DEA model with constant return and the DEA model with variable return were used to evaluate the candidates with the DEA method. The DEA model with constant return to volume had fewer efficient DMUs than the DEA model with variable return to volume, but the DEA method did not rank the efficient DMUs. Therefore, after evaluating the candidates using the DEA method, an AHP analysis was performed using the same criteria. This method was used to rank the DMUs in addition to evaluating their efficiency. The criteria used in the analysis with these methods comprised three inputs and two outputs.

The inputs considered were:

1 the candidate's professional experience in the field of sustainable tourism;

2 the average grade of the candidate's study programme/orientation course - ecology and sustainable tourism (it should be higher than 8, grading scale 5–10);

3 knowledge and use of modern information and communication technologies.

On the output side, the following points were considered:

1 the candidate's score in the knowledge test on the Law on Tourism ("Official Gazette of the RS", No. 17/2019) and the Law on Hospitality ("Official Gazette of the RS", No. 17/2019);

2 Evaluation of candidates at the interview by the team of experts based on a universal/identical questionnaire.

The team of experts consisted of three professors (Ph.D. from the Faculty of Technical Sciences in Novi Sad), three graduate engineers from the Municipality of Environmental Protection Agency in Novi Sad and three assistants from the Faculty of Natural Sciences and Mathematics, Department of Geography, Tourism and Hotel Management from Novi Sad.

In the second step, the ranking of the selected/efficient DMUs was created using the AHP method, where the weights determined by AHP defined the importance of all efficiency measures included in the analysis.

DEA is a relatively new method for empirically determining the best practical efficiency frontier. DEA is a non-parametric method that does not require any assumptions about the analytical form of the objective function. This was the reason for choosing the method as it is very difficult to determine the analytical form of the optimality criteria for the study of candidate selection in sustainable tourism. Another reason for choosing the DEA method in the first stage of candidate selection was the fact that DEA was a borderline method where performance was determined by efficiency rather than average performance. DEA also makes it easier to solve problems with multiple inputs and multiple outputs, which was unavoidable in this case, and led to greater accuracy as it was a boundary value method. What is a bit tricky with the DEA method is the ranking of efficient DMUs. Therefore, the AHP method was applied in the second part of the candidate evaluation. The inputs/outputs of the DEA method were converted into criteria in the AHP method. The data set after the DEA analysis was represented by candidates A, B, C, D and E, which existed as alternatives in the AHP method. The final solution or goal was represented by alternative/candidate B. The consistency index was 0.03, indicating that the finalized solution was good.

**DEA (Data Envelopment Analysis) Method**

Suppose we have input and output data for each of the n DMUs whose efficiency is to be evaluated. Let the observed input set be of the i-th type and the observed output set be of the r-th type for $DMU_j$, where:

$x_{ij} > 0, i = 1, 2, \ldots, m; j = 1, 2, \ldots, n$ and
$y_{rj} > 0, r = 1, 2, \ldots, s; j = 1, 2, \ldots, n.$

According to Banker *et al*. (1984)[32] suggestion that for each $DMU_k$, k =1, 2, ..., n, an optimization problem (CCR ratio model) should be solved in which the values for the weighting are given. The coefficients $u_r$ and $v_i$ should be determined so that the efficiency of the unit is maximum.

$$(max)h_k = \frac{\sum_{r=1}^{s} u_r y_{rk}}{\sum_{i=1}^{m} v_i x_{ik}} \quad \ldots (1)$$

under restrictions (u.r.)

$$\frac{\sum_{r=1}^{s} u_r y_{rk}}{\sum_{i=1}^{m} v_i x_{ik}} \leq 1, j = 1, 2, \ldots, n \quad \ldots (2)$$

$$u_r \geq 0, r = 1, 2, \ldots, s \quad \ldots (3)$$

$$v_i \geq 0, i = 1, 2, \ldots, m, \quad \ldots (4)$$

where, $h_k$ = the relative efficiency of k-th DMU, $m$ = number of inputs, $v_i$ = weighting coefficient for the input i, $s$ = number of outputs, $u_r$ = weighting coefficient for the output r, $n$ = number of DMUs to be compared.

The relative efficiency $h_k$ of $DMU_k$ is the ratio between the weighted sum of its outputs (virtual output) and the weighted sum of its inputs (virtual input). The virtual output/input is the product of the value of a particular output/input and the weighting coefficient assigned to it. The value $h_k$ does not depend on the units in which the inputs and outputs are considered. It therefore for$h_k$ applies that $0<h_k<1$. If the value of in the objective function is equal to one, then the k-th DMU is relatively efficient. However, if the value of $h_k$in the objective function is less than one, then the DMUk is relatively inefficient, and the value $h_k$ indicates the percentage by which this unit must reduce its inputs in order to become efficient. A $DMU_k$ can be considered fully efficient if the results of other DMUs do not allow it to improve some of its inputs or outputs without worsening the remaining inputs or outputs. Condition (2) applies to all DMUs and shows that each of them is at or below the efficiency frontier. The unknowns in the model $u_r$ and $v_i$ are the weighting factors, which indicate the degree of importance of each input and output that each unit chooses to be as efficient as possible. The weighting factors need to be admissible for all DMUs included in the efficiency measurement and fulfill the condition that for each DMU the ratio of virtual output to virtual input is less than or equal to one. The restrictions (5) and (6), which state that the weighting factors may only have positive values, were later converted into restrictions:

$$u_r \geq \varepsilon, r = 1, 2, \ldots, s \quad \ldots (5)$$

$$v_i \geq \varepsilon, i = 1, 2, \ldots, m, \quad \ldots (6)$$

where, $\varepsilon$ = small positive value.

The most common suggestion is that this value is $\varepsilon = 10^{-6}$. According to Banker *et al.* (1984)[32] the role of the parameter in weight-based DEA models is to prevent a DMU from being falsely labeled as relatively efficient based only on the values of an input and an output for which appropriate values are chosen.

In order to measure pure technical efficiency, an extension to the original CCR DEA models was made. This extension can best be understood using the example of a dual DEA model. The dual BCC-DEA model is obtained by adding the following condition to the dual CCR-DEA model:

$$\sum_{j=1}^{n} \lambda_j = 1 \quad \ldots (7)$$

Next:

$$(max)h_k = \sum_{r=1}^{s} \mu_r y_{rk} + u^* \quad \ldots (8)$$

u.r.

$$\sum_{i=1}^{m} v_i x_{ik} = 1 \quad \ldots (9)$$

$$\sum_{r=1}^{s} \mu_r y_{rj} - \sum_{j=1}^{m} v_i x_{ij} + \mu \leq 0, j = 1, 2, \ldots, n \quad \ldots (10)$$

$$\mu_r \geq \varepsilon, r = 1, 2, \ldots, s \quad \ldots (11)$$

$$v_i \geq \varepsilon, i = 1, 2, \ldots, m \quad \ldots (12)$$

Constraint (7) allows variable returns to scale. Variable returns to scale mean that an increase in the inputs used does not necessarily lead to a proportional increase in the level of production. This constraint also ensures that the reference quantity is formed as a convex combination of the DMUs it contains (those DMUs that have positive values for $\lambda_j$ in the optimal solution). The efficiency frontier provided by the BCC DEA model has the form of a convex hull. Since the CCR DEA model measures the total technical efficiency (pure technical efficiency and volume efficiency) and the BCC DEA model measures the pure technical efficiency, the volume efficiency can also be determined as a quotient of the total technical efficiency determined with the CCR model and the pure technical efficiency determined with the BCC model.

**AHP (Analytic Hierarchy Process) Method**

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 based on 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 4 stages.

*The structuring of the problem* consists of creating a hierarchy of the given problem, with the objective at the top, the criteria and/or sub-criteria and the alternatives going down.

*Data generation* implies that the decision maker assigns relative scores to the attribute pairs at all levels of the hierarchy, except zero (the goal is not compared). The well-known nine-point scale (Saaty scale) is used.[33] The results of the comparison of elements at a certain hierarchy level are entered in the corresponding comparison matrices. The reciprocal value of the comparison result is placed in the corresponding position $a_{ji}$ in order to maintain the consistency of the argumentation. The weights of the criteria and/or alternatives should be determined by evaluating their coefficients $w_i/w_j$. The relative importance matrix A is formed from these relative importance coefficients.

$$A = \begin{bmatrix} a_{11} a_{12} & \cdots & a_{1n} \\ a_{21} a_{22} & \cdots & a_{2n} \\ \vdots \vdots & \vdots & \vdots \\ a_{n1} a_{n2} & \cdots & a_{nn} \end{bmatrix} = \begin{bmatrix} {w_1}/{w_1} \; {w_1}/{w_2} & \cdots & {w_1}/{w_n} \\ {w_2}/{w_1} \; {w_2}/{w_2} & \cdots & {w_2}/{w_n} \\ \vdots \vdots & \vdots & \vdots \\ {w_n}/{w_1} \; {w_n}/{w_2} & \cdots & {w_n}/{w_n} \end{bmatrix}$$

The matrix A for the case of consistent estimates for which the value $a_{ij} = a_{ik} a_{kj}$ satisfies the equation.

$$A_w = nw \qquad \ldots (13)$$

*The evaluation of relative weights* is the third stage in the application of the AHP method. The problem of determining the weights is reduced to solving the equation.

$$A_w = \lambda w, \lambda \neq 0 \qquad \ldots (14)$$

If the matrix A contains inconsistent estimates (in practical examples this is usually the case), the weight vector w can be obtained by solving the system of equations:

$$(A - \lambda_{max} I)_w = 0 \qquad \ldots (15)$$

$$\textstyle\sum_i w_i = 1 \qquad \ldots (16)$$

where, $\lambda_{max}$ is the largest value of the matrix is A. Taking the above equations into account, the following follows:

$$A_w = nw \qquad \ldots (17)$$

$$\textstyle\sum_j a_{ij} w_j = nw \qquad \ldots (18)$$

$$w = \frac{1}{n} \textstyle\sum_j a_{ij} w_j \qquad \ldots (19)$$

The solution to the problem is the last stage of the AHP method and consists of determining the so-called composite normalized vector. The AHP method can be used to determine and analyze the inconsistency of the decision maker when comparing the elements of the hierarchy.[33] Due to the properties of the matrix A $\lambda_{max}$, it is valuable. The difference $\lambda_{max}$ is used to measure the consistency of the estimates. The closer $\lambda_{max}$ to n is, the more consistent the estimate is. The AHP method makes it possible to check the consistency of the estimates at any point in the pairwise comparison procedure. In order to calculate the consistency ratio (CR), the consistency index (CI) must first be calculated according to the relationship:

$$CI = \frac{\lambda_{max}}{n-1} \qquad \ldots (20)$$

To determine $\lambda_{max}$, the comparison matrix must be multiplied by the vector of weighting coefficients to determine the vector b, and then the corresponding elements of the vector w and b are obtained by dividing them:

$$\lambda_{max} = \frac{1}{n}\sum_{i=1}^{n}\lambda_i \quad \dots (21)$$

The degree of consistency is the quotient of the consistency index and the random index, RI, (Random Index). The form has the form:

$$CR = \frac{CI}{RI} \quad \dots (22)$$

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.

## Results and Discussion

Considering that the DEA method quickly and unambiguously reveals sources of inefficiency, the authors' idea was to first use the DEA method for employee selection and accordingly mark candidates as per good ratings so that the analysis could be complemented by using the AHP method.

The process of data collection was created with the aim of evaluating the effectiveness of interested candidates for the position of reservation manager in sustainable tourism. Thus, the authors' intention was to show how interested graduates are in working in sustainable tourism. Of course, this indicator is of limited value, as the survey was conducted at the local level, i.e. on the territory of AP Vojvodina, with the aim of extending it to the entire republic/country in the next survey. The data requested by the team of experts for the survey of candidates were collected on the territory of the 6 largest cities of AP Vojvodina (Novi Sad, Subotica, Pančevo, Zrenjanin, Sombor, Sremska Mitrovica) in the Republic of Serbia. 12 representative candidates were selected. These twelve DMUs/candidates formed the final sample for the analysis using the DEA method and the AHP method.

Values of considered inputs and outputs for candidates from 12 regional tourist destinations by this model are presented in Table 1.

Efficiency is usually defined as the quotient of input and output within the limits of 0 to 1. Accordingly, efficiency can be represented as the quotient of output and input.

This means that if the goal is to achieve the highest efficiency index, the inputs at a certain output level must be reduced, which has already been done, or the outputs at a certain input level must be increased. After data processing with decision support tools, i.e. DEA Frontier software, the results shown in Table 2 were obtained.

In column "Input-Oriented CRS Efficiency" DMU and their efficiency index are shown. It can be seen that from 12 DMU only 4 are efficient, that is, A, B, C and E are efficient, provided that DMU marked with letter D has the highest efficiency index of all inefficient units. Column "Sum of lambdas" shows which weight factors some DMU have used, while column "RTS (Return to Scale)" shows the nature of yield per volume. All of DMU which are efficient operate with constant yield per volume. Constant yield per volume implies that proportional increase of inputs results with proportional increase of outputs.

Table 1 — Input and output values of candidates from 12 regional tourist destinations

| Candidates from regional tourist destination | Work experience (years) | Studies average | Evaluation of application of ICT | Test evaluation | Interview evaluation |
|---|---|---|---|---|---|
| A | 10 | 8.3 | 7 | 8 | 9 |
| B | 7 | 8.5 | 8 | 9 | 10 |
| C | 15 | 8.4 | 8 | 8 | 9 |
| D | 19 | 7.8 | 6 | 7 | 7 |
| E | 8 | 7.7 | 7 | 10 | 8 |
| F | 12 | 8.9 | 8 | 7 | 9 |
| G | 15 | 8.6 | 6 | 7 | 6 |
| H | 10 | 7.2 | 7 | 8 | 7 |
| I | 16 | 8.5 | 8 | 6 | 6 |
| J | 18 | 8.8 | 9 | 6 | 7 |
| K | 17 | 8.5 | 10 | 7 | 6 |
| L | 22 | 8.6 | 9 | 6 | 7 |

Table 2 — Evaluation of DMU efficiency by using Input-Oriented CRS DEA model

| DMU No. | DMU Name | Efficiency | Sum of lambdas | RTS | Optimal lambdas with benchmarks |
|---|---|---|---|---|---|
| 1 | A | 1.00000 | 1.000 | Constant | 1.000 (A) |
| 2 | B | 1.00000 | 1.000 | Constant | 1.000 (B) |
| 3 | C | 1.00000 | 1.000 | Constant | 1.000 (B) |
| 4 | D | 0.94231 | 0.808 | Increasing | 0.538 (A) |
| 5 | E | 1.00000 | 1.000 | Constant | 1.000 (E) |
| 6 | F | 0.88968 | 0.941 | Increasing | 0.413 (A) |
| 7 | G | 0.85256 | 0.731 | Increasing | 0.154 (A) |
| 8 | H | 0.90228 | 0.821 | Increasing | 0.214 (B) |
| 9 | I | 0.62269 | 0.643 | Increasing | 0.429 (B) |
| 10 | J | 0.67614 | 0.700 | Increasing | 0.700 (B) |
| 11 | K | 0.66050 | 0.714 | Increasing | 0.143 (B) |
| 12 | L | 0.69186 | 0.700 | Increasing | 0.700 (B) |

Table 3 — Evaluation of DMU efficiency by using Input-Oriented VRS DEA model

| DMU No. | DMU Name | Efficiency | Optimal lambdas with benchmarks |
|---|---|---|---|
| 1 | A | 1.00000 | 1.000 (A) |
| 2 | B | 1.00000 | 1.000 (B) |
| 3 | C | 1.00000 | 1.000 (B) |
| 4 | D | 1.00000 | 1.000 (D) |
| 5 | E | 1.00000 | 1.000 (E) |
| 6 | F | 0.91736 | 0.322 (A) |
| 7 | G | 1.00000 | 1.000 (G) |
| 8 | H | 1.00000 | 1.000 (H) |
| 9 | I | 0.85714 | 0.143 (D) |
| 10 | J | 0.81818 | 1.000 (H) |
| 11 | K | 0.84706 | 1.000 (H) |
| 12 | L | 0.83721 | 1.000 (H) |

All of inefficient DMU operate with increasing yield per volume.

In column "Optimal Lambdas with Benchmarks" are given values of weight factors with which inefficient DMU would become efficient and exemplary DMU or example of a good operational practice for inefficient DMU. For example, DMU with a mark D, which is inefficient and has an efficiency index of 0.94231 operates with weight coefficient $\lambda$ which is 0.808, and for it, the exemplary DMU is marked with A. However, if $\lambda$ had a value of 0.538, DMU marked with D would be efficient. For the purpose of comparing the results and better insight in quality choosing of employee selection in sustainable tourism, input oriented model with variable yield per volume was used. Variable yield per volume shows that proportional input minimizing does not have to result with proportional output minimizing. Results of use of this model are shown in Table 3.

The results show that by using an input-oriented model with variable yield per volume, the number of efficient DMUs is significantly higher. Now 7 out of 12 observed DMUs are efficient. The DMUs labeled F, I, J, K and L are inefficient. The large number of efficient DMUs analyzed with the VRS model compared to the CRS model shows that VRS allows greater freedom in the choice of weighting factors.

Comparing the results obtained with these models, it can be seen that the results of DMUs A, B, C and E are identical and these units are efficient in the CRS and VRS models, while unit D is inefficient in the CRS model but efficient in the VRS model. Only units G and H are efficient in the VRS model, while they are also inefficient in the CRS model. Considering that the CRS model has shown more stringent results compared to the VRS model and that only units A, B, C and E are efficient in the CRS model, provided that unit D has the highest efficiency index of all inefficient units, this was the reason for the authors to decide to select this DMU by analyzing the results using the AHP method, which is characterized by a large number of scores.

On the other side, AHP provides interactive analysis of evaluation procedure sensitivity to final ranks of hierarchies' elements.

- Structuring problems and creating a hierarchy (presented in Fig. 1).

Goal — Choosing of employee selection in sustainable tourism criteria: Professional experience, average grade of studies, skills in environmental management, knowledge and use of modern information and communication technologies in the workplace, evaluation of applicants based on the test of knowledge of the Law on Tourism ("Official Gazette of the Republic of Serbia", No. 17/2019) and the Law on Hospitality ("Official Gazette of the Republic of Serbia" No. 17/2019). The growing concern about air pollution, climate change and environmental protection is another criterion for good employees. Therefore, another criterion is added, namely the environmental awareness and sensitivity of the candidates. The assessment assigned to the candidates during the interview by the expert is based on a universal/identical questionnaire.

Alternatives: A, B, C, D and E.

- Data generating:

The importance given to certain criteria in the definition of the problem was expressed as a percentage, so that the sum of the percentage of all criteria is 100 (%), and the data are presented in Table 4.

The highest importance is assigned to the criterion "evaluation of the interview", which was assessed by the team of experts. Then the criteria "test evaluation" and "knowledge of ICT" and "knowledge of environmental management" were given appropriate importance. Less importance in the selection of applicants was given to the "average study grade", which is approximately the same for most applicants, and "professional experience", which is more dominant compared to the "average study grade". Another novelty in this process was the introduction of questions related to environmental issues and attitude towards dealing with them properly.

- Evaluating relative weights:

Evaluating relative weights is performed by applying Saaty scale[34,35] and the values assigned to certain criterion are presented in Table 5.

The definition of the problem solution is the last phase of the AHP method and includes the determination of the so-called composite normalized vector. After determining the vector of the order of criteria activity in the model, in the next round it is necessary to determine the order of alternative meaning in the model within each observed criterion

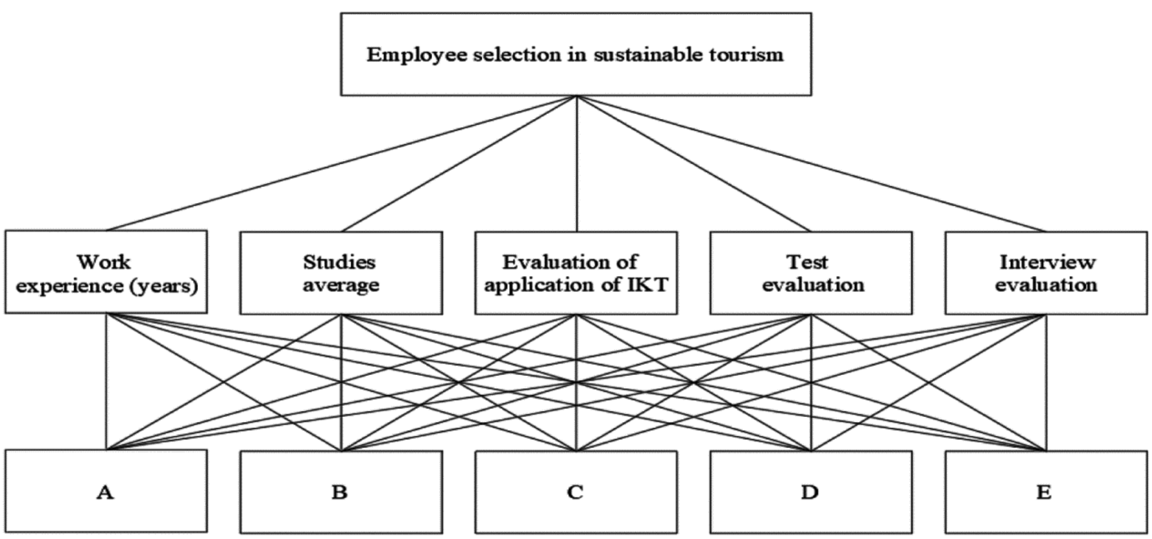


Fig. 1 — Structure and hierarchy of the problem of employee selection in sustainable tourism

Table 4 — Percentage significance of criteria in analysis of AHP method results

| Work experience (years) | Studies Average | Evaluation of application of ICT | Test evaluation | Interview evaluation |
|---|---|---|---|---|
| 8.5% | 4.3% | 18.2% | 26.7% | 42.3% |

Table 5 —Matrix of criteria comparing by using Saaty scale

| | Work Experience (years) | Studies average | Evaluation of application of ICT | Test evaluation | Interview evaluation |
|---|---|---|---|---|---|
| Work experience (years) | 1 | 4 | 1/3 | 1/4 | 1/7 |
| Studies average | ¼ | 1 | 1/4 | 1/5 | 1/7 |
| Evaluation of application of ICT | 3 | 4 | 1 | 1/2 | 1/2 |
| Test evaluation | 4 | 5 | 2 | 1 | 1/2 |
| Interview evaluation | 7 | 7 | 2 | 2 | 1 |

Table 6 — Evaluation of the alternatives in candidate selection by applying Saaty scale

| Criterion Alternative | Work experience (years) | Studies average | Evaluation of application of ICT | Test evaluation | Interview evaluation |
|---|---|---|---|---|---|
| A | 0.095 | 0.337 | 0.208 | 0.104 | 0.299 |
| B | 0.043 | 0.138 | 0.296 | 0.261 | 0.287 |
| C | 0.222 | 0.421 | 0.232 | 0.058 | 0.288 |
| D | 0.575 | 0.063 | 0.110 | 0.058 | 0.061 |
| E | 0.066 | 0.042 | 0.154 | 0.519 | 0.066 |

for five criteria included in the candidate selection. The results are shown in Table 6.

The overall synthesis of the problem is carried out in the following way: the participation of each alternative is multiplied by the weight of the observed criterion, and then these values are added for each alternative separately. The data obtained represents the weight of the observed alternative in the model. The weighting is determined in the same way for all other alternatives, after which the final order in the model can be determined.

- Defining problem solution.

Once the weighting of the alternatives has been determined, the final order of the alternatives is shown in Fig. 2.

It can be seen that alternative B performs best, followed by alternatives C, A, E and D. The only alternative considered in the analysis is D which is not defined as efficient by the DEA, and the AHP method also shows that it performs worst. This alternative only has the best ratings for the "professional experience" criterion, and the worst results for the other criteria. When it comes to the “professional experience” criterion, the ranking according to alternative D is as follows: C, A, B and D.

When analyzing the criterion “average studies grade", which is the least important in the analysis (4.3%) because it is not considered decisive in the selection of candidates, alternative C achieves the best results, followed by alternative A, which, however, does not mean a better ranking for these alternatives given the importance attached to this criterion. The worst results for the criterion “average studies grade" are achieved by alternatives D and E.

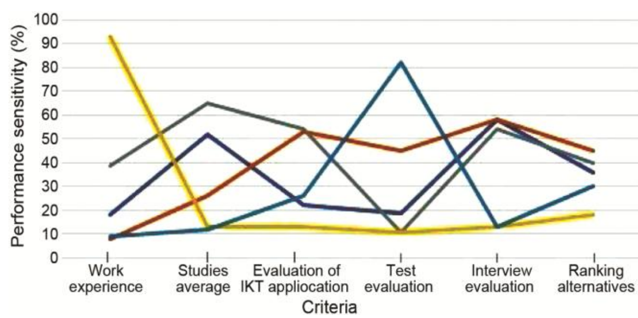


Fig. 2 — Ranking alternatives in employee selection in sustainable tourism by using Expert Choice software

When analyzing the criterion “working with ICT”, which was slightly more important in the selection of applicants (18.2), alternatives C and B have the best and almost identical results. The alternatives, E and A performed similarly well, but significantly worse.

For the criterion “test evaluation”, which requires knowledge in the areas of ICT and environmental management, the alternative E shows the best results, followed by alternative B. Alternatives A, C and D have significantly poorer results. It should be noted that alternative C had a very good ranking until the appearance of this criterion, where it shows poor results, which is the main reason why it does not have the best ranking at the end of the analysis.

The last criterion considered, “interview evaluation”, shows very similar results with three alternatives. The best result has the alternative A, then B, and then alternative C. Poor results, when it comes to this criterion, show alternatives E and D. Finally, it can be concluded that both methods, DEA and AHP, have given similar results. DEA method has identified very quickly efficient units, and AHP method has confirmed that and ranked alternatives by their significance: B, C, A, E and D, which can be seen in Fig. 3.

Dynamic sensitivity is presented in Fig. 4, that is, candidate rating in relation to observed deciding criteria, that is, linear dependence between alternatives and criteria is shown. Vertical slider (vertical red colored line) is set to a value that approximates to 0.1 or 10%, which represents consistency ratio.

If a small change in the importance of the criteria also changes the final decision, then the solution is said to be sensitive to changes in evaluation. In such cases (which is not the case in this example), it cannot be stated with certainty that the solution is unambiguous, so that other alternatives are considered to be approximately equally good. If the consistency ratio (CR) is less than 0.10, the result is accurate enough, the solution is stable, so that no corrections are necessary when comparing and repeating the calculations.

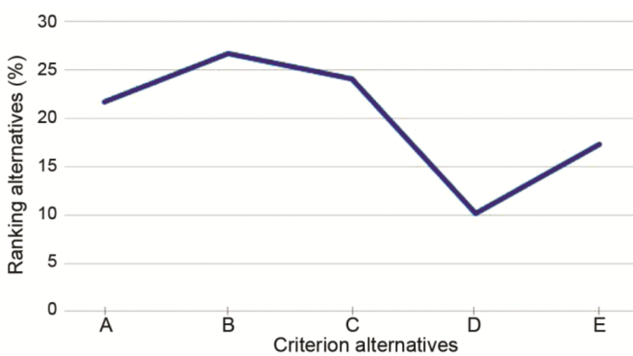


Fig. 3 — Synthesis with respect to Employee selection in sustainable tourism

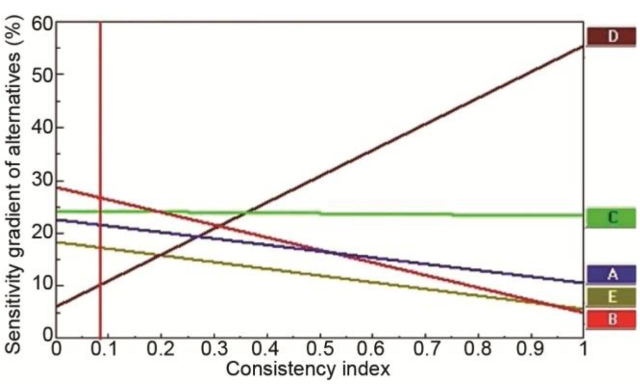


Fig. 4 — Sensitive analysis on employee selection in sustainable tourism using Expert Choice

If the consistency ratio is significantly greater than 0.10, the results should be analyzed again and the reasons for the inconsistency determined. These should be eliminated by partially repeating the pairwise comparisons, and if repeating the procedure in a few steps does not lead to a reduction of the consistency ratio to the tolerance limit of 0.10, all results should be discarded and the entire procedure repeated from the beginning.

If there is no change in significance, i.e. the ranking of alternatives, when the slider (vertical line) is moved by 10%, the selected solution can be considered a good choice.

When it comes to selecting candidates for the tourism industry, the slider can be moved more than 10% to the right and the ranking of the alternatives does not change, which means that alternative B is the correct/stable solution (Fig. 4).

The final list of candidates, previously selected through a questionnaire by the team of experts, comprises 12 candidates. The average professional experience of the candidates is 14.08 years (entry 1), the average grade of study, environmental management skills is 8.32 (entry 2) and the grade for knowledge and use of modern information and communication technologies is 7.75 (entry 3). It can be concluded that the sample represents a relatively younger generation of people interested in working in sustainable tourism, with an average age of 39. The analysis of the results obtained with the DEA model with CRS showed that the number of efficient DMUs, i.e. DMUs with an efficiency of 1, is only 4 out of 12 or 33.33%, namely DMUs A, B, C and E. This model is very rigorous as it excludes 8 candidates from further analysis. When using the DEA model with variable volume returns, the number of efficient DMUs is higher due to the nature of the model and in this case there are effectively 7 DMUs, namely DMUs A, B, C, D, E, G and H. Considering that the number of efficient DMUs is lower when using the DEA model with CRS and that the DMUs that are efficient in both DEA with CRS and DEA with VRS are A, B, C and E, this means that the sample used in the next stage of candidate evaluation remains at such a sample. In addition to the selected efficient DMUs, a further DMU labelled D with the highest efficiency index of all DMUs declared inefficient by DEA and CRS was included in the analysis.

These 5 DMUs represented 5 alternatives for the AHP method in the next phase of the candidate evaluation. The AHP method provides a ranking of the alternatives, i.e. the candidates, in addition to the pairwise evaluations/comparisons. The input labelled as input 1 in the DEA, "the candidate's professional experience in sustainable tourism", represents criterion 1 in the AHP method, input 2, defined as “the average study grade of the candidate's study programme/orientation course - ecology and sustainable tourism” in the DEA method, represents criterion 2 in the AHP method, and so on. In this way, the 3 inputs and 2 outputs used for the DEA method represent the criteria for the AHP method. The AHP method was used due to its structural approach to the evaluation of alternatives and the principle of consistency that the method follows until the final solution.

In the AHP analysis the criterion "interview evaluation" is given the greatest importance with 42.3%, followed by "test evaluation" with 26.7%, "evaluation of application of ICT" with 18.2%, "work experience" with 8.5% and "study average" with an importance of 4.3%. As the criteria "study average", "professional experience" and "evaluation of application of ICT" do not show any significant differences between candidates A, B, C, D and E, these criteria are weighted with lower marks in contrast to the criteria "interview evaluation“ and “test evaluation". Once the criteria had been defined, a pairwise comparison was carried out on the basis of the Saaty scale (Table 5) and then the alternatives were evaluated and ranked using the Expert Choice. The results obtained are shown in Table 6, and the appearance and ranking of the alternatives, as well as the importance of certain criteria influencing such a result, can be seen in Fig. 2.

The development of tourism requires more consideration for the natural environment, so a new approach is emerging, known as sustainable and green tourism. This approach to tourism is becoming increasingly popular as it contributes to the sustainable development of destinations and the conservation of natural resources, which is important for the long-term competitiveness of the tourism sector. Knowledge and experience in this area is an advantage for managers in the sector. It should be emphasized that the success of the project led by the managers is an important indicator for assessing their quality, i.e. their competence. If the project is carried out successfully, it provides valuable insights into the qualities of the managers, such as resource management, environmental awareness, team leadership, strategic planning and problem-solving skills. Based on these results, it can be decided which manager is best suited to lead the next project, i.e. to move up the hierarchy of business system. The success of a business system is closely linked to the management of human resources, as in this case of the tourism company.[36] The complexity of the system itself necessitated the application of analytical methods to improve data analysis in decision making.

If we analyze the given approach in more detail, this process of managing human resources, i.e. knowledge, becomes iterative and focuses on the development of crisis managers of a certain level. On average, each manager is gradually developed through more complex projects, starting with simpler tasks and moving on to more complex projects. These tools allow you to track how a manager is using their skills at each stage, which helps to identify the areas in which they are particularly good.

Next, tailored training and education - by monitoring the manager's progress, tools can recommend or personalize training programs aimed at improving specific knowledge and skills, such as the use of sustainable technologies, environmental knowledge, cost management, communication skills, etc. Focus on talent and personal strengths: Automated processes enable real-time analysis of work performance and results. Using the data, the platform can identify managers' talents and unique skills, such as innovative approaches. Monitoring development through feedback and results: Setting measurable goals for each project and analyzing results after each phase helps evaluate progress. By monitoring performance, managers receive feedback that helps with development. Mitigating weaknesses through development strategies: When weaknesses are identified, the platform can automatically recommend solutions.

This approach leads to more comprehensive development of managers, that enable them to acquire the necessary skills or knowledge and develop in line with the requirements of modern, sustainable tourism. In this way, the hotel complex can develop a knowledgeable and adaptable management staff, which has a positive impact on the long-term success and competitiveness of the hotel.

We can say the following: the complexity of human psychology, i.e. the complexity of the work environment, defines the natural need for experienced quality employees who, with their experience and knowledge, manage human resources development, i.e. train younger employees by carrying out projects, i.e. jeopardize their development, and that the very parameters that define these processes are used in the development of the knowledge management system, i.e. training. In this process it is necessary to apply the given tools, but it should be pointed out again that they cannot completely replace experienced management. Personnel selection is part of the overall picture of any business system and must be constantly improved both through the organization of the development process itself and through the development and application of powerful IT tools to improve the quality of business in the tourism sector.

## Conclusions

The essence of the research is the effort to create and facilitate with this model, a combining of DEA and AHP methods, the issue of candidate selection and objectivity in the selection of candidates for a job in green and sustainable tourism. It is statistically justified that this approach contributes to a high-quality practical decision in this area of research.

The results show that a well-trained and environmentally aware workforce can advance the goals of sustainability in tourism. The study shows the great interest of the highly educated population in sustainable tourism (among the relatively young population, with average age of 39). Further, the analysis shows the likelihood of developing the organization of the human resource management system. Future research should be extended to a larger sample and wider area of the country and the use of advanced IT tools for data processing, such as artificial intelligence and machine learning.

## References


1 Garg H, Hesitant Pythagorean fuzzy Maclaurin symmetric mean operators and its applications to multi-attribute decision making process, *Int J Intell Syst*, **34(4)** (2019) 601–626, https://doi.org/10.1002/int.22067.

2 Shrestha Y R, Ben-Menahem S M & Von Krogh G, Organizational decision-making structures in the age of artificial intelligence, *Calif Manag Rev*, **61(4)** (2019) 66–83, https://doi.org/10.1177/0008125619862257.

3 Pažun B, Nikolić M, Grujčić Ž, Ugrinov D & Langović Z, Optimization model of infectious medical waste disposal using it tools: Case of Serbia, *Fresenius Environ Bull*, **31(9)** (2022) 9417–9423.

4 Diaz-Balteiro L, González-Pachón J & Romero C, Measuring systems sustainability with multi-criteria methods: A critical review, *Eur J Oper Res*, **258(2)** (2017) 607–616, https://doi.org/10.1016/j.ejor.2016.08.075.

5 Nalmpantis D, Roukouni A, Genitsaris E, Stamelou A & Naniopoulos A, Evaluation of innovative ideas for Public Transport proposed by citizens using Multi-Criteria Decision Analysis (MCDA), *Eur Transp Res Rev*, **11(1)** (2019) 1–16, https://doi.org/10.1186/s12544-019-0356-6.

6 Godara S & Toshniwal D, Sequential pattern mining combined multi-criteria decision-making for farmers' queries characterization, *Comput Electron Agric*, **173** (2020) 105448, https://doi.org/10.1016/j.compag.2020.105448.

7 Lakhani A, Zeeman H, Wright C J, Watling D P, Smith D & Islam R, Stakeholder priorities for inclusive accessible housing: A systematic review and multicriteria decision analysis, *J Multi-Criteria Decis Anal*, **27(1-2)** (2020) 5–19, https://doi.org/10.1002/mcda.1689.

8 Martins I D, Moreas F F, Távora G, Soares H L F, Infante C E, Arruda E F, Edilson F, Bahiense L, Caprace J & Lorenço M I, A review of the multicriteria decision analysis applied to oil and gas decommissioning problems, *Ocean Coast Manag*, **184** (2020) 105000, doi: 10.1016/j.ocecoaman. 2019.105000.

9 Zhang T, Lan J, Yu J, Liu Z & Yao S, Assessment of forest restoration projects in different regions using multicriteria decision analysis methods, *J For Res*, **25(1)** (2020) 12–20, https://doi.org/10.1080/13416979.2019.1704360.

10 Kizielewicz B, Shekhovtsov A & Sałabun W, A new approach to eliminate rank reversal in the MCDA problems, In *Int Conf Comput Sci*, Proceedings Part I (2021) 338–351, https://doi.org/10.1007/978-3-030-77961-0 29.

11 Shahraki S R, Maleki A, Haghighat S & Ghalandari M, Using multi-criteria decision-making methods to select the best location for the construction of a biomass power plant in Iran, *J Therm Anal Calorim*, **145(5)** (2021) 2105–2122, https://doi.org/10.1007/s10973-020-10281-1.

12 Baudry G, Macharis C & Vallée T, Range-based multi-actor multi-criteria analysis: A combined method of multi-actor multi-criteria analysis and monte carlo simulation to support participatory decision making under uncertainty, *Eur J Oper Res*, **264(1)** (2018) 257–269, https://doi.org/10.1016/ j.ejor.2017.06.036.

13 Beaudrie C, Corbett C J, Lewandowski T A, Malloy T & Zhou X, Evaluating the application of decision analysis methods in simulated alternatives assessment case studies: Potential benefits and challenges of using MCDA, *Integr Environ Assess Manag*, **17(1)** (2021) 27–41, https:// doi.org/10.1002/ieam.4316.

14 Angrave D, Charlwood A, Kirkpatrick I, Lawrence M & Stuart M, HR and analytics: Why HR is set to fail the big data challenge, *Hum Resour Manag J*, **26(1)** (2016) 1–11, https://doi.org/10.1111/1748-8583.12090.

15 Zavadskas E K, Antucheviciene J, Vilutiene T & Adeli H, Sustainable decision-making in civil engineering, construction and building technology, *Sustainability*, **10(1)** (2018) 14, https://doi.org/10.3390/su10010014.

16 Nilashi M, Abbas M, Huchang L, Hossein A, Azizah A M & Wafa A, A hybrid method with TOPSIS and machine learning techniques for sustainable development of green hotels considering online reviews, *Sustainability*, **11(21)** (2019) 6013, https://doi.org/10.3390/su11216013.

17 Karsak E E & Dursun M, An integrated fuzzy MCDM approach for supplier evaluation and selection, *Comput*

*Ind Eng*, **82** (2015) 82–93, https://doi.org/10.1016/ j.cie.2015.01.019.

18 Pažun B & Langović Z, Some key technology trends in tourism industry, *Serbian J Geosci*, University of Niš, Faculty of Sciences and Mathematics, **7(1)** (2021) 1–8, https://doi.org/10.18485/srbjgeosci.

19 Ibnou-Laaroussi S, Rjoub H & Wong W K, Sustainability of green tourism among international tourists and its influence on the achievement of green environment: Evidence from north cyprus, *Sustainability*, **12(24)** (2020) 5698, https:// doi.org/10.3390/su12145698.

20 Ahmad F, Draz M U, Su L, Ozturk I & Rauf A, Tourism and environmental pollution: Evidence from the one belt one road provinces of Western China, *Sustainability*, **10(10)** (2018) 3520, https://doi.org/10.3390/su10103520.

21 Malihah E & Setiyorini H P D, Tourism education and edu-tourism development: Sustainable tourism development perspective in education, in *The 1st Int Seminar Tourism (ISOT)-Eco-Resort Destination Sustain: Plan, Impact, Devel*, (2014) 1–7.

22 Mínguez C, Martínez-Hernández C & Yubero C, Higher education and the sustainable tourism pedagogy: Are tourism students ready to lead change in the post pandemic era?, *J Hosp Leis Sport Tour Educ*, **29** (2021) 100329, https://doi.org/10.1016/j.jhlste.2021.100329.

23 Downs C A, Cruz O & Remengesau Jr T E, Sunscreen pollution and tourism governance: Science and innovation are necessary for biodiversity conservation and sustainable tourism, *Aquat Conserv: Mar Freshw Ecosyst*, **32(5)** (2022) 896–906, https://doi.org/10.1002/aqc.3791.

24 Jurkus E, Povilanskas R & Taminskas J, Current trends and issues in research on biodiversity conservation and tourism sustainability, *Sustainability*, **14(6)** (2022) 3342, https:// doi.org/10.3390/su14063342.

25 EC, *Green Compthe European Sustainability Competence framework*, Joint Research Centre, (2022).

26 Chi X, Meng B, Lee H, Chua B L & Han H, Pro environmental employees and sustainable hospitality and tourism businesses: Exploring strategic reasons and global motives for green behaviors, *Bus Strategy Environ*, **32(7)** (2023) 4167–4182, https://doi.org/10.1002/bse.3359.

27 Alipour H, Safaeimanesh F & Soosan A, Investigating sustainable practices in hotel industry-from employees' perspective: Evidence from a Mediterranean Island, *Sustainability*, **11(23)** (2019) 6556, https://doi.org/10.3390/ su11236556.

28 Zografos C & Oglethorpe D, Multi-criteria analysis in ecotourism: Using goal programming to explore sustainable solutions, *Curr Issues Tourism*, **7(1)** (2004) 20–43, https:// doi.org/10.1080/13683500408667971.

29 Akbari R, Pourmanafi S, Soffianian A R, Galalizadeh S & Khodakarami L, Enhancing ecotourism site suitability assessment using multi-criteria evaluation and NSGA-II, *Environ Dev Sustain*, **26** (2023) 28663–28698.

30 Chaudhary S, Kumar A & Pramanik M & Negi M S, Land evaluation and sustainable development of ecotourism in the Garhwal Himalayan region using geospatial technology and analytical hierarchy process, *Environ Dev Sustain*, **24** (2022) 2225–2266, https://doi.org/10.1007/ s10668-021-01528-4.

31 Mansour S, Al-Awhadi T & Al-Hatrushi S, Geospatial based multi-criteria analysis for ecotourism land suitability using GIS & AHP: A case study of Masirah Island, Oman, *J Ecotourism*, **19(2)** (2020) 148–167, https://doi.org/10.1080/ 14724049.2019.1663202.

32 Banker R D, Charnes A & Cooper W W, Some models for estimating technical and scale inefficiencies in data envelopment analysis, *Manag Sci*, **30(9)** (1984) 1078–1092.

33 Saaty T L, Decision making with the analytic hierarchy process, *Int J Serv Sci*, **1(1)** (2008) 83–98, https:// doi.org/10.1504/IJSSCI.2008.017590.

34 Saaty T L & Tran L T, On the invalidity of fuzzifying numerical judgments in the analytic hierarchy process, *Math Comput Model*, **46(7/8)** (2007) 962–975, https:// doi.org/10.1016/j.mcm.2007.03.022.

35 Saaty T L, Continuous pairwise comparisons, *Fundam Inform*, **144(3-4)** (2016) 213–221, https://doi.org/10.3233/FI-2016-1330.

36 Saridakis G, Lai Y & Cooper C L, Exploring the relationship between HRM and firm performance: A meta-analysis of longitudinal studies, *Hum Resour Manag Rev*, **27** (2017) 87–96, https://doi.org/10.1016/j.hrmr.2016.09.005.