
An Analytic Hierarchy Process (AHP) model of tourism impacts in Cotopaxi National Park, Ecuador

Un modelo de Proceso Analítico Jerárquico (PAJ) de los impactos
turísticos en el Parque Nacional Cotopaxi, Ecuador

Um modelo de Processo Analítico Hierárquico (PAH) dos impactos turísticos
no Parque Nacional Cotopaxi, Equador

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Abstract

This research determined a Hierarchical Analytic Process (HAP) model that considers tourism impacts and their possible solutions to generate a hierarchy of all of them. The main trails and tourist sites in Cotopaxi National Park were identified using geographic information systems in order to investigate the main impacts of tourism activities and propose possible solutions. The prioritization of impacts was based on the use of the AHP, as well as on the proposed solutions to reduce these impacts in the park. The results show that the prioritized tourism impacts are: erosion, pollution, waste generation, loss of biodiversity, and job and income generation. Subsequently, the proposed solutions were the monitoring of tourist activities, environmental education, control of tourist entry, and the signposting of trails and tourist sites. The PAJ model was evaluated through surveys of experts, with erosion being identified as the most significant impact, while the preferred solution was the monitoring of tourist activities.

KEYWORDS: tourism; tourist impacts; monitoring of tourist activities.

Resumen

Esta investigación determinó un modelo de Proceso Analítico Jerárquico (PAJ) que considera los impactos turísticos y sus posibles soluciones para generar una jerarquía de todos ellos. Se identificaron los principales senderos y sitios turísticos del Parque Nacional Cotopaxi mediante sistemas de información geográfica, a fin de investigar los principales impactos de las actividades turísticas y proponer posibles soluciones. La priorización de los impactos se basó en el uso del PAJ, así como en las soluciones propuestas para disminuir estos impactos en el parque. Los resultados demuestran que los impactos turísticos priorizados son: erosión, contaminación, generación de residuos, pérdida de biodiversidad y generación de empleo e ingresos económicos. Posteriormente, las soluciones propuestas fueron la vigilancia de las actividades turísticas, la educación ambiental, el control de entrada de turistas y la señalización de senderos y sitios turísticos. La evaluación del modelo PAJ se realizó mediante encuestas a expertos, obteniendo como impacto más importante la erosión, mientras que la solución preferida fue la vigilancia de las actividades turísticas.

PALABRAS CLAVE: turismo; impactos turísticos; vigilancia de las actividades turísticas.

Resumo

Esta pesquisa determinou um modelo de Processo Analítico Hierárquico (PAH) que considera os impactos turísticos e suas possíveis soluções para gerar uma hierarquia de todos eles. Foram identificadas as principais trilhas e locais turísticos do Parque Nacional Cotopaxi por meio de sistemas de informação geográfica, a fim de investigar os principais impactos das atividades turísticas e propor possíveis soluções. A priorização dos impactos baseou-se no uso do PAJ, bem como nas soluções propostas para diminuir esses impactos no parque. Os resultados demonstram que os impactos turísticos priorizados são: erosão, poluição, geração de resíduos, perda de biodiversidade e geração de empregos e renda econômica. Posteriormente, as soluções propostas foram a vigilância das atividades turísticas, a educação ambiental, o controle da entrada de turistas e a sinalização de trilhas e locais turísticos. A avaliação do modelo PAJ foi realizada por meio de pesquisas com especialistas, obtendo como impacto mais importante a erosão, enquanto a solução preferida foi a vigilância das atividades turísticas.

PALAVRAS-CHAVE: turismo; impactos do turismo; fiscalização das atividades turísticas.

1. Introduction

The tourist activities in natural areas have many environmental impacts, which needs to be avoided or at least diminished by performing a sustainable tourist plan or following some ecological practices (Belsoy *et al.*, 2012; Canteiro *et al.*, 2018; GhulamRabbany *et al.*, 2013). The tourism in protected natural areas in Ecuador is increasing day by day, as well as its impacts (Montoya *et al.*, 2020; Rivera, 2017; Vladimir *et al.*, 2019). Nowadays, the number of tourists in the Protected Areas National System of Ecuador (Sistema Nacional de Áreas Protegidas -SNAP) is about 1.5 million visitors per year (Ministerio de Turismo, 2023), and the visitors in the Cotopaxi National Park (PNC) reaches about 200,000 visitors per year (Díaz *et al.*, 2024; Rodas *et al.*, 2024).

There are several methodologies to prevent the environmental impacts due to the tourism, hereby, one of the best is to consider the carrying capacity of the natural areas (Matias *et al.*, 2022; Neto, 2003; Smeral, 1996). This means that the number of visitors must not exceed a threshold or maximum number of tourists that the area might receive (Kuss & Morgan, 1986; Pulido-Fernández *et al.*, 2024; Peng *et al.*, 2016). Therefore, the carrying capacity considers three main characteristics of a natural area, being the physical, biological and management conditions, in order to result with such a maximum number of visitors (Gutiérrez *et al.*, 2021; Coccossis, 2022).

Recent research about the carrying capacity of the Cotopaxi National Park, determined three phases to compute the maximum number of visitors to the park, that include Physical Carrying Capacity, Real Carrying Capacity and Effective Carrying Capacity (Díaz *et al.*, 2024). This allowed to determine the carrying capacity of the PNC, being some 1,722 visitors per day. Even though there is a complete calculation of the carrying capacity of the park, its implementation lacks to be in effect, due to several factors, one of them being the lack of budget.

Another methodology to contribute the management of diverse impacts due to the tourism in natural areas, is the Analytic Hierarchy Process (AHP), (Saaty, 1980). The AHP is a

quantitative method which allows multicriteria decisions, that lead to generate scales of priorities based on expert judgments, which are judged through pairs comparisons by using a preference scale. This scale also allows to incorporate in a decision model, judgments about intangibles, representing the dominance or preference of one alternative or solution against another, according to one attribute or criterion (Nantes, 2019).

Based on the aforementioned context, the current research proposes an AHP model to hierarchize the environmental impacts due to the tourism activities in the PNC. This shall be complementary to obtain a hierarchy of the possible and potential solutions, in order to contribute to the management of the natural area and thus to conserve the touristic sites, based on the consideration that all tourist activities have some or certain environmental impacts.

2. Study area

The Cotopaxi National Park (PNC), which is located in the central part of Ecuador (FIGURE 1), was created in 1975 and shortly later in 1979 it was declared a National Park within the National System of Protected Areas (MAATE, 2022). The PNC has an area of 33,393 ha, of which its main tourist attraction is the active Cotopaxi Volcano with a height of 5,897 meters above sea level (Jácome *et al.*, 2013; Mora *et al.*, 2022; Aguilera & Toulkeridis, 2005). The main goal of the park is the conservation of the natural resources present in this area, especially the Cotopaxi volcano. This volcano is an icon and emblematic symbol of Ecuador, because of its natural beauty and its cultural and historical importance, but also due to its devastating past with far-reaching hazards and its recent signs of activity (Rodríguez *et al.*, 2017; Padilla *et al.*, 2022; Toulkeridis *et al.*, 2015; Echegaray-Aveiga *et al.*, 2020; Vaca *et al.*, 2016; Toulkeridis & Zach, 2017). It is necessary to mention that it was the first National Park within the continental area of Ecuador but the second National Park of Ecuador (Ministry of Tourism, 2009). Various geosites of the National Park recently became part of the aspiring UNESCO

Geopark of the Metropolitan District of Quito (Toulkeridis *et al.*, 2025). Nowadays, in the country there are 78 protected natural areas, of which 14 are considered national parks (MAATE,

2024), among them the Cotopaxi National Park, which is considered to be the most important and most visited in continental Ecuador (Ecotec University, 2021).



FIGURE 1. Location of the Cotopaxi National Park in Ecuador (Diaz *et al.*, 2024)

A protected area, like the PNC, is a geographically defined surface and established by a law or legal norm, in order to meet certain conservation goals (Chape *et al.*, 2005). Likewise, protected natural areas are clearly determined geographical spaces, recognized and managed through legal regulations, which shall achieve the long-term conservation of nature, its ecosystem services and its associated cultural values (Dudley, 2008). Protected areas are those of land and/or seas especially dedicated to the protection and maintenance of biological diversity, as well as natural resources and associated cultural resources, being managed through legal or other effective means (UICN, 1998). In Ecuador, protected areas represent approximately 20% of the national territory. These areas fall within the highest category of protection in accordance with

national environmental legislation (MAATE, 2023). According to the Constitution of the Republic of Ecuador of 2008, the protected natural areas make up the National System of Protected Areas (SNAP), which was subdivided into four subsystems, being the most important the 'Heritage of Natural Areas of Ecuador' (PANE). PANE contains national parks such as the PNC.

3. Methodology

3.1 Main trails and tourist sites

To elaborate a hierarchy of the generated impacts due to tourism, it has been fundamental to determine the main trails and tourist sites of the Cotopaxi National Park. Hereby, the PNC has various tourist trails, among which may be highlighted as the Limpiopungo Lagoon trail, the Parking lot - Shelter trail, the Rumiñahui Volcano

trail and the Springs trail (Díaz *et al.*, 2024). The entire park area was mapped, including the four identified trails (FIGURE 2), by using Geographic Information Systems (ArcGIS 10.8). This will serve

to evaluate the AHP model and correspondingly the environmental impacts and their potential solutions.

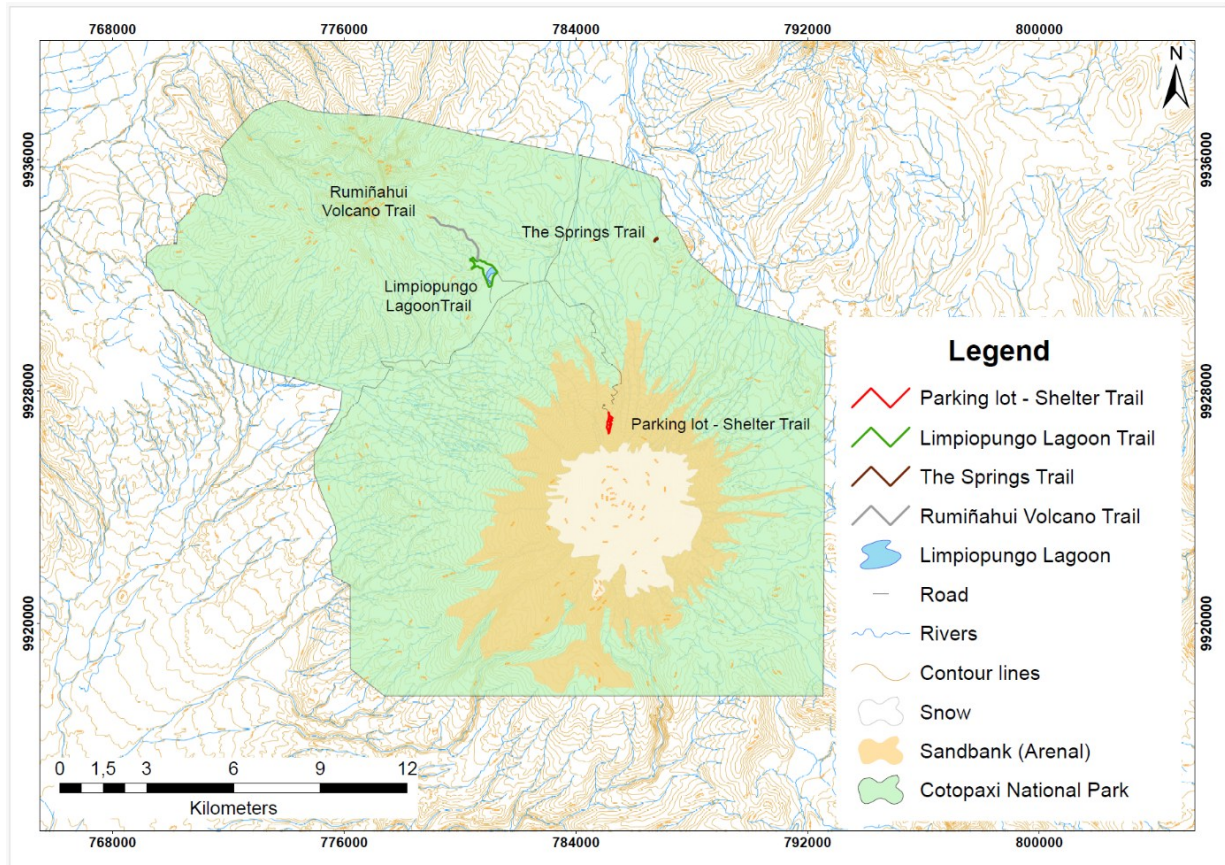


FIGURE 2. Map of the PNC and the ecotourism trails (Díaz *et al.*, 2024)

3.2 Analytic Hierarchy Process (AHP)

The AHP is a theory of measurement for dealing with multiple, quantifiable and/or intangible criteria that has encountered rich applications in a regularly used decision-making tool (Vaidya & Kumar, 2006; Vargas, 1990; Ho, 2008). In the present case, it shall perform ecological tourism

in the PNC whose methodology used to develop the AHP model, in order to evaluate the environmental impacts and solution alternatives. Therefore, the impacts are the minimum possible, as presented in the diagram of FIGURE 3 (Kaya & Kahraman, 2011; Sólmes, 2003; Abba *et al.*, 2013).

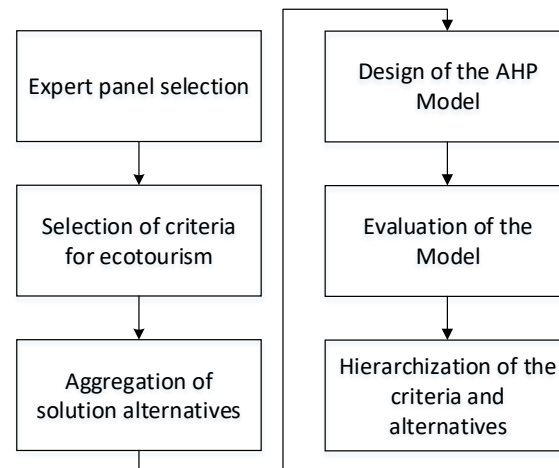


FIGURE 3. Methodology to develop the AHP model

3.3 Decision-making model design

The AHP model serves to evaluate alternatives for action on a certain social, economic or environmental aspect or problem. In the present case, the environmental aspect or problem constitutes the uncontrolled tourism, in other words, the main aspects that the PNC has to deal with all the environmental impacts generated by tourism. Therefore, the given AHP model, which has been the result of the current research, constitutes a choice among several alternatives for action to perform ecological tourism. This has been based on evaluation criteria, which are directly related to the characteristics of the problem and its goals of solution. This research activity required the participation of a panel of three experts, to establish the evaluation criteria and alternatives, as well as evaluate the environmental impacts and solutions, according to the Saaty Scale (Saaty, 1977; Saaty, 2001). A group of just three experts could perfectly well be formed using Saaty's AHP methodology, as there is no theoretical limitation that invalidates a panel of this size. A group of three is a common and very viable sample size in practical studies for several reasons, due to its ease of coordination, being simpler to coordinate and manage a small group of highly qualified experts than a very large one, as well as due to consensus management, as it allows for constructive debate and the aggregation of judgments (usually through the

geometric mean of the comparison matrices) in a manageable way, reflecting different points of view. The six different phases to get the AHP model will be indicated and described in detail and include an expert panel selection, the selection of criteria, the aggregation of solution alternatives, the design of the AHP Model, the evaluation of the model and finally the hierarchization of the criteria and alternatives.

a. Expert panel selection

For the selection of the criteria, action alternatives and design of the decision model, in accordance with the AHP procedure, three experts were selected. This has been based on professional experience related to ecotourism management of natural areas, academic and research level, and obviously, according to the theme of the present research. Additionally, we tried to ensure that they are representative actors of the PNC and the ecotourism in particular. The members of the expert panel are in charge of identifying the most relevant criteria for conducting ecotourism in the PNC, as well as identifying alternative solutions or strategies for ecotourism.

The experts selected to participate in the development of the AHP model were a PNC representative, an Academy representative and a Tourism representative in the PNC. The first is a

professional expert in protected natural areas, in charge of the conservation and protection of the PNC. The second is a university teaching professional, with extensive experience in natural resource management and conservation of natural areas, while the third is a professional expert in ecotourism, university professor and consultant on environmental issues.

b. Selection of criteria

To design the chosen model, the experts established the criteria related to the tourism problem, which allow the decision model for ecotourism to be adequately evaluated. To accomplish this, the experts meet and consider several aspects. First, the conservation goals of the PNC were considered; second, the weaknesses and threats or hazards of the strategic management tool of Strengths-Weaknesses-Opportunities-Threats (SWOT), were analyzed, to later determine the various environmental problems generated by tourism (Helms & Nixon, 2010; Sabbaghi & Vaidyanathan, 2004; Puyt *et al.*, 2023). With all this material, and after the field visits as well as the additional support by the existing literature on the PNC and ecotourism, the criteria were discussed and organized in a way that allows evaluating the problems derived from tourism. The criteria selected by the panel of experts are detailed as biodiversity loss, erosion, waste generation, pollution, and generation of employment as well as economic income.

c. Aggregation of solution alternatives

Once the criteria that influence the evaluation and decision-making to have ecological tourism, were established, the expert panel oversaw proposing different strategies or alternatives for

action (solutions). To fulfill this issue, a bibliographic review was performed as well as interviews with two representatives of the Park Administration (different actors of the expert panel), so that, they could contribute their ideas on possible strategies that contribute to promoting ecotourism in this protected area. Subsequently, the experts meet to propose several strategies or alternatives for action to perform ecotourism in the PNC, of which the experts finally chose four:

- ✓ Alternative 1. Tourist entry control;
- ✓ Alternative 2. Surveillance of tourist activities;
- ✓ Alternative 3. Signage of trails and tourist sites
- ✓ Alternative 4. Environmental Education.

These alternatives that the experts chose after a meeting, together with the identified criteria, are part of the AHP model, whose main goal is to develop an ecological tourism or ecotourism, which will be evaluated by the panel of experts.

d. Design of the AHP Model

The hierarchical structure of the model has as the main goal the ecotourism the criteria to reach the goal are the minimum environmental impacts generated by the activity, which is ecotourism, as well as the alternatives which are the solutions to overcome the environmental impacts (FIGURE 4).

e. Evaluation of the Model

Once the criteria and alternatives were selected for ecological tourism in the PNC, the corresponding surveys were conducted on each of the experts, following the Saaty methodology (Saaty, 2008), whose assessment scale varies from 1 to 9, as indicated in TABLE 1.

TABLE 1. Fundamental Scale of Saaty (Modified from Saaty, 2008)

Scale	Preference	Description
1	Equal	Equal importance
3	Moderate	Slight importance of one over another
5	Strong	Moderate importance of one over another
7	Very strong	Very strong importance of one over another
9	Extreme	Extreme importance of one over another

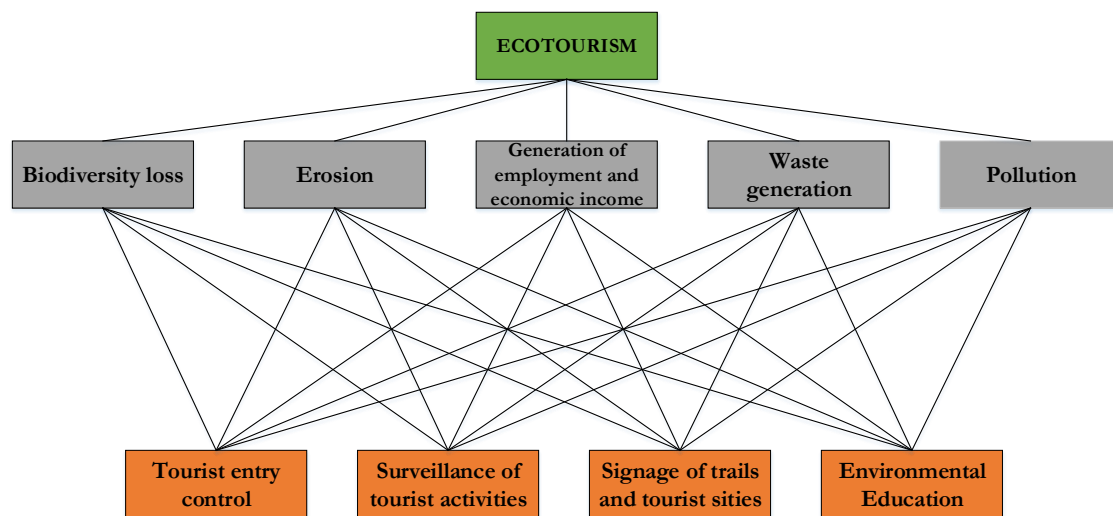


FIGURE 4. AHP Model of the study case

An example of a question related to environmental impacts may serve the following affirmations. In relation to the environmental impacts caused by tourism, which do you think is more important: erosion or pollution? How much more important: 1 3 5 7 9? Likewise, an example of a question about preferences for alternative for action or solutions may serve as that which follows. In relation to the alternatives for action to avoid or reduce the environmental impacts caused by tourism, which solution do you prefer or is more important, to develop ecological tourism: Tourist entry control or Environmental education? How much more important: 1 3 5 7 9?, amongst others.

f. Hierarchization of the criteria and alternatives

To get the priorities of the criteria and solution alternatives, the following five steps need to be developed: **a)** Elaboration of the judgment value matrices about the criteria and alternatives; **b)** Normalization of the judgment value matrices; **c)** Computing the weight vector and the consistency ratio for criteria; **d)** Computing the weight vector and the consistency ratio for alternatives; **e)** Application of the weights by multiplying the matrices of the alternatives

weights by the criteria weights, in order to obtain the weight vector of the alternatives.

In order to compute the weight vector (eigenvector) of the criteria and alternatives, it is necessary to work with the normalized matrices of the judgment value matrices about the criteria and alternatives respectively. Such eigenvector (W) is the average by rows of the normalized matrix N . Furthermore, in order to compute the consistency ratio, the following four-step procedure and equations were used, according to Saaty's methodology:

First, the vector λW must be computed by multiplying the matrix A by the weight vector W , following the equation: $A \cdot v = \lambda v$; for our case: $A \cdot W = \lambda \cdot W$, where A is the square matrix of judgment values about the criteria, W is the eigenvector (weight vector), and λ is the eigenvalue.

Second, λ_{max} must be computed by summing the rows of the λW vector, in order to determine the Consistency Index (CI).

$$CI = \frac{\lambda_{max} - n}{n - 1}$$

Third, the Aleatory Index (AI) is determined by using the following TABLE 6 (Saaty, 1990):

TABLE 6. Aleatory Index (AI) for values of n (number of variables)

n	1	2	3	4	5	6	7	8
AI	0	0	0,525	0,882	1,115	1,252	1,341	1,404
n	9	10	11	12	13	14	15	16
AI	1,452	1,484	1,513	1,535	1,555	1,570	1,583	1,595

Fourth, the Consistency Ratio (CR) is calculated by dividing CI over AI: $CR = \frac{CI}{AI}$

The Consistency Ratio (CR) of the judgment value matrices must be lower than the admissible value given by the Saaty Methodology ($\leq 0,10$).

4. Results and discussion

According to the methodology, the evaluation of the AHP model elaborated by the expert panel

was realized by surveys, and the results are described in detail below.

4.1 Matrices of judgment values about the criteria and alternatives

Primarily, the results of the surveys generated by a pairwise comparison, by using the Saaty's Scale, about the indicators or environmental impacts generated by the tourism, are presented in TABLE 2. Furthermore, the results of the surveys about the solution preferences are presented in TABLE 3.

TABLE 2. Matrix (A) of judgment values about the criteria

CRITERIA	Biodiversity loss	Erosion	Waste generation	Pollution	Generation of employment and economic income
Biodiversity loss	1,00	0,14	0,25	0,17	3,00
Erosion	7,00	1,00	5,00	0,14	2,00
Waste generation	4,00	0,20	1,00	7,00	2,00
Pollution	6,00	7,00	0,14	1,00	4,00
Generation of employment and economic income	0,33	0,50	0,50	0,25	1,00

TABLE 3. Matrix (A1) of judgment values about the alternatives with respect to the criterion "biodiversity loss"

ALTERNATIVES	Tourist entry control	Surveillance of tourist activities	Environmental Education	Signage of trails and tourist sites
Tourist entry control	1,00	3,00	3,00	5,00
Surveillance of tourist activities	0,33	1,00	1,00	3,00
Environmental Education	0,33	1,00	1,00	3,00
Signage of trails and tourist sites	0,20	0,33	0,33	1,00

Then, the AHP methodology is applied to determine the prioritization of the impacts due to the tourism as well as of the solution alternatives.

4.2 Normalization of the judgment value matrices

Based on the judgment value matrices, the normalized matrices are obtained and presented in TABLES 4 and 5.

TABLE 4. Normalized matrix (N) of the criteria

ENVIRONMENTAL IMPACTS	Biodiversity loss	Erosion	Waste generation	Pollution	Generation of employment and economic income
Biodiversity loss	0,05	0,02	0,04	0,02	0,25
Erosion	0,38	0,11	0,73	0,02	0,17
Waste generation	0,22	0,02	0,15	0,82	0,17
Pollution	0,33	0,79	0,02	0,12	0,33
Generation of employment and economic income	0,02	0,06	0,07	0,03	0,08

TABLE 5. Normalized matrix (N1) of the alternatives which were evaluated according to the criterion biodiversity loss

ALTERNATIVES	Tourist entry control	Surveillance of tourist activities	Environmental Education	Signage of trails and tourist sites
Tourist entry control	0,5357	0,5625	0,5625	0,4167
Surveillance of tourist activities	0,1785	0,1875	0,1875	0,2500
Environmental Education	0,1785	0,1875	0,1875	0,2500
Signage of trails and tourist sites	0,1071	0,0625	0,0625	0,0833

4.3 Weight vector and consistency ratio for the criteria

The weight vector and the consistency ratio are computed following the steps indicated in the methodology.

The values of the previous vector are the weights of the criteria (eigenvector W).

Computing the Weight Vector or eigenvector (W):

	0,059471725
	0,32290107
W =	0,268289034
	0,292147385
	0,057190786

Computing the vector λW :

	λW
	0,39278426
	1,72743699
A*W=	1,87373844
	0,98178617
	0,43394437
λ_{max}	5,40969019

Computing the consistency ratio (CR):

CONSISTENCY			
CI	0,10242263	(n=5)	
AI	1,115	(n=5)	
CR	0,09185886	admissible inconsistency	

The Consistency Ratio (CR) of the judgment value matrix about the criteria is 0.09 which is lower than 0.10, it means that the judgment values given by the expert panel are consistent.

4.4 Computing the weight vector and the consistency ratio for alternatives

In order to obtain the eigenvector and the consistency ratio for alternatives, the process just stated above needed to be followed accordingly. Thus, the weight vector for the matrix A1 (judgment values about the alternatives with respect to the criterion 'biodiversity loss') or eigenvector is computed and it is necessary to use with the normalized matrix of the matrix of

judgment values about the alternatives with respect to the criterion 'biodiversity loss', as indicated below.

Weight vector or eigenvector (W1) (Average by rows of the normalized matrix N1):

W1 =	0,519345238
	0,200892857
	0,200892857
	0,078869048

In the same way, the consistency ratio of the judgment-value matrix about the alternatives was computed, being the CR=0,02, which is lower than 0,10, it means that the judgment values given by the expert panel are consistent. The just stated methodology is generated in the same way in order to obtain the weight vectors of the alternatives for each criterion. The five weight vectors (W1, W2, W3, W4, W5) are presented in the following matrix (A'), (TABLE 7).

TABLE 7. Matrix of the weight vectors of the alternatives for each criterion

		W1	W2	W3	W4	W5
CRITERIA ALTERNATIVES		Biodiversity loss	Erosion	Waste generation	Pollution	Generation of employment and economic income
A' =	Tourist entry control	0,519345238	0,218921703	0,182683271	0,157222222	0,319535581
	Surveillance of tourist activities	0,200892857	0,218921703	0,510032895	0,543333333	0,49982385
	Environmental education	0,200892857	0,50051511	0,184891917	0,191388889	0,061545365
	Signage of trails and tourist sites	0,078869048	0,061641484	0,122391917	0,108055556	0,119095205

4.5 Application of the criteria weights into the alternative weights

According to the Saaty methodology, the application of the criteria weights into the alternative weights, are applied by multiplying the matrices of the alternative weights (A') by the

criteria weights (W), in order to obtain the weight vector or eigenvector related to the alternatives.

$$\text{Priorities vector} = A' * W =$$

ORDER	PRIORITIES	
3	Tourist entry control	0,21479
1	Surveillance of tourist activities	0,40679
2	Environmental Education	0,2826
4	Signage of trails and tourist sites	0,09581

By realizing this, the hierarchy of the perform an ecological tourism, are presented in environmental impacts and their solution to the following matrices (TABLE 8 and 9).

TABLE 8. Hierarchy of the criteria

ORDER	PRIORITIES VECTOR	PRIORITIES (%)	Environmental Impacts (criteria)
4	0,059471725	5,9	Biodiversity loss
1	0,32290107	32,3	Erosion
3	0,268289034	26,9	Waste generation
2	0,292147385	29,2	Pollution
5	0,057190786	5,7	Generation of employment and economic income

TABLE 9. Hierarchy of the alternatives

ORDER	PRIORITIES VECTOR	PRIORITIES (%)	ALTERNATIVES (solutions)
3	0,214794880	21,4	Tourist entry control
1	0,406792461	40,7	Surveillance of tourist activities
2	0,282602375	28,3	Environmental Education
4	0,095810285	9,6	Signage of trails and tourist sites

According to the results about the hierarchy of the criteria, the main impact of the tourist activities is erosion which account with 32,3% in the ranking. This resulted due to many tourism activities that cause severe damage to the fragile ecosystems (moorland, sandy paths and ecological sites) of the national park (Díaz *et al.*, 2024). The second important impact is contamination (29,2%), which is due to the tourist activities that cause contamination of the water

areas, the air and the ground (soil). The third important impact is waste generation (26,9%) due to the tourism activities which are generating solid and liquid waste as well as waste gases. This impact contributes to the contamination of the environmental components. However, it was fundamental to analyze this separately due to the big problem that this impact is causing to the conservation of the park (Jácome *et al.*, 2013).

The fourth impact in the hierarchy is biodiversity loss (5,9%). This impact appears to be less important in the ranking, but it should be considered in the management plan of the PNC. Such issue appears especially when the park is dealing with provoked fires, even though these are rare lately, the park manager should not discard it. The fifth impact is generation of employment and economic income. This is the less important one due to the tourist activities in the PNC, it still little important for the local economy, as most tourism activities are lasting less than a day (Ministerio de Turismo, 2023). Therefore, the generation of employment and income for local population remains still low.

To solve all these environmental impacts, the AHP model allows the solution-alternative hierarchy, being the surveillance of tourist activities the most preferred by the expert panel, with a hierarchy of 40,7%. This is because of the surveillance of the tourists is a key issue in order to avoid or diminish all the just stated environmental impacts due to the high influx of tourists and the lack of surveillance of all activities done by the tourists. Besides, there are various environmental impacts caused in ecological zones by uncontrolled tourism, among which the most representatives are the different types of pollution to the environment by the different residues emitted by uncontrolled tourist activities (Sadeghian, 2019; Murava & Korobeinykova, 2016). Moreover, the excess population and its agglomeration in the paths and ecological sites, generate land use problems, ecological breakdown, damage to nature, and alterations in the landscape due to loss of biodiversity (Jácome *et al.*, 2013).

The second preferred alternative is the so-called environmental education, which is obviously fundamental to be considered to formulate a successful park management plan (Rickinson, 2001; Carleton-Hug & Hug, 2010; Potter, 2009). This alternative is very important as well the training of the personnel involved in environmental activities and projects (Floyd *et al.*, 1997; Oleśniewicz *et al.*, 2020; Deng *et al.*, 2003) and in the management of the protected natural areas (MAATE, 2023). Therefore, the

environmental management plans of the natural areas, contain the Environmental Education Program according to the guidelines from the Environmental Ministry of Ecuador (MAATE, 2023). Environmental education and training must be understood as an instrument of very effective impact prevention (Tilbury, 1995; Monroe *et al.*, 2008). Thus, by implementing this alternative of Environmental Education in the Cotopaxi National Plan, there will be a success in the fulfillment of the main goals in the management of such area.

The third preferred solution alternative is the tourist entry control (21,4%). This is also fundamental to the conservation of the park, as controlling the tourist entry is a priority issue to deal with (Han *et al.*, 2021; Hampton, 2003). By implementing this, there will be less environmental impacts, and these will be the least possible and almost compatible with the environment.

Finally, the least preferred alternative is the signage of trail and tourist sites. This solution to the environmental impacts caused by the tourism, is also essential to be implemented to avoid many environmental impacts due to the lack or little signage on the trails and tourist sites. The lack of it, may mislead visitors in sensitive places of the environment, leading to potential damage (Deri *et al.*, 2023; Hughes & Morrison-Saunders, 2002; Wolf *et al.*, 2012).

5. Conclusions

The AHP methodology to hierarchize the environmental impacts and its solution, due to the tourism activities, was extraordinarily applicable to the Cotopaxi National Park, obtaining adequate results for the ecotourism in the park trails and tourist sites.

The most important environmental impact obtained by the AHP methodology was erosion due to the tourist activities, and the most preferred solution alternative was surveillance of tourist activities.

The judgment values about the criteria and the alternatives given by the expert panel were consistent because all the consistency ratios obtained were less than 0.10.

Finally, to avoid the environmental impacts due to the tourism, besides of the program of surveillance of tourist activities, a program of the tourist entry control should be implemented in the Cotopaxi National Park. This should be realized especially during the national holidays, when the carrying capacity of the area is overpassed.

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Lugar y fecha de finalización del artículo:
Quito, Ecuador; agosto, 2024