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Proposal for a Framework to Develop Sustainable Tourism on the Santurbán Moor, Colombia, as an Alternative Source of Income between Environmental Sustainability and Mining

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Abstract: The main goal of this paper was to propose a program to develop sustainable tourism at Santurbán moor in Colombia. This would open new paths toward economic growth for the communities inhabiting this sector who are currently facing a serious dilemma. First, the moor is an area of vital importance to the sustainability of more than two million people, who depend on water generated in the area. On the other hand, this land contains great mineral wealth and agricultural resources. This has generated an already long-lasting conflict of interest between environment conservation and the possible economic exploitation of the Santurbán moor through industrial mining. To this end, we conducted bibliographic research on sustainable tourism, specifically with scientific ends, that considered the potential of this area for its implementation. Prospective methodology was applied, beginning with the selection of a panel of experts to identify the most important external and internal variables that could affect the area. Then, Impact Matrix Cross-Reference Multiplication Applied to a Classification (MICMAC) software was used to identify the correlation between the different actors and their possible contributions. As a result of this research, a proposal is presented that is focused on the needs of the community living in the area, as supported by science and the academic community, and by the use of Industry 4.0 and related new technologies. This strategy could be used in other protected areas in Colombia, or throughout the world, that are currently being visited by tourists who, maybe unwillingly, are actually putting the sustainability of these areas at risk. In the future, this strategy will be consolidated and will lead to technological applications. This will allow tourists to enjoy protected places without threatening the conservation of these habitats.

Keywords: sustainable tourism; Colombia; Santurbán moor; MICMAC; Industry 4.0

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1. Introduction

High mountain equatorial moors, located between 3000 and 4700 m altitude, represent a unique type of region in the world, given their importance as generators and regulators of water resources. The water in their contained wetlands and lakes flows into river catchments extending their areas of influence. Most of these moors are in the Andes, and Colombia contains about 50% of these areas. In addition to their hydrological importance, moors provide unique habitats with many endemic species, and they exist in beautiful landscapes that can be accessed and enjoyed through tourism in a sustainable manner.

The Santurbán moor is a natural resource measuring 138,699 hectares located in the eastern region of Colombia. It is shared by the departments of Santander and Norte de Santander, as it is an area of vital importance for sustainability. More than 15 Santander

municipalities derive their water resources from it, including the metropolitan area of the city of Bucaramanga, the capital city of the Santander department, which has more than one million inhabitants. However, there has been a continuous dispute in recent years between the ancestral inhabitants of the moor, who have taken advantage of the habitat through agriculture, maintaining livestock, and gold mining [1], and the inhabitants of the municipalities that use the water downstream. The latter have requested that the moor be declared a vital resource and that such activities in it cease, which would leave the former communities without means of livelihood.

The greatest threat to the sustainability of Santurbán moor is its great mining wealth. According to geological estimates, there are more than 7 million ounces of gold and more than 80 million ounces of silver in the moor. Such resources are highly sought after by large multinational mining companies and have been traded for more than 200 years by artisanal miners living in the natural park. In any case, large-scale extraction of this mining potential is very likely to contaminate the area. This situation has been magnified since the natural park was declared an environmental reserve and mining was banned in some areas, generating a boom in illegal mining that leaves uncontrolled pollutants, such as mercury, in the area [2].

Sustainable tourism, and especially scientific tourism, has a great potential to reduce the economic problems that the resident populations in the nature reserve will face, since in the latter, the tourists are mostly scientists who want to explore and discover new environments that allow them to generate new knowledge. A related example of this is the expert-guided tours that are conducted in technological institutes, such as the European Organization for Nuclear Research (CERN), which implies that this is a concept that can be adapted to different contexts, whether a natural space, a laboratory, or a research center [3].

1.1. Current Status of Sustainable Tourism in the Area

A systematic bibliographical search was conducted for articles related to the Santurbán moor across the most important bibliographic reference databases, such as Scopus, ScienceDirect, and the Web of Science, among others, to find any research on this area that had been previously published. We found that there were very few such publications, and these mostly concentrated on the effects of mining in the area. Works such as [4–7] focused on the impact of mining on the water resources generated in the moor. Other studies, such as [8,9], focused on the relationships of mining companies with the community and on the legal conflicts that are looming, given the delimitation of the area as of environmental interest.

Regarding the possible tourism exploitation of the area, the written works found were master's and undergraduate thesis reports in the repositories of educational institutions, and no work that related to a practical implementation of tourism in the area could be found. This does not mean that tourism activities are not being carried out. A simple web search on tourism offers in Santurbán returned several offers for adventure tourism, landscape recognition, and hotel services for camping in the area. A reference was found stating that, in 2015, technical assistance was provided by ALBA SUD, a Catalan entity that specializes in research and communication for development, in which community leaders were trained in ecotourism concepts. But according to what was found in this work, that effort was not consolidated in the field visits.

It is necessary to integrate the tourism services currently offered with the new sustainable tourism policy issued in Decree 646 of 2021, through which Colombia formally adopted a sustainable tourism policy called 'United by Nature'. This national decree delegated the Ministry of Commerce, Industry and Tourism to generate the technical documents for its implementation. According to government estimates, it is expected that by 2030, this policy will become a reality.

1.2. Importance of the Study

The importance of this study is directly related to the need to present alternatives for the sustainable development of a region that is currently convulsed by the urgency of

protecting the water sources that supply water to more than two million people and the needs of a community that for more than four hundred years has exploited this soil either with artisanal mining or agriculture. Tourism is another option given its attractions and the unique fauna of the Andean moorland [10], in addition to the economic benefits such as job creation and the strengthening of the native culture. Currently, the locals have become aware of this possibility and have implemented incipient efforts to exploit the resources present in the area, such as the lagoons, but as was noted during field visits, there is no real work towards environmental protection. An entrance fee is charged, and tourists are left to their own devices without any control nor guidance. It is necessary to generate a culture of protection for the environment and that is precisely what this work wants to initiate [11], besides a strategy that involves the community, tourism entrepreneurs, the state, academia, as intertwined through the technology of Industry 4.0. To this end, we started with a study of the challenges currently faced by the implementation of tourism in the Santurbán moor. Interviews were conducted with tourism experts, tourism promoters and the community that currently exploits this resource. Several results were obtained, such as the absence of the government in the control of tourism issues, the lack of infrastructure, and the lack of knowledge of the locals on environmental protection issues. These circumstances must be considered in a proposal that involves all the actors of the process.

1.3. Objectives

The main objective of this work is to make a proposal for the development of sustainable tourism in the Santurbán moor region, based on the identification of the main variables and actors that affect its development. Based on this knowledge, a conceptual framework is proposed, which involves these variables and allows the future implementation of tourism activities that benefit the communities whose economic income has been decimated by the delimitation of the protected area. The specific objectives of this work were the following:

- Identifying the actors of the tourism chain in the Santurbán moor region and their profiles based on direct contact with them, which will allow firsthand knowledge of their needs through the development of this conceptual framework.
- To identify the obstacles and strengths of the Santurbán moor region for the implementation of sustainable tourism.
- To propose a conceptual framework for the development of the Santurbán moor as a center for sustainable tourism, based on the opinion of the experts, the techniques applied, and the needs detected in the field.

The development of the first objective made it possible to learn about the social reality in the area, which indicated the possible strengths and weaknesses in the future implementation of a tourism network in the area. The development of the second objective made it possible to determine the baseline from which the proposal was formulated.

For the development of these objectives, prospective methods of analysis of social problems were combined, such as the Delphi method involving the opinion of experts, together with the application of the Mic-Mac software tool to visualize the incidence of the different actors.

2. Theoretical Background

2.1. Sustainable Tourism

Given the ecological and strategic importance of the Santurbán moor in the region, it is necessary that all ventures that are carried out in the sector tend to its conservation. Therefore, any tourism initiative should be framed within the category of sustainable tourism [12,13], with the objective of mitigating the negative effects on the environment that the influx of tourists to the protected area may have, considering all the social and economic characteristics of its inhabitants. This premise should be included in the generation of new value chains and economic variants resulting from their implementation.

Tourism initiatives are expected to have the following premises:

- Protecting the moor biome. Without the unique vegetation of the Andean moorlands, it would not be possible to generate water and this in turn would not be attractive to potential visitors, therefore poor conservation of this resource would spoil any initiative [14,15].
- Promote a culture of preservation among tourists and residents. Without the support of the people who live in the area daily, the conservation of the biological resource will not be possible, and it is they who must strongly transmit this concept to visitors [16,17].
- Economic development. The long-term benefits generated by tourism activity in the region should be fundamentally distributed among the locals, becoming an engine of wealth and social prosperity for the region [18,19].

Given all the controversy raised by the discussion around the use of the Santurbán moor area, debating between economic, social interests and ecological sustainability [20], an alternative is needed to allow the locals to obtain resources and maintain the moor resources for future generations. Following this line of thought, scientific tourism is considered as a sustainable tourism option.

2.2. Scientific Tourism

The traveler interested in scientific tourism wants to expand and complement their knowledge. Therefore, this tourism should be developed in environments related to science and technology and can be complemented with adventure tourism and ecotourism [21].

Authors such as [22] see scientific tourism as a possibility for the economic development of fragile ecosystem areas that must be protected, but at the same time need to produce resources for their inhabitants. This is due to the combination of scientific tourism with other branches of tourism such as adventure and cultural tourism. Besides, such tourism contributes new knowledge as the traveler learns about the ecosystem and contributes his own knowledge to local knowledge networks. This exchange favors the creation of new knowledge networks, as well as economic resources to the intervened territories.

Given the similarities within cultural tourism whose purpose is to have contact with the different cultural expressions of the visited sites, such as museums, art exhibitions, theater etc., scientific tourism includes in itself a scientific dimension [23]. Authors such as [24] classify scientific tourism in four categories that are combined with other forms of tourism such as:

- Adventure tourism with a scientific dimension: Defined as that which allows the combination of scientific research, adventure, and sports practices such as climbing large peaks or expeditions in places of difficult access where the main motivation can be adventure or science, but in its development, both are achieved. In the case of the Santurbán moor, adventure is guaranteed as it is a high mountain terrain that requires the tourist to be in good physical condition.
- Cultural tourism with scientific content: The main objective of this type of tourism is to take tours where the tourist contacts cultural or industrial aspects of the site being visited, and its main purpose is to acquire some type of scientific knowledge during the tour. Given the unique biota present in the tropical moor, it is very feasible to learn about new environments and generate new scientific knowledge.
- Scientific eco-volunteering: In this type of trip, the tourist is directly involved in scientific aspects such as sampling and data collection guided by scientific personnel who organize the actual research in the environment being studied.
- Scientific research tourism: This category is related to the scientific delegation that travels to study a particular site. In this case, given that the tropical moor is an environment found in only a few countries in the world, the structuring of a scientific tourism system in Santurbán would be very attractive for specialists from first world countries.

In this context, scientific tourism is oriented to tourists interested in the world of science from first world countries with high resources [25], who would come and study environments such as the Santurbán moor. In addition to bringing resources to the local

economy, this would provide more tools and knowledge and allow a sustainable use of this natural park.

An information-based technologies framework that is also capable of integrating communities, the productive sector and the protection of existing biodiversity is needed [26]. Another paramount factor needed for the development of scientific tourism is to have qualified locals, capable of playing the role of hosts and guides effectively. Conducive to this, they must be taught how to appreciate their environment and how to live sustainably in it [27].

Scientific tourism is a very appropriate strategy for areas, such as the Santurbán moor, that have conflicts over the use of resources and the economy. It is a strategy that involves the community in its development and the scientific community, leaving in its wake resources, knowledge, and a sense of belonging to environmental conservation.

2.3. Scientific Tourism in the International Context

Scientific tourism continues to develop as an alternative in various parts of the world, so several authors have studied its implications. Authors such as in [28] studied the implications of scientific tourism in the communities settled in the Ecuadorian Amazon that are visited by various types of scientists. This type of exchange has created a favorable environment for communities to value their cultural and territorial heritage, in addition to leaving economic benefits. The community is comfortable with the process and has improved their level of appreciation for the natural resources by taking care of them in a more sustainable way. There are still things to improve, such as the lack of knowledge on the part of tour operators about the type of activity, as in most cases they consider them to be scientific or scientific outreach events, and there is still a lack of awareness among them.

Authors such as in [29] have shown the achievements of scientific tourism in the Aysén Region, in southern Chile, during the last 15 years. They show that for the locals, scientific tourism has been an integrator that in addition to providing economic resources has strengthened conservation processes in the area. This occurs because it has revalidated the value of the geographical resources present in this territory, increasing awareness of their importance, which results in greater learning and deliberation about it. Although it also highlights the need for the immersion of high-quality products and landscape management.

Works, such as that of [3] in relation to scientific tourism in the French Alps, exemplify where this type of tourism can be integrated with the adventure tourism offered by the mountainous landscapes, but also where there is a need for the process to be reinvented based on creativity and innovation, which in the case of the present work offers the technologies of Industry 4.0.

Authors such as those in [11,30,31] present theoretical research on the advantages of the implementation of scientific tourism in areas with cultural and geographical potential, having as a premise the conservation of these heritages, the increase of the knowledge that exists for them, and the increase of the value that the native communities perceive for them. They were framed in strategies that involve them in the development of associations and/or cooperatives that exploit for their benefit the tourist resources that they possess appealing to resources such as digital media.

The literature consulted shows a common axis that highlights the importance of integrating the community with the development of tourism projects to make them sustainable in the long term and the need to innovate using new technologies.

2.4. Frameworks Based on Industry 4.0 Technologies for Tourism Development

The use of frameworks for the development of processes involves the standardization of the developed product [32], as the process involves the use of common procedures for the generation, interpretation, and analysis that can then be reused in a specific application area. Therein lies the importance of the studies of the concepts of Industry 4.0 within the bibliography of this paper, because it is intended that the result can be replicated in other areas with tourism potential that are similarly sensitive as the Santurbán moor.

Works such as [33] bring together a confluence of technologies and industry standards, such as cloud computing, metadata, generation and management of ontologies, artificial intelligence, pattern recognition, and decision support systems. This paper [33] presents a structure applicable to tourism developments such as the one needed for Santurbán moor. The authors of [34] presented a Big Data based knowledge system framework in a form of creative computing, which was a new concept on how to guide human beings to create fresh, surprising, and useful systems to achieve effective work in different fields. According to the authors, it combined knowledge from different disciplines using ontologies and Big Data algorithms. Thanks to that combination, they obtained as a result an algorithm was able to achieve data integration and extensible synchronization access of the sensing node. It allowed them to expand the volume of information storage in the system of tourism organizations and improve the accuracy of data integration by combining knowledge and cloud computing. However, there were still some outstanding issues, especially the problem of information privacy and security, during the operation period of the system, which should be overcome in the future.

In the paper [35], the author presents a new local community tourism system based on LOD (Linked Open Data). In this study, the tourism related data were converted into RDF (Resource Description Framework) and stored as an LOD database in the local community system. From there, a prototype was derived whose validity of the proposed system was confirmed by the field experiments.

The paper [36] presented a related work on an intelligent tourism information system in the Big Data environment, using semantic description and link building methods to complete intensive, intelligent, and unified tourism management. This consisted of cu layers: metadata layer, ontology layer, linked data layer, data application layer. The main roles of these layers and their relationships were described. An RDF Link approach among tourism linked data was presented to build the semantic association of tourism linked data, showing that Big Data based linked data can solve the problem of uniformity and interoperability of heterogeneous data sources encountered in tourism systems.

The use of Industry 4.0 technologies can provide the level of innovation described by the authors as a requirement of scientific tourism described above, so this proposal implements its use to contribute to the solution of a solid technological structure in this case study.

2.5. Colombia's Potential for Scientific Tourism

Colombia is in a privileged situation for the development of scientific tourism given its geographic location, being the only country in South America bathed by two oceans with 1818 km of coastline on the Atlantic Ocean [37] and 1300 km of coastline on the Pacific. It is outstanding for its great variety of fauna and flora in which South American and Central American elements converge [38]. Among the existing attractions in Colombia that are very famous, there are sandy beaches, such as the island of San Andres and Cartagena, and the paradises for marine fauna, such as the volcanic island of Malpelo.

Another important aspect is that Colombia is that its interior is crossed by the Andes mountain range, which support ecosystems across all altitudinal temperature zones. In the Amazon rainforests to the south, there is the Amacayacu National Natural Park with exuberant animal life, including more than four hundred endemic bird species, the Amazonian manatee, and the pink Amazon dolphin among others [39]. This area is diverse in indigenous communities that offer ecotourism services and has a cultural and anthropological potential.

To the east are the floodplains of the tributaries of the Orinoco, where you can find the natural parks of the Sierra de la Macarena embedded in the Guiana shield with ecosystems typical of rainforests, flooded forests, and vegetation of the Amazonian savannah [40]. It is also possible to find archeological traces such as pictographs and petroglyphs of the ancestral indigenous cultures that inhabited the area. Another important park in this area is the Tuparro Natural Park, which has been declared a national monument because of its

environmental importance. But it still has great potential for the discovery of new species because it has not been surveyed in detail for insects and amphibians.

To the west of Colombia on its Pacific coast are the natural parks of Utria, Gorgona and the Malpelo Island Flora and Fauna Sanctuary. There it is possible to see whales, such as humpback whales and sperm whales. It is a nesting area for hawksbill turtles and a wide range of crustaceans. Additionally, you can dive in its coral areas full of an explosion of marine life of its own. On the other hand, this area is culturally rich with the presence of African sourced communities with their typical dances such as the Currulao, the Patacoré, the Perejú.

To the north of Colombia, is the Caribbean zone with natural parks such as the Rosario and San Bernardo corals with a wide marine fauna where diving activities can be performed. The Tayrona natural park has beautiful beaches and natural scenery where you can see many birds typical of the Colombian Caribbean and a great diversity of reptiles [41]. In the Caribbean zone there are white beaches such as those of Santa Marta Bay, which is a very popular tourist destination in Colombia.

The Andes crosses Colombia through its central part and in this area, there are several natural parks such as the Nevados National Park with its volcanic peaks and the Nevado del Ruiz, the Cocuy Natural Park, which is the largest glacier area in Colombia with altitudes of more than 5000 m, moors, and Andean forest areas with a great variety of fauna and flora.

Colombia has a great variety of protected areas that occupy about 15% of its territory (Ministry of Environment, 2019), with one of the highest levels of biodiversity in the world. This makes it an appropriate destination for scientific tourism, as in only one territory it is possible to find diverse ecosystems from marine territories to those of cold climate and high mountains.

3. Methodology

This work applied a structural analysis approach using the methods of foresight [42]. This methodology allows that the opinions of a group of experts who individually analyze each of the parts of the system feed the MICMAC software platform, greatly reducing biases in the opinions, and increasing the overall appropriation of knowledge regarding the subject in question.

The following steps were implemented to carry out this process [43]:

1. A bibliographic study of the problems and characteristics of the study area, the Santurbán moor, was carried out [44], based on previous studies by various organizations, both public and private, to obtain a first approximation of the possible study variables and a baseline of the situation that is currently being experienced there.
2. A group of experts was selected based on their knowledge of topics related to sustainable tourism, environment, or topics closely related to the study area's problems [45]. In addition, people from the area were selected who were currently involved in tourism and social processes in the field and had an interest in the research study [46]. The recommended number of experts was 10 to 15 for the size of the research planned [47]. A group of twelve experts in different areas was selected: four representatives of the academic sector, including tourism experts and ecologists; three business-people, including hoteliers, developers and transporters; two representatives from the community of tourism associations in the area; one representative from the official sector; and two experts in innovation and technology. This group carried out an iterative process, maintaining the anonymity of the participants to avoid bias [48].
3. Once the group of experts had been selected, a questionnaire was prepared so that they could evaluate both the questions and their relevance in the first round and make suggestions for improvement in the following rounds. These first questions arose from the baseline information obtained from the bibliographic analysis [49]. Considering those that, in the opinion of the authors, could affect the implementation of tourism in the area, internal and external variables were chosen associated with

natural resources, sustainability, community, state entities, mining, culture, tourism companies, tourism promoters, guides, infrastructure, among others. In the second and third round, the experts evaluated the adjusted forms and were able to make contributions to improve the process. This work resulted in a SWOT analysis for the Santurbán moor.

4. They were asked to do pairwise analysis of the connections between the variables, and to decide if there was a connection between them. If so, to then determine a numerical valuation of the type of connection, from weak to a strong connection.
5. The analysis of the key variables was carried out using MICMAC software.

3.1. Contextualization of the Santurbán Moor

The Santurbán moor is in South America, in the eastern mountain range of Colombia, between the departments of Santander (28%) and Norte de Santander (72%) with approximately 140,000 hectares [9] (Figure 1). The climate of the moor is high mountain cold, with temperatures below zero degrees ranging up to 15 degrees in its warmest areas, altitudes from 2800 m to 4300 m, and annual rainfall from around 700 mm to 200 mm annually according to the location in the reserve.

Figure 1. Location of Santurbán moor in Colombia, Reference image. Source: own elaboration.

Given its high altitude, solar radiation, and rainfall, it is a suitable place for growing onions and potatoes, crops that have been grown in the area for many years. Another form of farming is cattle and sheep ranching. Both activities are supported by water from the abundant wetlands and springs in the area that feed the watersheds below with more than two and a half million people in 48 Colombian municipalities, including the urban area of the capital of Santander Bucaramanga with more than one million inhabitants. Its water also influences Venezuela where its rivers flow into Lake Maracaibo [50].

The Santurbán moor area sits on a mining wealth estimated at nine million ounces of gold [51], which has been exploited in an artisanal way since colonial times, for more than four hundred years. In the area, there are miners who are not regulated, who use cyanide and mercury without control to extract gold, contaminating water sources [51]. Currently there are multinationals interested in exploiting this resource, which has generated a conflict

with people interested in conserving the natural resource. In 2014, the national government presented a proposal for delimitation of the moor, leaving some sidewalk, such as La Copa with an area of 400 hectares within the protected area out of a total of 570 ha, which left the land unusable for agricultural and mining exploitation causing complete damage to this community that radically opposed this intervention. This is just one example of the many communities affected by this delimitation with no short-term solution alternatives. The conflict between the park's environmentalists, the people who have for ages lived off the park's resources, and the new companies that see the park as a new pot of gold and silver, is getting increasingly stronger. In addition, there are major deficiencies in the integrated management of biodiversity and potential ecosystem services in the area [52].

The delimitation of the moor will leave some areas out of agricultural and livestock exploitation, leaving people without their traditional livelihoods. With this present problem, it is necessary to offer these communities another way to take advantage and value the moor resource. It is important to show them that it can become an important area for sustainable and scientific tourism given the biotic resources that exist in the sector such as its lagoons, the floral diversity [53] and the diverse ecosystems of moss that only exist in these latitudes and that are a potential attraction for foreign tourists [54].

Apart from this problem, in the area there are still protected sites that are pristine and little affected by humans, such as the Súrcura lagoon. You must walk about eight hours to reach this locality, so you require a good physical condition and a spirit of adventure, because in such high mountains the oxygen level is lower and problems such as altitude sickness may occur for some visitors.

This effort is worthwhile because the region contains a unique biodiversity that is present only in the northern Andean moors, with more than forty species of birds and mammals, 457 varieties of flora and 26 lagoons [9] with impressive landscapes that can be the delight of visitors committed to their conservation.

3.2. Application of the Prospective Methodology

3.2.1. Analysis of the Experts

To ensure the success of the application of the prospective methodology, a panel of experts was formed in accordance with the description detailed in the methodology. The purpose of this panel was to obtain their vision on the realities, trends, needs and possible evolution of sustainable tourism in the region. These experts were chosen based on their academic, political, administrative, business and logistics backgrounds, which were the areas identified as having the greatest impact on the development of the project. Among them were specialists in tourism services, transportation entrepreneurs, environmentalists, and residents with notoriety from the area influenced by the Santurbán moor.

These experts worked anonymously as suggested by the methodology, to avoid the dominant effect of any one of them, creating biases in the data obtained. The feedback was done in a controlled manner by the researchers using an iterative process.

The information obtained in the different iterations of the process was codified and analyzed by tabulating the different variables present in the survey to obtain descriptive statistical information such as standard deviation and interquartile range to determine how close the opinions of the experts were in the different iterations carried out [55].

The first work done with the experts was to carry out a SWOT analysis on the strengths, opportunities, weaknesses, and threats for the implementation of a tourism corridor around the Santurbán moor, whose most important contributions are shown in the results.

3.2.2. Analysis of Variables and Actors with Mic-Mac

To perform a deeper structural and prospective analysis with the help of experts, key variables that define the behavior of the system were defined for subsequent analysis using Mic-Mac software. Thirty (30) independent variables were determined to cover the most relevant aspects of the problem.

When using the Mic-Mac software, a qualitative structural analysis of the system is performed by using a matrix of crossed impacts. These impacts are measured according to the weight of one variable over another. These weights were determined based on the judgment of the experts according to the influence of one variable over the other. If there is no relationship the impact is weighted with (0), if the influence is weak with (1), medium (2) and strong (3).

To implement the influence matrix, the group of experts analyzed the connections among the variables, reviewing them in pairs and determining an assessment of the dependence of one variable on the other according to the values expressed above. The process was repeated with each expert until a total of 15 opinions were obtained for each pair of variables. To obtain the final value to be assigned in the table of influences, descriptive statistics such as standard deviation, interquartile range and mode were applied to determine how close the various opinions were.

Once the valuation for each pair of variables was defined, it was assigned to the matrix of influences. The complete matrix has a size of 30 × 30. Table 1 presents an example showing the first ten variables and the weight assigned in relation to the others.

Table 1. Sustainable tourism influence matrix for the Santurbán moor.

	1: GuiasTur	**2: Transpor**	**3: HabiVetas**	**4: MinVetas**	**5: Turistas**	**6: AgeTur**	**7: Ecologista**	**8: ComZona**	**9: GenBuc**	**10: EmpTransp**
1: GuiasTur	0	2	3	1	3	3	2	2	3	3
2: Transpor	1	0	1	0	3	3	1	2	3	3
3: HabiVetas	1	1	0	2	1	2	3	3	2	2
4: MinVetas	1	1	3	0	1	1	1	1	1	1
5: Tourists	3	3	2	1	0	3	2	3	2	3
6: AgeTur	2	2	1	1	3	0	2	2	3	2
7: Ecologista	2	1	2	3	2	1	0	2	1	1
8: ComZona	1	1	3	0	3	2	1	0	3	2
9: GenBuc	1	2	1	0	3	3	1	3	0	2
10: EmpTransp	3	2	1	1	3	3	1	1	2	0

For example, variable 5, "tourists", had a strong relationship (3) with variables 1, 2, 6 and 8, which in their order are: tourist guides, transporters, tourist agencies and community of the area, and a weak influence (1) with variable 4 "mining in the municipality of Vetas". The influence of the variable with itself is considered zero.

The complete matrix was entered for analysis in the MICMAC software. This software provides indicative graphs about its influence on the system. Figure 2 shows the plane of influence and dependence of the variables of the system under study, which were categorized as secondary, target variables, key variables, result variables, autonomous variables, and determinant variables.

The software MICMAC presents the results using four quadrants. The explanation of them is given below:

- Variables located in the lower left are those with no significant influence on the others as they have little dependence on each other.
- The variables located in the upper left part are variables with high mobility and influence on the others but which in turn have little dependence on each other.
- The variables located in the lower right part are variables that have little influence, but high dependence on the others.
- The variables in the upper right part have high influence and high dependence that will significantly influence the implementation of sustainable tourism in the region.

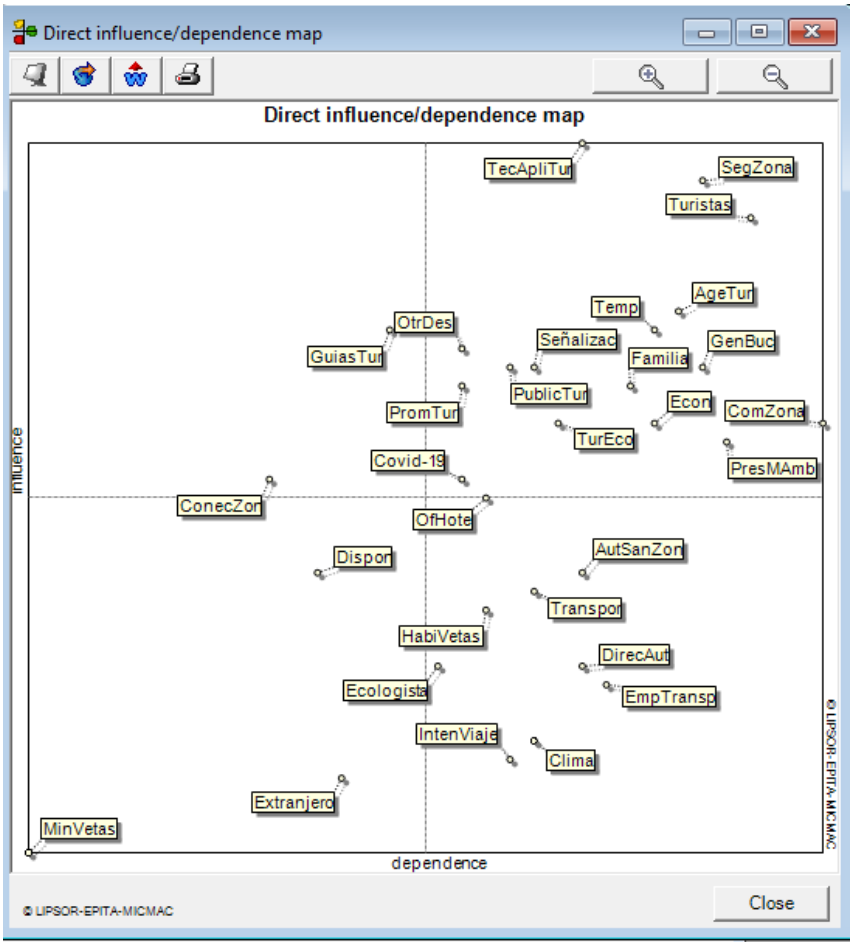

Figure 2. Influences map. Source: Prepared using LIPSOR-EPITA-MICMAC software.

It was observed that variables such as COVID-19 and the availability of specialized tourist guides can hinder the development of sustainable tourism in the region. Among the key variables are the technology applied to tourism, security in the area and the correct use of the ecosystem by tourists.

Once the variables and their effect on the system were identified, the actors were studied according to their impact on the key variables and the project objectives. Then the influence among the different actors was studied to determine which of them have the highest impact on the development of the project. This step determined that the surrounding community, tourism promoters, government agencies, academia, and the behavior of the tourists themselves are the keys to the successful development of any sustainable tourism project in the Santurbán moor.

Subsequently, surveys were conducted with each of the identified stakeholders to learn about their specific interests in the development of a possible tourism project.

4. Results

4.1. SWOT Analysis and Identification of Key Stakeholders

The development of the SWOT matrix with the experts made it possible to identify the strengths, opportunities, threats, and weaknesses that may impact on the implementation of a solid structure to support sustainable tourism in the Santurbán moor, as well as the most influential stakeholders. The analysis produced the following results:

Strengths:

- The vegetation present in the moor is unique in the world and it exists only in a few countries worldwide.

- In the area, there are many lagoons and landscapes with touristic potential.
- Santander department has other nearby areas available for adventure activities and scientific tourism.
- The municipalities of Santander have a great cultural potential due to their colonial architecture.
- The proximity of Bucaramanga's Palo Negro International Airport, less than 60 km from the area of interest.
- The community is engaged to build partnerships and projects of common interest.

Opportunities:

- The Colombian government is interested in developing tourism programs that take advantage of Colombia's natural resources, which would allow leveraging projects for this purpose in the area.
- The relative proximity to Panama, a one-hour direct flight away, where the Smithsonian Tropical Research Institute is located.
- The proximity to Venezuelan border could allow the flow of tourists to the area.
- The delimitation of the moor as a natural reserve and the political implications for its conservation.

Weaknesses:

- The lack of hotel and service infrastructures in the area surrounding the moor.
- The lack of digital connectivity (Internet) in the area.
- The technological backwardness of the tourism system in the region.
- There are not institutionalized programs in the local colleges to train specialized guides with a good command of English.
- The lack of accessibility in infrastructure.
- A public policy for the use of the moor as a tourist destination has not been defined.
- There is still not enough publicity about the nature reserve's tourist attractions.

Threats:

- The destruction of the ecosystem by tourists.
- The interest in mining in the area.
- Restrictions due to possible pandemics such as COVID-19.
- Climate change and its implications on the nature of the area.
- Public order in Colombia and social problems due to the advance of poverty.
- Social grievances in the area may lead to an increase in violence rates.

Based on the SWOT analysis conducted with the thematic experts, it was concluded that there is a great opportunity for tourism development, but it is necessary to improve key aspects such as hotel infrastructure, guide training, and technological and digital infrastructure.

4.2. Proposed Framework for the Implementation of Sustainable Tourism

Once the structural prospective analysis of the system was carried out, a framework was proposed based on the main actors that are present in the area influenced by the Santurbán moor. Therefore, sustainable tourism was taken as a fundamental pillar to minimize the effect that visitors have on this territory. In addition, it contributes to the local economy [56], generating new knowledge because of the exchange with specialists in biological and conservation issues.

Figure 3 shows the axes on which the proposed framework for the implementation of science-based sustainable tourism is based for Santurbán moor. The fundamental objective is the equation of this system where the community, science, the academic and productive sector, the state, and technology are intertwined to generate their contributions and grow together.

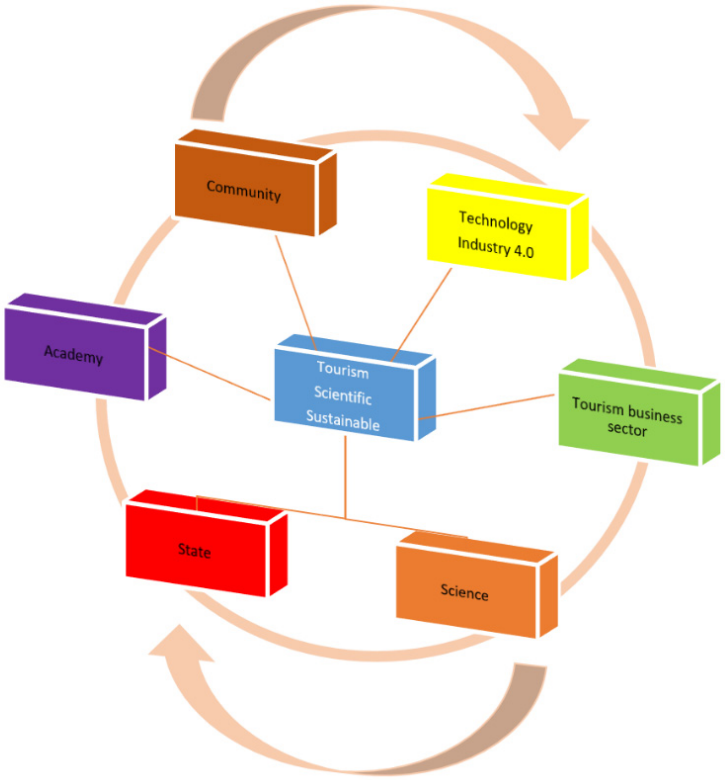

Figure 3. Pillars of the framework.

4.3. Social Dimension

To achieve a proper implementation of sustainable and scientific tourism in Santurbán, it is necessary that each part of this system makes a significant contribution. In the next section, we present a brief analysis of the current situation of each actor and their possible contribution.

4.3.1. The community of Santurbán: A History Linked to the Mining Industry

The Santurbán moor region had its first indigenous settlements in the first century B.C. with four ethnic groups: Guane, Chitareros, Yariguies, and Lacches. These communities lived in harmony with their environment and exploited gold for their ritual expressions. But it was the knowledge of the existence of gold that initially attracted the Spanish colonizers in the sixteenth century [57], who began the exploitation of this resource for commercial purposes using methods that cause damage to the environment and banished or eliminated these indigenous communities.

The community of the Santurbán moor for about 400 years has been dedicated to the artisanal exploitation of gold. In the middle of the last century, the first multinationals presented intentions to extract gold, although these projects did not crystallize. However, there was an increase in artisanal mining, with a greater growth in the municipalities of Vetas and California, where much of the community is formed by artisanal miners. At the beginning of the 1990s, multinationals became interested in investing in this sector and the Canadian company Greystar began the exploitation of a mining title, and in 2011 it obtained another license to exploit in the upper part of the moor, which alerted environmental groups and so began a struggle between the community that benefits from jobs generated by mining and the inhabitants of the basin who receive water contaminated with mercury, cyanide and other mining waste [58].

Other activities such as agriculture, livestock and fish farming have developed around this activity. According to Colombia's National Administrative Department of Statistics (DANE), the Santurbán area produces 90% of the onion consumed in the metropolitan area of Bucaramanga and Cúcuta, capitals of the two departments that contain the reserve. Crops

are grown by family groups in plots of 5 to 10 hectares and mainly onion monocultures and others combined with potatoes [59]. Given the high altitude of the reserve, other food products must be brought in from warmer areas, which leaves these farmers vulnerable to harvest failure or not being allowed to continue cultivating in traditional cultivation areas.

The community in the Santurbán moor should benefit with alternatives to replace the income lost with the delimitation of the protected area. Sustainable tourism is a viable option, but to achieve it, a structured framework must first be created to allow the community to manage tourism services such as specialized guides, lodging, and food sales. Without the community's active participation, tourism development would not be possible.

4.3.2. The Government and Its Regulatory Role

Government intervention appeared to mediate conflict of interests between those who want to exploit the resources of the moor and those who advocate for its conservation as a source of water. In 2014, the Ministry of Environment made the first delimitation of the moor as a protected area, leaving out some areas with possibilities of being exploited by mining and other economic activities, however the constitutional court, in 2017, decreed the impossibility of any type of mining exploitation in the moor areas of the country and ordered the central government to carry out the process of limitation of the moor in consultation with the communities, a scenario that continues to today with no results.

The Colombian government, aware of the advantages that our territory has for ecotourism in all its manifestations, has enacted initiatives and bills for its development. The Administrative Department of Science, Technology and Innovation, Colciencias, turned into a ministry, raised the project offer "COLOMBIA BIO-NATURE SCIENTIFIC TOURISM", which highlighted weaknesses for the sustainable use of biodiversity in the different departments of Colombia. These included, the lack of valuation of biocultural assets, the lack of tools and the little participation of communities with this project. This department sought for projects to take advantage of these resources in a sustainable manner. In the sectoral tourism plan document 2018–2022 "TOURISM: THE PURPOSE THAT JOINS US", new policies were proposed in favor of scientific tourism, such as promoting the digitalization of tourist attractions, products, and services, as well as the awareness and communication required for the use and appropriation of new technologies by the producers and consumers of this information.

In the last decade, the departmental government has made strong economic investments that have boosted the growth of new alternatives in the field of tourism. This is evident in Chicamocha Park with the construction of the cable car that connects this park with Mesa de los Santos. Another example is the Ecoparque Cerro del Santísimo, created in 2015 and located at an altitude of 1380 m in the mountains of Floridablanca. On the other hand, improvements were made to the Palonegro airport with a view to strengthening the massive arrival of tourists. However, according to figures from the Colombian Tourism Information Center-CITUR of the Ministry of Commerce, Industry and Tourism hotel occupancy in the department from 2014 to 2018 has remained stable at a level close to 45%, and last year only increased by 0.06%, despite having infrastructure. This denotes a stagnation of the sector.

Authors such as [60–62] agree that the role of the government is fundamental for the development of tourism, representing its greatest contribution for the case of the area in question in the following topics:

- Policy formulation: in this aspect it is necessary to implement regulations that ensure the protection of natural resources [63], such as the delimitation of the Santurbán moor and establish environmental resource management planning. In economic aspects, it is also important to provide tax benefits or incentives for the establishment of community-based tourism enterprises [64].
- Infrastructure development: a contribution that can only be made by the government for the development of the infrastructure that is needed, such as improvements in access roads, stability in the provision of public services such as electricity, drinking

water and access to Internet connectivity, that are still a weakness in the area, and that are a source of comfort for tourists [65].

- Credit opportunities: the communities settled in the Santurbán moor will be hard hit by the delimitation and the restriction of land use, so they will need access to soft loans to leverage the start-up of tourism businesses in the region [66].
- Promotion of education: the absence of trained personnel for the attention of tourists was one of the weaknesses detected in the analysis, so the creation of continuous training programs on tourism issues, training of tour guides, and training in foreign languages will be necessary [60]. For that, the communion between the academy as trainer and the state as sponsor of these programs is necessary.

Government participation in tourism development should focus on improving the existing regulatory framework, introducing community training programs, and generating soft loans for ecotourism ventures, in short, providing legal and financial support for the growth of tourism in the region.

4.3.3. Incorporating Technology as a Challenge for the Tourism Business Sector

The department of Santander in Colombia shares the natural reserve of the Santurbán moor and, in recent years, it has shown interest in developing tourism ventures given the potential that exists, strengthening mainly adventure tourism. Due to the characteristics of the terrain, such as waterfalls, caves, steep trails, added to the colonial architecture of the municipalities of Socorro, San Gil, Barichara, among others, has made Santander a department to visit by nationals and foreigners.

According to Colombian Ministry of Industry and Commerce in Santander, in 2019, there were 186 registered travel agencies, 148 lodgings or accommodations available and 36 duly registered tour guides (Ministry of Commerce, Industry and Tourism, 2019). Those companies were enabled to manage tourism in the department according to [67], but most are not standardized with quality standards that govern their operations, and sustainability protocols are known but not applied. Their databases are obsolete, and their national tourism registry does not reflect their current status, which denotes lack of control by the authorities. Most tour guides have a paper registry that is used by travel agencies to reduce the cost of paying for specialized personnel.

Given this scenario, tourism companies in Santander need to enter fully into Industry 4.0 technologies and ostensibly improve the training of their operators to be able to offer intelligent and scientific tourism.

4.3.4. The Academy and Its Training Role

The active intervention of the Colombian and Santander academia is necessary for the strengthening of individual and collective capacities of tour operators, because in Colombia there is currently a deficit of trained personnel for the management of scientific tourism or ecotourism [68]. In most cases, the personnel associated with tourism have the following shortcomings according to the study of competitiveness of the nature tourism sector in Colombia [4]:

- Lack of trained personnel with skills in operation, customer service, and tourism product design; the concept of tourism products that are well oriented to the market has not yet been developed.
- Limitations in bilingual staff in all areas of customer service.
- Specialized service: professional guide services, ornithologists, good transportation, and logistical services, among others.
- Lack of specialized and bilingual guides, where the basic guide is only useful for general tours. As of 2015, it was estimated that there was a 70% deficit of specialized guides.
- Lack of greater knowledge about the history and culture of the regions where tourism activities are developed.

Among this range of difficulties is the lack of training and languages, which would be a serious difficulty when it comes to attracting international tourists, and the lack

of knowledge of the local fauna. Therefore, within the framework of scientific tourism development in Santurbán Natural Park, it is necessary to include training for the personnel that will be in contact with tourists.

Specifically, in Santander, there are currently two undergraduate programs and three technological programs related to tourism and hotel administration that are needed to train personnel involved in the management of this type of tourism. These programs should be called upon to train the personnel needed for the implementation of sustainable tourism in the region.

4.4. Science

The Potential of Scientific Knowledge Present in Santurbán Moor

The tourists that we want to motivate to visit the zone of influence of the Santurbán moor, and Colombia in general, are people with scientific knowledge that may possibly come to study and learn in areas of knowledge such as:

- Study of the unique varied vegetation that presents the reserve, developed according to its altitude, such as arboreal in its lower altitudes (2800 m), shrubby in the middle altitudes (3000 m) and herbaceous and shrubby at altitudes above 3400 m [50].
- The study of ornithology that has a variety 29 orders covering 86 families [69]. Among which, species such as the chirriador, the ruddy duck, the moor duck, and in the last decade, the condor that has been reintroduced to these places, stand out.
- The fish present in the Colombian moors and wetlands that are presented in 13 orders covering 50 families [69]; the Santurbán complex has 26 lagoons that allows this study.
- The study of the insects presents in the frailejones that are of great abundance of which there is little information and of the amphibians found in the multiple wetlands.
- Another scientific attraction is the study of the mosses present in the moor that are widespread in all wetlands forming sponges that retain water, providing habitat for insects and amphibians, making a substantial contribution to water regulation [70].

This natural variety is a treasure for science, as it is an exclusive spot in few countries of the equatorial strip and can be included in field visits made by students from developed countries to equatorial zone, such as those offered by the Smithsonian Tropical Research Institute based in Panama, with a flow of 1400 scientists per year and located an hour and a half from Bucaramanga by direct flight.

The possible visit of the scientific community would help to increase knowledge about the species of the area, which would be achieved by implementing a technological infrastructure of Industry 4.0, for the acquisition of knowledge in situ, that would then be appropriated by the Santander and Colombian academia. On the other hand, although there is tourism potential in the area for this type of tourism, it is necessary to create the technological and infrastructure capacities for its development.

4.5. Industry 4.0 Technology

For the development of scientific tourism in Colombia, and particularly in the protected area of Santurbán, it is necessary to implement the required technical conditions so that tourists, in addition to enjoying and learning, contribute to the scientific and academic growth of the region. For this, the framework proposes the implementation of a software and hardware platform typical of Industry 4.0 [71], such as the digitization of the information that can be obtained in the tours of the tourists, automatically using their mobile devices turning each of them, into a means to grow the database of the information of the biotics of the reserve. Applying artificial intelligence [72] during the tour with the information that has been previously collected in the recognition of the flora and fauna of the place, allowing scientific tourists technical information of a plant or animal with the focus of these with the camera of their mobile device. Likewise, it includes the ability to make tourist recommendations such as food sites and attractions in the visitor's immediate environment. The structure proposed for the development of the framework is presented in Figure 4 and the contribution of its components will be detailed below.

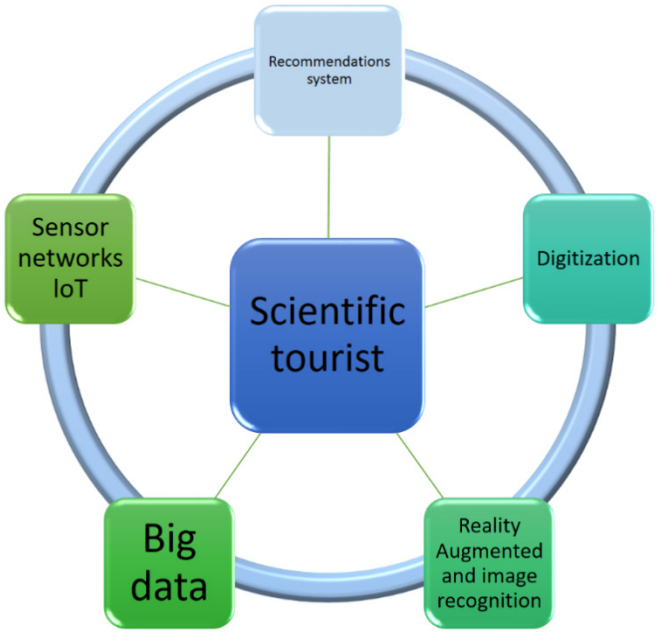

Figure 4. Structure of the technological framework system. Source: own elaboration.

4.5.1. Artificial Intelligence and Recommender Systems to Support Environmental Protection

In this fragile system, where tourists can have a destructive effect on the environment, the development of a system of recommendations associated with the use of cell phones may have a practical advantage to lessen the effect of tourists and in turn to provide them with a better experience.

This system will be designed to be implemented in a cell phone application, as usually tourists always have such phones. This application will be designed to detect by location and recommend to its users, sites to visit inside the reserve without internet connection. These recommendations could be, for example, some type of plants that are nearby or outside the reserve but connected to it, and possible cultural or gastronomic, leisure or adventure sites that could be of interest [73]. Ubiquitous semantic recommender systems based on ontologies will be taken as a reference [74]. The latter being a conceptualization coming from the philosophy, that in software engineering is applied to generate conceptualizations for users coming from diverse sources with the support of artificial intelligence. It allows representing knowledge in a way that improves its understanding [75]. To achieve this link between the dispersed data in a complex information system, the application of software techniques such as Big Data is necessary to complete the information and perform the semantic construction [36].

4.5.2. Technological Surveillance with IoT Sensor Networks

Another component included in the framework is related to the possibility of monitoring the environmental quality of the reserve, for which we propose the development and implementation of a software and hardware platform that allows the integration of data from multiple sensors of environmental conditions present in the Santurbán moor, including the following:

- Implementation of a low power consumption pH sensing system to monitor water quality.
- The amount of solar radiation with low energy consumption, powered by solar panels to measure UVA, UVB and UVC radiation.
- Air quality in terms of the amount of particulate matter, carbon monoxide and carbon dioxide, humidity, temperature, rainfall, and atmospheric pressure.

All these IoT sensors [76] are strategically distributed throughout the reserve and connected with the LORAWAN protocol [77], which in turn allows the transmission of

these data in real time under the Industry 4.0 paradigm, so that these data serve as a reference for scientists in their study of the park and at the same time can generate alerts to the environmental authorities of the environmental evolution of the reserve.

4.5.3. The Application of Big Data Techniques in Information Processing

Big Data analytics is described as the analytical framework that provides approaches to extract information from this type of environment and characterize the data source that is large, complex, heterogeneous, unstructured, unpredictable, and exposed to Scalability Issues [78]. This analytical framework not only provides theory and methods, but also facilitates the selection of systems and software. In general, Big Data analytics adopts machine learning as one of the supporting tools to formulate this analytical framework. Therefore, it depends on the successful advancements of its complementary field of machine learning and other alternatives, such as data mining [79].

Cloud computing allows the increase in the volume of data to be processed, improve storage procedures and data processing [80]. These techniques can be employed for the project to process information related to plant and animal species present in the Santurbán moor.

Authors such as [81] consider that Big Data can enhance the development of tourism in the territories, proposing a digital model for tourism management, which provides data and statistics so that, the different actors involved in the value chain of the tourism industry, such as tour operators at different levels and policy makers are updated to reach international competitiveness standards, increasing the value of their tourism products.

4.5.4. The Use of Augmented Reality and Image Recognition to Provide a Meaningful Experience for Tourists

Augmented reality techniques allow the user of mobile devices to interact with information related to images that the camera is focusing on in real time, increasing the learning experience, because more images, 3D models and videos are displayed on the screen to complement the related information that a flat image does not allow to see [82].

This feature of augmented reality would be of great importance when applied massively to tourism, as it allows visualizing environments spatially. This technique has been used in advertising brochures to invite tourists to visit specific sites with a higher degree of persuasion than looking at the same information in a normal way [83].

Its application becomes more relevant in the concept of scientific tourism, within the possibilities that augmented reality brings to tourism, including visits to museums that incorporate smart glasses to enhance the experience of visiting these sites [84]. The use of augmented reality generates different levels of immersion in the subject.

Its application in scientific tourism in the Santurbán moor will provide greater learning of geo-referenced highlighted areas where the tourist through the alert system according to their location in the reserve, will know that they can visualize a part of the landscape in a highlighted way with relevant scientific and cultural information.

On the other hand, the use of Big Data image recognition techniques will allow them to focus on the reserve's flora and obtain information about its biological characteristics, common names, and possible uses and/or applications. Because the reserve is an area without internet coverage it will be necessary to combine techniques that can be used in situ without the support of cloud resources, this problem has already been addressed by authors such as [85], with results of 90% effectiveness in the recognition of flora.

4.5.5. Digitization as a Mean to Increase Scientific Knowledge of the Area

In this era of massive use of digital electronic devices, where knowledge is increasingly transmitted electronically, it is necessary to generate databases that allow the dissemination of scientific information, which increases productivity in its use [86]. Considering threatened biological systems such as those of the Santurbán moor, digitization is a great

contribution, because increasing the knowledge of their importance contributes positively to their conservation and sustainability over time.

It is necessary to take advantage of the fact that in the group of scientific tourists there are usually experts in biological topics that can contribute to the growth of the database on the ecosystems they visit. In this aspect, this model is designed to help them take photos and make classifications when they travel through the nature reserve, using their mobile devices, which will then be validated by experts who will support the system. This will allow for positive feedback and growth of the knowledge base.

To achieve this objective, the model shown in Figure 5 is proposed as an integral part of the digitalization and use of information, which would result in a mutual use of technology and a better experience for both parts of the system.

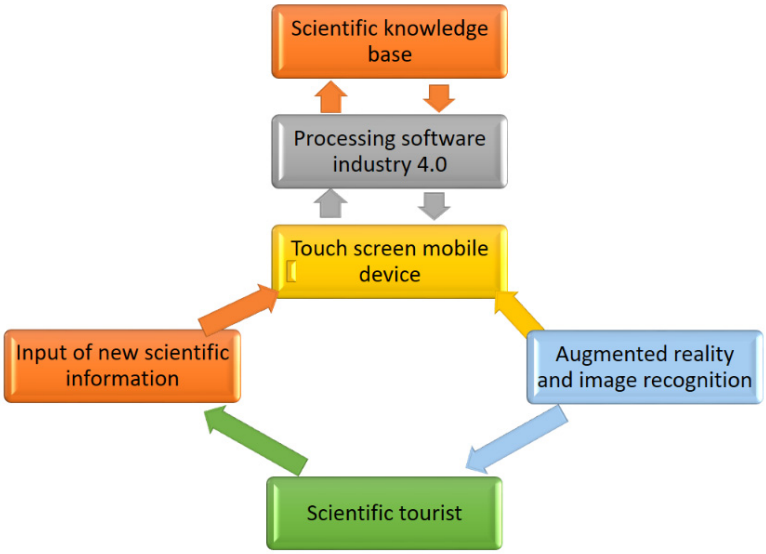

Figure 5. Structure of the digitization and information visualization process. Source: own elaboration.

5. Discussion

The starting point was the evaluation of the current situation in the ecological, social, and economic fields, based on a bibliographic review, which formed a global contextualization of what is the current situation in this area. As a result of this work, it was possible to identify outstanding aspects, such as the natural resources present in the moor, for example, some lagoons, an endemic vegetation, and the various cultural heritage in the vicinity. These strengths, with governmental support could result in more Colombian tourists but also foreign scientific tourists interested in its flora.

Based on expert opinions, a theoretical framework investigated application of the Mic-Mac software and contact with stakeholders, and defined variables that have the greatest influence for the implementation of tourism in the area were identified.

As a result of this analysis, weaknesses such as the lack of hotel infrastructure, technological backwardness, the lack of specialized personnel for tourist management, and environmental preservation were detected [67,68]; the latter may be one of the main threats to the ecosystem when combined with possible large-scale mining in the reserve [9,20].

A concordant point among the experts was the lack of infrastructure in the area to accommodate visitors, the absence of a technological platform for tourism management, and the almost non-existent presence of specialized personnel to attend to the flow of tourists while guaranteeing the conservation of the natural heritage [4]. It was agreed that state intervention is necessary to present a regulatory framework acceptable to both the communities and the business sector, so that tourism activities can be carried out without undermining their eco-systemic importance for the region [58]. At present, there is no place in the region classed as a tourist destination, despite that currently owners of

land adjacent to some lagoons are exploiting in an unstructured way the access to these tourist attractions [12,87].

Once defined stakeholders and variables and a conceptual framework for the development of sustainable tourism based on scientific knowledge is presented, the local community should be fundamental pillar, because they shall receive the possible negative impacts [19]. At the moment, it was found that some landowners have charged for entry into their land to reach the lagoons, and while the tourists enter without a guide on a delimited road with some rudimentary fences, there is no provision for the care of the moss and other species that support the generation of the water.

On the other hand, it was found that there is no relationship between the community and the tourism companies; the latter are limited to offering plans that include transportation and daily meals, bringing tourists from the capital to the entrance of the lagoons and waiting for them at the exit with very little feedback between the community, tourists and businessmen.

A factor that was evidenced in the analysis by the experts and in the surveys conducted was the lack of technological infrastructure [26]. The entrepreneurs and tourists consulted made it clear that the total absence of technological means is a clear competitive disadvantage for tourism in general in the department of Santander. Therefore, the emphasis of the proposed conceptual framework on the implementation of Industry 4.0 for tourism [71], allows integrated management by entrepreneurs, community and tourists. This will support the care of the environment, for which the implementation of IoT sensor networks is required to monitor the conditions of the reserve and provide real-time information, the digitization of information. This will provide meaningful experiences, such as augmented reality and image recognition [36,76,80,83], together aiming for the result that the experience of visiting the protected area is in accordance with the needs of today's tourist.

The framework proposed in this research picks up aspects presented in previous works, such as that of [14] who conducted a review analysis of the existing literature on sustainable tourism from about 97 works indexed in Scopus. This work highlighted that the most relevant issues were those related to economic aspects, community inclusion and environmental protection, and that there is a tendency to leave aside the governance in planted schemes and a lack of commitment by tourists in the aspects of environmental protection. It suggested that future works on the topic should integrate in a better way policies and institutional design. This aspect is consistent with what is presented by [88–90], but the latter in turn advocated the inclusion of technology as a dominant factor to achieve truly transformative changes with an interdisciplinary vision.

Another important aspect highlighted in the literature is the importance of education to strengthen the transition to true long-term sustainability [91] and the inclusion of systems thinking to better understand the interactions that occur around protected areas that attract tourists [92] and the integration between businesses, managers, academics, and communities [93]. The framework presented for sustainable development in the Santurbán moor considers many of these needs and attempts to address them with a technology-based approach.

This paper presented a possible framework for sustainable tourism development in the Santurbán moor protected area in Colombia. It highlights the following aspects:

The SWOT analysis on the strengths, opportunities, weaknesses, and threats for the implementation of this tourism corridor, gives an overview of the current situation and may eventually allow the governance entities to generate some policies to mitigate the weaknesses and enhance the strengths.

Another important result is to identify the variables that have most influence to boost or stop the possible progress of tourism enterprises in the sector. But the most important contribution was the presentation of a framework that integrates the most relevant stakeholders and integrates them with a holistic approach based on science and new technologies.

This work is limited to the establishment of the correct policies that emerge from the regional and national government, in addition to the need to improve the basic infrastructure for the real development of tourism in the area.

6. Conclusions

This document presents a conceptual proposal looking for the development of an area that is protected from an environmental point of view, but unprotected from the social dimension, because of poverty, and the dependence of artisanal mining and monoculture smallholdings. The limitation of these activities presents a dark outlook for the future of this community. To contribute to the solution of this problem, the proposed framework considers the interrelationship between the three dimensions, because if the problem is not seen as a complex system where each component influences the others, the real implementation would be destined to failure.

To achieve the complete evolution of this framework, a very positive synergy is needed in the community, the state, the academy, and the tourism industry. The first must be willing to participate in its implementation, the state must provide the legal framework and infrastructure, the academy must prepare and transmit the necessary knowledge so that there are knowledgeable guides not only of the terrain but also of the surrounding nature and biota, and the tourism companies must be the engine for its promotion and expansion at the national level.

The contribution of the technological dimension of Industry 4.0 with the internet of things, Big Data, augmented reality, and the recommendation system working in parallel is the differentiating element of this conceptual framework. It will allow tourists not only to enjoy the terrain, to learn, but also to make their contributions with the advantages offered by the flexible technology of mobile devices, leaving in its wake not only economic benefits but also a legacy of knowledge.

Once this conceptual framework is implemented, its results can be extrapolated to other regions of Colombia with the same potential for scientific tourism given the extensive areas of pristine natural parks that this territory has.

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