# ECOPACAYA 4.0: An Innovation Augmented Reality Based Application for Ecotourism and Scientific Tourism in the Pacaya Samiria Amazon Lodge Private Reserve in the Amazon Jungle of Loreto, Peru.

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## Abstract

ECOPACAYA 4.0 is a Tourism 4.0 project carried out by an eco-lodge located in the Peruvian Amazon. The eco-lodge has been on the market for more than fifteen years and owns a private reserve of one hundred and thirty hectares that shelters great biodiversity of flora and fauna. The project's objective was to facilitate the entry of the ecolodge into the "experience economy" by the creation of memorable experiences for its visitors through focused and innovative tourism products and services. In this sense, five themed routes called Eco trails (ethnobotanical, mythological, fauna, worldview, and an interactive game) were developed to provide visitors with expert knowledge about the biodiversity and culture of the area. For this purpose, an intelligent platform was designed and implemented using Industry 4.0 technologies such as augmented reality (AR), the Internet of Things (IoT), and cloud computing. This platform allows visitors to experience the following through mobile devices: 1.) Get automatic assistance on positioning while touring each Eco trail. 2.) Get an integrated view of digital information (virtual guides and characters) with the eco-lodge private reserve´s physical environment in real time. 3.) Online connection of visitors with their social networks. This posed the great challenge of implementing a complex and efficient communications system to make it possible for such a remote and previously unconnected area to finally get integrated into the digital world. Another achievement of the project is the Biodiversity Portal, a collaborative site that allows researchers, students, and academics to access qualified scientific information on the biodiversity of the area, thus facilitating their research efforts. Finally, we highlight that we are currently in the process of packaging this experience not only to optimize its use in the ecolodge but also to expand its use to other environments.

## Keywords
Tourism 4.0, Industry 4.0, Pacaya Samiria, Amazon jungle, augmented reality, IoT, ecotourism, ecolodge, experience economy, and scientific tourism.

## 1. Introduction

Pacaya Samiria National Reserve is a protected area in the Peruvian Amazon and is one of the most biodiverse regions and rich in natural resources in the world, with great ecological and cultural importance for the inhabitants of the region and for humanity in general. In recent years, ecotourism has become a way to promote the sustainable development of the Amazon region of Peru, through the offer of tourist activities that promote environmental conservation and appreciation of local culture.

Pacaya Samiria Amazon Lodge has the privilege of being the only Ecolodge located on 130 hectares of primary forest and its conservation is one of our biggest responsibilities. The visitors have access to this private reserve and the incredible biodiversity it houses including more than 200 species of fauna and more than 300 species of flora through a set of thematic activities: Primates watching route; reptile watching route; Shiringa (rubber tree) route; observation of 107 species of birds; and day and night excursions that enrich the visitors' experience.

The private reserve is under frequent research by the Pacaya Samiria Amazon Lodge itself and by scientists who are experts in Amazonian flora and fauna.

A strategy to implement for the ecolodge is the "experience economy" that is all about providing guests with immersive and memorable experiences that allow them to fully engage with the natural environment and the local culture. It is important for the ecolodge to enter the "experience economy" because this can provide a competitive advantage in the tourism industry. This can include activities such as guided hikes through the jungle, wildlife watching, and other unique experiences that cannot be replicated as well as the use of augmented reality (AR) that is presented as an innovative and promising tool to improve the visitor experience and promote education and environmental awareness in Amazonian ecotourism. By providing these types of experiences, the ecolodge can differentiate itself from other lodging options and attract travelers who are looking for more meaningful and authentic experiences. This can also lead to increased customer loyalty and positive word-of-mouth marketing, as guests share their experiences with others. In addition to the business benefits, entering the "experience economy" can also have positive impacts on the local community and environment. By creating experiences that showcase the importance of preserving the Amazon jungle and its indigenous cultures, the ecolodge can help raise awareness and support for conservation efforts. It can also provide economic opportunities for local communities by hiring local guides and promoting locally-made products. Overall, entering the "experience economy" can be a win-win for the ecolodge, its guests, and the local community and environment.

Tourism 4.0 is a term used to describe the latest trend in the tourism industry that emphasizes the use of technology and innovation to provide a more personalized and immersive travel experience for visitors. The term "Tourism 4.0" is derived from the concept of Industry 4.0, which refers to the fourth industrial revolution driven by automation, data exchange, and emerging technologies. In the context of tourism, Tourism 4.0 involves the integration of digital technologies, such as artificial intelligence, the Internet of Things (IoT), augmented reality (AR), and virtual reality (VR), to enhance the visitor experience. This can include the use of mobile apps, social media, and other digital platforms to provide personalized recommendations for activities, attractions, and accommodations based on visitor preferences and behaviors. Tourism 4.0 also involves the use of data analytics to improve decision-making and create more efficient and sustainable tourism practices.

ECOPACAYA 4.0 is a project that consists of the development of an AR platform and a biodiversity database for eco-tourism and scientific tourism sector in the private reserve of Pacaya Samiria Amazon Lodge that was designed with technologies of AR, geolocation, internet services, social networks, streaming and integration with other applications, all are part of the industry 4.0. Guests can go on themed routes called eco trails about the flora, fauna, mythological, worldview, and interactive game to facilitate the transmission of expert knowledge about the area through a platform that uses AR technology that allows guided visitors in each eco-trail in which physical reality is merged with virtual images that narrate the characteristics of what is being viewed. Also, guests can connect to their social networks and make streaming, which makes it possible for a very remote area where that wasn't previously connected, to integrate into the digital world thanks to an implementation of a complex communications infrastructure. Another of the achievements of ECOPACAYA 4.0 is the Biodiversity Portal, a collaborative resource that allows researchers to access information on the biodiversity of the area, facilitating their work, by having a quality reference.

ECOPACAYA 4.0 is important for several reasons: Enhance the tourist experience, that is, the use of AR technology can provide a unique and interactive experience for tourists by overlaying virtual content onto the physical environment. This can help visitors learn more about the local flora and fauna, and cultural heritage, improving their overall experience. Allows support biodiversity conservation, which means, the development of a biodiversity database can help the eco-tourism company and researchers in the region monitor and document the local biodiversity. This information can be used to develop conservation strategies and support the protection of the unique species and habitats in the Amazon jungle. Environmental education can be encouraged, this means that the AR platform can be used as an educational tool to teach tourists and local communities about the importance of conservation and the

sustainable use of natural resources. This can help raise awareness about environmental issues and promote responsible tourism practices. Research efforts can be supported by a biodiversity database that can be a valuable resource for researchers studying the biodiversity of the Pacaya-Samiria National Reserve. The data collected can help researchers better understand the unique ecosystems in the region and support ongoing research efforts.

In addition to increasing the company's competitiveness by using innovative technologies such as AR, it allows it to stand out from the competition and attract more tourists interested in unique and immersive experiences. In general, the development of an AR platform and a biodiversity database for the research tourism sector in the Amazon rainforest can have significant benefits for biodiversity conservation, environmental education, research efforts and tourism competitiveness.

The steps to carry out the project consisted of defining the project objectives which included developing an AR platform and a biodiversity database to enhance the tourist experience and support conservation efforts in the Pacaya Samiria Amazon Lodge private reserve. After that, we conduct a feasibility study to assess the technical, economic, and environmental feasibility of the project. This study also identified any potential challenges or risks and ways to mitigate them. Then, we developed a project plan that outlines the project's scope, timeline, budget, and resources required. This plan included the roles and responsibilities of the project team members. Later, we developed the AR platform that will be used by guests to learn about the local biodiversity and cultural heritage. This platform had to be user-friendly, engaging, and informative. At the same time, we developed the biodiversity database that will be used by researchers to monitor and document the local biodiversity. This database is comprehensive, accurate, and regularly updated. Finally, we tested the AR platform and biodiversity database to ensure they meet the project's objectives and specifications. This testing included user acceptance testing, functionality testing, and integration testing. Once the testing is complete, we implemented the AR platform and biodiversity database in the Pacaya Samiria Amazon Lodge private reserve. This included training the staff to use the platform and database and promoting it to tourists. We evaluated the project's impact on the tourist experience, conservation efforts, and research activities. This evaluation included collecting feedback from tourists, researchers, and the ecotourism company staff. Also, we continuously improve the AR platform and biodiversity database based on feedback and ongoing research efforts. This ensures the project remains relevant and effective over time.

As part of the project, a technology package was developed for transferring the technology that includes the following: Detailed documentation of the AR technology, including its software and hardware components, specifications, and instructions for use. The developed software with instructions on how to install and use the software. A list of hardware requirements for implementing the AR project, including telecommunications equipment, computers and mobile devices, and other necessary equipment. Educational resources to train the recipients on how to use the AR technology, including user manuals and other learning materials, and access to technical support and assistance to resolve any issues or problems that may arise during the implementation and use of the technology.

## 1.1 Objectives

Research main objective:

- To execute an applied research project that consists of the development of a technological platform supported by industry 4.0 technologies that allow facilitates the entry of a company in the ecotourism and scientific tourism sector of the Amazon jungle into the "experience economy" through the creation of memorable experiences for its visitors through focused and innovative tourism products and services.

Specific research objectives:

- To identify the needs and preferences of tourists interested in ecotourism and scientific tourism in the Amazon jungle, to determine what kind of memorable experiences can be offered using AR.
- To develop a platform that integrates biodiversity and technology in five circuits supported by AR technology, for the ecotourism and scientific tourism segments.
- To develop the area's first scientific knowledge base of flora and fauna species.
- To use technology to transmit expert knowledge about the natural wealth of the area (Pacaya Samiria Amazon Lodge private reserve, 130 hectares of undisturbed forest) and create memorable experiences.
- To develop a project aligned with the leading global trends in the ecotourism sector.
- To implement the telecommunications infrastructure for connectivity in a remote place inside the Amazon jungle, to spread the Amazon destination to the world.
- To make that visitors will share their experiences in their networks through their mobile phones.
- To integrate the surrounding communities in the management and maintenance of the platform.
- To implement a collaborative portal with a community of users that includes Citizen Science for the first time in Peru.

- Facilitate the effective transfer of the AR technology through a technology package that provides the receiving party with all the necessary information, tools, and resources to implement and utilize the technology effectively, thereby facilitating the transfer process.

## 2. Literature Review

The literature review about platforms of AR applied to tourism is necessary for several reasons: to identify knowledge gaps, inform research design, evaluate the feasibility of the project, identify potential collaborators, and identify potential impact.

One study by Han et al. (2013) identified user requirements for the implementation of mobile AR applications in the context of urban heritage tourism. The study found that prior user requirements in the software and mobile computing context are still relevant, and new themes such as Map systems, easy navigation functionality through GPS, multi-lingual aspects, and internationalization. Safety and security issues, which were previously a key theme, were still relevant but tended to be overshadowed by social network exposure. The study also found that AR is a young technology with potential yet to be discovered and has particular interest for the tourism industry as it can reveal information on the immediate surroundings by putting relevant data into a virtual space. The study concludes that the proper implementation of AR as the new media in tourist destinations could improve competitiveness and attractiveness for tourists and recommends that an AR application should provide up-to-date information relevant to the timeframe and residing area, consider social networking to encourage repetitive use, have a user-friendly interface, and multi-language capabilities.

The article "Implementing Augmented Reality to Increase Tourist Attraction Sustainability" (E. Cranmer et al., 2016) discusses how AR can be used to enhance the tourist experience and promote sustainable tourism. The authors argue that traditional forms of tourism can have negative impacts on the environment and local communities, and that AR can offer a more sustainable and interactive alternative. The article presents case studies of how AR has been implemented in various tourist attractions, such as museums, historical sites, and natural parks, to enhance the visitor experience and promote sustainability. The authors highlight the benefits of AR, such as reducing the environmental impact of traditional forms of tourism, providing a more immersive and interactive experience for visitors, and promoting education and awareness about sustainability and conservation. The article also discusses the challenges of implementing AR, such as technological limitations and the need for appropriate content and design. The authors suggest that collaboration between tourism professionals, technology experts, and sustainability experts is necessary to successfully implement AR in tourism.

Da Costa & Prata (2019) introduces an AR project called "Animal Trail" that allows users to explore the Amazon rainforest and learn about the region's fauna and flora. The project uses AR technology and was developed in collaboration with local communities and ecology experts. The app allows users to explore different trails in the forest, where they can find and learn about different species of animals and plants. The app also includes educational games that help users learn about the ecology of the region in a fun and interactive way. The project was evaluated through a user survey, which found that most users found the app interesting and educational. In addition, the project also helped promote sustainable tourism in the region and raise awareness about the importance of protecting the Amazon Forest and its biodiversity.

Kawakami & Prata (2019) presented a study on the technology of AR applied within the Bosque da Ciência in Brazil. This study was conducted through the Design Thinking methodology in which the stages of immersion, ideation and prototyping were used to generate a better experience for Bosque visitors through AR. The immersion stage provided a theoretical basis for the concepts of AR and topics related to providing a database so that it was possible to identify the pain points of the visitors. In the ideation stage, it was possible to elaborate ideas according to the detected pain points, associating them with AR technology. And finally, in the prototyping stage, the validation of the suggested solution was carried out through the tests, followed by the development of the final product.

The project "Development of an application based on augmented reality for the promotion of the Yasuní National Park" (Maldonado Guerrón, 2019) consists of the creation of a mobile application based on augmented reality to promote tourism in the Yasuní National Park in Ecuador. The app uses augmented reality technology to provide information about tourist attractions in the park, including images, videos, and detailed descriptions. It also includes interactive games and educational activities for visitors. The work included field tests and evaluations were carried out with potential users to ensure that the application was easy to use and that it met the expectations of tourists. This work concludes that the application based on augmented reality is an effective tool to promote tourism in the Yasuní National Park since it allows visitors to access detailed information and enrich their tourist experience in the park. Furthermore, it is recommended that a proper promotional campaign be conducted to increase awareness and adoption of the app among tourists.

Gardoni et al. (2020) presented the development of two interactive augmented reality experiences aimed at raising awareness about the negative impacts of human activities on natural environments, particularly the Amazon rainforest and coral reefs. The experiences use multisensory feedback to create an immersive and engaging learning experience for users. This work discusses the development of the experiences, including the use of 3D models, interactive animations, and sound and haptic feedback. The article also presents the results of a study evaluating the effectiveness of the experiences in increasing users' knowledge and awareness of the environmental issues addressed in the experiences. The study found that the experiences were successful in increasing users' knowledge and awareness, as well as their willingness to change their behavior to help protect natural environments. The authors suggest that these types of interactive augmented reality experiences have great potential for education and raising awareness about environmental issues.

Cranmer et al. (2020) aim to explore the potential value of augmented reality (AR) for the tourism industry. The authors conducted a comprehensive review of the existing literature and identified the benefits and limitations of AR in the tourism context. The authors found that AR has the potential to enhance the tourist experience by providing interactive and immersive content, facilitating navigation, and enriching learning opportunities. AR can also help tourists to better understand and appreciate cultural heritage sites and to visualize potential travel destinations. However, the authors also highlighted several limitations and challenges associated with the use of AR in tourism, such as the need for significant financial and technical resources, the potential for distraction and disorientation, and the risk of over-reliance on technology. The authors emphasized the importance of considering these limitations and challenges when designing AR applications for the tourism industry.

Bautista et al. (2022) described an augmented reality-based gamified local tourism and cultural heritage promotion and preservation application called "IJUANDERER." The application was developed to promote and preserve the cultural heritage of the Philippines. The app uses augmented reality to enhance the user's experience of the cultural heritage site by providing information, interactive games, and multimedia presentations. The application also includes gamification elements to motivate users to explore and engage with cultural heritage sites. The authors suggest that the application can be used to support sustainable tourism by promoting responsible tourism practices and raising awareness of the importance of cultural heritage preservation. The article presents the results of a user study that showed the potential of the application to enhance the tourist experience and promote cultural heritage preservation. The study also identified areas for improvement, such as the need for more engaging gamification elements and better integration with social media.

The review of the literature suggests that AR has the potential to enhance the study and conservation of biodiversity in the Amazon jungle. AR can be used to create immersive and interactive experiences that allow users to explore and learn about the flora and fauna species in the jungle. AR can also be used to collect data and monitor species populations, providing researchers with valuable information to inform conservation strategies.

In addition, this revision reveals that the development of a scientific knowledge base of flora and fauna species in the Amazon jungle is crucial for conservation efforts. Such a knowledge base can be used to identify threatened or endangered species, track population changes, and inform management decisions. However, the creation of such a knowledge base requires a multidisciplinary approach that involves collaboration between researchers, conservationists, and local communities.

Furthermore, the literature highlights the importance of ensuring that the development of an AR platform and the scientific knowledge base are culturally sensitive and inclusive of local communities. Involving local communities in the development process can help to ensure that the platform and knowledge base are relevant and useful to the communities, as well as promote community engagement and ownership of the project.

Based on the reviewed literature review, it is concluded that the development of an AR platform in the Amazon jungle and the area's first scientific knowledge base of flora and fauna species has the potential to significantly enhance our understanding of the jungle's biodiversity and support conservation efforts. However, careful consideration must be given to the development process to ensure that the platform and knowledge base are culturally sensitive, inclusive, and effective in supporting conservation efforts.

## 3. Methods

This project involved the development of a technological platform supported by industry 4.0 technologies that allow facilitates the entry of the Pacaya Samiria Amazon Lodge into the eco-tourism and scientific tourism sector of the Amazon jungle with the "experience economy" through the creation of memorable experiences for its visitors with focused and innovative tourism products and services, in addition to allowing the creation of a scientific knowledge base of flora and fauna species in an Amazon jungle area. The steps required to reach the objectives were the following:

1. Defining the problem and the research questions: We started by defining the problem that the project is addressing and the research questions that need to be answered to solve the problem. This step helped us to identify the scope of the project and the expected outcomes.
2. Conducting a literature review: We conducted a literature review to identify the current state-of-the-art technologies and practices that can be used to address the problem. This step helped us to identify the best practices and technologies that can be applied in the context of the ecotourism and research tourism sector in the Amazon jungle.
3. Formulation of the research methodology: Based on the problem and research questions, we formulated a research methodology that guided the project's execution. The process included the geographical area of interest, the specific flora and fauna species to be studied and the methods for data collection and analysis, the research design, the sample selection criteria, and the ethical considerations.
4. Technological platform development: Based on the research findings and methodology, we developed the technology platform using industry 4.0 technologies such as RA, IoT, and cloud computing. The platform was designed to address the specific needs and requirements of the eco-tourism and scientific tourism sector in the Amazon jungle.
5. Testing and validation of the platform: The platform was tested and validated to ensure that it meets the project objectives and requirements. The testing was done in a controlled environment before deploying the platform in a real-world setting.
6. Implementation of the platform: We implemented the platform in the company's operations and trained the staff on how to use the platform. The implementation process was monitored to ensure that the platform is being used effectively.
7. Communication of the results: We communicated the results of the project to stakeholders, including the company's management, employees, customers, and partners. The communication included the project objectives, methodology, findings, and recommendations for future research and development.
8. Maintenance and improvement of the platform: Continually we maintain and improve the platform based on the feedback received from the stakeholders (general and specialized travel agencies, visitors, specialized press, scientific tourism, academic and research organizations, and others) and the changing needs of the company's operations. The platform is continually updated to ensure that it remains relevant and effective in addressing the company's needs.

## 4. Data Collection

To determine the success of ECOPACAYA 4.0 in the Pacaya Samiria Amazon Lodge, we collected the data about the experience of users when using the AR application, such as their level of satisfaction, the ease of use of the application, the perception of the quality of the graphics and the interaction with the content of the application. Furthermore, related to the Biodiversity Portal, we collected the data about the species occurrence records, which include information about the location and time of observation, as well as other details such as the habitat type, taxonomic information about different species, their scientific name, common name and other environmental factors. Citizen science data can be used to study the patterns and trends in species occurrence and distribution over time.

## 5. Results and Discussion

The results of the ECOPACAYA 4.0 project are presented below.

### 5.1 Needs and Preferences

After the literature review was performed, we made surveys to visitors about their needs and preferences that were taken into consideration for designing memorable experiences using AR technology. Some of these needs and preferences include:

a. Authenticity: Visitors interested in ecotourism and scientific tourism in the Amazon jungle place a high value on authenticity. They seek experiences that are immersive and allow them to connect with nature and the local culture in a meaningful way.
b. Education: These visitors are often looking for educational experiences that provide them with a deeper understanding of the Amazon jungle, including its flora and fauna, history, and cultural significance.
c. Sustainability: Visitors interested in ecotourism and scientific tourism in the Amazon jungle are concerned about the impact of tourism on the environment and local communities. They prefer experiences that are sustainable, responsible, and respectful of the local ecosystem and culture.

d.  Engagement: AR technology can provide a highly engaging experience that allows tourists to interact with their surroundings and learn in a hands-on way. Tourists are looking for experiences that are interactive, immersive, and memorable.
e.  Safety: While adventure is important, tourists are also looking for safe and well-organized experiences.

Based on these needs and preferences, some possible AR experiences that can be offered to tourists interested in ecotourism and scientific tourism in the Amazon jungle might include:
1.  AR-guided tours of the jungle, led by experienced naturalists and local guides, use AR technology to provide an immersive and educational experience.
2.  Interactive AR exhibits at eco-lodges provide visitors with a deeper understanding of the local culture, history, and ecosystem.
3.  AR-enhanced trekking tours to remote areas of the jungle, offering a true wilderness adventure while learning about the importance of conservation and sustainable development.
4.  AR-enhanced scientific expeditions, giving tourists the opportunity to participate in fieldwork and research projects, gaining a deeper understanding of the Amazon's ecological and cultural significance.

## 5.2 ECOPACAYA 4.0 Platform

As a result of the project, we developed an AR platform and a biodiversity database for the eco-tourism and scientific tourism sector in the private reserve of Pacaya Samiria Amazon Lodge supported in technologies such as AR, geolocation, internet services, social networks, streaming and integration with other applications.

The Pacaya Samiria mobile application includes functionalities of AR, information about the eco trails designed for the visitor experience, and gamification. The application allows the guests to carry out interactive activities planned as part of the experience economy offered to visitors during their stay. With the support of AR technology, the application provides detailed information on five themed routes called eco trails, which are ethnobotanical, mythological, fauna, worldview, and an interactive game. Guests can connect in real-time to their social networks and make streaming. Also, it allows them to interact, through gamified activities, with the application's characters and obtain rewards that give greater satisfaction to the lodge visitor. The app was developed to provide visitors with expert knowledge about the biodiversity and culture of the area. Figure. 1 shows the user interfaces of the Pacaya Samiria mobile application.
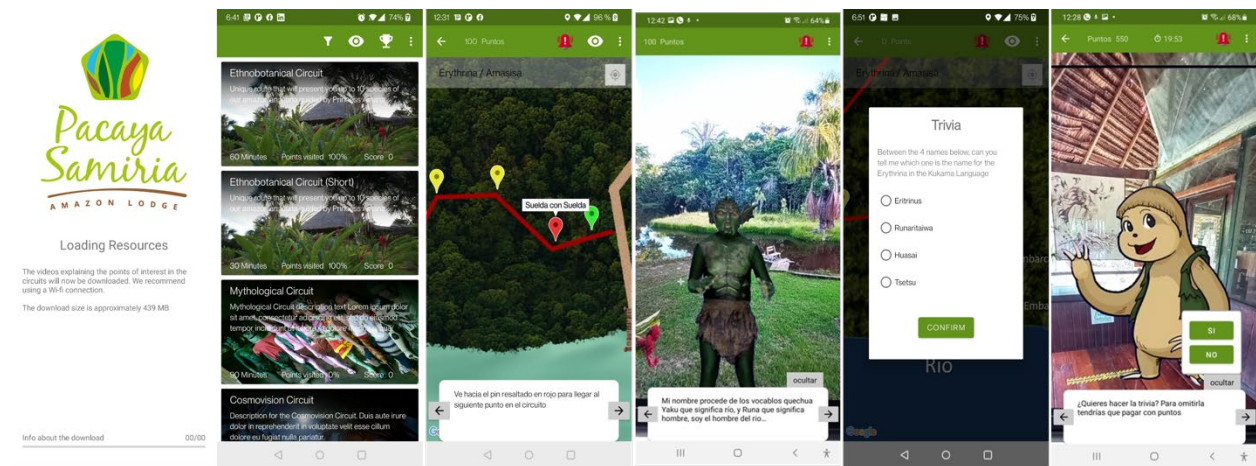


Figure 1. Pacaya Samiria mobile application GUI.

The Biodiversity Portal allows researchers and academics to access scientific information about the area's biodiversity. The Biodiversity Portal has a user community for considering the first Citizen Science in Peru that can be used to study the patterns and trends in species occurrence and distribution over time. Furthermore, the Biodiversity Portal is the area's first scientific knowledge base of flora and fauna species. The data records about the species contain information such as location, habitat type, taxonomic information, and environmental factors. Figure 2 shows the landing page for the Biodiversity Portal, the fauna catalog, and the detail of a specie.
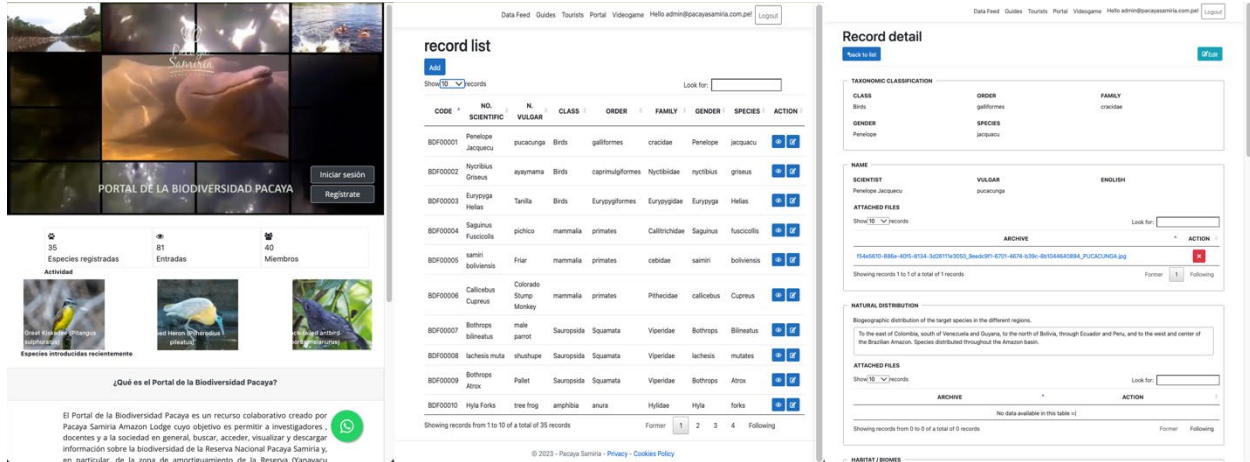
Figure 2. Biodiversity Portal landing page, list of fauna species, and the detail of a specie.

Due to the physical location of the ecolodge in a rural area, the telecommunications coverage by the providers is limited, which became a severe difficulty for the interconnection to the Internet service. It is for this reason that the improvement of access to this service was sought, for which a telecommunications network was deployed in strategic spaces within the coverage area of the lodge, whose connection topology is shown in Figure 3, which allows providing the Internet service wirelessly permanently and roaming. This means that in the first case the access to the service is continuous, while, in the second case, the service is provided partially upon request, which is carried out only on the fauna eco trail, due to the dense vegetation existing in the place.
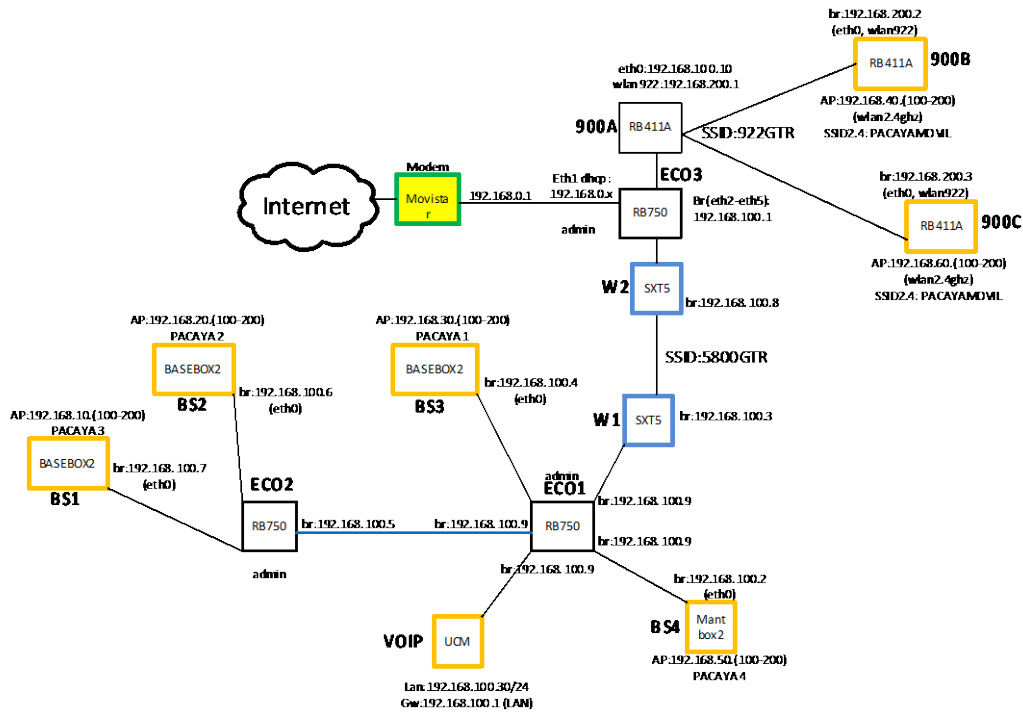


Figure 3. Connection topology, telecommunications network.

As a complement, Figure 4 (a) shows the coverage areas where the service is provided permanently and roaming, while Figure 4 (b) and Figure 4 (c) show part of the facilities used for this purpose. It is important to mention that, owing to the different administrative and logistical processes of the company, as well as the connectivity requirement of users or visitors, the continuity of the Internet access service is vital for the continuity of the company's business model. And is that the cut of the service or too much latency would generate delays in the different processes mentioned, in addition to influencing the perception of visitors about the quality of the service provided.
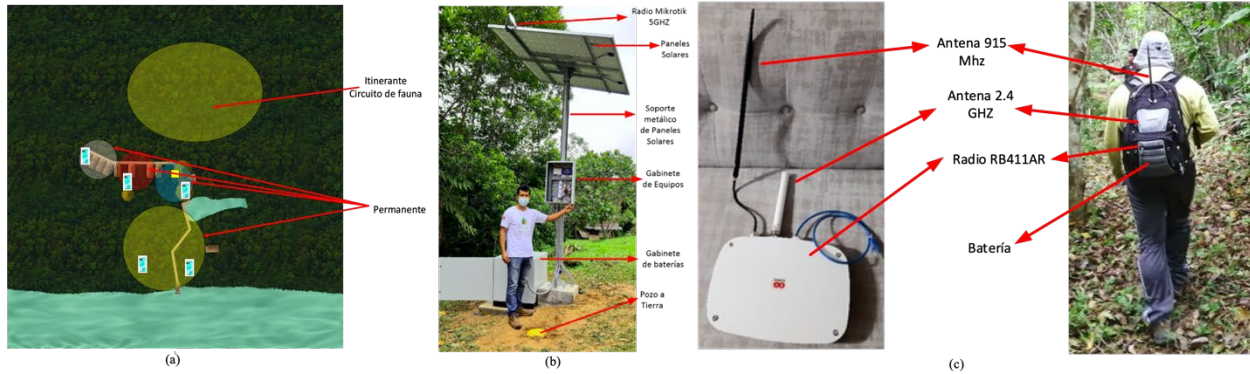
Figure 4. (a) Space where Internet service is provided permanently and roaming. (b) Equipment and infrastructure for Internet service permanently. (c) Equipment and infrastructure for roaming Internet service

To integrate surrounding communities, we build a partnership with the Kukama Kukamiria ethnic group to involve them in the management of the technological platform establishing an agreement that outlines the responsibilities of both parties. Furthermore, we involve them in the creation and development of tourism products and services that are focused and innovative. This is possible, due to community consultations and feedback sessions to ensure that their needs and preferences are considered. Finally, it is important to communicate regularly with the communities to keep them informed about the progress of the technological platform and its impact on the tourism sector. This will help build trust and ensure that the community remains engaged and invested in the project.

The results of the evaluation of the ECOPACAYA 4.0 project are:

1. Visitor experience: Overall, the AR-based application was well-received by visitors to the Pacaya Samiria Amazon Lodge private reserve. Most visitors reported that the application enhanced their experience by providing them with a more immersive and interactive way of learning about the flora and fauna of the region. Visitors appreciated the ability to see the virtual representations of animals and plants and to interact with them in real-time.
2. Sustainable tourism practices: The AR-based application was also found to have a positive impact on sustainable tourism practices in the region. By providing visitors with an educational and interactive experience, the application helped to raise awareness about the importance of conservation and environmental protection. Visitors reported that the application inspired them to be more mindful of their impact on the environment and to adopt more sustainable practices during their stay.
3. Scientific research: The AR-based application also contributed to scientific research in the region by providing a platform for data collection and analysis. Through the application, researchers were able to collect data on the location and behaviour of different species, which can be used to inform conservation efforts and scientific research.

## 5.3 Proposed Improvements
Some proposed improvements that enhance the implementation of the ECOPACAYA 4.0 are:

- The implementation of AR technology requires reliable internet connectivity, sufficient processing power, and appropriate hardware such as smartphones or AR glasses. Therefore, improving the infrastructure to support the use of this technology would help to provide a better experience for tourists.
- Creating virtual reality (VR) content that is tailored to the specific culture, history, and environment of the Amazon jungle of Peru can enhance the experience for tourists. Developing content that is unique to the area can help to create a sense of authenticity and immersion, which is highly valued by eco-tourists and scientific tourists.
- Regular evaluation and feedback from tourists and local stakeholders can provide insights into the effectiveness of the technology and identify areas for improvement in the implementation of the other technologies about Industry 4.0 in the Amazon jungle of Peru.

## 5.4 Validation
The validation of the platform was carried out within the lodge facilities using tablets and mobile devices to track and monitor the execution of eco trails. In every point of interest, the AR app was validated, including contents, subtitles, geolocation, animations, and trivia of the challenges, as well as the scope of the beacons to activate the appearance of the characters.

To test connectivity coverage in the fauna eco trail, we used an access point portable backpack which offers signal levels from the communications tower. As part of the validation of connectivity, coverage, and access to the Internet service was carried out in the areas corresponding to spaces such as bungalows, rest spaces, and ethnobotanical and mythological eco trails, respectively, and the access to the Internet service level was acceptable in sectors of permanent connectivity.

The user experience test evaluated the level of satisfaction, the ease of use of the application, and the interaction with the content of the application, Table 1 presents the results of the UX test.

Table 1. Results of the Eco trails satisfaction survey

| Guest | Eco trail | Ease of use of the application | Clarity of instructions | Quality of experience | Overall satisfaction | Would recommend to others | AVERAGE RATING | Comments |
|---|---|---|---|---|---|---|---|---|
| 1 | Ethnobotanical | 4 | 4 | 4 | 4 | 4 | 4 | It works well. It is suggested that it be done between activities. |
| 3 | Ethnobotanical | 3 | 5 | 4 | 4 | 4 | 4 | He liked it. Suggest as an extra activity to do in free time. |
| 2 | Interactive game | 5 | 4 | 5 | 5 | 5 | 4.8 | Quite fun. In addition, children 9 and 11 years old participated. |
| 4 | Interactive game | 5 | 4 | 5 | 5 | 5 | 4.8 | At some point the drawing stopped. Children 4 and 11 years. |
| 5 | Interactive game | 4 | 3 | 5 | 5 | 5 | 4.4 | Very innovative. Review instructions. Boy 11 years |
| 6 | Mythological | 5 | 5 | 3 | 3 | 4 | 4 | App very well made although I did not expect to use the cell phone in the jungle. |
| 7 | Mythological | 4 | 5 | 4 | 4 | 4 | 4.2 | Very good to sensitize the visitors. It should be passed at night after dinner. |
| 8 | Mythological | 4 | 4 | 4 | 4 | 4 | 4 | That the App have breaks. That it can be done in a group and not 1 by 1 |
| 9 | Mythological | 5 | 4 | 5 | 5 | 4 | 4.6 | N/A (foreign) |
| 10 | Mythological | 5 | 5 | 5 | 5 | 5 | 5 | Well. (foreign) |
| 11 | Mythological | 5 | 4 | 4 | 4 | 4 | 4.2 | Fun and informative (foreign) |
| 12 | Mythological | 5 | 5 | 4 | 4 | 4 | 4.4 | N/A (foreign) |
| 13 | Mythological | 5 | 5 | 4 | 4 | 5 | 4.6 | Informative (foreign) |
| 14 | Mythological | 5 | 5 | 4 | 4 | 4 | 4.4 | Informative (foreign) |
| | Average results | 4.6 | 4.4 | 4.3 | 4.3 | 4.4 | 4.4 | |

Based on the results obtained about the ECOPACAYA 4.0 platform in the Amazon jungle of Peru, the Pacaya Samiria AR application shows a positive impact on user satisfaction, it is considered innovative, easy to use, flexible to the motivations of each user, adapts to the current offer and enriches the experience. However, the design and location of the routes could be improved. Taking user feedback would allow us to adjust and improve the platform because the platform has the potential to be a successful tool in enhancing the experience of users in the Amazon jungle of Peru.

## 6. Conclusion

ECOPACAYA 4.0 is the first platform of Tourism 4.0 in the Amazon jungle of Peru that includes an AR application, and a Biodiversity Portal, all supported by telecommunications infrastructure sustainable. It is an innovative and sustainable initiative that has the potential to revolutionize tourism in the region with a forward-thinking approach to tourism that prioritizes both the visitor experience and environmental conservation.

The AR application provides visitors with an interactive and immersive experience of the Amazon jungle, enhancing their understanding and appreciation of the region's unique biodiversity. The Biodiversity Portal serves as a valuable resource for visitors, providing information about the region's flora and fauna and promoting sustainable tourism practices. The sustainable telecommunications infrastructure is an essential component of the platform, ensuring that visitors can stay connected and engaged while minimizing the environmental impact of their stay. By providing sustainable infrastructure, the platform helps to promote responsible tourism and minimize the negative impacts on the local environment.

There are many exciting opportunities related to the implementation of the other Industry 4.0 technologies to enhance the tourist experience and develop new and engaging content with the creation of new AR experiences specifically designed for the unique environment and culture of the Amazon jungle of Peru. Always involving collaborations with local communities and stakeholders to ensure that the content is culturally appropriate and respectful.

ECOPACAYA 4.0 can be integrated with other technologies such as Virtual Reality (VR), artificial intelligence, and machine learning to enhance the tourist experience. For example, tourists could use AR technology to scan plants and animals and receive real-time information about them using machine learning algorithms to create even more immersive and educational experiences. This could involve the development of long-term monitoring programs that track the impact of the technology over time and identify any potential negative effects that need to be addressed and could serve as a model for other regions that are interested in promoting sustainable tourism practices to reach a wider audience.

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