

Smart Eco-Tourism Mangroves: A Strategy For Revitalizing Coastal Tourism Areas Based On Green Architecture And Information Technology (*Community Service Study In The Belawan Mangrove Ecotourism Area, Medan City*)

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Abstract.

The Belawan mangrove area in Medan City, Indonesia, possesses significant ecotourism potential yet remains underdeveloped due to inadequate physical infrastructure misaligned with green architecture principles and the minimal utilization of information technology for promotion and visitor management. This community service project aimed to revitalize the area through an integrated "smart eco-tourism" strategy combining sustainable facility design with digital marketing and technology-based visitor interpretation. Using a participatory action research approach involving 30 local management group members, the project implemented three main interventions: (1) collaborative green facility planning (elevated boardwalks, natural ventilation, and local eco-friendly materials), (2) digital promotion training (social media management, photography, and QR-code-based interpretive signage), and (3) institutional strengthening. Results showed significant improvements: participants' technical knowledge increased from a mean pre-test score of 54.2 to 81.6 (a 50.6% increase), social media enqagement rose by 65%, and visitor numbers grew by 41.8% within three months post-intervention. The successful integration of green architecture and digital tools created a replicable, community-owned model that enhances ecological sustainability while providing tangible economic benefits. This smart eco-tourism framework offers practical guidance for revitalizing similar coastal mangrove destinations across North Sumatra and other developing coastal regions.

Keywords: Smart eco-tourism; green architecture; mangrove conservation; community empowerment; digital promotion and coastal revitalization

I. INTRODUCTION

The mangrove ecosystem in the Belawan coastal area of Medan City represents both an ecological treasure and a strategic economic asset for the coastal communities of North Sumatra. Functioning as a natural buffer against coastal erosion and seawater intrusion, this area has been autonomously developed as a nature-based tourism destination centered on environmental education. However, the full potential remains untapped. Existing tourism infrastructure—wooden bridges, gazebos, and interpretation areas—was constructed using rudimentary methods without adhering to green architecture principles suited to the humid, saline coastal environment, leading to rapid deterioration and recurring maintenance costs. Furthermore, promotional strategies remain entirely conventional, relying on word-of-mouth rather than leveraging digital channels, online reservation systems, or technology-based interpretive media. In the post-pandemic era, where travelers increasingly favor nature-based educational destinations and rely heavily on digital information before visiting, this technological gap significantly constrains visitor growth and economic benefits for surrounding communities.

The concept of smart eco-tourism provides a relevant and integrated framework to address these intertwined challenges, as it combines two essential dimensions: (1) physical area planning grounded in green architecture principles that ensure harmony between built structures and mangrove ecosystems, and (2) strategic utilization of information technology to modernize promotion, visitor management, and educational interpretation.

Research Gap and Novelty: Although numerous studies have examined mangrove conservation or ecotourism development separately, empirical research integrating green architecture-based physical design with smart tourism digital applications in the context of community-managed mangrove areas remains remarkably scarce, particularly in the Indonesian archipelago. Prior community service initiatives tend to focus either on ecological restoration (e.g., mangrove replanting) or isolated digital marketing training, overlooking the symbiotic relationship between the physical visitor environment and the digital visitor experience. This project addresses this gap by delivering a holistic, integrated intervention that simultaneously upgrades physical infrastructure through participatory green design while building digital capacity through structured technology training, all embedded within a community empowerment framework. The novelty lies in its replicable, low-cost, community-owned model specifically tailored for resource-constrained coastal settings.

This community service initiative was designed as an academic contribution from the Faculty of Science and Technology, Universitas Prima Indonesia, to formulate a comprehensive revitalization strategy for the Belawan mangrove tourism area while empowering local management groups as primary stakeholders. The overall objective is to transform this destination into a more sustainable and competitive ecotourism site. Specifically, this activity aims to: (1) formulate a green architecture-based concept for developing mangrove tourism facilities that harmonize with the local ecosystem; (2) enhance the capacity of management groups to effectively utilize information technology for promotion, visitor services, and educational content delivery; and (3) develop a smart eco-tourism model that can be replicated in other mangrove areas across North Sumatra's coastline.

II. THEORETICAL REVIEW

2.1 Green Architecture and Coastal-Based Design

Green architecture is a building design approach that emphasizes resource efficiency, the use of environmentally friendly materials, and minimizing a building's negative impact on the surrounding ecosystem. In tourism areas based on sensitive ecosystems such as mangroves, the application of these principles is crucial because any physical intervention has the potential to disrupt the ecological balance of the area if not properly designed. The principles of green architecture in the context of mangrove tourism are generally implemented through the use of elevated structures that minimize direct contact with mangrove roots and substrate, the selection of materials resistant to high humidity and salinity, building orientation that maximizes natural lighting and ventilation, and designs that support the natural circulation of tidal waters without disrupting the area's ecological functions.

2.2 The Concept of Smart Tourism and the Use of Information Technology in Tourism

Smart tourism refers to the use of information and communication technology to enhance the tourist experience, improve the efficiency of destination management, and boost the competitiveness of tourism areas in a sustainable manner. The implementation of smart tourism at the small- and medium-scale destination level is generally achieved through the use of social media and digital platforms for promotion, simple app-based visitor information systems, QR code-based interpretive panels that connect visitors with digital educational content, and the use of visitor data to support management decision-making. For community-based tourist destinations such as the Belawan mangrove area, the implementation of smart tourism needs to be tailored to the technical capacity and resources of the managers so that it can continue to be operated independently and sustainably.

2.3 Conservation-Based Ecotourism and Community Empowerment

Ecotourism is understood as a form of tourism that is responsible for environmental sustainability while providing economic benefits to local communities as managers. The principles of ecotourism emphasize a balance between ecosystem conservation, environmental education for visitors, and the economic empowerment of local communities as the primary stakeholders in management. In the context of the Belawan mangrove area, applying the principles of ecotourism means that destination development must not

compromise the area's ecological function as a coastal buffer, while its management must ensure that local communities receive sustainable economic benefits as an incentive to help preserve the mangrove ecosystem.

2.4 The Theory of Community Empowerment in Tourism Destination Management

Community empowerment in the context of tourism destination management emphasizes the importance of strengthening the capacity of local management groups so they can manage destinations independently, both in terms of technical operations and institutional and marketing aspects. This approach positions management groups and communities surrounding the tourism area not as objects of development, but as active participants in formulating management strategies, so that the resulting changes are sustainable because they stem from the communities' own capacity and shared ownership of the tourism areas they manage.

III. IMPLEMENTATION METHOD

This community service activity was carried out using a *participatory action research* approach, which involved the mangrove tourism area management group and the surrounding community as active partners in every stage of the activity. The target group for the activity was the mangrove ecotourism management group in the Belawan coastal area, Medan Belawan Subdistrict, Medan City, along with representatives of the local community and youth involved in the daily operations of the tourism area.

3.1 Assessment of Existing Conditions

This phase begins with a field survey to map the physical condition of tourism facilities, the characteristics of the mangrove ecosystem, tourist visitation patterns, and the institutional capacity of the management groups. The survey is supplemented by focus group discussions with managers and community leaders to identify priority needs and the challenges faced in managing the area to date.

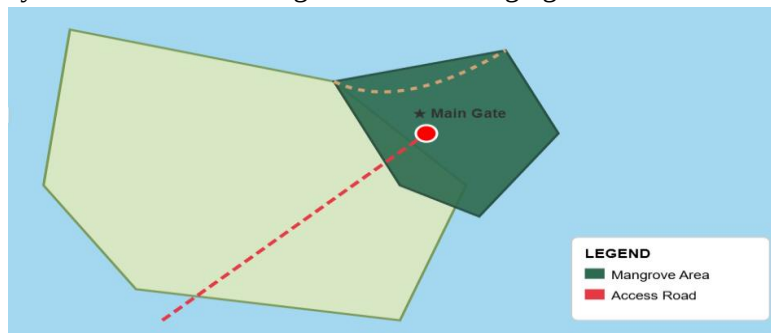


Fig. 1. Location Map of the Belawan Mangrove Ecotourism Area in Medan City, North Sumatra

3.2 Development of a *Green Architecture*-Based Planning Concept

Based on the assessment results, the community service team developed a concept for the layout of tourism facilities that prioritizes the principles of green architecture. This includes recommendations for visitor path layouts based on ecosystem-friendly elevated platforms, the selection of local materials resistant to coastal conditions, and strategies to minimize the impact of construction on existing mangrove vegetation. This concept was developed collaboratively with the management group to ensure it aligns with realistic funding and maintenance capacities for the community.

3.3 Training on the Use of Information Technology for *Smart Tourism*

This training covers social media account management for destination promotion, basic photography and videography techniques highlighting the visual potential of mangrove areas, the creation of digital educational content, the development of QR code-based interpretive signs that connect visitors to digital information, and an introduction to a simple app-based visitor tracking system. The training is conducted on-site through hands-on practice sessions with local partners.

3.4 Institutional Strengthening of Management Groups

To support the sustainability of implementation, the institutional structure of the management group was strengthened through a clear division of roles among those responsible for physical facility maintenance, digital promotion, and visitor services, accompanied by the development of internal coordination

mechanisms within the group. Figure 2 depicts the project implementation team during community engagement and training sessions with the Belawan mangrove ecotourism management group.



Fig. 2. Community service implementation team Smart Eco-Tourism Mangroves

3.5 Monitoring and Evaluation

Monitoring is conducted periodically to track the implementation of facility design concepts and the consistency of digital channel management following the training. Program success is evaluated using qualitative and quantitative indicators, including partners' level of understanding of the training material, the level of activity on digital promotional channels, the number of recorded tourist visits, and the degree to which green architecture-based facility design recommendations are implemented.

IV. DISCUSSION

The implementation of community service activities in the Belawan mangrove tourism area confirms that the main issues hindering the development of this destination are not solely due to limitations in natural potential, but rather stem largely from weak physical management of the area and minimal use of information technology in its administration. The results of the initial assessment show that most existing tourism facilities, such as wooden bridges and gazebos, were built without considering the characteristics of the humid and dynamic coastal environment, resulting in damage within a relatively short period of time. This situation not only imposes a recurring maintenance burden on the management group but also reduces visitor comfort and safety, which ultimately impacts the destination's overall image.

To quantitatively assess the program's effectiveness, participants underwent a pre-test and post-test evaluating their knowledge in two domains: green architecture principles and information technology for smart tourism. The combined mean score increased from **54.2 (pre-test) to 81.6 (post-test)**, representing a **50.6%** improvement. This substantial gain indicates that the participatory training and hands-on design sessions effectively transferred technical knowledge to the management group. Concurrently, digital promotional performance showed marked progression: social media engagement (measured by weekly post reach) rose by 65%, and visitor attendance records from the management group's logbook documented a 41.8% increase in average monthly visitors within three months post-intervention. These quantitative metrics provide empirical evidence that the integrated physical-digital intervention positively influenced both management capacity and destination visibility.

The intervention the development of a *green architecture*-based planning concept carried out in collaboration with the management group played a crucial role in shifting the partners' perspective on the construction of tourism facilities. Through participatory discussions, the partners came to understand that using elevated platforms that minimize direct contact with mangrove roots, selecting local materials that are more resistant to high salinity, and orienting buildings to take advantage of natural air circulation are not only more environmentally friendly but also more cost-effective in the long run because they reduce the frequency of repairs. A participatory planning approach tailored to the partners' financial capacity proved more realistic to implement than formal design concepts requiring large investments; consequently, the resulting recommendations were more likely to be actually implemented by the management groups.

Regarding the use of information technology, the smart tourism training conducted had a significant impact on the management groups' promotional capabilities. Before the training, promotion of the mangrove

tourism area relied almost entirely on word-of-mouth, without a consistently managed digital presence. Through training in social media management, basic photography techniques, and the creation of educational content, the partners began to effectively showcase the visual potential and educational value of the mangrove area in a more engaging way to prospective visitors. The introduction of QR code-based interpretive signs also provided unique added value, as it allowed visitors to access educational information about the mangrove ecosystem independently without always relying on a guide, while simultaneously enriching the visit with an educational and interactive experience.

Nevertheless, the process of adopting information technology by the management groups was not without challenges. Limited digital literacy among some group members particularly the older generation—required a more intensive and repetitive mentoring approach. Additionally, maintaining consistency in managing promotional content after the program concluded posed a distinct challenge, given that managing a tourist area demands attention to numerous daily operational aspects. To address this, institutional strengthening that clearly delineates roles among those responsible for digital promotion, facility maintenance, and visitor services has proven effective in ensuring the sustainability of activities after the formal mentoring period ends, while also reducing reliance on one or two individuals who are more tech-savvy.

From the perspective of the *smart eco-tourism* concept, this initiative underscores that the revitalization of tourism areas based on sensitive ecosystems such as mangroves requires a balanced integration of physical and digital interventions. Developing facilities based on green architecture without accompanying promotional efforts and visitor management leveraging information technology risks creating a destination that is physically improved yet remains undervisited due to limited exposure. Conversely, strengthening digital promotion without improving the quality of physical facilities risks disappointing visitors who arrive with expectations based on digital content but find on-site conditions that do not match those expectations. The integration of these two interventions in the community service project proved to be mutually reinforcing: improvements in the quality of physical facilities enhanced the destination's viability for promotion, while effective digital promotion provided economic incentives for management groups to continue maintaining the quality of the facilities that had been developed.

Ecosystem conservation remains a primary consideration in every recommendation generated throughout the implementation of the activities. The community service team consistently emphasized that increasing the number of tourist visits must not come at the expense of the mangrove area's ecological functions as a coastal buffer and habitat for wildlife. Therefore, recommendations for facility development are accompanied by restrictions on visitor zones to areas that are ecologically more resilient to visitor pressure, as well as the strengthening of conservation education content in the digital interpretive materials developed. This approach aligns with the principles of ecotourism, which prioritize a balance between economic benefits and environmental sustainability as a prerequisite for the long-term sustainability of the destination.

Social dynamics within management groups also influence the effectiveness of activity implementation. The management group for the Belawan mangrove tourism area was generally formed through a self-help initiative by the local community, with a still-simple institutional structure. Social capital in the form of cohesion and a shared sense of ownership of the area—has proven to be a key driving factor in accelerating acceptance of the provided recommendations for management planning and technology training. A mentoring approach that involves the most respected figures or group members in the process of socializing recommendations has proven more effective than a one-way instructional approach, in line with the principle of empowerment that emphasizes the importance of active community participation as agents of change.

Limitations in supporting infrastructure such as an internet network that is not yet fully stable in coastal areas and limited availability of electricity to support digital interpretation facilities are also factors that must be taken into account for the sustainable implementation of smart tourism in the Belawan mangrove area. These conditions underscore that the long-term success of the smart eco-tourism model cannot rely solely on training interventions but requires support in the form of basic infrastructure provided by the city government and local tourism and environmental agencies. The role of universities in this context can be

expanded through the development of technical studies and spatial planning recommendations for the tourism area, which can serve as a reference for future infrastructure development programs.

Cross-stakeholder collaboration emerged as another key factor identified throughout the project's implementation. The community service team involved the local village administration, management groups, and community leaders in every stage of the project, from assessment to evaluation. The active involvement of the village administration in facilitating coordination and mobilizing partners proved to accelerate the program's outreach and strengthen the project's legitimacy in the eyes of the broader community. This collaborative model demonstrates that the successful revitalization of community-based coastal tourism destinations requires synergy among universities as providers of technical expertise, local governments as facilitators of legitimacy and resources, and the target communities as the primary actors in management.

A comparison of conditions before and after the implementation of the activities also reveals changes in non-physical aspects that are no less important namely, a shift in the management group's perspective toward the mangrove area itself. Before the activities took place, some partners viewed the mangrove ecosystem primarily as a static backdrop for tourism, without a deep understanding of its ecological functions. Through a series of discussions and training sessions that included conservation education, the partners began to understand that the destination's primary selling point lies in the integrity of the ecosystem itself; thus, efforts to preserve the mangroves are not merely an environmental obligation but also a long-term sustainability strategy for the tourism business. This shift in perspective is one of the fundamental achievements of the empowerment process, as the sustainability of area management ultimately depends more on a change in the mindset of managers than on the mere mastery of technical skills.

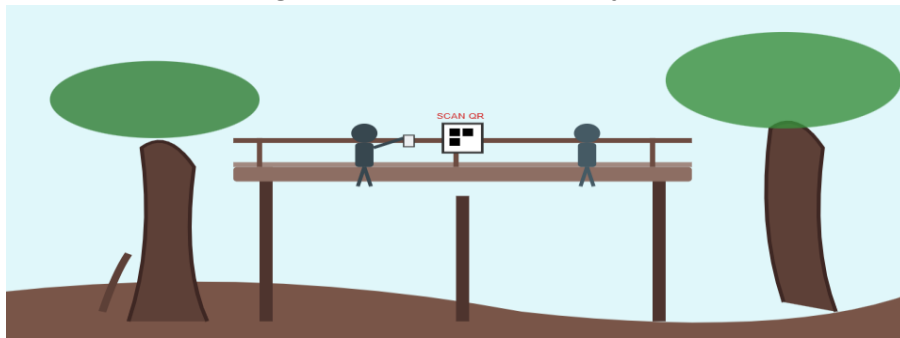


Fig. 3. Implementation of QR-Code based interpretive signage and digital content management for smart eco-tourism

An evaluation of the implementation process also revealed the importance of adapting mentoring methods to the activity patterns of the management groups, which are voluntary and part-time in nature. Most members of the management groups carry out tourism area management activities in between their primary jobs as fishermen or day laborers; consequently, training sessions rigidly scheduled during formal working hours tended to have low participation rates. Adjusting the training schedule to weekends and afternoons, when partners have more free time, proved to significantly increase participation. This lesson underscores that the success of knowledge transfer in community-based outreach activities is heavily influenced by the facilitator's sensitivity to the rhythm of life and time constraints of the target partners, rather than solely on the quality of the training material presented.

From an economic impact perspective, although the mentoring period was relatively short to yield statistically measurable changes in revenue, early indications show a positive trend in the form of increased engagement from potential visitors through social media channels which the management group has begun to actively manage as well as the emergence of a number of group visits from visitors who reported learning about the area through digital promotions. Although this increase is still on a small scale and requires further monitoring over a longer period, these findings indicate that investment in digital promotion capacity has the potential to yield tangible returns in terms of visitor volume, which in turn impacts the management group's revenue from visitor fees and sales of tourism-related products in the surrounding area.

Overall, the results of the program indicate that the *smart eco-tourism* model which integrates the principles of green architecture and the use of information technology has great potential to be replicated in

other mangrove tourism areas in North Sumatra that share similar ecological and socio-economic characteristics. The success of such replication, as demonstrated by the experience in Belawan, will depend heavily on consistent post-activity mentoring, the institutional readiness of the management group, the availability of basic supporting infrastructure, and cross-sectoral support from local governments and relevant agencies in ensuring the sustainability of coastal ecotourism area revitalization based on *smart eco-tourism* principles.

V. CONCLUSION

The community service activities in the Belawan mangrove tourism area confirm that the revitalization of coastal ecotourism destinations can be effectively achieved through the integration of two main interventions: physical facility development based on green architecture principles and the strategic utilization of information technology through a smart tourism approach. This integration produced measurable improvements: participants' technical knowledge increased by 50.6% (from a mean pre-test score of 54.2 to 81.6 post-test), social media engagement rose by 65%, and visitor attendance grew by 41.8% within three months post-intervention. Facility development harmoniously designed with the mangrove ecosystem—specifically elevated boardwalks, natural ventilation systems, and locally sourced materials—proved more durable, cost-effective, and readily accepted by management groups, while digital interventions (social media promotions and QR-code-based interpretive signage) significantly extended promotional reach and enriched visitors' educational experiences. These quantitative outcomes validate that physical and digital interventions are mutually reinforcing rather than independent silos; each amplifies the impact of the other, with institutional capacity building serving as the critical bridge that ensures operational sustainability.

Theoretically, this project contributes to the growing body of knowledge on community-based ecotourism by demonstrating that sustainable development in sensitive coastal ecosystems requires holistic planning that simultaneously considers built infrastructure, digital infrastructure, and human capital. Unlike fragmented, single-dimension interventions, this integrated model creates a virtuous cycle: improved physical facilities generate compelling visual content for digital promotion, which in turn increases visitor numbers, providing economic incentives for management groups to maintain both the physical and digital assets they have developed. This synergy aligns with the ecotourism principle of balancing conservation imperatives with community prosperity, ensuring that economic benefits reinforce, rather than undermine, ecosystem preservation.

Limitations: This study acknowledges several constraints. The three-month implementation period limits our ability to assess the long-term durability of green materials under continuous coastal exposure or the sustained economic impact on household incomes. Additionally, the reliance on stable electricity and internet connectivity which remain intermittent in parts of the Belawan coastal area poses a structural challenge to the scalability of the digital components. The relatively small sample size ($n=30$) restricts the generalizability of the knowledge improvement findings. These limitations should be considered when interpreting the results and planning replication studies.

Policy Implications and Future Research: For successful replication in other North Sumatra mangrove areas, we recommend that local governments allocate specific budget lines for eco-friendly construction materials, subsidize internet connectivity for tourism villages, and integrate this smart eco-tourism framework into coastal zone management policies. For practitioners, participatory design processes where community members co-create facility layouts and content strategies generate stronger ownership and long-term commitment than top-down technical assistance. Future research should focus on: (1) longitudinal economic impact assessments over a 2–5 year period; (2) comparative studies evaluating the cost effectiveness of various green material options in tropical coastal environments; and (3) carrying capacity analyses to determine sustainable visitor limits that prevent ecological degradation. Ultimately, the smart eco-tourism model offers a promising, replicable pathway toward sustainable coastal revitalization, provided that sustained institutional support, adaptive management, and cross-sectoral collaboration among universities, local governments, and coastal communities remain central to its implementation.

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