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META-DSS: A SMART DECISION SUPPORT SYSTEM FRAMEWORK FOR SUSTAINABLE MANGROVE ECOTOURISM MANAGEMENT

DARWIN YUWONO RIYANTO[1] , RUDI SANTOSO[2*] , JANUAR WIBOWO[3] , MOCHAMMAD ARIFIN[4]

[1,4]Visual Communication Design, Faculty of Design and Creative Industry, Universitas Dinamika, Surabaya, Indonesia
[2]Accounting Program, Faculty of Economy and Business, Universitas Dinamika, Surabaya, Indonesia
[3]Management Program, Faculty of Economy and Business, Universitas Dinamika, Surabaya, Indonesia
E-mail: [1]darwin@dinamika.ac.id, *[2]rudis@dinamika.ac.id, [3]januar@dinamika.a.c.id, [4]marifin@dinamika.ac.id

ABSTRACT

Mangrove ecotourism has emerged as a strategic approach to achieving environmental conservation, community empowerment, and sustainable coastal economic development. However, the management of mangrove tourism destinations in Indonesia continues to face significant challenges, including fragmented stakeholder coordination, limited digital integration, inadequate tourism information management, and the absence of systematic decision-support mechanisms. These limitations hinder the ability of tourism managers and policymakers to make data-driven decisions that balance ecological sustainability, visitor experience, and local economic growth. This study aims to develop META-DSS (Mangrove Ecosystem Transformation Approach–Decision Support System), a smart decision support system framework designed to support sustainable mangrove ecotourism management through the integration of digital technologies, stakeholder collaboration, and sustainability indicators.

This research employed a qualitative exploratory approach involving in-depth interviews, field observations, document analysis, and focus group discussions with tourism managers, local communities, MSMEs, government representatives, academics, and tourists at selected mangrove ecotourism destinations in East Java, Indonesia. The collected data was analyzed using thematic analysis, stakeholder mapping, ecosystem analysis, and framework synthesis techniques to identify critical components required for an integrated tourism decision support system.

The findings reveal that sustainable mangrove ecotourism management requires the integration of five key components: stakeholder collaboration, tourism information systems, digital marketing and visitor engagement, environmental sustainability monitoring, and community-based economic development. Based on these findings, the study proposes the META-DSS framework consisting of a stakeholder layer, data acquisition layer, analytics layer, decision support layer, and sustainability outcomes layer. The framework enables systematic information flow, real-time tourism monitoring, evidence-based decision-making, and collaborative governance among tourism stakeholders.

The study concludes that META-DSS provides a comprehensive smart tourism framework capable of enhancing destination management effectiveness, strengthening sustainability performance, supporting local economic participation, and facilitating digital transformation in mangrove ecotourism ecosystems. The proposed framework contributes to the development of tourism decision support systems and smart sustainable tourism management in emerging coastal destinations.

Keywords: *Decision Support System; Smart Tourism Ecosystem; Mangrove Ecotourism; Digital Transformation; Sustainable Tourism Management*

1. INTRODUCTION

1.1 Background

Digital transformation has become one of the main drivers of change in various sectors of the economy, including the tourism industry. The development of information technology, artificial intelligence, the Internet of Things (IoT), big data analytics, and decision support systems has encouraged the emergence of the concept of smart tourism that integrates digital technology with the management of tourist destinations more effectively and sustainably [1]. In this context, smart tourism focuses not only on providing digital services to

tourists, but also on the ability of the system to support data-driven decision-making for all stakeholders involved in the management of tourist destinations.

In Indonesia, the tourism sector is one of the important contributors to national and regional economic development. One form of tourism that has experienced significant growth in recent years is mangrove ecotourism [2]. Mangrove ecotourism not only offers economic value through tourist visits but also has an important ecological function as a protector of coastal areas, carbon sinks, habitats for marine life, and buffers for environmental sustainability. Therefore, the management of mangrove tourism requires a balance between economic, social, and environmental goals so that the resulting benefits can last in the long term.

East Java Province is one of the regions that has great potential in the development of mangrove ecotourism. Various mangrove tourism areas have developed as tourist destinations based on conservation and community empowerment. However, these developments still face various challenges in terms of destination management, coordination between stakeholders, digital marketing, tourist data management, and environmental sustainability monitoring. Most mangrove tourism is still carried out conventionally and has not been supported by information systems that are able to provide real-time information to support the decision-making process.

In the digital economy, effective decision-making requires accurate, integrated, and easily accessible data support. The concept of Decision Support System (DSS) has been widely used in various fields to assist decision-makers in analyzing data, evaluating alternatives, and determining optimal strategies [3], [4]. In the tourism sector, DSS can be used to support destination management, analysis of tourist behavior, development of marketing strategies, environmental management, and evaluation of tourist destination performance. The integration of DSS with the concept of smart tourism ecosystem allows for the creation of a more adaptive, collaborative, and sustainable tourism management system.

1.2 Research Problem

Although various digitalization initiatives have been implemented in the tourism sector, the management of mangrove ecotourism still faces several fundamental problems. First, the information needed by stakeholders is often spread across multiple platforms and has not been integrated into one structured system. As a result, the decision-making process becomes less effective because the available data cannot be used optimally.

Second, coordination between local governments, tourism managers, local communities, MSME actors, academics, and tourists is still partially ongoing. Each stakeholder has different information needs and goals, but there is no digital mechanism that can connect all parties in one integrated decision-making ecosystem.

Third, most mangrove tourism destinations do not have a monitoring system that is able to integrate economic, social, and environmental indicators simultaneously. In fact, the success of mangrove ecotourism is not only determined by the number of tourist visits, but also by the success of environmental conservation and the improvement of the welfare of local communities. The absence of a system that can integrate these various dimensions causes decision-making to be often done intuitively and less data driven.

Fourth, the development of smart tourism in Indonesia is still more focused on aspects of digital promotion and tourism services, while the development of a decision support system to support the governance of sustainable tourist destinations is still relatively limited. This condition shows the need for a system framework that can integrate data, technology, stakeholders, and sustainability goals in one comprehensive management model.

1.3 Research Gap

Research on smart tourism has grown rapidly in recent years. Most studies [5], [6] highlight the use of digital technology to improve the tourist experience, service quality, and competitiveness of tourist destinations. However, many studies still focus on aspects of customer experience, mobile applications, and digital marketing without discussing how technology can be used to support strategic decision-making in the management of tourist destinations.

Research related to tourism decision support system [7], [8], [9] It has also produced a variety of models to support trip planning, destination recommendations, and traveler behavior analysis. However, most of the DSS models are designed for the needs of tourists as end-users, not to support decision-making by destination managers and tourism stakeholders.

On the other hand, research on mangrove ecotourism [10], [11], [12] generally focuses on environmental conservation, community empowerment, and local economic development. Although the sustainability aspect has been widely discussed, the integration between the smart tourism ecosystem, decision support system, and mangrove

ecotourism management is still very limited. There are not many studies that offer a system framework that is able to connect environmental data, tourism activities, digital marketing, community participation, and stakeholder needs in one integrated decision-making model.

Based on the study, there is a significant research gap related to the development of smart decision support systems that are specifically designed to support sustainable mangrove ecotourism management. This gap is the basis for the development of META-DSS as a new framework that integrates the principles of the smart tourism ecosystem with the needs of sustainability-based tourism management.

1.4 Research Objective

This research aims to develop META-DSS (Mangrove Ecosystem Transformation Approach–Decision Support System), which is a framework for smart decision support systems to support sustainable mangrove ecotourism management. In particular, this study aims to: (1) identify the need for information and stakeholder interaction in mangrove tourism management; (2) analyze the main components needed in the development of a sustainability-based smart tourism ecosystem; (3) designing the META-DSS information architecture and flow; and (4) develop a conceptual framework that can be used as a basis for the development of decision support systems in mangrove ecotourism destinations.

1.5 Research Contribution

This research makes theoretical and practical contributions. Theoretically, this study expands the literature on smart tourism ecosystem and tourism decision support system by introducing META-DSS as an integrative framework that connects the dimensions of information technology, tourism management, environmental sustainability, and community empowerment. This framework enriches the study of DSS in the context of conservation-based tourist destinations which are still relatively limited in the current literature.

Practically, this research offers a framework of systems that can be used by local governments, tourism managers, local communities, and tourism industry players to support data-driven decision-making. META-DSS is expected to be able to increase the effectiveness of mangrove tourism destination management through information integration, increased stakeholder collaboration, sustainability monitoring, and strengthening digital transformation in the tourism ecosystem. Thus, the resulting framework can be the foundation for the development of smart sustainable tourism management in coastal areas and other ecotourism destinations in Indonesia.

2. RELATED WORKS

2.1 Smart Tourism Ecosystem

The development of information technology has encouraged the emergence of the Smart Tourism Ecosystem concept as a new paradigm in the management of tourist destinations. This concept integrates various digital technologies, data, stakeholders, and tourism services into an interconnected ecosystem to improve the efficiency of destination management and tourist experience. Smart tourism focuses not only on the use of digital technology for tourism promotion, but also on the use of data and information systems to support the decision-making process in real-time.

According to [2], The Smart Tourism Ecosystem consists of a network of actors involving tourists, destination managers, governments, local communities, service providers, and digital platforms that interact with each other through the exchange of data and information. In this ecosystem, technology serves as an enabler that allows for information integration, stakeholder collaboration, and the development of tourism services that are more adaptive to user needs.

Meanwhile, research [13] Explained that the Smart Tourism Ecosystem is built through the integration of three main components, namely digital technology, stakeholder collaboration, and intelligent decision-making. These three components allow destination managers to utilize data generated by tourists and various tourism activities as a basis for developing destination development strategies.

In the context of conservation-based tourism, the smart tourism ecosystem has a more complex role because it must be able to integrate economic, social, and environmental goals simultaneously. Therefore, the development of smart tourism is not only oriented towards increasing tourist visits, but also on sustainable management of natural resources and improving the welfare of local communities. This integration requires the support of information systems that can connect various stakeholders in one integrated digital ecosystem.

Although the concept of smart tourism ecosystem has been widely developed in urban destinations and smart city tourism, its implementation in mangrove ecotourism areas is still relatively limited. Most mangrove tourism destinations still rely on manual management systems with a low level of digital integration. This condition shows the need to develop a smart tourism framework that is

specifically designed to support sustainability-based ecotourism management.

2.2 Tourism Decision Support System (DSS)

Decision Support System (DSS) is a computer-based system designed to assist decision-makers in solving semi-structured and unstructured problems using data, analytical models, and relevant information. In the field of tourism, DSS has been used to support various activities such as travel planning, destination management, tourism marketing, resource management, and tourism policy evaluation.

According to [3], DSS consists of four main components, namely the data management subsystem, the model management subsystem, the user interface subsystem, and the knowledge management subsystem. The integration of these four components allows users to obtain recommendations and alternative decisions based on the available data. In the context of smart tourism, DSS is an important instrument to turn data into valuable information in the decision-making process.

Research related to DSS tourism has developed in various fields. [14] develop DSS to help travelers choose destinations based on travel preferences. Research conducted [15] develop a DSS model to support destination management through stakeholder network analysis. Other research utilizes DSS for destination capacity management, tourist behavior analysis, and the development of data-driven marketing strategies.

Nevertheless, most DSS research in tourism is more oriented towards tourists as end-users. There is still relatively little research that develops DSS to support sustainability-based tourism destination management, especially in mangrove ecotourism areas. In addition, most existing models have not integrated environmental indicators, community participation, and digital marketing in a single, integrated system framework.

In the context of this research, DSS is seen as a core component that can bridge the information needs of various stakeholders. Through the integration of environmental data, tourist data, local economic data, and digital marketing data, DSS can produce more comprehensive recommendations to support sustainable management of mangrove tourism.

2.3 Sustainable Ecotourism Management

The concept of sustainable tourism developed in response to the increasing negative impact of tourism activities on the environment and local communities. Sustainable tourism emphasizes the importance of balancing economic growth, environmental conservation, and social well-being. In the context of mangrove ecotourism, sustainability is a very important issue because tourism activities take place in ecosystems that are vulnerable to environmental degradation.

Study [16] explained that sustainable tourism management must pay attention to three main dimensions, namely environmental sustainability, economic sustainability, and social sustainability. These three dimensions must be integrated in every planning and management process of tourist destinations so that the benefits produced can be felt in the long term.

Mangrove ecotourism is a form of nature-based tourism that combines recreational activities, environmental education, and local community empowerment. Various studies show that mangrove ecotourism can increase the income of coastal communities while supporting environmental conservation. However, the success of mangrove tourism management is highly dependent on the ability of stakeholders to manage conflicts of interest between economic goals and conservation goals.

In the digital era, the concept of sustainable tourism is increasingly related to the use of information technology to support environmental monitoring, tourist management, and destination performance evaluation. Digital-based information systems allow tourism managers to obtain real-time data on environmental conditions, the number of visitors, local economic activities, and the level of community participation. This information becomes an important basis for a more accurate and sustainable decision-making process.

Therefore, the development of a decision support system that can integrate sustainability indicators is an important need in mangrove ecotourism management. This approach allows the creation of a tourism management model that is more adaptive to changes in the environment and the needs of stakeholders.

2.4 Existing Tourism Information System Models

The development of information technology has produced various models of tourism information systems that are used to support tourism activities and destination management. Most of these systems focus on providing tourist information, online reservations, destination recommendations, and customer relationship management. Modern tourism information systems generally integrate websites, mobile applications, social media, Geographic Information Systems (GIS), and cloud computing to improve the quality of tourism services.

The Tourism Information System (TIS) model developed by [17], [18] emphasizing the importance of integrating destination information, traveler data, and digital services in one easy-to-access platform. Furthermore, the development of smart tourism has encouraged the emergence of various platforms that integrate the Internet of Things (IoT), big data analytics, and artificial intelligence to improve the quality of services and tourist experience.

However, most existing tourism information system models are still focused on serving tourists and have not been specifically designed to support strategic decision-making by destination managers. In addition, existing models generally do not integrate the dimensions of environmental sustainability and community empowerment in the architecture of the system.

In mangrove ecotourism areas, the need for information systems is much more complex because it involves various types of data from the environment, tourists, local communities, and other stakeholders. Therefore, an information system model is needed that can integrate these various data sources into a more comprehensive decision-making framework.

The limitations of the previous models became the basis for the development of META-DSS which was designed as a decision support system framework for sustainable mangrove tourism management. This framework not only serves as an information system, but also as an analytical platform that is able to generate strategic recommendations for stakeholders.

2.5 Research Positioning

Based on the literature review that has been conducted, it can be concluded that previous research generally discussed smart tourism ecosystem, tourism decision support system, sustainable tourism, and tourism information systems separately. There has not been much research that integrates these four aspects into a single framework specifically designed to support sustainable mangrove ecotourism management.

The position of this research is at the intersection between smart tourism ecosystem, decision support system, sustainable ecotourism management, and tourism information systems. In contrast to previous research that focused more on tourist services or destination promotion, this study places stakeholder decision-making as the focus of system development.

Through the development of META-DSS (Mangrove Ecosystem Transformation Approach–Decision Support System), this research offers a new framework that integrates stakeholder collaboration, tourism information systems, sustainability indicators, digital tourism ecosystem, and intelligent decision support in one conceptual model. Thus, this research is expected to contribute to the development of smart tourism theory and decision support systems while providing a conceptual foundation for the development of a sustainable tourism system based on information technology.

Table 1. Research Gap Analysis

Authors	Research Focus	Method	Key Contribution	Identified Limitation	Research Gap Addressed by META-DSS
[19]	Tourism Information Systems	Conceptual	Introduced integrated tourism information systems for destination management	Focused primarily on information delivery and tourism services	Does not provide an intelligent decision-support mechanism integrating sustainability indicators and stakeholder collaboration
[20]	Smart Tourism Ecosystem	Conceptual	Established the concept of interconnected tourism ecosystems through ICT and data	Emphasized technological connectivity but lacked a practical decision-support	Limited integration of sustainability management and destination-level decision

			exchange	framework	support
Buhalis & Amaranggana (2015)	Smart Tourism Destination	Qualitative	Highlighted the role of technology in enhancing tourism competitiveness and visitor experience	Focused on smart destinations rather than management decision-making processes	Absence of DSS architecture for sustainable ecotourism governance
[21]	Tourism Decision Support Systems	System Development	Developed DSS models for travel planning and destination selection	Primarily designed for tourists as end-users	Limited applicability for destination managers and tourism stakeholders
[15]	Destination Management Networks	Qualitative	Demonstrated the importance of stakeholder collaboration in tourism governance	Did not incorporate information system architecture or DSS mechanisms	Lack of integrated stakeholder-based decision-support framework
[22]	Sustainable Tourism Governance	Conceptual	Emphasized sustainability and governance in tourism development	Focused on policy and governance perspectives	Did not address digital transformation and intelligent information systems
[23]	Community-Based Tourism	Qualitative	Highlighted community participation in sustainable tourism development	Limited technological and system-oriented discussion	No framework for integrating communities into digital tourism decision systems
[24]	Digital Tourism and Smart Tourism	Literature Review	Explained the role of digital technologies in tourism transformation	Concentrated on digital experience and service innovation	Limited focus on sustainability-driven DSS models
[25]	META (Mangrove Ecosystem Transformation Approach)	Development Research	Proposed a transformation model for sustainable mangrove ecotourism	Focused on tourism sustainability and ecosystem resilience	Did not incorporate DSS architecture, information flow, and system-based decision-making mechanisms
This Study	**META-DSS: A Smart Decision**	**Framework Development**	**Develops an integrated smart DSS**	**Addresses limitations of previous**	**Provides a novel smart tourism**

	on Support System Framework for Sustainable Mangrove Ecotourism Management	Research	framework combining tourism information systems, stakeholder collaboration, sustainability indicators, digital tourism ecosystem, and intelligent decision support for mangrove ecotourism management	ous studies by integrating sustainability, information systems, stakeholder management, and decision support into a unified framework	DSS architecture specifically designed for sustainable mangrove ecotourism management

Unlike existing tourism information systems that primarily focus on tourist services, META-DSS is designed as a managerial decision-support framework capable of assisting governments, tourism managers, local communities, and MSMEs in making data-driven decisions to achieve sustainable mangrove ecotourism development.

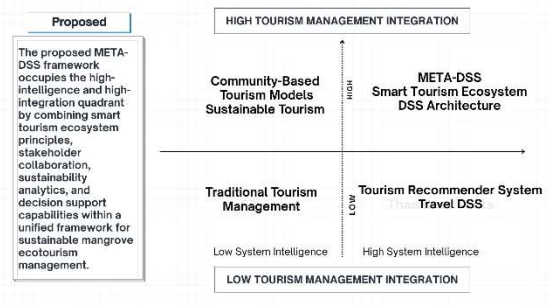

Figure 1. Research Positioning Map

3. RESEARCH METHODOLOGY

3.1 Research Design

This study uses an exploratory qualitative approach with the orientation of Framework Development Research to develop META-DSS (Mangrove Ecosystem Transformation Approach–Decision Support System) as a decision support system framework for sustainable mangrove ecotourism management. This approach was chosen because the research aims to produce a conceptual framework that integrates the principles of smart tourism ecosystem, decision support system, and sustainable ecotourism management in one structured model. In contrast to research that is oriented towards hypothesis testing, this research focuses on identifying system needs, analyzing the relationship between components, and developing conceptual architectures that can be used as a basis for the development of information systems in the future.

The qualitative approach allows researchers to gain an in-depth understanding of the actual conditions of mangrove tourism management, stakeholder information needs, decision-making mechanisms, and digital transformation challenges faced by destination managers. In addition, this approach also supports the process of exploring the components needed in the development of a decision support system that is in accordance with the characteristics of mangrove ecotourism in Indonesia.

3.2 Data Collection

The research data was obtained through a combination of several data collection techniques to increase the depth and credibility of the information. The main techniques used are in-depth interviews, field observations, documentation studies, and Focus Group Discussions (FGD).

Interviews were conducted in a semi-structured manner with various stakeholders involved in mangrove tourism management. The interview questions are focused on the destination management process, the use of digital technology, information needs, decision-making challenges, and expectations for the development of decision support systems.

Field observations were carried out to understand the actual condition of mangrove tourist destinations, interactions between stakeholders, tourist activities, the use of digital media, and the environmental management practices applied. Meanwhile, the documentation study was used to collect information from tourism management reports, policy documents, social media content, destination websites, and various other supporting data sources.

In addition, Focus Group Discussions were held to gain a collective perspective on system needs, decision-making processes, and opportunities for META-DSS implementation. The combination of various data collection techniques allows for a triangulation process that increases the validity of research results.

3.3 Stakeholder Identification

Stakeholder identification was carried out to map the main actors who play a role in the mangrove tourism ecosystem and become potential users of the META-DSS framework. The identification process is carried out through stakeholder mapping based on the level of importance and influence on the management of tourist destinations.

The main stakeholders identified include local governments, mangrove tourism managers, tourism awareness groups (Pokdarwis), local communities, MSME actors, academics, environmental organizations, and tourists. Each stakeholder has different information needs in the decision-making process.

Local governments need data to support tourism development and environmental conservation policies. Tourism managers need information about the number of visits, tourist preferences, and the effectiveness of digital promotions. Local communities and MSME actors need access to market information and economic opportunities. Meanwhile, tourists need accurate information about available destinations, facilities, and tourist activities. Identifying the needs of these stakeholders is the basis for designing the structure and function of META-DSS.

3.4 Framework Development Procedure

The development of the META-DSS framework is carried out through five main stages. The first stage is the identification of problems and system needs based on the results of interviews, observations, and documentation studies. At this stage, a mapping of various problems faced in mangrove tourism management is carried out, especially those related to data integration, stakeholder coordination, and decision-making processes.

The second stage is stakeholder requirement analysis which aims to identify the information needs, system functions, and data flows needed by each stakeholder. The results of this analysis are used to formulate the functional needs of the framework.

The third stage is ecosystem mapping which maps the relationship between stakeholders, data sources, tourism activities, and sustainability indicators. This stage produces an overview of the structure of the mangrove tourism ecosystem that is the basis for the development of the framework.

The fourth stage is the design of the META-DSS architecture which includes the stakeholder layer, data acquisition layer, analytics layer, decision support layer, and sustainability outcome layer. This architecture is designed to describe how data is collected, processed, analyzed, and converted into decision-making recommendations.

The fifth stage is a synthesis framework that integrates all components into a complete META-DSS model that is ready to be validated by experts and practitioners.

3.5 Validation Method

Framework validation was carried out using an expert validation approach to evaluate the conceptual feasibility and practical relevance of META-DSS. The validation process involves a panel of experts consisting of academics in the field of information systems, sustainable tourism experts, mangrove tourism management practitioners, and local government representatives.

Experts were asked to assess several key aspects of the framework, namely the completeness of system components, relevance to stakeholder needs, clarity of information flow, support for decision-making, and potential implementation in mangrove tourism management. The assessment was carried out using indicator-based evaluation instruments developed from the DSS literature and the smart tourism ecosystem.

In addition to expert validation, a focus group discussion was also held to obtain feedback on the potential development and implementation of the framework in the context of mangrove tourism destinations. The validation results were used to improve the structure of META-DSS so that the resulting framework has a higher level of relevance, feasibility, and usability in supporting sustainable mangrove ecotourism management.

4. META-DSS FRAMEWORK DEVELOPMENT

4.1 Existing Mangrove Tourism Ecosystem

The results of observations and interviews show that mangrove ecotourism management in East Java has developed as a form of conservation-based tourism involving various stakeholders, including local governments, tourism managers, local communities, MSME actors, environmental organizations, academics, and tourists. However, interaction between stakeholders is still partially ongoing and has not been supported by a digital system that is

able to integrate all destination management activities.

Under existing conditions, most of the tourism management process still relies on conventional communication and the use of separate digital platforms. Information on the number of tourist visits, promotional activities, environmental conditions, and local economic development is generally stored in a variety of different sources. As a result, decision-making is often based on the manager's experience or intuition without being supported by integrated data.

In addition, the use of digital technology is still dominating using social media as a means of tourism promotion. Platforms such as Instagram, Facebook, TikTok, and YouTube are used to increase the visibility of destinations and attract tourists. However, the use of the platform is not yet connected to an analytics system that is able to generate strategic information to support destination management.

From an ecosystem perspective, mangrove tourism involves various components that interact with each other. The government plays a role in policy formulation and supervision, tourism managers are responsible for destination operations, local communities and MSMEs provide tourism products and services, while tourists are the main source of data on market behavior and preferences. The absence of a system that can connect all these components causes the potential for the available data to be utilized optimally.

These findings show that the development of mangrove ecotourism requires a systems approach that can integrate data, stakeholders, and decision-making processes in one structured digital framework. Therefore, META-DSS was developed as a solution to bridge these needs through a smart tourism ecosystem approach based on a decision support system.

Figure 2. Existing Mangrove Tourism Ecosystem

4.2 Stakeholder Requirement Analysis

Stakeholder needs analysis is carried out to identify the information needed by each actor in the decision-making process. The results of the analysis show that each stakeholder has different information needs, but they are interrelated in the management of mangrove tourist destinations.

Local governments need information on tourist visitor rates, local economic impacts, tourism policy effectiveness, and environmental conditions to support the planning and evaluation process of tourism development programs. Tourism managers need operational data such as the number of visitors, visit patterns, tourist satisfaction, the effectiveness of digital promotions, and the condition of tourist facilities.

Local communities and MSME actors need market information that can help them develop products and services that suit the needs of tourists. On the other hand, travelers need access to accurate destination information, easy-to-use digital services, and a more personalized and interactive travel experience.

The analysis also shows that most stakeholders face obstacles in the form of limited access to integrated data. The information available is often partial and cannot be used directly to support strategic decision-making. This condition shows the need for a system that can collect, process, and present relevant information for all stakeholders.

Based on the results of the needs analysis, META-DSS is designed to fulfill four main functions, namely information integration, stakeholder collaboration, decision support, and sustainability monitoring. These four functions are the foundation in the development of the proposed framework.

Table 2. Stakeholder Requirements Analysis

Stakeholder	Primary Role	Information Requirements	Current Challenges	Required META-DSS Functions
Government Agencies	Tourism policy formulation, destination regulation, environmental monitoring	Visitor statistics, tourism performance, environmental indicators, economic impact data	Fragmented data sources, delayed reporting, limited real-time monitoring	Integrated dashboard, sustainability monitoring, policy decision support

Stakeholder	Primary Role	Information Requirements	Current Challenges	Required META-DSS Functions
Tourism Managers	Destination operations and service management	Visitor behavior, service quality, promotional effectiveness, facility utilization	Limited analytics capability, manual reporting, lack of integrated information	Visitor analytics, performance monitoring, operational decision support
Local Communities	Tourism participation and resource management	Tourism opportunities, community participation data, environmental information	Limited access to tourism information and digital platforms	Community engagement monitoring, participation tracking, information sharing
MSMEs	Tourism-related product and service providers	Tourist preferences, market demand, promotional opportunities, sales trends	Low market visibility, limited digital marketing capability	Market intelligence, digital promotion support, tourism marketplace integration
Tourists	Tourism consumers and information users	Destination information, attractions, facilities, environmental conditions, travel recommendations	Incomplete information, fragmented communication channels	Personalized information services, destination recommendations, digital interaction platform
Environmental Organizations	Ecosystem conservation and sustainability monitoring	Mangrove conditions, conservation activities, environmental impact data	Limited access to integrated environmental information	Environmental monitoring dashboard, sustainability reporting tools
Academics and Researchers	Knowledge development and policy evaluation	Tourism statistics, environmental data, stakeholder information	Data accessibility constraints and fragmented information repositories	Research database, analytics platform, knowledge-sharing system
Tourism Associations / NGOs	Stakeholder coordination and tourism development support	Tourism performance indicators, collaboration opportunities, destination development information	Weak coordination mechanisms among stakeholders	Stakeholder collaboration platform, communication and networking support

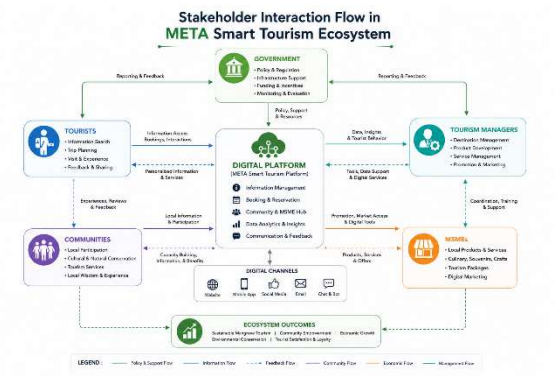

Figure 3. Stakeholder Interaction Flow

4.3 META-DSS System Architecture

Based on the needs of stakeholders and the results of ecosystem mapping, this study developed the META-DSS System Architecture as the main

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structure that supports the process of data collection, information analysis, and decision-making.

The META-DSS architecture consists of five main layers that are interconnected. The first layer is the Stakeholder Layer which includes all actors involved in the mangrove tourism ecosystem, namely the government, tourism managers, local communities, MSMEs, academics, environmental organizations, and tourists. This layer serves as a data source as well as a user of the information generated by the system.

The second layer is the Data Acquisition Layer. In this layer, data is collected from a variety of sources, including social media, tour reservation systems, tourist surveys, environmental management reports, local economic activity, and destination documentation. The integration of multiple data sources allows the system to obtain a more comprehensive picture of destination conditions.

The third layer is the Analytics Layer. The data that has been collected is processed using various analysis techniques to produce valuable information. The analysis carried out includes visitor analytics, digital engagement analytics, sustainability indicators analysis, stakeholder participation analysis, and destination performance analysis. This layer functions to transform raw data into insights that can be used in the decision-making process.

The fourth layer is the Decision Support Layer. At this stage, the results of the analysis are used to produce strategic recommendations for stakeholders. The system can provide recommendations related to digital promotion strategies, tourism facility development, environmental management, strengthening local MSMEs, and improving the quality of tourism services.

The last layer is the Sustainability Outcome Layer. This layer describes the expected results of the implementation of META-DSS, namely improving environmental sustainability, growing the local economy, improving the quality of the tourist experience, and strengthening the governance of tourist destinations.

The layered structure allows META-DSS to function not only as an information system, but also as a decision-making platform that supports the digital transformation of mangrove tourism destinations in a sustainable manner.

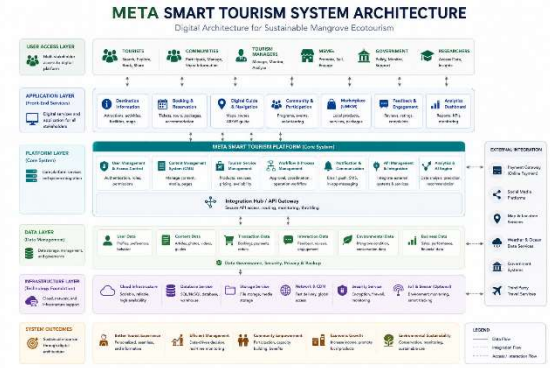

Figure 4. META-DSS System Architecture

4.4 Information Flow Design

The success of a Decision Support System is greatly influenced by the system's ability to manage the flow of information effectively. Therefore, this study designed an Information Flow Diagram to describe the process of data and information exchange between components in META-DSS.

The process starts by collecting data from stakeholders and various digital sources. Travelers generate data through information search activities, social media interactions, tour reservations, online reviews, and visit activities. Governments and tourism managers produce administrative data, management reports, and policy information. Meanwhile, local communities and MSMEs provide data related to economic activities and participation in tourism activities.

The collected data is then entered into the data integration system for validation, storage, and classification processes. After that, the data is processed on an analytics engine that is tasked with generating various destination performance indicators. The results of the analysis are then forwarded to the decision support module to produce recommendations that can be used by stakeholders.

The flow of information in META-DSS is two-way. In addition to receiving data from stakeholders, the system also provides feedback in the form of reports, dashboards, and strategic recommendations that can be used in the decision-making process. This mechanism creates a continuous learning cycle so that the system can continue to evolve according to the needs of users.

The structured information flow design allows META-DSS to support the principle of evidence-based decision making, which is decision-making based on valid data and information. This approach is expected to increase the effectiveness of mangrove tourism management compared to conventional methods that are still widely used today.

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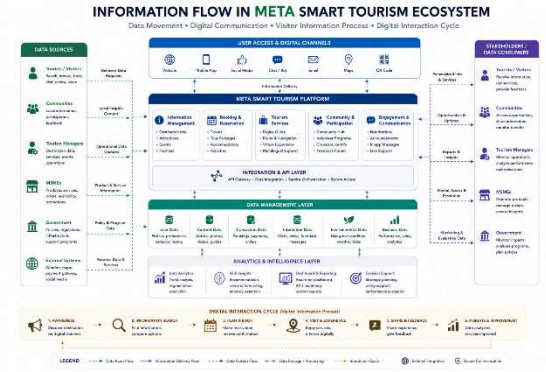

Figure 5. Information Flow Diagram

4.5 META-DSS Framework

As the result of the research, the META-DSS Framework was developed which integrates all components of the smart tourism ecosystem into one comprehensive conceptual model. This framework is designed to answer the needs of mangrove tourism management that requires integration between information technology, environmental sustainability, and stakeholder collaboration.

META-DSS consists of four main domains. The first domain is the Digital Tourism Domain which includes digital marketing, social media engagement, tourism information systems, and visitor interaction platforms. This domain aims to increase the visibility of destinations and strengthen tourist engagement.

The second domain is the Sustainability Domain which focuses on environmental monitoring, mangrove conservation, natural resource management, and evaluation of the impact of tourism on coastal ecosystems. This domain ensures that tourism activities continue to run according to the principles of sustainability.

The third domain is the Community Empowerment Domain which includes capacity building of local communities, empowering MSMEs, creating jobs, and strengthening community participation in destination management. This domain places the community as a major actor in sustainable tourism development.

The fourth domain is the Decision Intelligence Domain which is the core of META-DSS. This domain integrates data from all components of the system and turns it into strategic recommendations for stakeholders. Through this domain, decision-making can be done in a more objective, transparent, and data-driven manner.

The integration of the four domains results in a smart decision support system that is able to support the management of mangrove tourism more effectively and sustainably. Thus, META-DSS not only serves as a conceptual framework, but also as a foundation for the development of information systems and digital platforms in subsequent research.

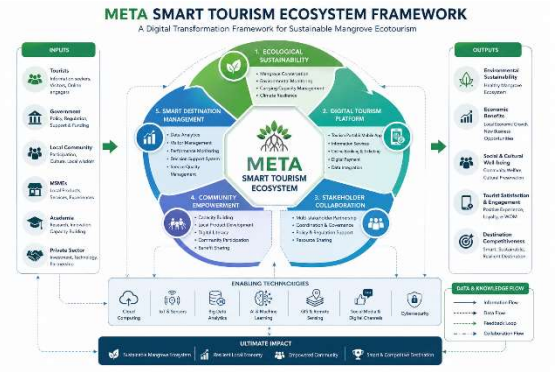

Figure 6. META-DSS Framework

Table 3. META-DSS Components Description

META-DSS Component	Main Function	Input Data	Processing Activities	Output	Primary Users
Stakeholder Layer	Connect all actors within the tourism ecosystem	Stakeholder profiles, tourism activities, community participation data, governance information	Stakeholder identification, role mapping, interaction management	Stakeholder collaboration network	Government, Tourism Managers, Communities, MSMEs
Data Acquisition Layer	Collect and integrate data from multiple sources	Visitor data, environmental data, tourism transaction data, social media data, destination reports	Data collection, validation, classification, integration	Centralized tourism database	System Administrator, Decision Makers
Tourism Informatio	Manage tourism-related informa	Tourism services,	Information storage,	Tourism information	Tourists, Tourism

META-DSS Component	Main Function	Input Data	Processing Activities	Output	Primary Users
n Management Module	tion and destination knowledge	attractions, facilities, event information	retrieval, updating, dissemination	repository	Managers
Visitor Analytics Module	Analyze tourist behavior and visitation patterns	Visitor demographics, travel preferences, engagement metrics, visitation records	Behavioral analysis, segmentation, trend analysis	Visitor insights and tourism intelligence	Tourism Managers, Government
Digital Engagement Analytics Module	Evaluate digital marketing and online engagement performance	Social media interactions, website traffic, online reviews, content engagement data	Engagement analysis, performance measurement, sentiment analysis	Digital marketing performance reports	Tourism Managers, MSMEs
Environmental Monitoring Module	Monitor sustainability indicators and ecosystem conditions	Mangrove condition data, biodiversity records, environmental assessments	Sustainability analysis, environmental performance evaluation	Environmental sustainability reports	Government, Environmental Organizations
Community Empowerment Module	Monitor community participation and local economic contribution	Community activities, MSME performance, emplo	Participation analysis, economic impact assessment	Community development indicators	Communities, Government

META-DSS Component	Main Function	Input Data	Processing Activities	Output	Primary Users
		yment data			
Analytics Layer	Transform raw data into actionable information	Integrated tourism database	Data mining, aggregation, pattern recognition, indicator calculation	Strategic insights	All Stakeholders
Decision Support Layer	Generate recommendations for destination management	Analytics outputs, sustainability indicators, stakeholder requirements	Scenario evaluation, recommendation generation, priority assessment	Decision recommendations	Government, Tourism Managers
Knowledge Management Module	Store and disseminate organizational knowledge and best practices	Research findings, tourism reports, policy documents	Knowledge codification, indexing, sharing	Knowledge repository	Academics, Practitioners
Sustainability Outcome Layer	Measure long-term tourism sustainability performance	Decisions, policies, management interventions	Impact evaluation and performance monitoring	Sustainability outcomes and performance indicators	All Stakeholders

4.6 Decision Intelligence Engine

The Decision Intelligence Engine (DIE) constitutes the core analytical component of the META-DSS framework, transforming integrated tourism data into actionable recommendations that support sustainable mangrove ecotourism management. While the previous sections describe the system architecture, stakeholder interactions, and information flow, the Decision Intelligence Engine explains how the system processes heterogeneous information and generates evidence-based recommendations for various stakeholders. This

component distinguishes META-DSS from conventional tourism information systems by embedding analytical intelligence into the decision-making process rather than merely providing descriptive information.

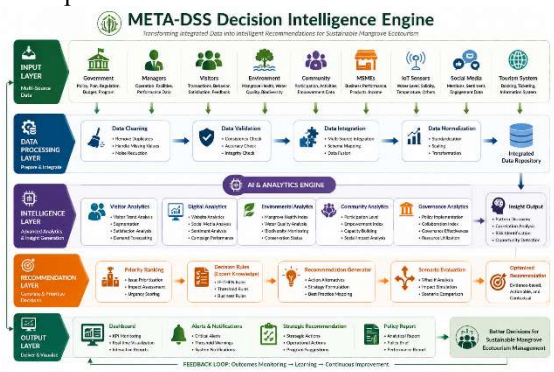

Figure 7. META-DSS Decision Intelligence Engine

Figure 7. The Decision Intelligence Engine operates through a multi-stage analytical workflow designed to accommodate the complexity of mangrove ecotourism management. The workflow begins with the acquisition of data from multiple internal and external sources, including visitor transaction records, social media interactions, environmental monitoring reports, tourism facility assessments, community participation records, MSME performance indicators, and government policy documents. Because these data originate from different platforms and possess varying formats, the first responsibility of the engine is to establish a unified data environment that enables consistent analysis across all sustainability dimensions.

After data acquisition, the engine performs a preprocessing stage consisting of data validation, cleaning, normalization, and integration. Incomplete records, duplicated information, and inconsistent data structures are identified and corrected before further analysis. This preprocessing stage is essential to ensure that recommendations generated by the system are based on reliable and high-quality information. The integration process also enables the combination of quantitative indicators, such as visitor statistics and environmental measurements, with qualitative information obtained from stakeholder interviews, online reviews, and community feedback. Consequently, the system develops a comprehensive representation of the current condition of the mangrove tourism ecosystem.

The processed data are subsequently transferred to the analytical module, where multiple analytical mechanisms operate simultaneously to evaluate destination performance from different perspectives. Visitor analytics examines tourist demographics, travel patterns, seasonal demand, satisfaction levels, and destination preferences. Digital engagement analytics evaluates the effectiveness of online marketing campaigns through indicators such as website traffic, social media engagement, content interaction, and online sentiment. Environmental analytics continuously monitors ecosystem conditions by assessing mangrove health, biodiversity indicators, waste management performance, and conservation activities. Community analytics evaluates local participation, MSME development, employment generation, and community empowerment outcomes. By integrating these complementary analyses, the engine produces a multidimensional assessment that reflects the overall sustainability performance of the destination.

Unlike traditional Decision Support Systems that primarily generate static reports, the Decision Intelligence Engine incorporates a recommendation generation mechanism that converts analytical findings into strategic decision alternatives. The recommendation engine applies predefined decision rules based on sustainability principles, stakeholder requirements, and tourism management objectives. Instead of presenting raw analytical outputs, the system prioritizes actionable recommendations according to the urgency of identified issues and the potential impact of alternative interventions. For example, declining visitor engagement may trigger recommendations related to digital marketing enhancement, while deteriorating environmental indicators may prioritize conservation initiatives and visitor capacity management. Similarly, weak MSME performance may generate recommendations for capacity-building programs and digital marketplace integration.

An important characteristic of the Decision Intelligence Engine is its capability to support multi-stakeholder decision-making. Different stakeholders require different forms of information to accomplish their responsibilities. Local governments require strategic indicators for policy formulation and tourism planning, destination managers need operational intelligence for daily management activities, community organizations require information related to participation and local economic opportunities, while researchers and environmental organizations need sustainability indicators for monitoring and evaluation. Therefore, the engine delivers customized recommendations through stakeholder-specific dashboards, ensuring that each decision-maker receives relevant information without unnecessary complexity.

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The Decision Intelligence Engine also establishes a continuous feedback mechanism that enables adaptive system learning. Every managerial decision implemented by stakeholders generates new operational data, which are subsequently reintroduced into the analytical process. This continuous feedback loop allows META-DSS to evaluate the effectiveness of previous recommendations, monitor changing tourism conditions, and improve future decision quality. Consequently, the system evolves from a static information repository into a dynamic decision-support environment capable of responding to environmental changes, visitor behavior, and emerging stakeholder needs.

Overall, the Decision Intelligence Engine represents the intelligence layer that integrates data management, analytical processing, sustainability assessment, and strategic recommendation generation within the META-DSS framework. Through this mechanism, META-DSS not only facilitates information integration but also enables evidence-based, collaborative, and adaptive decision-making for sustainable mangrove ecotourism management. The introduction of this intelligent analytical component significantly strengthens the technological contribution of the proposed framework and provides a practical foundation for future implementation of smart tourism decision support systems in coastal conservation destinations.

4.7 Decision Recommendation Algorithm

The Decision Recommendation Algorithm is the operational mechanism that transforms analytical outputs generated by the Decision Intelligence Engine into structured decision recommendations for sustainable mangrove ecotourism management. Unlike conventional tourism information systems that merely present descriptive reports, META-DSS incorporates an algorithmic decision process that systematically evaluates multiple sustainability indicators and prioritizes strategic alternatives based on stakeholder needs. This algorithm serves as the computational bridge between data analytics and managerial decision-making within the META-DSS architecture.

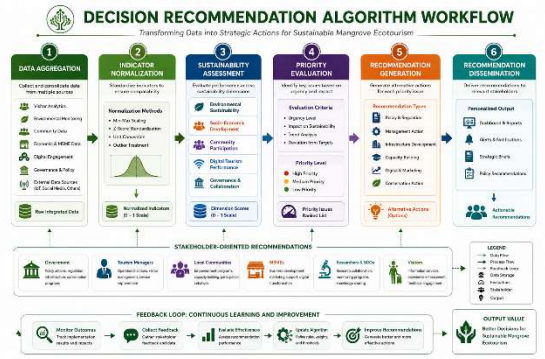

Figure 8. Decision Recomendation Algorithm Workflow

Figure 8. shows that the algorithm operates through a sequential decision-making workflow consisting of six major stages: data aggregation, indicator normalization, sustainability assessment, priority evaluation, recommendation generation, and recommendation dissemination. These stages ensure that diverse information collected from multiple stakeholders is processed consistently before actionable recommendations are delivered to decision-makers.

The first stage is **data aggregation**, where information from various system modules is consolidated into a unified analytical repository. The algorithm receives inputs from visitor analytics, digital engagement analytics, environmental monitoring, community empowerment indicators, tourism information management, and stakeholder databases. Because the collected data vary in scale and format, aggregation ensures that all variables are prepared for subsequent analytical processing.

The second stage involves **indicator normalization**. Since tourism performance indicators possess different measurement units, raw values are standardized to facilitate meaningful comparison across dimensions. This process minimizes inconsistencies caused by heterogeneous data sources and enables balanced evaluation of economic, environmental, social, and digital performance indicators. The normalized dataset represents a comprehensive description of destination conditions from multiple sustainability perspectives.

The third stage performs **sustainability assessment**, where the normalized indicators are evaluated according to predefined sustainability criteria embedded within the META-DSS framework. Instead of emphasizing only visitor growth or tourism revenue, the algorithm simultaneously considers environmental conservation, stakeholder participation, community empowerment, digital engagement, and governance effectiveness. This

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multidimensional assessment ensures that recommendations reflect the fundamental principles of sustainable ecotourism management.

Following sustainability assessment, the algorithm conducts **priority evaluation** by identifying the most critical issues requiring managerial intervention. Decision rules embedded in the system compare current indicator values with expected sustainability objectives and classify them according to their urgency and potential impact. For example, declining environmental indicators may receive higher priority than promotional activities because ecosystem degradation directly threatens the long-term viability of mangrove ecotourism. Similarly, low community participation may trigger recommendations aimed at strengthening local empowerment programs before expanding tourism infrastructure.

The fifth stage is **recommendation generation**, where the algorithm formulates alternative managerial actions based on the identified priorities. Each recommendation is linked to the stakeholder responsible for implementation. Governments may receive policy recommendations related to environmental protection or infrastructure investment, tourism managers may obtain operational recommendations concerning visitor management and service improvement, while MSMEs and local communities receive recommendations focused on business development, digital marketing, and capacity-building initiatives. This stakeholder-oriented recommendation mechanism ensures that generated outputs are practical, relevant, and directly applicable.

Finally, the recommendation dissemination stage delivers personalized decision outputs through the META-DSS dashboard. Recommendations are presented in the form of performance summaries, sustainability alerts, strategic priorities, and suggested interventions, enabling stakeholders to make timely and evidence-based decisions. Furthermore, every implemented recommendation is continuously monitored through the system's feedback mechanism, allowing META-DSS to evaluate decision outcomes and refine future recommendations based on newly acquired data.

The proposed Decision Recommendation Algorithm demonstrates that META-DSS is not merely an information management platform but an intelligent decision-support framework capable of systematically transforming integrated tourism data into strategic actions. By combining multidimensional sustainability assessment, stakeholder-oriented decision rules, and adaptive recommendation mechanisms, the algorithm enhances transparency, consistency, and accountability in mangrove ecotourism management while providing a practical computational foundation for future smart tourism decision support systems.

4.8 Computational Decision Model

To operationalize the Decision Recommendation Algorithm, the META-DSS framework introduces a Computational Decision Model that quantitatively evaluates the sustainability performance of mangrove ecotourism destinations. The objective of this model is not to replace managerial judgment but to provide a structured analytical mechanism capable of transforming multidimensional tourism indicators into measurable decision scores. By integrating environmental, economic, social, governance, and digital transformation dimensions, the model supports transparent, evidence-based, and consistent decision-making across multiple stakeholder groups.

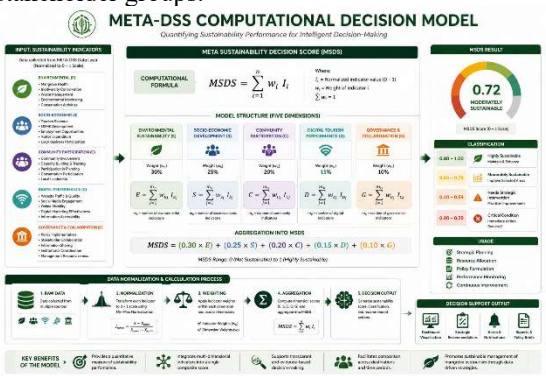

Figure 9. META-DSS Computational Decision Model

The computational model in **Figure 9** is founded on the principle that sustainable mangrove ecotourism cannot be evaluated using a single performance indicator. Instead, destination performance should be assessed through a composite sustainability index that reflects the interdependence between ecological conservation, community welfare, tourism competitiveness, institutional governance, and digital innovation. Accordingly, META-DSS proposes the **META Sustainability Decision Score (MSDS)** as the primary decision metric.

The overall sustainability score is calculated using a weighted aggregation model:

$$MSDS = \sum_{i=1}^{n} w_i I_i$$

where:

- **MSDS** = META Sustainability Decision Score;

- **(I_i)** = normalized value of indicator *i*;
- **(w_i)** = weighting coefficient assigned to indicator *i*;
- **(Sum w_i =1)**.

Each indicator is normalized to a value between 0 and 1, enabling the integration of heterogeneous variables originating from different data sources. The weighting coefficients represent the relative contribution of each sustainability dimension to the overall destination performance. Rather than assigning equal importance to all indicators, the weighting mechanism reflects the strategic priorities of sustainable mangrove ecotourism management.

The proposed computational model consists of five principal sustainability dimensions:

$$MDSS = w_{EE} + w_{SS} + w_{CC} + w_{DD} + w_{GG}$$

where:

- **E** = Environmental Sustainability Index;
- **S** = Socio-Economic Development Index;
- **C** = Community Participation Index;
- **D** = Digital Tourism Performance Index;
- **G** = Governance and Collaboration Index.

Each dimension is derived from several measurable indicators collected through the META-DSS data acquisition layer.

Table 4. Sustainability Indicators and Weighting Scheme of the META Sustainability Decision Score (MSDS)

Dimension	Indicator	Weight	Data Source
Environmental Sustainability	Mangrove health, biodiversity, waste management	30%	Environmental Monitoring
Socio-Economic Development	Tourism revenue, MSMEs, employment	25%	Tourism & Economic Database
Community Participation	Community engagement, training, conservation	20%	Community Records
Digital Tourism Performance	Website traffic, social media engagement	15%	Digital Analytics
Governance & Collaboration	Policy implementation, stakeholder collaboration	10%	Government & Stakeholder Reports

The **Environmental Sustainability Index (E)** evaluates ecosystem resilience through indicators such as mangrove health, biodiversity conservation, waste management performance, environmental monitoring results, and conservation activities. Since environmental sustainability represents the primary objective of mangrove ecotourism, this dimension receives the largest weighting within the decision model.

The **Socio-Economic Development Index (S)** measures tourism's contribution to local economic growth through visitor expenditure, MSME development, employment generation, tourism revenue, and local business participation. These indicators demonstrate whether tourism activities generate inclusive economic benefits for surrounding communities.

The **Community Participation Index (C)** reflects the level of stakeholder engagement in tourism governance. Indicators include community involvement in tourism planning, participation in conservation programs, training activities, collaborative initiatives, and local leadership. Higher participation levels indicate stronger community ownership and greater sustainability potential.

The **Digital Tourism Performance Index (D)** evaluates the effectiveness of digital transformation by measuring online visibility, website utilization, social media engagement, digital marketing performance, online visitor interactions, and information accessibility. These indicators demonstrate the destination's ability to leverage digital technologies for tourism competitiveness.

The **Governance and Collaboration Index (G)** measures institutional effectiveness through stakeholder coordination, policy implementation, inter-organizational collaboration, information sharing, and management responsiveness. Strong governance improves coordination among tourism managers, government agencies, community organizations, academics, and private-sector partners.

To reflect the sustainability priorities embedded in the META-DSS framework, the initial weighting scheme is proposed as follows: Environmental Sustainability (30%), Socio-Economic Development (25%), Community Participation (20%), Digital Tourism Performance (15%), and Governance and Collaboration (10%). These weights may be refined in future empirical studies using expert judgment or multi-criteria decision-making techniques.

Based on the calculated META Sustainability Decision Score, destinations are classified into four decision categories. Scores above **0.80** indicate *Highly Sustainable*, suggesting that current

management practices should be maintained and continuously improved. Scores between **0.60 and 0.79** represent *Moderately Sustainable*, requiring incremental improvements in selected dimensions. Scores ranging from **0.40 to 0.59** indicate *Needs Strategic Intervention*, where corrective actions should be prioritized. Finally, scores below **0.40** are classified as *Critical Condition*, requiring immediate policy intervention and intensive ecosystem restoration.

The proposed Computational Decision Model provides a quantitative foundation for the META-DSS framework while remaining sufficiently flexible to accommodate different destination characteristics. More importantly, the META Sustainability Decision Score transforms fragmented tourism information into an integrated sustainability metric that supports transparent, consistent, and evidence-based managerial decisions. This model therefore strengthens the computational capability of META-DSS and establishes a practical basis for future implementation of intelligent decision support systems in sustainable mangrove ecotourism management.

4.9 Prototype Dashboard

To demonstrate the practical implementation of the proposed framework, this study presents a prototype dashboard that serves as the primary user interface of the META-DSS. The dashboard is designed to transform complex analytical outputs into an intuitive visual environment that supports evidence-based decision-making for sustainable mangrove ecotourism management. Rather than functioning solely as a reporting interface, the prototype integrates data visualization, sustainability monitoring, spatial analysis, and strategic recommendations within a unified decision support platform. This design enables stakeholders to access comprehensive destination information through a single interface, thereby improving the efficiency and transparency of tourism governance.

Figure 10. Prototype Dashboard

The dashboard at **Figure 10** adopts a web-based architecture with a responsive interface that can be accessed from desktop and mobile devices. A role-based access mechanism is incorporated to accommodate the different information requirements of stakeholders, including government agencies, tourism managers, local communities, MSMEs, environmental organizations, and researchers. Although all users interact with the same system, the dashboard dynamically presents information that is relevant to each stakeholder's responsibilities and decision-making authority.

The upper section of the dashboard provides an overview of the destination's sustainability performance through the **META Sustainability Decision Score (MSDS)** and five key sustainability dimensions: Environmental Sustainability, Socio-Economic Development, Community Participation, Digital Tourism Performance, and Governance and Collaboration. These indicators are presented using gauges, scorecards, and visual performance metrics, allowing decision-makers to quickly assess the overall condition of the destination without reviewing extensive statistical reports. The dashboard therefore functions as an executive summary that supports rapid strategic assessment.

The central section focuses on operational monitoring through interactive analytical panels. These panels display visitor trends, mangrove ecosystem health, community participation levels, digital engagement performance, and tourism activity statistics using line charts, bar charts, and key performance indicators. In addition, an integrated Geographic Information System (GIS) module visualizes the spatial distribution of tourism facilities, visitor density, conservation zones, and environmental conditions. This geospatial capability enables managers to identify high-risk areas, monitor environmental changes, and allocate tourism resources more effectively.

Another important component of the dashboard is the Recommendation Panel, which presents prioritized managerial actions generated by the Decision Recommendation Algorithm. Recommendations are categorized according to issue type, implementation priority, responsible stakeholder, urgency level, and expected impact. By converting analytical findings into actionable guidance, the dashboard supports strategic planning while reducing the complexity of interpreting multidimensional tourism data. Complementing this function, the Alerts and Notifications panel provides real-time warnings regarding critical sustainability issues such as declining mangrove health, excessive

visitor concentration, negative online sentiment, or reduced community participation, enabling stakeholders to respond promptly before these conditions adversely affect destination sustainability.

Finally, the dashboard includes a knowledge management module that provides access to tourism statistics, environmental reports, policy documents, research publications, and best-practice guidelines. This feature strengthens organizational learning by integrating operational information with strategic knowledge resources. Overall, the prototype dashboard demonstrates how the META-DSS framework can be translated into an intelligent decision-support interface that combines sustainability assessment, data analytics, spatial visualization, and recommendation services into a comprehensive smart tourism management platform. Consequently, the prototype not only illustrates the feasibility of the proposed framework but also provides a practical foundation for the future development of fully operational decision support systems for sustainable mangrove ecotourism.

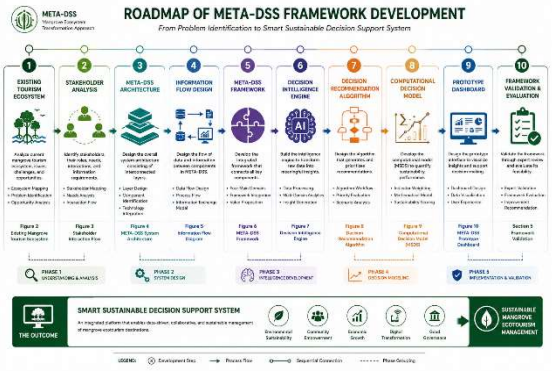

Figure 11. Road Map of META-DSS Framework Development

Figure 11 illustrates the overall roadmap of the META-DSS framework development, presenting the systematic progression from problem identification to the establishment of an intelligent decision support system for sustainable mangrove ecotourism management. The development process consists of five sequential phases. The first phase focuses on understanding the existing tourism ecosystem through ecosystem analysis and stakeholder identification, providing a comprehensive understanding of current challenges, opportunities, and information requirements. The second phase emphasizes system design by developing the META-DSS architecture, information flow, and integrated framework that collectively define the structural foundation of the proposed system. The third phase introduces the intelligence layer, where the Decision Intelligence Engine transforms integrated tourism data into meaningful insights through analytical processing and decision support mechanisms. Subsequently, the fourth phase operationalizes these analytical results through the Decision Recommendation Algorithm and the Computational Decision Model, enabling the calculation of the META Sustainability Decision Score (MSDS) and the generation of evidence-based strategic recommendations. Finally, the fifth phase demonstrates the practical implementation of the framework through a prototype dashboard and expert-based validation, confirming its feasibility and applicability. Collectively, this roadmap illustrates that META-DSS is developed through a structured and iterative process that integrates system architecture, analytical intelligence, computational modeling, and user-centered decision support into a comprehensive smart tourism framework for sustainable mangrove ecotourism management.

5. FRAMEWORK VALIDATION AND DISCUSSION

5.1 Framework Validation Results

After the META-DSS framework development process is completed, the next stage is conceptual validation to evaluate the feasibility, relevance, and potential implementation of the framework in the context of sustainable mangrove ecotourism management. Validation is carried out through expert reviews involving academics in the field of information systems, sustainable tourism experts, mangrove tourism management practitioners, and local government representatives who have experience in developing community-based tourist destinations.

The validation process is focused on five main aspects, namely the completeness of the framework components, the clarity of the system architecture, the relevance to stakeholder needs, support for decision-making, and the potential for implementation in mangrove tourism destinations. The results of the evaluation show that META-DSS has a high level of relevance in supporting the decision-making process because it can integrate various previously fragmented data sources into a single structured system framework.

Experts consider that the existence of the stakeholder layer and the sustainability outcome layer are the main advantages of the framework because it allows the system not only to function as a tourism manager, but also as an instrument for monitoring the sustainability of destinations. In addition, the integration of the analytics layer and decision support layer can improve the quality of decision-

making using more systematic and evidence-based data.

The validation results also show that the framework has a high enough level of flexibility so that it can be adapted to various conservation-based tourist destinations with different characteristics. However, some evaluators have suggested the need to develop more specific analytics modules, such as predictive analytics and sustainability forecasting, to improve the system's ability to support long-term decisions.

Overall, the validation results show that META-DSS meets the criteria as a conceptual framework that is suitable for use as a basis for the development of a decision support system for sustainable mangrove ecotourism management.

Table 5. Framework Validation Results

Validation Criteria	Expert 1	Expert 2	Expert 3	Mean Score	Interpretation
Framework Completeness	5	4	5	4.67	Excellent
Clarity of System Architecture	5	4	4	4.33	Excellent
Relevance to Sustainable Tourism Management	4	5	5	4.67	Excellent
Stakeholder Integration Capability	5	5	4	4.67	Excellent
Information Flow Clarity	5	4	4	4.33	Excellent
Decision Support Functionality	5	4	5	4.67	Excellent
Sustainability Monitoring Capability	4	5	5	4.67	Excellent
Practical Applicability	4	4	5	4.33	Excellent
Scalability for Future Development	5	4	4	4.33	Excellent
Potential for Digital Transformation Support	5	5	5	5.00	Excellent
Overall Average	**4.70**	**4.40**	**4.60**	**4.57**	**Excellent**

5.2 Framework Evaluation

Following the expert validation process, a comprehensive framework evaluation was conducted to assess the overall quality, applicability, and technological robustness of the proposed META-DSS framework. While expert validation confirms the conceptual appropriateness of the framework, framework evaluation focuses on determining whether the proposed architecture adequately satisfies the fundamental characteristics of an intelligent Decision Support System for sustainable mangrove ecotourism management. The evaluation therefore emphasizes system-oriented attributes rather than solely assessing conceptual completeness.

Table 6. Framework Evaluation Criteria of META-DSS

Evaluation Criteria	Description	Assessment
Framework Completeness	Integration of all DSS components	Excellent
Architectural Consistency	Logical interaction among system layers	Excellent
Stakeholder Integration	Support for multi-stakeholder collaboration	Excellent
Decision Intelligence	Ability to generate strategic recommendations	Excellent
Scalability	Capability for future system expansion	Very Good
Practical Applicability	Potential implementation in real destinations	Excellent
Sustainability Support	Integration of environmental, social, economic, digital, and governance dimensions	Excellent

The evaluation was performed using seven assessment criteria derived from the literature on Decision Support Systems, Smart Tourism Ecosystems, and Information Systems Framework Development. These criteria include framework completeness, architectural consistency, stakeholder

integration capability, usability, scalability, decision intelligence capability, and sustainability support. Collectively, these dimensions represent the essential characteristics expected from an integrated smart tourism decision-support framework.

The first criterion, **framework completeness**, evaluates whether the proposed architecture contains all essential components required to support sustainable destination management. The evaluation indicates that META-DSS successfully integrates stakeholder management, data acquisition, information processing, analytics, decision support, and sustainability outcome monitoring within a unified architecture. Unlike many existing tourism information systems that primarily emphasize visitor services, META-DSS provides a comprehensive managerial perspective capable of supporting strategic planning and governance.

The second criterion concerns **architectural consistency**, which assesses the logical relationships among system components and the continuity of information flow. The evaluation demonstrates that the layered architecture enables systematic transformation of raw tourism data into strategic recommendations through clearly defined analytical processes. Each layer performs a distinct function while maintaining seamless interaction with adjacent components, thereby ensuring structural coherence throughout the framework.

The third evaluation criterion focuses on **stakeholder integration capability**. Sustainable mangrove ecotourism requires effective collaboration among governments, tourism managers, local communities, MSMEs, environmental organizations, researchers, and tourists. The evaluation confirms that META-DSS accommodates the diverse information requirements of these stakeholder groups through role-based information access and customized decision support services. This capability represents one of the principal advantages of the proposed framework over conventional tourism information systems.

The framework was further evaluated in terms of **decision intelligence capability**, which measures the ability of the system to transform analytical findings into actionable managerial recommendations. The integration of the Decision Intelligence Engine, Decision Recommendation Algorithm, and Computational Decision Model enables META-DSS to move beyond descriptive reporting by supporting evidence-based, transparent, and adaptive decision-making. This intelligent recommendation mechanism significantly enhances the technological contribution of the framework.

The evaluation also considered **scalability and practical applicability**. Because the proposed architecture adopts a modular design, additional analytical modules, artificial intelligence techniques, Internet of Things (IoT) sensors, Geographic Information Systems (GIS), and predictive analytics can be incorporated without fundamental architectural modifications. This flexibility increases the potential applicability of META-DSS across different mangrove ecotourism destinations as well as other conservation-based tourism environments.

Finally, the evaluation confirms that META-DSS effectively supports the principles of sustainable tourism by simultaneously integrating environmental conservation, socio-economic development, community empowerment, digital transformation, and collaborative governance into a single decision-support environment. This multidimensional integration distinguishes the framework from previous tourism management models that generally address these dimensions separately. Overall, the evaluation demonstrates that META-DSS satisfies the essential characteristics of an intelligent smart tourism decision-support framework while providing a scalable and practically relevant foundation for future implementation and empirical validation in sustainable mangrove ecotourism management.

5.3 Discussion

The results of the study show that mangrove ecotourism management requires a more integrated approach than conventional tourism management models. In the context of digital transformation, the success of destination management is no longer only determined by the quality of tourism services, but also by the organization's ability to manage data and turn that data into information that supports decision-making processes. These findings are in line with the concept of smart tourism ecosystem which emphasizes the importance of integrating technology, data, and stakeholders in the development of modern tourist destinations [2].

From the perspective of the Decision Support System, META-DSS expands the function of the tourism information system from just an information provider to a platform capable of generating strategic recommendations. This is in accordance with the view [3] which states that DSS must be able to support the process of analysis and evaluation of alternative decisions through the integration of data and analytical models. In the developed framework, the analytics layer and decision support layer are the main components that enable the process of

transforming data into knowledge that can be used by stakeholders.

This research also shows that environmental sustainability needs to be an integral part of the decision-making system in conservation-based tourist destinations. Unlike most smart tourism models that focus on improving the tourist experience, META-DSS includes sustainability indicators as one of the main components in the framework. These findings support the view [16] that sustainability must be a core element in every tourist destination development process.

From the perspective of stakeholder theory, the results of the study confirm that the success of mangrove tourism management is greatly influenced by the quality of collaboration between stakeholders. The government, tourism managers, local communities, MSME actors, academics, and tourists have different but interrelated information needs. Therefore, a system that can integrate the information needs of all stakeholders will have a greater chance of producing effective and sustainable decisions. These findings are in line with research [15] which emphasizes the importance of collaborative networks in the governance of tourist destinations.

The main contribution of this research lies in the development of META-DSS as a framework that connects smart tourism ecosystems, tourism information systems, sustainability management, and decision support intelligence in one conceptual model. This integration has not been found in many previous studies, especially in the context of mangrove ecotourism management. Thus, this research makes a theoretical contribution to the development of smart tourism and DSS literature while offering practical implications for the development of sustainable tourism information systems.

In terms of implementation, META-DSS can be the foundation for the development of digital platforms that support destination monitoring, tourist behavior analysis, environmental management, and local community empowerment in an integrated manner. This framework also opens opportunities for the development of advanced technologies such as artificial intelligence, predictive analytics, Internet of Things (IoT), and big data analytics to support data-driven tourism management in the future.

6. CONCLUSION

6.1 Conclusion

This research has succeeded in developing META-DSS (Mangrove Ecosystem Transformation Approach–Decision Support System) as a decision support system framework designed to support sustainable mangrove ecotourism management. This framework was developed in response to various challenges faced in mangrove tourism management, including information fragmentation, limited integration between stakeholders, low data utilization in the decision-making process, and the need for a system that can integrate economic, social, and environmental aspects simultaneously.

The results of the study show that mangrove ecotourism management requires a smart tourism ecosystem-based approach that can connect various actors, data sources, and development goals in one integrated system. Through stakeholder needs analysis, ecosystem mapping, system architecture design, and information flow development, this research produces the META-DSS framework consisting of a stakeholder layer, data acquisition layer, analytics layer, decision support layer, and sustainability outcome layer. The structure enables the process of transforming data into information and recommendations that can be used to support more effective, transparent, and evidence-based decision-making.

In addition, the validation results show that the proposed framework has a high level of relevance to the management needs of mangrove tourist destinations. The integration between tourism information systems, sustainability indicators, stakeholder collaboration, and decision intelligence makes META-DSS have different characteristics compared to the smart tourism framework and tourism information systems that have been developed previously. Thus, this research makes a new contribution to the development of the concept of smart tourism decision support systems that are oriented towards the sustainability of conservation-based tourist destinations.

6.2 Practical Implications

From a practical perspective, META-DSS can be used as a conceptual foundation for local governments, tourism managers, local communities, and MSME actors in building a more integrated and data-based tourism management system. This framework can also be a reference in the development of destination management dashboards, sustainability monitoring systems, tourism analytics platforms, and tourism information systems that support digital transformation in mangrove ecotourism areas.

6.3 Limitations

This research still has some limitations. First, the framework developed is still in the conceptual stage

and has not been implemented in the form of a software system that can be tested operationally. Second, the research uses a qualitative approach so that the results obtained are greatly influenced by the context of the research location and the characteristics of the stakeholders involved. Third, framework validation is still limited to expert assessments and does not involve empirical testing using real-time operational data.

6.4 Future Research Directions

Further research is suggested to develop META-DSS into a prototype system that can be implemented in mangrove tourism destinations in real terms. In addition, the integration of technologies such as Artificial Intelligence (AI), Internet of Things (IoT), Big Data Analytics, Geographic Information Systems (GIS), and predictive analytics can be carried out to improve the system's ability to produce more accurate and adaptive recommendations. Future research can also test the effectiveness of the framework through quantitative approaches and Design Science Research to obtain empirical evidence on the impact of META-DSS implementation on the performance of tourist destinations and the sustainability of mangrove ecosystems.

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