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Interpretive Structural Modeling-Based Decision Support System for Marine Tourism Strategy

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Abstract

Marine tourism in Madura has great potential for economic growth, but its unsustainable management threatens the ecosystem and community welfare. A development strategy is needed that balances economic, social, and environmental aspects. The main challenge is the complexity of sustainable marine tourism development, where various factors are interrelated and require a holistic approach. Previous studies have identified factors that influence marine tourism, but have been lacking in integrating them into a comprehensive decision-making framework. This study aims to fill this gap by developing a Decision Support System (DSS) to help stakeholders formulate sustainable marine tourism development strategies. The main objective of this study is to develop a DSS based on Interpretive Structural Modeling (ISM) to map the relationships between key variables and provide strategy recommendations. The ISM approach is used to identify, analyze, and interpret the relationships between key variables. Data were collected through expert interviews, surveys, and literature studies. The study produced a hierarchical model that describes the influence and relationships between variables, as well as a DSS that is able to provide development strategy recommendations based on priorities and objectives. This study contributes to providing a structured and evidence-based decision-making tool for sustainable marine tourism development in Madura. The originality of this study lies in the integration of ISM into DSS for sustainable marine tourism, offering a new perspective in strategic decision-making.

Keywords: *Sustainable Marine Tourism, Decision Support System, Interpretive Structural Modeling, Development Strategy.*

1. Introduction

Marine tourism in Indonesia, including Madura Island, has great potential to drive regional economic growth [1]. However, uncontrolled tourism development can have negative impacts on the environment and local communities [2]. To optimize this potential sustainably, a strategy is needed that balances economic growth, environmental conservation, and community welfare [3][4]. The role of government, private sector, local communities, media, and academics is very important in sustainable tourism development [5]. Digitalization and utilization of new media can help market tourism potential and build a positive image. Tourism development must also pay attention to local wisdom and involve local communities to ensure fair economic benefits.

Sustainable marine tourism development in Madura faces complex challenges that require a holistic approach. Key factors include environmental quality, community participation, investment, government policy, and technology [5]. Empowerment of local communities and development of institutions such as tourism awareness groups are important for sustainability [6][7]. Sustainable tourism policies must consider economic, socio-cultural, and environmental aspects [8][9]. Community participation is influenced by government support, superior tourist attractions, infrastructure, and training [10][11]. Development of small-scale ecotourism with local management is recommended for sustainability [12]. Sustainability strategies include pollution prevention, waste reduction, and local community involvement [3][13]. Factors in developing marine tourism include tourist attractions, infrastructure, community participation, and marketing.

Recent studies have explored various factors influencing sustainable marine tourism development using both qualitative and quantitative methods. Qualitative approaches, such as interviews and case studies, have been employed to understand local community perceptions and experiences [14]. Quantitative methods, including regression and path analysis, have been used to examine relationships between factors and their impact on tourism [15]. Several studies have developed models and frameworks to evaluate tourism sustainability[16].

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Community empowerment and participation have been identified as crucial elements in sustainable tourism development [17][18]. Research has also highlighted the positive economic impact of tourism development on local communities [19]. However, most of these models remain general and not specific to the Madura context.
Recent studies highlight the importance of developing comprehensive decision support systems (DSS) for sustainable marine tourism and fisheries management, particularly in small island regions of Indonesia. Web-based intelligent DSS have been proposed to integrate socio-economic, marine, and empirical data for better planning and development of marine sectors [20][21]. These systems aim to optimize profitability while preserving marine resources [21]. Research gaps exist in integrating various factors affecting tourism into decision-making frameworks specific to contexts like Madura[22]. Studies emphasize the need for community involvement in coastal tourism development[23][24] and the potential of ecotourism for conservation efforts [25]. Assessments of marine ecosystems, such as seagrass beds and coral reefs, have been conducted to evaluate their suitability for ecotourism activities [26][27], providing valuable insights for sustainable marine tourism development.
This study aims to develop a DSS that uses the Interpretive Structural Modeling (ISM) approach to map the relationship between key variables and provide recommendations for sustainable marine tourism development strategies in Madura. This DSS is expected to help stakeholders, such as local governments, tourism industry players, and local communities, in making better and more strategic decisions to achieve tourism development goals that are balanced between economic, social, and environmental aspects. This study used the ISM approach to identify, analyze, and interpret the relationship between key variables in the development of sustainable marine tourism in Madura. Data will be collected through interviews with experts, surveys to tourists and local communities, and literature studies.
This research is expected to provide significant contribution to the development of sustainable marine tourism in Madura by providing a structured and evidence-based decision-making tool. The developed DSS will assist stakeholders in formulating effective policies and strategies to achieve sustainable tourism development goals. The originality of this study lies in the integration of the ISM approach into the DSS for the development of sustainable marine tourism in Madura. This approach has not been widely applied in this context, thus offering a new perspective in strategic decision making. By utilizing the ISM-based DSS, it is hoped that Madura can develop sustainable marine tourism, provide economic benefits to local communities, while preserving the environment and culture for future generationsquestion.

2. Methods

Describe The stages and methods of this research are as follows:

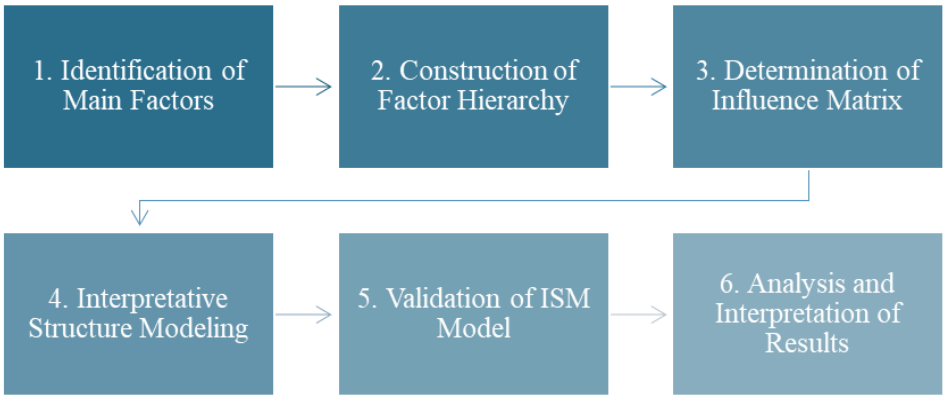

Figure 1. Research Steps

Table 1. Stages of Research Methods with Interpretive Structural Modeling (ISM)

No	ISM Stages	Description	Target	Outcome
1	Identify Key Factors	Identify the main factors influencing the development of sustainable marine tourism.	Understanding the key factors	List of key factors relevant to sustainable marine tourism development.
2	Construction of Factor Hierarchy	Building a hierarchy that describes the relationships between these factors based on	Understanding the relationship between factors	A hierarchy of interpretive structures that describes the relationships between factors that influence marine tourism

		causal interactions.		development.
3	Determination of Influence Matrix	Determine the influence matrix that maps the relationships between key factors.	Analyzing the relationship between factors	Matrix reflecting the interrelationships between the main factors in marine tourism development.
4	Interpretative Structural Modeling	Building an interpretive structural model based on a predetermined influence matrix.	Analyzing interactions between factors	The ISM model describes the structure and interactions between factors in marine tourism development.
5	ISM Model Validation	Validate the ISM model by involving experts and relevant stakeholders.	Ensuring model accuracy	The ISM model has been validated and received input from experts and relevant stakeholders.
6	Analysis and Interpretation of Results	Analyze and interpret the results of the ISM model to identify strategic priorities.	Identifying priorities	Recommendations for sustainable marine tourism development strategies based on ISM analysis.

3. Results and Discussion

Based on the identification of problems, strategies, and matters related to Factor affecting marine tourism in the coastal area of Madura Island, then the ISM framework model was built for several desired objectives. In this case, it is related to aspects of the problems or challenges faced, development strategies, and stakeholders involved in Factor affecting marine tourism in the coastal area of Madura Island. To build contextual relationships between variables in the model, the ISM method uses opinions from experts with the VAXO framework. The connection with this study is that a group of experts were involved in compiling the model consisting of academics and smart city practitioners.

To build a model, the researcher decided to follow the traditional method commonly used through brainstorming and in-depth interviews with experts, to receive input and revise the model periodically. Several related literatures and studies were also discussed with experts to validate and perfect the model. To analyze the relationship between variables or inter-enablers of each group of objectives, the contextual relationship is selected by defining the influence of one variable on another variable: whether it influences, is influenced, influences each other, or there is no relationship at all. From this basis, contextual relationships between variables are built. Experts are asked to justify in a questionnaire format to compare statements in columns with rows for each question box by choosing a value between V, A, X, or O, to represent their perception of the relationship between the variables.

3.1. Identify Key Factors for Sustainable Marine Tourism Development

Sustainable marine tourism development in Madura is influenced by various interrelated factors. Based on literature review and in-depth interviews with experts and stakeholders, these key factors can be grouped into five main categories: Environmental, Socio-Cultural, Economic, Institutional, and Technological. The following table summarizes the main factors and related sub-factors that have been identified:

Table 2. Key Factors for Sustainable Marine Tourism Development

No	Main Factors	Sub Factors	Symbols
1	Environment	Sea Water Quality	Env1
		Beach Conditions	Env2
		Mangrove Ecosystems	Env3
		Existence of Small Islands	Env4
2	Socio-cultural	Community Participation	SC1
		Community Acceptance	SC2
		Community Acceptance	SC3
		Community Skills and Capacity	SC4
3	Economy	Investment	E1
		Marketing and Promotion	E2
		Tourism Product Diversification	E3
		Connectivity and Accessibility	E4
4	Institutional	Policy and Regulation	Ins1

		Inter-Agency Coordination	Ins2
		Law Enforcement	Ins3
		Capacity Development	Ins4
5	Technology	Digital Infrastructure	T1
		Product Innovation	T2
		Information Systems	T3
		Renewable energy	T4

Marine tourism is based on several key factors, including environmental quality, socio-cultural support, economic factors, and institutional factors. Environmental quality, including seawater quality, coastal conditions, mangrove ecosystems, and small islands, is crucial for attracting tourists and ensuring the long-term sustainability of the tourism industry. Socio-cultural participation and support from local communities are essential for the development of marine tourism. Economic factors include investment, marketing, product diversification, and connectivity and accessibility. Institutions play a crucial role in the growth of marine tourism, with clear policies, regulations, coordination between institutions, strict law enforcement, and human resource capacity. Technological factors, such as digital infrastructure, product innovation, information systems, and renewable energy utilization, can improve the efficiency, competitiveness, and sustainability of marine tourism. Digital infrastructure supports online marketing, product innovation creates a more memorable tourism experience, and information systems help manage destinations effectively. Understanding these factors will be essential for formulating a strategy for developing sustainable marine tourism in Madura.

3.2. Structural Self Interaction Matrix

There are five variables related to actors who play a role in implementing smart cities in Pemekasan Regency which are arranged in row and column format. The variables in rows and columns are represented by the letters i and j respectively. Thus, each pair of variables is analyzed separately after the formation of the grid, which is obtained in the process above. Four keywords are used to represent the direction of the relationship between a set of variables (i and j), where:

a. V indicates that variable i affects variable j.
b. A indicates that variable j affects variable i.
c. X indicates that variable i affects variable j and vice versa variable j affects variable i, or in other words there is a relationship of mutual influence between variables i and j.
d. O indicates that variables i and j are not related to each other.

The relationship between variables in the model is represented in a matrix called the structural self interaction matrix (SSIM), with the value for each pair of variables being the value agreed upon among the experts.

Table 3. Structural Self Interaction Matrix (SSIM)

	Env1	Env2	Env3	Env4	SC1	SC2	SC3	SC4	E1	E2	E3	E4	Ins1	Ins2	Ins3	Ins4	T1	T2	T3	T4
Env1	NA	A	X	A	A	X	O	X	X	V	X	V	A	X	O	V	O	V	A	V
Env2	NA	NA	O	A	V	A	X	X	X	X	X	V	A	X	A	V	V	V	A	O
Env3	NA	NA	NA	A	X	V	V	X	X	V	X	V	O	X	O	V	X	X	X	V
Env4	NA	NA	NA	NA	X	V	O	A	X	V	X	X	X	X	V	O	O	O	O	O
SC1	NA	NA	NA	NA	NA	X	O	O	X	X	X	X	O	V	X	X	X	X	X	V
SC2	NA	NA	NA	NA	NA	NA	X	O	O	O	X	X	X	X	O	X	X	X	X	A
SC3	NA	NA	NA	NA	NA	NA	NA	X	V	V	O	X	A	X	A	X	X	X	A	A
SC4	NA	NA	NA	NA	NA	NA	NA	NA	V	X	V	O	X	X	A	X	X	X	X	A
E1	NA	NA	NA	NA	NA	NA	NA	NA	NA	X	V	A	O	X	X	V	V	X	X	V
E2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	O	A	A	O	X	V	X	O	A	V
E3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	X	A	A	V	X	A	O	O	V
E4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	A	A	X	A	X	X	X	X
Ins1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	O	X	A	O	V	X	X
Ins2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	O	A	O	O	X	A
Ins3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	A	X	O	X	A
Ins4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	O	A	A	A
T1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	O	A	A
T2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	O	A
T3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	A
T4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

3.3. Reachability Matrix

Reachability Matrix (RM) is obtained from the structural self interaction matrix (SSIM) using a two-step process. In the first step, the alphabet used to indicate the relationship between variables in SSIM is replaced with “0” or “1”. The value in RM depends on the type of relationship in SSIM (Faisal, 2015) and is summarized in the following relationships:

a. If the relationship between a variable in one row and another variable in a column is “V”, then in the initial RM, the row entry becomes “1”, while the column entry between these two variables becomes “0”;
b. If the relationship between a variable in one row and another variable in a column is “A”, then in the initial RM, the row entry becomes “0”, while the column entry between these two variables becomes “1”;
c. If the relationship between a variable in one row and another variable in a column is “X”, then in the initial RM, the row entry becomes “1”, while the column entry between these two variables becomes “1”;If the relationship between a variable in a row and another variable in a column is "O", then in the initial RM, the row entry becomes "0", while the column entry between these two variables becomes "0".

Based on the above rules, the initial RM for the challenge enabler in the development of sustainable smart salting technology. Furthermore, by incorporating the concept of transitivity, the final RM is obtained. Transitivity in contextual relationships is a basic assumption made in ISM. This concept states that if variable X is related to Y and Y is related to Z, then X must be related to Z.

Table 4 . Final Reachability Matrix (RM)

	Env1	Env2	Env3	Env4	SC1	SC2	SC3	SC4	E1	E2	E3	E4	Ins1	Ins2	Ins3	Ins4	T1	T2	T3	T4		
Env1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	0	1	1	1	17	2
Env2	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	18	1
Env3	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	1	1	18	1
Env4	0	1	1	1	1	1	0	1	1	1	1	1	1	1	1	0	0	0	0	0	13	6
SC1	1	0	1	0	1	1	0	0	1	1	1	1	0	1	1	1	1	1	1	1	15	4
SC2	1	1	1	1	1	1	1	0	0	0	1	1	1	1	0	1	1	1	1	1	16	3
SC3	1	1	1	1	0	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	18	1
SC4	1	1	1	0	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	18	1
E1	1	1	1	1	1	0	1	1	1	1	1	1	0	1	1	1	1	1	1	1	18	1
E2	1	1	0	1	1	1	0	1	1	1	0	1	1	0	1	1	1	0	1	1	15	4
E3	1	1	1	1	0	0	0	1	1	0	1	1	1	1	1	1	1	0	0	1	14	5
E4	1	0	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	18	1
Ins1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	17	2
Ins2	1	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	0	0	1	1	16	3
Ins3	1	1	1	1	1	0	0	1	1	1	1	1	0	1	1	1	1	0	1	1	16	3
Ins4	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	0	1	1	1	18	1
T1	1	1	0	0	1	1	0	0	1	1	1	1	1	1	0	1	1	0	1	1	14	5
T2	0	1	1	0	1	1	1	1	1	1	0	1	1	0	0	1	0	1	0	1	13	6
T3	1	0	1	1	1	1	1	1	1	0	0	1	0	1	1	1	1	1	1	1	16	3
T4	1	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18	1
	18	15	16	15	18	17	12	17	19	17	15	19	15	17	14	19	14	14	17	18		
	2	5	4	5	2	3	7	3	1	3	5	1	5	3	6	1	6	6	3			

From the final RM, the next step is to construct the reachability set and antecedent set. The reachability set for a particular enabler consists of the enabler itself and other enablers that can help achieve it. Similarly, the antecedent set consists of the enabler itself and other enablers that influence it. The intersection of these sets is derived for all enablers. Enablers whose antecedent set and reachability set are the same, form the top level of the hierarchy in the ISM model. These enablers will not help achieve other enablers above their level (Jabeen & Faisal, 2018). The identified levels help in constructing the quadrants and the final ISM model.

3.4. MICMAC Quadrant Analysis

In his research, Godet (1986) has popularized the matrix of cross impact multiplications applied to classification (MICMAC) to classify the variables of the system studied. The basis of this classification is the driving power and dependence power calculated in the final RM. In addition, MICMAC analysis can be used to examine the direct and latent relationships among enablers obtained from the ISM technique. So, based on the driving power and dependence power, the enablers in this study are classified into four groups, as shown and explained below:

a. Autonomous Variables: These variables do not have high influence or high dependence. They are independent of the system, where they have some links that may be very strong. Quadrant I represents autonomous variables. In this study, there are no enablers included in this category.

b. Dependent Variables: Quadrant II is a dependent variable that has low influence and high dependence. Quadrant I represents autonomous variables. In this study, there are no enablers included in this category. Independent Variables: These variables have high influence and high dependency. Their characteristic is that any action on them will have an effect on the variables above their level and a feedback effect on themselves. In this study, enablers Env2, Env3, SC3, SC4, E1, E4, Ins4, T4, SC2, Ins2, Ins3, T3, Env1, Ins1, E3, T1, SC1, E2, Env4, T2 fall into this category.
c. Linkage variables: These variables have high influence and low dependency. They represent Quadrant IV. In this study, there are no enablers in this category

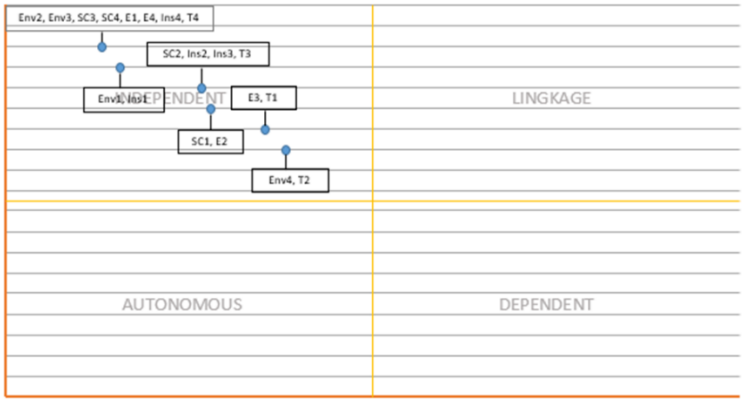

Figure 2. MICMAC Quadrant Analysis of Factors Affecting Marine Tourism in Coastal Areas of Madura Island

The study highlights the interrelationships between factors in the "Independent" Quadrant, emphasizing the importance of a holistic approach to sustainable marine tourism development in Madura. Changes in one factor can have a domino effect on others, necessitating a simultaneous consideration of all factors. Marine tourism planning and management are complex, necessitating in-depth analysis and adaptive strategies to overcome challenges and maximize potential. Potential conflicts of interest exist due to the influence of all factors, necessitating good communication and collaboration among stakeholders. Continuous monitoring and evaluation are crucial to ensure the sustainability of marine tourism, as changes in one factor can affect others, necessitating periodic adjustments to strategies and policies.

3.4. Discussion

The results of the ISM and MICMAC analyses reveal the complexity of sustainable marine tourism development in Madura. All variables studied are in the "Independent" quadrant, indicating strong interrelationships and interplay between various environmental, socio-cultural, economic, institutional, and technological factors. These findings underline the importance of a holistic approach in marine tourism planning and management in this region.

3.4.1. Strategic Priorities

Based on the ISM analysis, several factors emerged as top priorities that need special attention:

a. Coastal Conditions and Mangrove Ecosystems (Env2, Env3): The quality of the coastal and marine environment is the main foundation of marine tourism. Conservation of mangrove ecosystems and sustainable coastal management must be top priorities to maintain tourist attractiveness and environmental sustainability.
b. Community Acceptance and Capacity (SC2, SC3, SC4): Active participation and support from local communities are key to the success of sustainable tourism. Capacity building and community empowerment programs need to be improved to ensure they receive economic and social benefits from tourism.
c. Investment, Connectivity, and Accessibility (E1, E4): Adequate investment is needed to build infrastructure and supporting facilities for tourism. In addition, good connectivity and accessibility will make it easier for tourists to reach tourist destinations in Madura.
d. Capacity Development and Renewable Energy (Ins4, T4): Capacity development of human resources in the tourism sector and utilization of renewable energy are important steps to improve service quality and reduce environmental impacts from tourism activities.

3.4.2. Policy Implications

Integrated Approach: Local governments need to adopt an integrated approach that involves all stakeholders in the planning and management of marine tourism. Coordination between agencies and collaboration between the government, private sector, and local communities are essential to ensure the sustainability of tourism.

Environmental Protection: Strict policies and regulations need to be implemented to protect coastal and marine environments from the negative impacts of tourism. Monitoring of seawater quality, waste management, and conservation of mangrove ecosystems should be an integral part of tourism development strategies.
Community Empowerment: Capacity development and empowerment programs for local communities need to be improved to ensure they receive economic and social benefits from tourism. Skills training, development of micro, small, and medium enterprises (MSMEs), and participation in decision-making will improve community welfare and reduce potential conflicts.
Investment and Infrastructure: The government needs to encourage investment in the marine tourism sector, especially for the development of sustainable infrastructure and supporting facilities. In addition, increasing connectivity and accessibility to tourist destinations in Madura will increase tourist visits.
Utilization of Technology: Technology can play an important role in improving the efficiency, competitiveness, and sustainability of marine tourism. Utilization of information and communication technology, such as tourism information systems and online marketing, will expand market reach and improve tourist experiences. In addition, the use of renewable energy will reduce the environmental impact of tourism activities.

3.4.3. Innovation and Sustainability

This study makes a significant contribution by developing an ISM-based DSS for the development of sustainable marine tourism in Madura. This DSS can help stakeholders in making better and more strategic decisions, by considering the interrelationships and influences between various factors. The ISM approach integrated into the DSS is an innovation in this study. This model provides a comprehensive and structured framework for understanding the complexity of sustainable marine tourism development. The resulting DSS can be a valuable tool for local governments, tourism industry players, and local communities in formulating effective policies and strategies to achieve tourism development goals that are balanced between economic, social, and environmental aspects.
The sustainability of marine tourism in Madura is not only the responsibility of the government, but also requires collaboration and commitment from all parties involved. By utilizing this DSS and implementing the resulting strategic recommendations, it is hoped that Madura can develop sustainable marine tourism, provide economic benefits to local communities, while preserving the environment and culture for future generations.

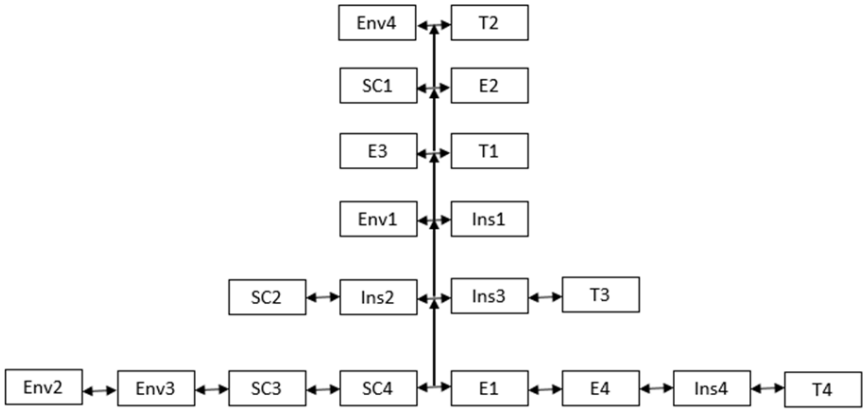

Figure 3. Problem Level Factors affecting marine tourism in the coastal area of Madura Island

Figure 3 illustrates the severity of the issue and the impact of the advancement of intelligent and environmentally-friendly sanitation technologies. The key variables to investigate are Env2 (beach condition), Env3 (mangrove ecosystem), Sc3 (community acceptability), Sc4 (community skills and capacity), E1 (investment), E4 (connectivity and accessibility), Ins4 (capacity development), and T4 (renewable energy). Furthermore, the variables SC2 (community acceptance), Ins2 (inter agency collaboration), Ins3 (poor enforcement), and T3 (information system) are also included. Immediately following are the variables Env1 (sea water) and Ins1 (policy and regulation). Following are the variables E3, which represents tourism product diversification, and T1, which defines digital infrastructure. Following are the variables SC1, which represents community participation, and E2, which corresponds to marketing and promotion. Finally, there are two variables: Env4 (indicating the presence of small islands) and T2 (indicating product innovation).

4. Conclusion

In This study successfully identified and analyzed key factors influencing the development of sustainable marine tourism in Madura through the Interpretive Structural Modeling (ISM) approach. The results of the analysis show that all factors are strongly related and influence each other, so a holistic approach is needed in tourism

planning and management. Environmental factors such as coastal conditions and mangrove ecosystems, as well as socio-cultural factors such as community acceptance and capacity, are the main priorities that need special attention. In addition, investment, connectivity, capacity development, and technology utilization also play an important role in supporting the sustainability of marine tourism.

This study contributes a comprehensive framework to understand the complexity of sustainable marine tourism development in Madura. The developed DSS can be a valuable tool for stakeholders in making the right and strategic decisions to achieve tourism development goals that are balanced between economic, social, and environmental aspects.

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