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Article

Implementation of Twin Digital Technology for Marinery Management and Conservation on Sulampua: An Innovative Approach in Blue Economy Optimization

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Abstract: This research explores the implementation of Digital Twin technology in tourism management and marine conservation in Sulawesi, Maluku and Papua (Sulampua) as an innovative approach to blue economy optimization. Digital Twin enables real-time digital modeling and simulation of the physical environment, improving the efficiency of natural resource management and tourism activities in a sustainable manner. The research method used Systematic Literature Review (SLR) to analyze related studies. The results show the great potential of this technology in supporting tourism management and marine conservation through real-time monitoring, prediction of environmental conditions, and data-driven decision-making. Challenges faced include limited technological infrastructure, lack of human resource capacity, resistance to adoption of new technologies, and coordination issues among stakeholders. Recommendations include increased investment in infrastructure, intensive training, and inclusive policy support to accelerate the adoption of Digital Twin technologies, supporting sustainable economic growth and marine ecosystem conservation in Sulampua.

Keywords: Digital Twin, Tourism, Marine Conservation, Sulawesi, Maluku, Papua

1. Introduction

The tourism industry plays an essential role in the global economy, providing jobs and a source of income for many countries (Lukito, 2022). However, the expansion of the tourism sector can also have a significant impact on marine ecosystems if not managed wisely (Naser, 2014). Economically, tourism can be a significant source of revenue through increased foreign exchange, job creation, and the growth of local businesses such as hotels, restaurants, and souvenir shops. Moreover, it encourages investment in infrastructure such as airports, roads, and public facilities, which benefit not only tourists but also locals (Ahmad, 2022). Tourist spending on accommodation, food, transportation, and recreation flows into the local economy, helping to improve the well-being of local communities (Gai et al., 2023).

The growth of the tourism industry can also have a significant impact on marine ecosystems if not managed wisely. In order to sustainable tourism development, an approach is needed that can integrate marine conservation efforts with the development of marine tourist destinations (Graci & Dodds, 2012). The Blue Economy concept is presented as a solution that emphasizes the importance of using marine resources sustainably to foster environmentally friendly economic growth (Phelan et al., 2020).

In the context of tourism, the implementation of the Blue Economy framework promotes the integration of marine conservation practices into the development and management of maritime tourist destinations (Silver et al., 2015). This includes efforts to

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minimize the negative impact of tourism activities, such as pollution, habitat damage, and disruption of marine life. Through this synergistic approach, tourism management and marine conservation can work in harmony, complement each other, and provide double benefits to economic and ecological systems (Parmawati et al., 2022).

Indonesia, as one of the island states and most of its territory is oceanic, has great potential in tourism and maritime development based on the Blue Economy (Yamin, 2015). According to Indonesia Blue Economy Index (IBEI) 2023, there are 5 provinces with the highest index (Kementerian PPN/Bappenas, 2024):

Table 1. Top 5 IBEI Data 2023

Province	**Index**
South sulawesi	80,86
Eats Java	71,63
Eats Nusa Tenggara	68,50
North sulawesi	67,98
Maluku	67,22

Source : Bappenas, Processed by Researcher

Based on Table 1, a unique fact that can be observed is that 3 out of the top 5 provinces with the highest index are located in Eastern Indonesia. The regions of Sulawesi, Maluku, and Papua (Sulampua) particularly emphasize the potential of maritime resources, especially in the development of the Blue Economy.

The province of South Sulawesi, for example, has significant potential in the marine export sector, particularly through its leading commodity, seaweed. This commodity contributes substantially to export value, with the main destinations being Japan and China. The Gross Regional Domestic Product (GRDP) for the fisheries sub-sector reached 30.2 trillion rupiah, with a growth rate of 7.4% during the 2018–2022 period (Sulsel, 2022). Similarly, in the Maluku region, the National Fish Barn brings new hope for the fisheries sector. With abundant natural resources, Maluku has significant fishing potential spread across three Indonesian Fisheries Management Areas (WPPNRI), namely WPPNRI 714, 715, and 718, which include the Banda Sea, Halmahera Sea, and Arafura Sea (Anugrah & Alfarizi, 2021).

The same situation can be identified in the Papua region through the issuance of the Minister of Marine Affairs and Fisheries Decree Number 32/2022 concerning the Conservation Area of Western Waigeo Islands and Surrounding Seas. As well as the Conservation Area of Raja Ampat Islands and Surrounding Seas in the Southwest Papua Province. These islands host at least 1,318 species of reef fish and 533 species of hard coral. The marine biota protected in the Raja Ampat waters include Napoleon fish, Manta rays, Sea bamboo, and Whale sharks (Kementerian Kelautan/Perikanan).

The rich and diverse marine natural potential, such as coral reefs, various fish species, and underwater beauty, faces significant challenges in its conservation due to over-exploitation, pollution, and climate change (Ali, 2024). One solution to address these challenges is by leveraging technological advancements. Modern technologies, such as satellite monitoring, underwater sensors, and big data analysis, can be used to monitor marine ecosystems in real-time, identify threats earlier, and implement more effective conservation measures (Mohsan et al., 2022).

Objective

The objective of this research is to implement digital twin technology in the management of tourism and marine conservation in the Sulampua region. Digital twin technology enables the digital modeling and simulation of physical environments, which can be used for optimization and innovation in the fields of tourism and marine conservation.

Problem

The research indicates a problem that needs to be addressed, specifically related to the management of tourism and marine conservation in the Sulampua region. This study aims to tackle the challenges of managing tourism and marine environments effectively. Potential issues include balancing tourism development with marine conservation efforts or optimizing the use of marine resources to support blue economy growth.

2. Materials and Methods

The research design employs a Systematic Literature Review (SLR). Data collection techniques involve searching for scientific articles, conference papers, and research reports from the Google Scholar database. The PICO (Population, Intervention, Comparison, Outcome) framework is used to ensure a focused and relevant search. The data sources are secondary data, consisting of scientific publications related to the implementation of Digital Twin technology in tourism management and marine conservation, as well as the application of the Blue Economy concept.

Data analysis is conducted using inclusion and exclusion criteria. The collected data is analyzed using the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework to ensure transparency and reproducibility. With this approach, the research aims to provide a comprehensive and evidence-based overview of the potential and challenges of implementing Digital Twin technology to optimize the Blue Economy in the Sulampua region.

3. Results

a. Identification Main Research Question

Based on the exposure of research questions in the formula of the problem, so made adjustments to this research. RQ identification results in three main questions:

Table 2. Research Question Identification (RQ)

Symbols	Research Questions
RQ1	How can Digital Twin technology be applied to enhance tourism management in Sulampua?
RQ2	What is the contribution of Digital Twin technology in supporting marine conservation in Sulampua?
RQ3	How can the implementation of Digital Twin optimize the blue economy in Sulampua?

Source: Processed by Researcher

b. PICO Scheme Identification

The next step is to develop research questions validated through the Population, Intervention, Comparison, and Outcome (PICO) method. The identification results are as follows::

Table 3. PICO Identification Results

Population	: Tourism management and marine conservation in Sulampua
Intervention	: Implementation of Digital Twin technology

Comparison	: No direct comparison mentioned in the title, but the main focus is on the application of Digital Twin technology as an innovative solution
Outcome	: Optimization of the blue economy through the use of Digital Twin technology in tourism management and marine conservation in Sulampua

Source : Processed by Researcher

The research population includes tourism management and marine conservation in Sulampua, which are key areas related to global issues of environmental sustainability and the blue economy. The proposed intervention is the implementation of Digital Twin technology, which offers an innovative approach to enhancing management efficiency through accurate digital replicas of the physical environment. Although no direct comparison is mentioned, the expected outcome of this research is the optimization of the blue economy in Sulampua.

c. Identification (Inclusion and Exclusion Criteria)

In conducting a Systematic Literature Review (SLR) on the implementation of Digital Twin technology for tourism management and marine conservation in Sulampua, an important initial step is to establish appropriate inclusion and exclusion criteria. The criteria are as follows:

Table 4. Results of Identification of Inclusion and Exclusion Criteria

Inclusion Criteria (IC)	**Exclusion Criteria (EC)**
Studies published in scientific journals or scientific articles	Studies published in the form of books, theses, or dissertations
Published between 2018-2024 with a limit of 100 journal/article findings	Journals or scientific articles with Systematic Literature Review (SLR) methods
Journals and scientific articles in Indonesian and English	Sourced from databases other than Google Scholar
Sourced from Google Scholar	

Source : Processed by Researcher

Including studies on Digital Twin in tourism management and marine conservation in Sulampua allows for the analysis of operational efficiency improvements and sustainability in the tourism industry and natural resource management. The exclusion criteria focus on research not relevant to the foundation of using Google Scholar as the sole source in this study, referring to the Systematic Review conducted by Risitano et al. in 2023, which used Scopus as the sole source (Risitano et al., 2023). Thus, the validity of an SLR study that uses only a single indexing source.

d. PRISMA Results

The initial stage of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA), a search protocol is created that includes keywords, boolean operators, and specific search criteria. These criteria must align with the research questions established in the SLR. Conduct an initial search using the keywords and boolean operators (AND and OR) defined in the search protocol. Apply relevant filters and

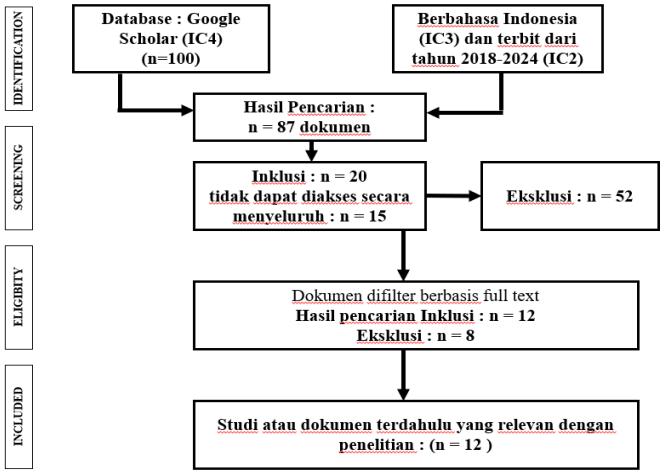
limitations, such as publication year or specific types of publications. This protocol will be implemented in searches using the Publish or Perish 8 application. The identification results found the following keywords::

Table 5. Boolean Operator Identification Results

Title Word	**: Digital Twin**
Keyword	**: Blue Economy; AND Ocean; OR Sea**

Source : Processed by Researcher

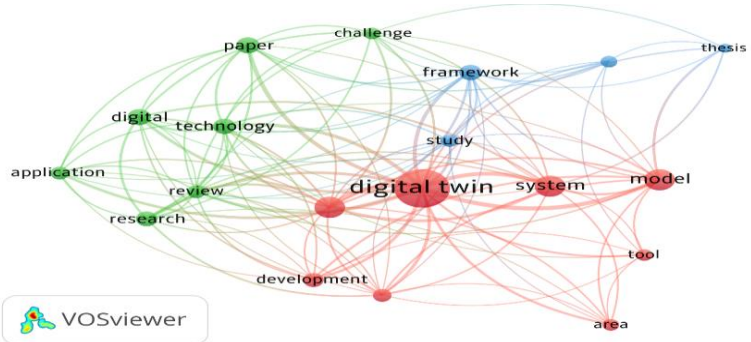
The next step is to use the method as a guide for reporting systematic literature reviews, including Systematic Literature Reviews (SLR). PRISMA provides guidelines on how to report the stages of searching, selecting, and evaluating articles. The results of the PRISMA method are explained in the following table::



Scheme 1. PRISMA Research Matrix

Source : Processed by Researcher

This process begins with the identification of documents from the Google Scholar database in Indonesian, published between 2018-2024, with a total of 100 initial documents found. After the identification stage, 87 documents were retained for the screening stage. At this stage, 52 documents were excluded because they did not meet the specified inclusion criteria, leaving 20 documents. Of these 20 included documents, 15 could not be fully accessed. Subsequently, the remaining 20 documents were further screened based on the full text, resulting in 12 documents that met the final inclusion criteria and 8 documents that were excluded at this stage. These results can be further illustrated through the connection between the scope of discussion of each literature using the Vos Viewer application as follows::



Picture 1. Literature Connection Scheme

Source : Processed by Researcher

The focus of this research is on development in the Sulawesi, Maluku, and Papua (Sulampua) region. The relevant keyword for this research is "Area." This keyword is

connected with several other keywords such as "digital twin," "system," "model," "development," and "application." Below are the implications or relevance of these connections to the research:

1) Digital Twin dan Area
   The implementation of Digital Twin technology in area management enables real-time visualization and analysis of data related to the region. This is highly relevant in the context of research in Sulawesi, Maluku, and Papua (Sulampua), where this technology can be used to model and manage natural resources and tourism activities more effectively.
2) System dan Area
   The development of systems capable of monitoring and managing an area holistically is crucial. In the context of this research, such systems could be used to monitor marine environmental conditions, manage tourism activities, and ensure sustainable conservation.
3) Model dan Area
   Models created for specific areas allow for the simulation and prediction of various scenarios, such as the impact of human activities on the marine environment or the effectiveness of implemented conservation strategies. These models will be essential tools for data-driven decision-making.
4) Development dan Area
   Focusing on the development of areas through Digital Twin technology can support better planning and management. In this research, area development includes optimizing tourism and marine conservation, contributing to the blue economy in Sulampua.
5) Application dan Area
   Practical applications of Digital Twin technology in managing an area span various fields, from tourism to conservation. In the context of this research, these applications will help in monitoring and managing tourism and marine conservation efforts in Sulampua more efficiently and effectively.

e. Literature Mapping

Based on the identification process results through PRISMA previously, 12 literatures were identified that support the implementation of Digital Twin technology for tourism management and marine conservation in Sulampua. The articles are further mapped through the following table:

Table 6. Literature Identification Results

No	Judul	Author	Year	Resech method	Research Results	Recommendations
1	Applications of Digital Twin across Industries: A Review (Singh et al., 2022)	Maulshree Singh, Rupal Srivastava, Evert Fuenmayor, Vladimir Kuts, Yuansong Qiao, Niall Murray, Declan Devine.	2022	Qualitative, Case Study.	Digital Twin is applied in 13 major industries including manufacturing, agriculture, education, construction, medicine, and retail. The application of DT encompasses objectives such as simulation, monitoring, control, design, validation, customization, optimization,	It is recommended to enhance further research and development of DT technology and to implement policies that support the adoption of DT across various sectors to increase operational efficiency and sustainability.

					prediction, and maintenance.	
2	Blue economy discourses and practices: reconfiguring ocean spaces in the Philippines (Satizábal et al., 2020)	Paula Satizábal, Wolfram H. Dressler, Michael Fabinyi, Michael D. Pido	2020	A mixed-methods approach involving critical discourse analysis and interviews with key informants at regional, national, and local scales in Southeast Asia and the Philippines.	New territorial processes create new boundaries and management structures that often neglect social and environmental protection, posing a significant threat to coastal inhabitants. More socially equitable and environmentally sustainable governance approaches are often overlooked.	Directing the blue economy should place the struggles and resistance of marginalized coastal actors at the forefront of decision-making in national, regional, and local governance arenas.
3	A New Era of Digitalisation for Ocean Sustainability? Prospects, Benefits, Challenges (Stevens et al., 2021a)	OECD Science, Technology and Industry Papers	2020	**Qualitative and Case Study:** Case studies related to technological innovation in marine observation and scientific-industry collaboration.	**Technological Innovation:** Discovery and development of sensor technology and marine observation platforms. **Collaboration:** Collaboration between science and industry to expand the scope of marine observation.	**Cost Reduction:** Reducing costs and increasing the production volume of marine observation technology. **Standardization:** Improving the standardization of processes and technology products.
4	A decade of the Blue Economy concept in the western Indian Ocean region: research and technology perspectives (Manyilizu, 2023)	Majuto C. Manyilizu	2023	A systematic review of the progress of the Blue Economy concept in the Western Indian Ocean region, focusing on research and technology between 2012 and 2021.	Most of the research focuses on the first thematic area (fisheries, aquaculture, and ecosystem conservation), the fourth (environmental sustainability, climate change, and coastal infrastructure), and the fifth (policy, institutions, and governance). Few studies are related to the second thematic area (maritime transport and trade) and the third (sustainable energy, extractive minerals, gas, and innovative industries).	Multidisciplinary and multi-institutional collaboration, as well as the identification and utilization of appropriate technology, are essential to enhance research supporting the development of the Blue Economy, marine science, and accompanied by innovation and technology.
5	Economic Assessment of Oceans for	Maria Corazon M. Ebarvia	2019	Economic analysis and	Marine economic activities contribute significantly to the GDP	Implementing a common marine economic

	Sustainable Blue Economy Development (Ebarvia, 2016)			evaluation methods.	of countries in the East Asian Seas region. However, many of these activities are not fully reflected in traditional national income accounts, which tend to overlook natural capital.	accounting framework in countries in the East Asian Seas region. Consistent methodology use and harmonization of statistical concepts are needed for more accurate assessments.
6	Optimalization the Blue Economy Policy of the Tourism Sector using E-Government in the Coastal Area of Ambon Island (Rahman et al., 2023)	Rahman Abdul, Mawar, Hermanto Agus	2023	A qualitative approach with case study methods. Data collected through digital observation, archival materials, and documentation.	The level of e-government adoption in the coastal areas of Ambon Island is still suboptimal. Influencing factors include the lack of dedicated websites or platforms for sharing information and knowledge among government entities.	The Ambon Government should develop an e-government platform in the form of websites, platforms, or tourism dashboards integrated with the Provincial and Central Government.
7	Tourism centres efficiency as spatial unites for applying blue economy approach: A case study of the Southern Red Sea region, Egyp (Kabil et al., 2022)	Moaaz Kabil, Ebtehal Ahmed AbdAlmoity, Katalin Csobán, Lóránt Dénes Dávid	2022	Two efficiency methods: Data Envelopment Analysis (DEA) and Free Disposal Hull (FDH).	Most of the tourism centers in the Southern Red Sea region of Egypt have high efficiency scores, reflecting readiness to implement various coastal tourism development strategies from a blue economy perspective.	This research recommends focusing on accurately determining the readiness of different units to implement a blue economy approach in various economic sectors.
8	Blue Tourism: Treating Marine Ecosystems and Increasing the Potential of Maritime Tourism in Indonesia (Supriyanto, 2022)	Eko Eddya Supriyanto	2022	Qualitative, Case Study.	The concept of blue tourism can be used as a model to implement coastal tourism in Indonesia. This concept includes the protection of marine ecosystems and the sustainable use of marine resources.	Recommending the use of digital twin technology to facilitate the sustainable development of the blue economy.
9	Digital Twins of the Ocean can foster a sustainable	Ute Brönner, Maike Sonnewald,	2023	A case study approach and the development of	Digital twin of the sea has great potential to provide valuable insights into current	merekomendasikan penggunaan teknologi digital twin untuk

	blue economy in a protected marine environment (Brönner et al., 2023)	Martin Visbeck		digital twin technology.	marine conditions and future projections.	memfasilitasi pengembangan berkelanjutan dari ekonomi biru.
10	Achieving circular economy through new blue economy initiatives: a road map for ports (Pacheco, 2022)	Ayo Olusola Pacheco	2023	Qualitative analysis. Primary data sources are official documents and publications, as well as relevant literature.	There is a strong relationship between the blue economy and the circular economy. The use of new blue economy initiatives can enhance sustainability at ports by leveraging digital technology and resources for more efficient marine resource management.	Recommending the development of policies and strategies that support the implementation of new blue economy initiatives to achieve a circular economy in ports. This includes the application of digital technology and ICT resources.
11	Enhanced monitoring of life in the sea is a critical component of conservation management and sustainable economic growth (Estes et al., 2021a)	Maurice Estes Jr., Clarissa Anderson, et.al	2021	Qualitative analysis. This study combines scientific observations and historical data.	Enhanced marine biological monitoring is crucial for conservation management and sustainable economic growth.	Recommending the use of new technology.
12	Challenges and future perspectives in ocean prediction (Davidson et al., n.d.)	Fraser Davidson (Chapter Coordinator) et.al	2022	Qualitative analysis.	The evolution of ocean forecasting systems will heavily depend on the increased integration of observation systems, numerical models, and artificial intelligence.	Enhancing sectoral observation integration with uniform standards and adopting artificial intelligence technology.

Source : Processed by Researcher

4. Discussion

a. Implementation Digital Twin in Sulampua

Based on previous literature analysis, it is generally known that the Digital Twin is a virtual representation of a physical object, system, or process used to understand, predict, and optimize performance through detailed digital modelling. This technology enables simulation and analysis in real-time by combining data from sensors, mathematical models, and information technology to create accurate digital models of the physical entity. The Digital Twin serves as a bridge between the physical and digital worlds,

enabling conditions monitoring, scenario testing, and more effective and efficient data-based decision-making.

The implementation of Digital Twin in efforts to manage tourism and marine conservation in the Sulampua region requires several stages in its process. These stages are based on a general analysis of the 12 main literature sources in this study, which are further detailed in the following table:

Table 7. Stages of Digital Twin Implementation in Sulampua

Stages	Stages	Description	Estimated
Initial Data Collection	Geospatial Data Collection	Geospatial data collection from the Sulampua marine area	2 months
	Marine Ecosystem Data Collection	Collection of marine ecosystem data such as coral reefs and marine life	3 months
	Tourism Data Collection	Collection of data on the number of tourists and popular tourist locations	1 months
	Weather Data Collection	Collection of local weather and climate data	1 months
Digital Twin Model Development	Marine Environment Modeling	3D modeling of the seabed and ecosystems	3 months
	Tourism Modeling	Modeling tourist flow and its impact on the environment	2 months
	Sensor Data Integration	Integration of sensor data for real-time monitoring	2 months
System Integration and Testing	Real-Time Data Integration	Connecting sensors to the Digital Twin system to obtain real-time data	1 months
	Management Scenario Testing	Tourism Management Scenario Simulation	2 months
	Conservation Scenario Testing	Conservation and Marine Ecosystem Recovery Scenario Simulation	2 months
Training and Outreach	Tourism Manager Training	Training for Tourism Managers on the Use of Digital Twin Technology	1 months
	Marine Conservation Manager Training	Training for Marine Conservation Managers on the Use of Digital Twin Technology	1 months
	Community Outreach	Education for Local Communities on the Importance of Marine Conservation and the Technology Used	1 months

Field Implementation	Sensor Installation	Installation of Sensors and Hardware at Strategic Locations	2 months
	Digital Twin Platform Use	Utilization of the Digital Twin Platform by Tourism and Marine Conservation Managers	1 months
Monitoring and Evaluation	Continuous Monitoring	Ongoing Monitoring of Real-Time Data	6 months
	Periodic Evaluation	Periodic Evaluation of the Effectiveness of Tourism Management and Conservation Efforts	3 months
Advanced Development and Innovation	Additional Feature Development	Predictive Analysis to Support Long-Term Planning	3 months
	Management Innovation	Development of Sustainable Tourism Business Models and Community-Based Conservation	3 months
Estimated Total Implementation Time			35 months

Source : Processed by Researcher

The development of a system capable of monitoring and managing an area holistically is crucial. In the context of this research, such a system could be used to monitor marine environmental conditions, manage tourism activities, and ensure sustainable conservation. Through the integration of Digital Twin technology, this system can provide accurate real-time data on various environmental parameters such as water quality, coral reef health, and marine life populations. This enables a rapid response to changes in environmental conditions and adaptive management. Additionally, continuous monitoring of tourism activities can help identify the impact of visitor presence and develop effective mitigation strategies. Implementing this system will support more efficient conservation efforts and provide long-term benefits for marine ecosystem sustainability and local economic well-being in the Sulampua region.

b. Benefits and Impacts of Implementation

The primary benefits of implementing Digital Twin technology include increased operational efficiency, where the management of marine resources and tourist destinations can be enhanced through more accurate environmental condition simulations and predictions. Additionally, this technology can improve marine conservation with continuous ecosystem monitoring, identifying potential risks, and creating effective mitigation plans based on real-time data. In decision-making, Digital Twin technology allows for more precise decisions and more effective strategic planning by leveraging real-time data and simulations of various scenarios.

The impact of implementing Digital Twin technology is evident in economic, environmental, and social aspects. Economically, this technology can enhance revenue from the tourism sector through better management and improved visitor experiences, as

well as reduce operational costs with more accurate predictions. Environmental impacts include the restoration of marine ecosystems and supporting sustainable development by maintaining a balance between resource use and conservation. From a social perspective, the quality of life for local communities can improve through increased economic activity and better environmental management, as well as heightened awareness and education about the importance of marine conservation.

c. Challenges and Obstacles

The implementation of Digital Twin technology for managing tourism and marine conservation in Sulampua (Sulawesi, Maluku, and Papua) faces several significant challenges and obstacles. First, inadequate technological infrastructure in the region is a major barrier. Limited internet access and uneven communication networks hinder the transmission of real-time data, which is essential for Digital Twin operations. Second, there is a limited pool of human resources with specialized expertise in this technology, necessitating intensive training and capacity building to ensure effective management and utilization of the technology.

Additionally, resistance to change and the adoption of new technology can be a social barrier, where local communities may not fully understand the benefits and importance of Digital Twin technology. Coordination among stakeholders, including local governments, conservation agencies, and tourism industry players, also presents a challenge. Integrating various information systems and data from different sources requires close collaboration and is often faced with bureaucratic issues and differing interests.

Another challenge is the high cost of financing for the initial implementation and maintenance of Digital Twin technology. The substantial initial investment may be difficult to cover with regional budgets or local investors without support from central government or international agencies. Finally, environmental issues, such as climate change and marine ecosystem damage, can affect the accuracy and reliability of Digital Twin models, necessitating ongoing mitigation efforts.

d. Program Recommendations and Policies

In general, the capabilities of each region in Sulampua are influenced by several factors. Efforts to minimize the challenges and obstacles previously described can be addressed through a Pre-Implementation Plan. This plan consists of several initial programs and policies that can be developed and implemented. There are several key indicators for determining the programs and policies for each region, including:

1. Technological Infrastructure Readiness

The readiness of technological infrastructure, such as internet access and communication networks, is a key indicator. Regions with more advanced infrastructure are generally better prepared for the implementation of Digital Twin technology (Davidson et al., n.d.) (Brönner et al., 2023; Estes et al., 2021b; Manyilizu, 2023; Pacheco, 2022; Singh et al., 2022; Stevens et al., 2021b).

2. Human Resource Capacity

The availability and capacity of local human resources in the field of information and communication technology (ICT) are important indicators. The level of education, skills, and technical training received by the local workforce determines how well the technology can be adopted and operated (Kabil et al., 2022; Manyilizu, 2023; Satizábal et al., 2020; Singh et al., 2022).

3. Government Policy Support:

The presence and support of government policies, including regulations that support the adoption of new technology and incentives for investment, are key indicators. Regions with supportive policy frameworks will find it easier to implement innovative programs (Rahman et al., 2023; Supriyanto & others, 2022)

4. Social and Economic Conditions:

Indicators of social and economic conditions, such as the level of community welfare, unemployment rates, and resistance to technological change, are highly influential. Areas with higher welfare levels and communities open to change will find it easier to adopt new technology (Brönner et al., 2023; Ebarvia, 2016; Estes Jr et al., 2021; Kabil et al., 2022; Pacheco, 2022; Satizábal et al., 2020).

5. Natural Ecosystem Presence

The presence and condition of natural ecosystems, such as marine biodiversity and environmental degradation levels, are also important indicators. Regions with rich and threatened ecosystems need this technology more urgently for conservation efforts. Source: International Union for Conservation of Nature (IUCN) (Manyilizu, 2023; Satizábal et al., 2020).

Based on these 5 indicators, the researcher recommends programs and policies that can be implemented according to the characteristics of each region, including:

Table 8. Programs and Policies for the Sulawesi Region

Programs	**Description**
Human Resource Training and Development	Conduct intensive training programs to enhance the local workforce's capabilities in Digital Twin technology
Infrastructure Technology Improvement	Invest in the development of telecommunications and internet infrastructure in remote areas
Academic and Industry Collaboration	Encourage cooperation between universities and industry for research and development of Digital Twin applications
Marine Data Center and Observation	Establish a data center focused on collecting and analyzing marine data to support management and conservation efforts
Community Education Program	Organize educational programs to increase local community understanding of the benefits of Digital Twin technology
Policies	
Technology Investment Incentives	Provide fiscal incentives for companies investing in Digital Twin technology
Data Standards Regulation	Develop standard regulations for data interoperability to facilitate integration of information from various sources
Public-Private Partnership	Facilitate partnerships between the public and private sectors for funding and implementing Digital Twin technology
Data Protection and Security	Create policies to ensure the security and privacy of data collected through Digital Twin technology
R&D Support	Increase funding for research and development in the field of Digital Twin technology and its applications

Source : Processed by Researcher

Tabel 9. Programs and Policies for Maluku

Programs	Description
Enhancement of Local Human Resource Capacity	Provide intensive training for local workers in the use and maintenance of Digital Twin technology
Development of Telecommunication Infrastructure	Establish a robust and stable internet network in coastal areas
Collaboration Program with NGOs	Collaborate with NGOs for the implementation of Digital Twin technology
Environmental Monitoring and Evaluation	Establish a Digital Twin-based environmental monitoring program for real-time surveillance of marine ecosystems
Workshops and Seminars	Organize workshops and seminars to enhance knowledge about Digital Twin technology
Policies	
Technology Infrastructure Subsidies	The government provides subsidies for the development of necessary technology infrastructure
Streamlining Bureaucratic Procedures	Reduce bureaucratic procedures to expedite the implementation of Digital Twin projects
Integrated Data Management Policies	Develop policies for integrated data management for relevant stakeholders
Inter-Regional Partnership Program	Promote partnerships among regions in Maluku to share knowledge and resources
International Financing Support	Seek support and financing from international agencies for Digital Twin projects

Source : Processed by Researcher

Tabel.10 Programs and Policies for Papua

Programs	Description
Technical Capacity Development	Technical training for local workforce in the operation and maintenance of Digital Twin systems
Internet Infrastructure Development	Development and enhancement of internet access in conservation and tourism focus areas
Collaboration with educational institutions	Collaboration with universities in research and development of Digital Twin applications
Integrated Sea Data Center	Establishment of data centers that collect marine ecosystem information for Digital Twin-based management
Socialization and Education Programme	Public awareness campaigns about the benefits and usage of Digital Twin technology
Policies	
Regional Budget Support	Significant allocation of regional budget for the development of Digital Twin technology infrastructure
Inclusive Policy	Development of policies involving indigenous and local communities in the implementation of Digital Twin technology

Process Standardization	Creation of standard operating procedures for the use and maintenance of Digital Twin technology
Ecosystem Protection Policy	Special policies focused on the protection of marine ecosystems with the help of Digital Twin technology
Fiscal incentives	Provision of tax incentives for investors who invest in Digital Twin technology for tourism and conservation

Source : Processed by Researcher

5. Conclusion

This research reveals that the implementation of Digital Twin technology for tourism management and marine conservation in Sulawesi, Maluku, and Papua has great potential in supporting the optimization of the blue economy. Digital Twin allows for accurate real-time modeling and simulation of physical environments, which can be used to improve the efficiency of natural resource management and sustainable tourism activities. However, several significant challenges are faced, including technological infrastructure limitations, a lack of competent human resource capacity, resistance to technological changes, and funding issues. Integrated data management and cross-sectoral collaboration are key to the successful implementation of this technology in the region.

The researchers recommend increasing investment in the development of technological infrastructure and human resource training. Providing equitable internet access, intensive training for the local workforce, and inclusive policy support can accelerate the adoption of Digital Twin technology. Additionally, fiscal incentives are needed to attract investors, and support from international institutions for financing strategic projects. Collaboration with educational institutions is also important for further research and development. The adoption of policies focused on marine ecosystem conservation and the standardization of operational processes will effectively support the implementation of this technology, fostering sustainable economic growth in Sulawesi, Maluku, and Papua.

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