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Original Article

Priority Strategy for Managing Water Settlement Using Eco-Settlement: SWOT-AHP Approach in Tobati Village, Jayapura, Indonesia

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Abstract *- Indigenous settlements in conservation areas situated on water frequently experience a paradox between substantial social and cultural capital and environmental degradation. To address this gap, this study aimed to formulate a sustainable management strategy for Tobati Village, Jayapura, Indonesia, by integrating local wisdom into an eco-settlement framework. Building on the previously published Fuzzy Delphi Method assessment to validate key aspects of environmental quality, this study proceeds to the strategy prioritization stage. This stage uses a sequential mixed method combining interviews and observations, SWOT to map internal and external factors, and AHP to prioritize strategic alternatives. The SWOT analysis positioned Tobati Village in the WO quadrant (IFAS = –0.98, EFAS = 0.02), indicating that weaknesses in sanitation, access to clean water, housing quality, and governance remain dominant despite existing policy and program opportunities. The AHP identified strategy WO1 (watertight communal sanitation with participatory floating waste collection points) as a top priority (global weight 0.340) due to its effectiveness in reducing pollution while simultaneously activating local institutions and community participation. In accordance with strategy WO1, the formulation of the "Latent Capacity Paradox" framework emphasizes the need for a connecting strategy based on environmental infrastructure and shared governance to facilitate the improvement of physical conditions within settlements and the sustainable management of coastal indigenous settlements.*

Keywords *- Coastal management, Eco-Settlement framework, Local wisdom, Strategic prioritization, SWOT-AHP.*

1. Introduction

1.1. Background

Coastal areas function as centers of economic activity and conservation zones, rendering them vulnerable to conflicts over spatial use and ecological pressures [1]. In Indonesia, community dependence on coastal resources increases anthropogenic pressures on marine and terrestrial ecosystems [2]. This condition necessitates integrated management through sectoral, ecological, and interdisciplinary approaches [1].

In settlements situated on water, these challenges are more pronounced due to the direct interaction between dwellings and domestic activities with the aquatic environment. Consequently, the effects of climate change, sea level rise, and household waste exert a direct impact on environmental quality. The Tobati Village settlement in Jayapura City (Papua, Indonesia) serves as a representative case study, located above the coastal waters of Youtefa Bay, which has been designated as the Youtefa Bay Nature Tourism Park area since 1996 (Regulation of the Minister of Forestry of the Republic of Indonesia No. 714/KPTS-II/1996). 714/KPTS-II/1996). The local community has local wisdom and customary laws, including the protection of mangroves in the "women's forest" area [3]. However, abrasion, mangrove damage, water pollution, and waste problems still persist, mainly due to domestic activities [4], and previous research has classified the environmental conditions as unsustainable [5].

This situation demonstrates a paradox frequently observed in traditional coastal settlements in Indonesia: communities possess robust social capital and local wisdom, yet continue to grapple with significant infrastructure and environmental degradation challenges.

Consequently, management strategies prove inadequate when predicated solely on technical solutions. Infrastructure interventions must be designed and integrated with institutional mechanisms and community social practices,

aligning with the principles of sustainable eco-settlement, wherein institutions serve as supportive actors at the settlement scale [6-8].

Despite extensive discussion regarding coastal settlement management and local wisdom, three primary research gaps persist: (1) eco-settlement studies predominantly focus on urban contexts and have not addressed traditional settlements on water in developing countries [8-10]; (2) research on Indigenous Knowledge/Traditional Knowledge frequently remains descriptive and lacks an explanation of how it is integrated operationally into a quantitative strategic decision-making framework [11-14]; and (3) the dichotomy between traditional and formal institutions is seldom positioned as a central strategic dimension in formulating management strategies [15-17].

Initial findings on key aspects of environmental quality in Tobati Village, previously published in the International Journal of Environmental Sciences [18] using a Fuzzy Delphi Method (FDM)-based assessment, provided a basis for diagnosis but did not establish a priority order for strategies. Therefore, this research continues to the strategy formulation and prioritization stages.

Consequently, this research progresses to strategy formulation and prioritization, shifting the focus from identifying important aspects to determining the optimal strategies for implementation and their corresponding order, with the goal of translating validated eco-settlement aspects into operational interventions.

Therefore, this study aimed to formulate and prioritize water settlement management strategies in Tobati Village by operationalizing eco-settlement aspects, validated through a structured SWOT-AHP analysis [19-21]. Specifically, this study sought to: (1) translate the validated aspects into internal and external strategic factors influencing settlement sustainability; (2) analyze the strategic position of water-based settlements using SWOT; (3) prioritize alternative management strategies using AHP; and (4) identify interventions to activate socio-cultural capacity and strengthen governance between traditional and formal institutions, thereby supporting strategy implementation.

The main novelty of this research lies in applying the Latent Capacity Paradox (LCP) framework to bridge the gap between the socio-cultural capital of indigenous communities and the degradation of infrastructure and environmental quality in water settlements. Unlike studies that have primarily focused on the description of local knowledge [11, 12] or on top-down technical interventions [11], this study presents a synthesis by identifying a specific paradox: strong, yet latent, social capital and customary institutions that have not been translated into physical environmental improvements within the Kampung Tobati settlement area.

This study represents the first operational integration of the LCP framework into the SWOT-AHP model and demonstrates that context-appropriate infrastructure interventions can catalyze the activation of institutional capacity by strengthening rules, coordination, and role-sharing between customary and formal institutions. Consequently, this research offers a novel theoretical lens examining the socio-technical interface, alongside a replicable methodological pathway for the sustainable management of indigenous coastal settlements [19-21].

Table 1. Comparison of the positions of the two studies

Aspect	Previous Studies	Current Studies
Main research objectives	Identification and validation of environmental quality aspects.	Formulation and prioritization of management strategies
Core research questions	What factors influence the environmental quality of water-based settlements?	Which strategies should be prioritized to improve settlement sustainability?
Analytical role	Diagnostic and evaluative	It is prescriptive and decision-oriented.
Main method	Fuzzy Delphi Method (FDM)	SWOT analysis combined with AHP
Unit of analysis	Environmental quality aspects	Management strategy
Main output	Aspects of environmentally friendly settlements are ranked	Ranked strategic alternatives (WO1–WO5)
Decision-making levels	Assessment and validation	Policy formulation and implementation
Theoretical contributions	Contextualized ecological settlement indicators	Latent Capacity Paradox Framework
Relationship between studies	Providing an empirical basis	Operationalizing and extending previous findings

Source: Author's Analysis (2025)

1.2. Relationship with Previous Studies

This study is conceptually and methodologically related to a previously published environmental quality assessment in Tobati Village, which utilized *the Fuzzy Delphi Method* (FDM). However, the two studies differ in their objectives, analytical focus, and scientific contributions (Table 1). A prior study identified and validated key aspects influencing the environmental quality of water settlements through expert consensus, resulting in a prioritized set of aspects describing essential components of environmental quality. Based on the validation results, this study proceeded to the strategy formulation and prioritization stage. SWOT-AHP was used to operationalize the validated aspects into strategic factors, evaluate internal and external conditions, and formulate priority-management strategies. Consequently, this study is prescriptive and policy-oriented, complementing the FDM study as a subsequent step within a single research trajectory and incorporating theoretical reinforcement through the Latent Capacity Paradox framework.

2. Literature Review

2.1. Eco-Settlement and Coastal Environmental Governance

The concept of ecological settlements provides a framework for integrating ecological, social, economic, and institutional dimensions to promote sustainable development at the settlement scale. This framework is particularly relevant in coastal and water-based settlements, where domestic activities directly interact with vulnerable aquatic ecosystems. Consequently, environmental quality is strongly influenced by basic infrastructure, daily practices, and local governance capacity [6-10].

However, the emerging eco-settlement literature predominantly focuses on assessment, developing indicators, measuring conditions, and evaluating sustainability performance. Consequently, it frequently lacks sufficient operational guidance on how assessment findings translate into prioritized action options within settlement contexts characterized by limited institutional constraints and implementation capacity issues [8-10].

2.2. Indigenous Knowledge/Local Wisdom and Institutional Dualism

Indigenous Knowledge (IK) and Traditional Ecological Knowledge (TEK) are defined as the accumulation of knowledge, practices, and beliefs concerning the relationship between humans and their environment, transmitted across generations [11]. Several studies have demonstrated that the recognition and integration of IK/TEK into formal governance can enhance environmental resilience, bolster policy legitimacy, and promote a more equitable distribution of benefits, provided the process respects the cultural context and ethical considerations of the knowledge [12].

The integration of IK/TEK into formal governance often faces institutional dualism, where formal state systems coexist with customary systems that have their own social legitimacy and rules. This dualism can result in overlapping authority, conflict, and hindered implementation due to a lack of coordinated mechanisms [15]. Empirical evidence indicates that conservation initiatives are more successful when an "institutional bridge" connects government and Indigenous communities, enabling formal rules and local norms to mutually reinforce each other [17].

2.3. Strategic Decision-Making and Prioritization Framework (SWOT-AHP)

To move beyond a purely descriptive/diagnostic approach, various decision-support tools are utilized for environmental and human settlement management. SWOT facilitates the organization of internal and external factors, while AHP enables the weighting and ranking of alternatives based on expert judgment within a multi-criteria framework. The integration of SWOT–AHP is widely used to mitigate the qualitative weaknesses of conventional SWOT analysis by incorporating quantitative weights and more transparent strategic priorities into the evaluation process. Evidence of its application to environmental issues indicates that SWOT–AHP is effective in generating strategic sequencing under conditions of competing objectives and uncertain information.

2.4. Research Gaps and Theoretical Position of the Study

Based on the literature, three consistent research gaps exist in this area. First, coastal eco-settlement research predominantly focuses on condition assessments rather than implementation pathways or prioritized actions [8-10]. Second, Indigenous Knowledge (IK) and Traditional Ecological Knowledge (TEK) and customary institutions are frequently recognized as important, yet they are often presented as descriptive findings without integration into decision-making mechanisms that guide intervention sequences. Third, hybrid institutional contexts, characterized by strong socio-cultural capital alongside persistent environmental infrastructure challenges, are rarely central to strategy formulation, particularly in coastal conservation areas necessitating trade-offs in area management design [22].

This study positions SWOT-AHP not only as a technical ranking tool but also as a means of translating diagnostic findings into actionable strategies, considering the dynamics of socio-cultural capacity and governance within an institutional context. Utilizing the Latent Capacity Paradox framework, this study explains why local capacity may be "dormant" in the face of physical-environmental weaknesses and how appropriate strategies can activate it through strengthened infrastructure and enhanced shared governance [17].

3. Materials and Methods

This study employed a sequential mixed methods design, integrating qualitative and quantitative approaches. A qualitative approach was utilized to identify strategic factors,

and a quantitative approach–including SWOT and AHP analyses–was used to formulate and prioritize strategies. Data validity was established through triangulation of sources, methods, and time, alongside *member checking* to ensure accurate interpretation [23, 24].

3.1. Case Study: Tobati Village

The research location is Tobati Village, South Jayapura District, Jayapura City, in Papua Province, Indonesia. Located above the coastal waters of Youtefa Bay, the village is part of the Youtefa Bay Nature Tourism Park. With a population of approximately 395 individuals (54 families), the majority of residents derive their livelihood from fishing. Demographically, the inhabitants of Tobati Village are indigenous people characterized by strong social structures and traditional institutions [25].

Fig. 1 Location and physical condition of Tobati Village as a water-based settlement within the Youtefa Bay conservation area
Source: Atlas of Jayapura City Regional Spatial Planning Map (RTRW); field photos by the author (2025)

3.2. Data Collection

Data collection was conducted over three months (June to August 2025) using the following methods:

1 In-depth interviews were conducted with 15 purposively selected key informants, including the Mayor, Village Head, traditional leaders (Ondoafi), community representatives (youth and women), and environmental experts from relevant agencies, such as Environmental Services, Public Works, Spatial Planning and Settlement Services, and academic institutions.
2 Direct observation was conducted to examine the physical conditions of the settlements, encompassing the mangrove ecosystem, sanitation systems, waste management practices, housing quality, and community socioeconomic practices.
3 Documentation comprises secondary data pertaining to regulations, environmental conditions, and prior research, gathered from diverse sources including government documents, technical reports, and scientific publications.

3.3. Data Analysis

3.3.1. Qualitative Analysis

Interview transcripts and field notes were analyzed using NVivo 12 software employing a thematic analysis approach [26]. This process involved three stages: (1) open coding to identify key concepts within the data; (2) axial coding to group these concepts into broader categories based on eco-settlement dimensions–ecological, social, economic, and institutional; and (3) selective coding to integrate these categories and identify key strategic factors (strengths, weaknesses, opportunities, and threats) for the SWOT analysis. Data validity was ensured through triangulation of sources (comparing data from traditional leaders, community leaders, and government officials) and member checking, involving the reconfirmation of initial findings with key informants.

3.3.2. Quantitative Analysis: SWOT and AHP

The quantitative analysis was conducted in two stages, involving a panel of experts. This panel comprised five experts selected according to strict criteria: (1) holding a doctoral or master's degree in a related field (such as settlements, environmental infrastructure, regional planning, and public policy); (2) possessing at least 10 years of research or professional experience in Papua; and (3) demonstrating scientific publications in reputable journals concerning coastal issues or development in Papua.

Stage 1: SWOT Analysis

In the initial stage, a SWOT analysis was employed as a strategic planning tool to identify and manage the internal strengths and weaknesses, as well as external opportunities and threats, of Tobati Village, a waterfront settlement [21, 22, 27, 28]. Its application in similar environmental contexts, such as the development of mangrove-based ecological settlements and community-based waste management initiatives, has been reported [29, 30]. The identified factors were subsequently summarized in the IFAS and EFAS matrices; each factor received a relative importance weight (totaling 1.0) and a score (on a scale of 1–4) based on the expert panel's assessment. Individual experts conducted the assessments independently, and the resulting weights and scores were

averaged to determine the final values, yielding a measurable IFAS–EFAS matrix.

Stage 2: Analytical Hierarchy Process (AHP)

The Analytic Hierarchy Process (AHP) is a Multi-Criteria Decision-Making (MCDM) method that structures problems into a hierarchy comprising objectives, criteria, and alternatives, subsequently determining priority weights through pairwise comparisons [25, 26]. In this study, a hierarchy was constructed with sustainable settlement management objectives (Level 1), ecological, social, economic, and institutional settlement criteria (Level 2), and alternative strategies (Level 3). A panel of experts conducted pairwise comparisons using the Saaty scale (1–9), and the consistency of the assessments was evaluated using the Consistency Ratio (CR); assessments were considered valid when CR < 0.10, and were reviewed if CR > 0.10. Subsequently, the global weight of each strategy was calculated through priority synthesis (aggregation of expert assessments), and the strategy with the highest global weight was identified as the top-priority strategy. Based on a review of previous empirical applications, SWOT–AHP is generally employed as a technical tool to prioritize strategies based on generic internal and external factors in urban development, tourism planning, or environmental management [19-21]. In most of these studies, the SWOT matrix is compiled using expert judgment, and AHP is subsequently used to calculate weights and determine strategy rankings.

Differing from conventional usage, this study modifies SWOT and AHP in three key ways. First, SWOT factors are organized into three interrelated dimensions: physical/environmental (F), socio-institutional (D), and cultural/knowledge (C), reflecting the pillars of eco-settlement pertinent to the context of indigenous peoples' water settlements. Second, social and institutional aspects, such as customary institutions, indigenous knowledge, and their interactions with formal institutions, receive more specific attention, moving beyond being treated solely as background information. Third, the SWOT–AHP results are interpreted using the Latent Capacity Paradox (LCP) framework, enabling this analysis to extend beyond ranking strategic alternatives and to explain how priority strategies can mobilize latent socio-cultural capacities in Tobati Village, linking them to existing policies and funding opportunities.

3.4. Ethical Considerations

This study adhered to the authors' institutional ethical standards for social research, upholding the rights, dignity, and privacy of participants. Prior to the interviews, the researchers explained the purpose of the study, the voluntary nature of participation, and the use of data. Informed consent was obtained, and participants were permitted to discontinue their participation at any time without consequence. Personal identities were anonymized in the data and publications. This study did not involve clinical interventions or experiments on humans or animals.

4. Results and Discussion

4.1. Identifying Strategic Factors

The thematic analysis of the qualitative data revealed five strengths (S), six weaknesses (W), five opportunities (O), and five threats (T), as detailed in Table 1.

Table 1. Strategic factor identification matrix for Tobati Village

Size	Strength (S)	Weakness (W)	Opportunity (O)	Threat (T)
Ecology	S1: Mangrove and coastal ecosystems are generally well-maintained.	W1: The sanitation system is inadequate (household waste is discharged directly into the sea)	O1: Availability of a legal umbrella for disaster risk reduction in coastal areas	T1: Coastal land conversion and mangrove forest degradation
		W2: Limited access to clean water		T2: Pollution from waste and sewage from rivers flowing into Youtefa Bay
Social	S2: Local wisdom of 'women's forest' still applies	W5: Waste management still relies on government garbage boats (2x/week)	O2: Existence of active youth organizations/communities	T3: Climate change and sea level rise
	S3: Strong social solidarity and mutual cooperation culture	W4: Housing is less adaptive to climate change	O3: Potential for developing culture-based ecotourism	T4: Weak law enforcement regarding environmental pollution
Economy	S4: The potential for capture fisheries is still good	W3: The community's productive economic skills are limited.	O4: Local government support for MSME development	T5: Conflict between interests in spatial utilization and urban development
Institutional	S5: Customary institutions (Ondoafi, tribal chiefs) are still respected	W6: Dualism of customary and formal leadership that has not yet synergized	O5: Funding programs from government and donor sources addressing environmental and Indigenous issues.	

Source: Author's analysis (2025)

Table 2. Strategy combinations in the SWOT matrix

IFAS / EFAS	**Strength** S1 Mangrove and coastal ecosystems in the region remain relatively well preserved. S2 Local knowledge regarding "women's forests" continues to be relevant. S3 Strong social solidarity and mutual cooperation culture S4 There are traditional institutions (Ondoafi) S5 The level of formal education in society is quite high	**Weakness** W1 Inadequate sanitation system (directly discharged into the sea) W2 Limited access to clean water (only 2x a week) W3 Economic dependence on the informal sector W4 Less adaptive housing/low thermal comfort W5 Waste management still depends on local governments W6 Dualism of customary and formal leadership
Threat T1 Coastal land conversion and environmental degradation T2 Garbage and waste pollution T3 Climate change and sea level rise T4 Weak enforcement of law and regulations T5 External infrastructure development pressure	**ST Strategy** ST1 Restoration and anti-abrasion mangrove green belt ST2 Citizen-based patrol and *trash boom* in rivers and estuaries ST3 Evacuation route/board; evacuation training is conducted twice a year. ST4 Coastal Friendly Development Pact ST5 Climate adaptation education and campaign	**WT Strategy** WT1 Emergency operations during the rainy season (garbage) WT2 Standard septic tank and backflow prevention valve in tidal zone WT3 Micro relocation/elevation of the most vulnerable houses WT4 Harmonization of rule enforcement through traditional village forums WT5 Food and fuel safety network during disasters
Opportunity O1 DRR/adaptation policy umbrella mandates coastal risk reduction. O2 is an active youth community committed to partnering for environmental sustainability, preparedness, and basic services. O3 Public health education program O4 Technical standards, implementing partners, and access to external financing are crucial for the development of stilt, coastal, and overwater residential buildings. O5 Access to funding: village funds, CSR, and partnerships that support program implementation.	**SO Strategy** SO1 PHBS/WASH Campaign in Schools and Communities SO2 Co-governance of customary and formal government for Disaster Risk Reduction SO3 Mangrove shield and customary zoning SO4 Pilot program for adaptive stilt houses with concrete foundations SO5 Coastal ecology MSME incubation	**WO Strategy** WO1 Communal sanitation, watertight septic tanks, and floating TPS WO2 Clean water: rainwater harvesting and solar-powered pumps/filtration WO3 Forum for co-governance between customary and formal government WO4 Retrofit adaptive stilt house (concrete foundation) WO5 Economic strengthening: incubators and access to microfinance

Source: Author's analysis (2025)

Table 2 presents an overview of the strategic conditions of Tobati Village as a waterfront settlement employing an eco-settlement approach. Internally, key strengths include relatively well-preserved mangrove and coastal ecosystems, local wisdom–such as the "women's forest" alongside– social solidarity and a culture of mutual cooperation, and recognition of customary authority (Ondoafi). These strengths demonstrate socio-ecological capacity that can drive spatial management, resource utilization control, and strengthened community-based governance. Conversely, significant weaknesses encompass sanitation and waste management (with most household wastewater discharged directly into the sea), limited access to clean water, economic dependency, and poor market/infrastructure connectivity. These weaknesses directly impact the quality of the aquatic environment, public health, and household economic resilience. Externally, there are opportunities to optimize, such as the momentum of coastal resilience policies and programs, youth engagement, environmental education (formal and informal), strengthening adaptive stilt house designs, and codifying customary values and rules to emphasize spatial rights and functions. The main threats are climate change (sea level rise and extreme weather), waste and waste pollution, coastal area conversion, and weak law enforcement against spatial planning and environmental violations.

4.2. Quantitative Analysis of Strategic Position (SWOT)

The following section presents a weighting analysis based on three sub-criteria–frequency (F), impact (D), and coverage (C)–for each SWOT factor. Weighting is performed separately for each group (S/W/O/T) to ensure that the sum of the weights within each group equals 1. Each factor is assigned three scores: frequency (F), reflecting the frequency or strength of its appearance in the findings (interview results, observations, and document coding); impact (D), representing the level of influence on health, the environment, and risks, or the magnitude of benefits for strengths or opportunities; and coverage (C), denoting the proportion of the population or area affected. Assessments use a scale of 1–4 (1 = low, 2 = moderate, 3 = high, 4 = very high) with the same rubric for all factors to ensure consistency. In this study, a modified weighting scheme was employed, assessing each SWOT factor using three components: frequency (F), impact (D), and coverage (C). These three components are then combined into a single composite score using the following formula:

$$Weight\ i = \frac{Fi \times Ci}{\sum(F \times C)group}$$

At the assessment stage, impact (D) is treated as a measure of influence; therefore, the factor score is obtained by multiplying the weight by the impact (D). The following formula is used to obtain the factor score:

$$Score\ i = Weight\ i \times Di$$

The Frequency (F) value is derived from the intensity of factor occurrences, as determined by coding recapitulation results using NVivo software, alongside the number of issues or themes identified in interview and observation data. The Impact (D) value is assessed using an impact/benefit assessment rubric, developed based on field indicators and agreed upon by the research team or experts. The Coverage (C) value represents the proportion of the population or area affected, estimated through narrative descriptions and field observations. Weighting is conducted separately for each factor group–Strengths, Weaknesses, Opportunities, and Threats–ensuring that the total weight within each group equals one (ΣW = 1). The total score, calculated by multiplying weights and values, is then used to determine the SWOT quadrant position (SO, WO, ST, or WT) and to prioritize management strategies. The F, D, and C assessment scale employs a value range of 1–4, with the following criteria:

- Frequency (F) represents the number of times an aspect appears in the narrative or observation, determined by frequency coding within NVivo software.
-
  1 = Rare/coincidental
  2 = Sometimes
  3 = Often
  4 = Very frequent/common
- Impact (D) indicates the degree to which a factor influences or benefits the outcome. Weaknesses and threats reflect the level of risk or potential loss, while strengths and opportunities describe the extent of benefit or protection.
  1 = Low (small local impact; changes are barely visible)
  2 = moderate (significant impact but limited to local areas)
  3 = High (widespread and significant impact on many households or activities)
  4 = very high/crucial (very important for quality of life, health, safety, or environmental sustainability)
- Coverage (C) indicates the area or proportion of the community affected, using the following rubrics:
  1 = Fraction;
  2 = Specific/limited groups
  3 = a lot/quite a large area
  4 = most/almost the entire community

Table 3. Internal Factor Analysis Summary matrix (IFAS)

Code	Aspect Description	Frequency (1-4)	Impact (1-4)	Coverage (1-4)	Heavy	Score (Weight x Impact)
STRENGTH						
S1	Mangrove and coastal ecosystems are generally well-maintained.	3	3	3	0.26	0.77
S2	The local wisdom associated with the 'women's forest' remains relevant.	3	3	3	0.16	0.77
S3	Strong social solidarity and a mutual cooperation culture	3	3	3	0.26	0.77
S4	Traditional institutions, including Ondoafi and tribal chiefs,	2	2	2	0.11	0.23
S5	The majority of the productive-age population possesses a high school education.	2	2	2	0.11	0.23
Total Weight S					1.00	

Total Score S						2.77
WEAKNESS						
W1	Inadequate sanitation system (discharge of domestic wastewater into the sea).	4	4	4	0.25	0.98
W2	Limited access to clean water	4	4	4	0.25	0.98
W3	Community economic diversification remains largely confined to the informal sector.	2	2	2	0.06	0.12
W4	Housing is less adaptive to a tropical climate/low thermal comfort	2	2	2	0.06	0.12
W5	Waste management still relies on government ships (2 times a week)	3	4	3	0.14	0.57
W6	There exists a duality between traditional and formal leadership.	4	4	4	0.25	0.98
Total Weight W					1.00	
Total Score W						3.75
IFAS Score (ΣS Score – ΣW Score)						**-0.98**

Source: Author's analysis (2025)

Table 4. External Factor Analysis Summary matrix (EFAS)

Code	Aspect Description	Frequency (1-4)	Impact (1-4)	Coverage (1-4)	Heavy	Score (Weight x Impact)
OPPORTUNITY						
O1	Availability of official provisions and legal frameworks requiring disaster risk reduction in coastal areas.	3	3	4	0.26	0.78
O2	The existence of active youth organizations and communities willing to partner for environmental activities, preparedness, and basic services.	3	3	3	0.20	0.59
O3	The existence of a public health education curriculum or program.	3	4	3	0.20	0.78
O4	The availability of technical standards, implementing partners, and access to external financing support stilt/water-based housing construction.	2	3	2	0.09	0.26
O5	Access to funding: village funds, CSR, and partnerships that support program implementation;	4	4	3	0.26	1.04
Total Weight O					1.00	
Total Score O						3.46
THREAT						
T1	Coastal land function is changing, and mangrove forest degradation is occurring.	3	4	3	0.28	1.13
T2	Pollution originates from refuse and waste, including riverine discharge into Youtefa Bay.	3	4	3	0.28	1.13
T3	Climate change and sea level rise	2	3	3	0.19	0.56
T4	Weak enforcement of laws and regulations	2	2	2	0.13	0.25
T5	External pressure on infrastructure development	2	3	2	0.13	0.38
Total Weight T					1.00	
Total T Score						3.44
EFAS Score (ΣO Score – ΣT Score)						**0.02**

Source: Author's analysis (2025)

Detailed internal and external factor scores are presented in Tables 3 and 4, which display the IFAS and EFAS matrices for Tobati Village.

- Strategic Placement

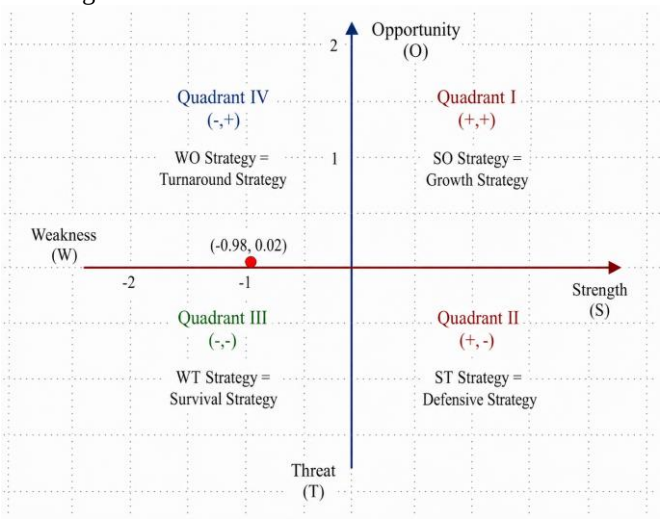

Fig. 2 Strategic position diagram of Tobati Village in the SWOT matrix. Position in the WO (Turn Around) Quadrant
Source: Author's analysis (2025)

The summary of the IFAS value is–0.98, and the EFAS value is 0.02, placing the strategy quadrant position in the WO (turnaround) quadrant. This position indicates that external opportunities remain available, yet internal weaknesses are more dominant, necessitating internal capacity strengthening to capitalize on these opportunities.

The red dot on the diagram illustrates the SWOT position of this study, located around the coordinates (IFAS ≈–0.98; EFAS ≈ 0.02), as shown in Figure 2.

4.3. Strategy Formulation and Prioritization (AHP)

The Analytic Hierarchy Process (AHP) was employed to transform SWOT results into a measurable and consistent strategic priority order by structuring the decision-making problem hierarchically and deriving priority weights through pairwise comparisons [31-33]. Assessments from each expert were arranged in a comparison matrix, combined using the geometric mean, and priority weights were subsequently calculated using the eigenvector method (row-column normalization) in Excel.

Each matrix was evaluated for consistency (CI, CR), and accepted only if CR ≤ 0.10; inconsistencies were resolved through review until acceptable levels of consistency were attained. The resulting dimension weights were: Ecology 0.4699, Social 0.2858, Institutional 0.1943, and Economic 0.0500. These findings suggest that ecological and socio-institutional factors are significantly more influential than economic factors in determining the priority of water settlement management strategies in Tobati Village.

Based on the weight of each dimension and the local weight of each strategy on those dimensions, a global weight was calculated for strategies WO1–WO5. This global weight was determined by multiplying the local weight of a strategy on a given dimension by the importance weight of that dimension, and then summing the resulting contributions. The global weight was calculated using the following formula:

$$Wglobal,i = \sum j\,(Wlocal,ij \times Wdimension,j)$$

The global weights and rankings of strategies WO1–WO5 are summarized in Table 5, and the Consistency Ratios (CRs) for all comparison matrices are presented in Table 6.

Table 5. Global weights of WO1–WO5 strategies and overall priority order

Strategy	Local Ecological Weight	%	Rank.
WO1 Watertight communal sanitation + floating TPS (participatory)	0.340	34%	1
WO3 Co-governance: integration of customary and formal institutions	0.205	20.5%	2
WO2 Access to clean water: Rainwater harvesting + solar powered pumps and filtration	0.191	19.1%	3
WO5 Entrepreneurship incubator + access to microfinance	0.134	13.4%	4
WO4 Adaptive stilt house renovation (concrete foundation)	0.130	13%	5

Source: Author's analysis (2025)

Table 6. Summary of CR values

Matrix	CR
Dimensions (Ecology–Social–Economy–Institutional)	0.061
Alternatives in the ecological dimension	0.050
Alternatives in the economic dimension	0.094
Alternatives in the social dimension	0.089
Alternatives in the institutional dimension	0.089

Source: Author's analysis (2025)

The global priority order of water settlement management strategies in Tobati Village, utilizing an ecological settlement approach, is as follows: WO1 is ranked highest, followed by WO3, WO2, WO5, and WO4. Specifically, strategy WO1 (communal sanitation plus floating TPS) is the most recommended initial implementation, followed by WO3 (institutional integration) as the second priority. WO1 holds the highest priority due to its superior ecological and social dimensions–the two dimensions with the greatest weight–and its relatively strong institutional framework. WO3 is ranked second, primarily due to its socio-institutional strength, which contributes to program sustainability. WO2 is ranked third, exhibiting ecological superiority and energy efficiency, but with a limited socio-institutional contribution. WO5 and WO4 are ranked fourth and fifth, respectively, and are considered important supporting or follow-up strategies to be implemented after the environmental and governance foundations have been established.

All matrices have passed the consistency test with a threshold of $CR \leq 0.10$, which indicates that the experts' assessments are logically consistent and the resulting weights are reliable for decision making.

4.4. Policy Implications

The policy implications of the strategic priorities suggest that interventions in Tobati Village should commence with WO1 and WO3. WO1 focuses on the development of watertight communal sanitation, incorporating floating waste collection points, and WO3 emphasizes co-governance through the integration of customary and formal institutions. These two initiatives are designed in tandem: the development of sanitation and waste management is integrated into existing city programs (KOTAKU and STBM) while utilizing a participatory approach. Furthermore, a co-governance forum will be established to facilitate the development of local regulations, settlement zoning, and mangrove forest protection between customary institutions and the government.

Once environmental conditions and institutional governance are strengthened, interventions WO2 (improving access to clean water through rainwater harvesting and solar-powered pumps and filtration) and WO5 (entrepreneurship incubators and microfinance schemes) can be developed as intermediate steps to improve water access and stimulate the local economy.

Over the long term, the WO4 (adaptive stilt house renovation) project is being implemented in stages through pilot projects and housing assistance schemes, enhancing the physical quality of houses and increasing their resilience to climate change. This phased and integrated approach is anticipated to yield environmental improvements, strengthen institutional and economic capacity, and improve housing quality, ultimately contributing to the realization of an eco-settlement concept in Tobati Village.

4.5. The Latent Capacity Paradox in the WO Position

The finding that Tobati Village occupies a strategic Weakness-Opportunity (WO) position suggests that internal weaknesses remain dominant, yet simultaneously reveals a paradox of latent capacity. A negative IFAS value indicates that structural weaknesses–specifically in sanitation, clean water, housing quality, and technical governance–are more prominent than strengths. However, the most significant internal strengths stem not from physical infrastructure, but from social capital and traditional institutions (S2, S3, S5), which possess high weight and serve as crucial foundations, though they have not been fully optimized to counteract these weaknesses. Consequently, the WO position should not be interpreted solely as a "weak" one, but rather as a foundation for change: internal weaknesses are acknowledged while external opportunities are leveraged to mobilize existing social and institutional capacity. This aligns with the *capability approach*, which defines development as an expansion of substantive freedom, rather than simply an increase in utility or income [34]. From this perspective, the primary objective of policy is to realize latent capabilities, enabling them to mitigate structural weaknesses through a targeted Weakness-Opportunity (WO) strategy.

4.6. The Central Role of Institutions: A Bridge Between Customary and Formal

Although AHP results identify the ecological dimension as the highest priority, institutional capacity is crucial. Strategy WO1, the top priority, explicitly requires active collaboration between customary and formal institutions for the planning, funding, and management of watertight communal sanitation and floating waste collection points. Furthermore, other highly ranked strategies, such as strengthening adaptive stilt house design and codifying customary spatial rules, rely on hybrid institutional arrangements that link customary authority with city regulations. These findings reinforce the view that improving physical environmental infrastructure in indigenous communities' waterfront settlements is inseparable from strengthening shared governance between customary and formal institutions.

4.7. Research Limitations

This study has several limitations. First, the perceptions collected are cross-sectoral and represent a single point in time, potentially leading to temporal changes. Second, while the expert panel was selected using strict criteria, the assessments provided contain an element of subjectivity. Third, this study does not include an analysis of the costs and benefits associated with the proposed strategies. Therefore, further research is recommended to (1) conduct longitudinal research to monitor dynamics of change; (2) involve a larger panel of experts with more diverse backgrounds; and (3) conduct economic feasibility studies for each priority strategy prior to full-scale implementation.

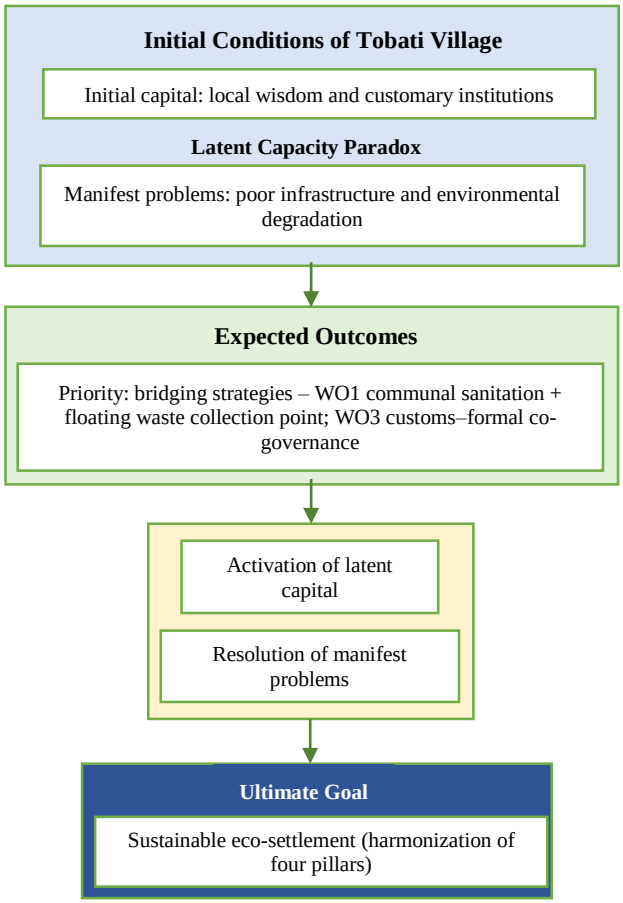

Fig. 3 Conceptual framework of the "Latent Capacity Paradox"
Source: Author's analysis (2025)

4.8. Conceptual Framework and Theoretical Contributions

This section presents a conceptual framework developed from the research findings and explains its theoretical contributions to the existing literature. These research findings led to the development of a conceptual framework called the "Latent Capacity Paradox Framework" (Figure 3). This framework explains a situation where a community (Tobati Village) simultaneously exhibits low well-being indicators but possesses strong social capital and customary institutions to support its members. This paradox arises from the unactivated latent capacity–socio-cultural capital–which has not been leveraged to address the physical environmental challenges evident in the area.

This framework proposes that in such circumstances, the most effective interventions are not simply technocratic interventions that directly target the real problems in isolation (e.g., a physical sanitation project alone), but rather "bridging strategies." In the context of the Tobati Village WO position, the bridging strategy is primarily embodied in WO1 (watertight communal sanitation with participatory floating waste collection points) and WO3 (shared governance between customary and formal institutions). These two strategies are deliberately designed to: (1) address structural weaknesses, including sanitation, waste management, and technical governance; and (2) integrate latent capacities–such as local wisdom, customary norms, and customary institutions–with external resources and opportunities, including government programs, environmental funding, and mentoring forums. This approach activates latent capital and strengthens the community's capacity to sustainably solve physical and environmental problems. Subsequently, with more robust ecological and institutional foundations, economic strategies, such as the development of micro-enterprises and community-based ecotourism, can be implemented based on a strengthened eco-settlement concept.

4.9. Theoretical Contributions

This research makes three main contributions to the development of the literature, namely.

1) This research expands the concept of eco-settlement by demonstrating that, within indigenous communities, the institutional pillar encompasses not only formal governance but also mechanisms for integrating and empowering indigenous institutions. Institutional capacity within the eco-settlement framework must be reformulated as a hybrid capacity that explicitly recognizes and bridges formal and informal systems [35-37].
2) The second contribution examines the relationship between strong sustainability and socio-cultural capital. Strong sustainability necessitates boundary mechanisms to protect crucial natural capital [7]. The findings of this study indicate that, in some instances, socio-cultural capital–such as local wisdom–can effectively fulfill this boundary function [36, 38]. For example, the customary law of " *women's forests* " in Tobati Village demonstrates how social capital can limit the overexploitation of coastal resources. This suggests that strong sustainability can be achieved not only through top-down regulation but also by strengthening bottom-up, culturally based conservation mechanisms [7, 11, 36].
3) This study demonstrates that when applying SWOT–AHP to complex sociocultural contexts, factor identification extends beyond the descriptive level and requires

exploring the tensions and paradoxes between internal and external factors [36, 37]. By examining the combination of dominant internal weaknesses and external opportunities (WO positions), this analysis identifies the "Latent Capacity Paradox"–a situation where a community appears physically weak but is socio-institutionally strong. The recognition of this paradox forms the basis for formulating a more innovative and transformative strategy, termed "bridging," compared to conventional strategies that merely address weaknesses or directly pursue economic opportunities.

5. Conclusion

This study advances ecological settlement research by shifting from environmental quality assessments to strategic decision-making and policy prioritization for Indigenous water-based settlements. Building on previously published findings from Fuzzy Dynamic Modelling (FDM)-based diagnostic assessments, this study demonstrates how validated aspects of ecological settlements can be operationalized into implementable management strategies and ranked using the SWOT-AHP framework.

The study's results indicate that Tobati Village occupies a strategically advantageous Weakness-Opportunity (WO) position, characterized by internal weaknesses concerning sanitation, access to clean water, housing quality, and institutional coordination, alongside external opportunities such as policy support and funding. The prioritization process identified a watertight communal sanitation system with participatory floating waste collection points as the most critical intervention, followed by strategies designed to strengthen co-governance between customary and formal institutions. These findings confirm that improvements to physical environmental conditions are inextricably linked to institutional integration and co-governance.

From a theoretical perspective, the introduction of the Latent Capacity Paradox framework offers a novel lens for understanding why strong socio-cultural capital and customary institutions do not invariably lead to improved environmental outcomes. This framework highlights the need for "bridging strategies" that connect latent sociocultural capacities with formal governance structures and targeted infrastructure interventions. This study expands the concept of ecological settlements by emphasizing the central role of hybrid institutional capacity in conservation-sensitive coastal settlements.

These findings offer a structured decision-making pathway for policymakers and practitioners seeking to prioritize interventions under conditions of limited resources and institutional complexity. Although this study is context-specific to Tobati Village, the proposed approach and conceptual framework may be applied to other indigenous and water-based settlements facing similar challenges. Future research should test the implementation and long-term effectiveness of the prioritized strategies, incorporate economic feasibility analyses, and apply the Latent Capacity Paradox framework in comparative coastal settlement contexts.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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Author Contribution

Author 1 was responsible for the initial concept and design of the study, fieldwork implementation, data analysis, and the drafting of the manuscript. Author 2 contributed to the development of the conceptual framework and the critical review of the manuscript. Author 3 contributed to data interpretation, the literature review, and substantial editing of the manuscript. All authors have read and approved the final version of the manuscript.

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