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Coastal Infrastructure and Social Dynamics in the Semarang – Demak Toll Road Project

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ABSTRAK

Infrastructure is a key driver of regional development, yet its long-term benefits depend on sustainable planning and governance. The Semarang–Demak toll road, a 27-kilometer coastal corridor completed between 2019 and 2025, presents a critical case study as it traverses areas highly vulnerable to land subsidence, flooding, and erosion. Numerous studies have examined the engineering and hydrodynamic aspects of coastal infrastructure in northern Java. However, limited attention has been given to how affected coastal communities perceive environmental change, governance transparency, and their participation in infrastructure decision-making processes. This study examines the project's environmental dynamics and social dimensions by combining a review of scholarly literature, books, and technical reports with an explanatory quantitative survey of affected residents in Semarang and Demak. The results indicate that most respondents recognize severe degradation of their coastal environment, including land loss and heightened exposure to tidal flooding. However, awareness of government policies and programs related to coastal management remains low, with 31.8% of respondents falling into the "limited policy awareness" category. This limited policy knowledge reflects broader environmental governance weaknesses, particularly transparency and communication. Furthermore, community participation in decision-making processes remains limited (56.8%), indicating that many residents feel excluded from the planning and implementation of infrastructure projects that directly affect their livelihoods. Despite this limited engagement, community perceptions reveal a strong ecological awareness shaped by direct experience with coastal hazards. The contrast between high environmental awareness and low policy involvement signals a growing risk of social resistance to coastal infrastructure if participatory mechanisms are not improved. Therefore, strengthening communication, transparency, and inclusive governance is essential to align infrastructure development with community resilience and long-term sustainability.

Kata Kunci: Semarang–Demak toll road; coastal infrastructure; land subsidence; environmental governance; community participation

INTRODUCTION

For coastal communities in Semarang and Demak, vulnerability is a persistent challenge affecting settlements, livelihoods, and social resilience (Sayekti, 2025). Recurrent tidal flooding, shoreline retreat, and land subsidence have significantly altered the coastal landscape over recent decades (Ibrahim et al., 2026). In areas such as Sayung District, severe erosion has led to the loss of settlements and productive land, while accretion-prone zones remain vulnerable to unstable sediment dynamics, chronic inundation, and ongoing subsidence (Arya et al., 2018; Dalimunthe et al., 2025).

Previous studies in the Semarang–Demak coastal region have primarily focused on physical coastal processes, including shoreline change, hydrodynamics, land subsidence, mangrove degradation, and coastal engineering interventions. Rapid urbanization, industrial expansion, intensive aquaculture, and excessive groundwater extraction have been identified as key drivers of accelerated land subsidence and increasing tidal flood exposure along the northern coast of Java (Bosserelle et al., 2022). At the same time, large-scale conversion of mangroves into aquaculture ponds and infrastructure corridors has weakened natural coastal defenses, exacerbating shoreline instability and coastal erosion (Solahudin et al., 2024). While these studies have substantially advanced understanding of the biophysical drivers of coastal degradation, they rarely integrate physical vulnerability with social dimensions, particularly community perceptions, public participation, and governance capacity in responding to coastal change.

The development of the Semarang–Demak Toll Road further illustrates the complexity of coastal infrastructure development in environmentally sensitive areas. The toll road has been promoted as a strategic adaptation measure to reduce tidal flooding and improve regional connectivity. Nevertheless, several recent observations suggest that the structure may also alter coastal hydrodynamics, sediment transport pathways, and local drainage systems, potentially generating new environmental pressures in adjacent coastal areas (Solahudin et al., 2024). While engineering-based studies have discussed the project's hydrodynamic implications, limited attention has been given to how coastal communities perceive these environmental changes, how they evaluate government responses, and how governance mechanisms influence local adaptation capacity.

This gap is important because coastal vulnerability is determined not only by physical exposure but also by social awareness, institutional communication, and community participation in decision-making processes. In many coastal regions, weak governance transparency and limited stakeholder involvement increase the risk of maladaptive infrastructure development, particularly when local ecological knowledge is insufficiently incorporated into planning processes. Understanding the interaction between physical coastal change and community perceptions is essential for developing sustainable and socially inclusive coastal management strategies.

This study offers a more holistic framework for assessing the long-term sustainability of coastal infrastructure by linking physical vulnerability with socioeconomic and governance dimensions and contributes a novel interdisciplinary perspective to coastal management studies in northern Java.

Literature review

Coastal vulnerability in the Semarang–Demak region is a complex socio-ecological issue driven by interactions among environmental change, infrastructure development, and governance capacity. Recurrent tidal flooding, land subsidence, shoreline retreat, and ecosystem degradation have significantly altered both the physical and socioeconomic conditions of coastal communities along the northern coast of Java (Putiamini et al., 2023). Understanding these impacts requires an integrated perspective that links environmental processes with social vulnerability, institutional responses, and adaptive capacity.

This study adopts the Socio-Ecological Systems (SES) framework, which views coastal regions as interconnected systems where ecological dynamics and human activities continuously influence one another (Refulio-Coronando et al., 2021). Within this framework, environmental degradation, including land subsidence, mangrove loss, and shoreline erosion, is closely associated with urbanization, groundwater extraction, aquaculture expansion, and coastal infrastructure development. These interactions have intensified tidal flooding, causing damage to settlements, disrupting livelihoods, accelerating land-use change, and reducing ecosystem services that support local communities (Putra & Handayani, 2013; Kusumaningsih et al., 2023; Diana, 2024).

The impacts of these changes can also be interpreted through Resilience Theory, which emphasizes the ability of communities to absorb disturbances and adapt to changing conditions. Repeated exposure to flooding and erosion has weakened socioeconomic resilience by reducing income stability, damaging infrastructure, increasing adaptation costs, and generating public health risks (Asrofi & Hadmoko, 2017; Sarkar et al., 2026). While coastal infrastructure projects such as the Semarang–Demak Toll Road are intended to reduce flood risk and improve connectivity, they may also alter hydrodynamic and sediment transport processes, potentially creating new environmental pressures (Nazarnia et al., 2020).

These challenges highlight the importance of Adaptive Governance and Integrated Coastal Zone Management (ICZM), which emphasize participatory, flexible, and cross-sectoral approaches to coastal management (Djalante, 2012; Bremer & Glavovic, 2013; Zhang et al., 2024). However, previous studies in the Semarang–Demak region have largely focused on physical processes and engineering solutions, with limited attention to the integration of physical vulnerability, community perceptions, and governance mechanisms. Consequently, the social dimensions of adaptation and coastal management remain insufficiently understood.

RESEARCH METHODS

Study Site

The study was conducted along the Semarang–Demak coastal corridor on the northern coast of Central Java, Indonesia, an area highly affected by tidal flooding, shoreline change, and land subsidence (Figure 1). Field observations and interview surveys were carried out in coastal villages of Genuk District (Tambakrejo, Terboyo Kulon, and Trimulyo) and Sayung District (Sriwulan, Bedono, and Timbulsloko), selected to represent diverse coastal conditions, including erosion, accretion, mangrove degradation, tidal inundation, and areas influenced by the Semarang–Demak Toll Road project.

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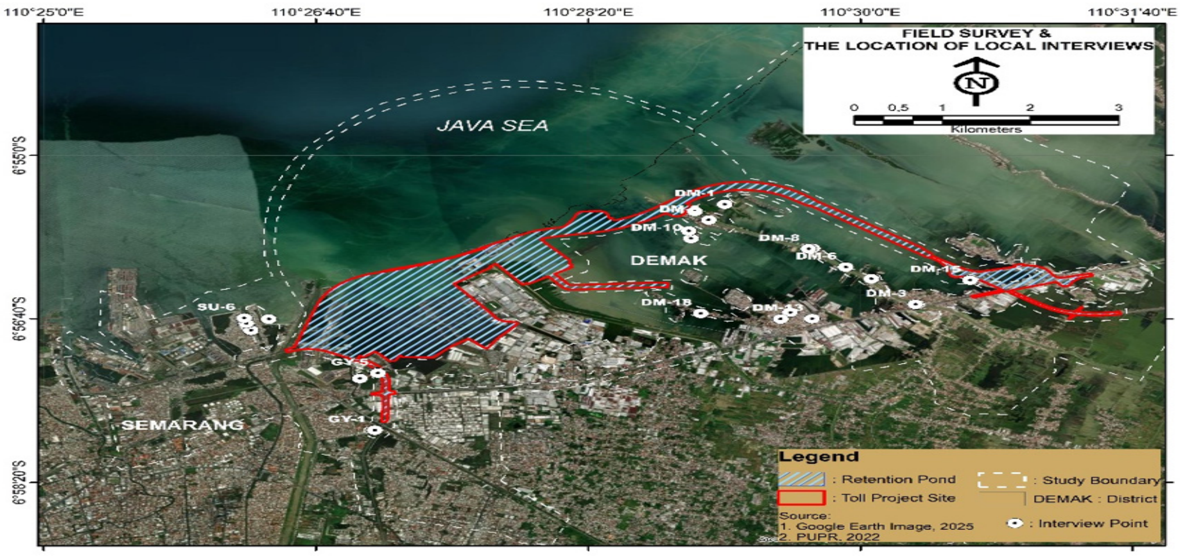

Figure 1. Study Area and the Location of Random Sampling Interviews.
(Source: Google Earth Image 2025, Ministry of Public Works and Housing 2022).

The region consists of low-lying alluvial plains, tidal flats, and estuarine environments that are highly dynamic due to mixed tides, monsoonal forcing, and intensive human activities. Land subsidence driven by groundwater extraction, urbanization, and sediment compaction has substantially increased tidal flood exposure (Abidin et al., 2011).

Socio-economically, the area supports major urban, industrial, fisheries, aquaculture, and agricultural activities, while coastal communities remain highly vulnerable to the impacts of erosion, flooding, mangrove loss, and coastal infrastructure development (Marfai et al., 2015; Solihuddin et al., 2021). Overall, the study area represents a coastal socio-ecological system experiencing significant pressures from both natural processes and human-induced environmental change.

Field Data Collection

sPrimary data were collected during July–August 2025 through field surveys, structured interviews, and focus group discussions (FGDs), complemented by secondary data sources (Table 1). Field surveys involved direct observations of shoreline dynamics, tidal flooding impacts, mangrove conditions, coastal infrastructure, and land-use change in selected coastal areas of Semarang and Demak. GPS coordinates and photographic records were collected to support qualitative assessments of erosion, accretion, and land-subsidence impacts.

Structured interviews were conducted with 88 respondents, including fishers, aquaculture farmers, traders, entrepreneurs, housewives, and village representatives whose livelihoods depend on coastal resources.

Table 1. Field Data Collection Summary.

Data Collection Method	Coverage Area	Number of Locations / Participants	Main Variables / Topics Observed	Sampling / Selection Method
Field Survey	Genuk District (Semarang) and Sayung District (Demak)	18 observation points (Figure 1)	Shoreline condition, erosion/ accretion features, tidal flooding extent, mangrove condition, land use, coastal infrastructure, and evidence of land subsidence	Observation points were selected purposively to represent different coastal conditions and areas influenced by the Semarang–Demak Toll Road
Structured Interviews	Coastal villages in Semarang and Demak	88 respondents consisting of fishers, aquaculture farmers, traders, housewives, entrepreneurs, community leaders, and local residents	Perceptions of coastal change, tidal flooding impacts, environmental degradation, livelihood disruption, adaptation strategies, and coastal management policies	Respondents were selected using purposive and random sampling approaches based on livelihood relevance and willingness to participate
Focus Group Discussions (FGDs)	Village-level discussions in Semarang and Demak	2 FGD groups involving local communities, village officials, and environmental stakeholders	Coastal vulnerability, shoreline change, tidal flooding, mangrove degradation, impacts of the Semarang–Demak Toll Road, and community adaptation priorities	Participants were selected to represent different stakeholder groups within the coastal communities

Source: Field data collection, 2025.

The interviews explored perceptions of environmental change, flood impacts, livelihood vulnerability, coastal management policies, and local adaptation strategies.

Two village-level focus group discussions (FGDs) were held to validate survey findings and gather stakeholder perspectives on coastal hazards, shoreline change, tidal flooding, mangrove degradation, and the perceived impacts of the Semarang–Demak Toll Road on coastal sustainability and community resilience.

Secondary data were collected from government agencies, published reports, and satellite imagery, including information on shoreline change, tides, land subsidence, land use, and socioeconomic conditions. These datasets were integrated with primary survey results to support the coastal vulnerability assessment and analysis of coastal change in the Semarang–Demak region.

Data Analysis Methods

Descriptive Statistical Analysis

Descriptive analysis was used to systematically summarize and interpret the findings of the field surveys, interviews, and FGD. Data from field surveys were analyzed by organizing observations into thematic categories and presenting them in tabular and narrative forms to describe site characteristics and observed phenomena.

Interview data were analyzed by classifying respondents' answers based on recurring themes, patterns, and perspectives relevant to the research objectives. The frequency of similar responses was identified to highlight the dominant views and significant concerns of the respondents. The FGD findings were analyzed through thematic content analysis, where discussion results were categorized according to major topics, agreements, differing opinions, and participants' recommendations.

The results of these analyses were then interpreted descriptively to explain the relationships among the observed conditions, stakeholder responses, and collective insights from the discussions. This approach provides a comprehensive understanding of the research context and supports the formulation of conclusions and recommendations based on empirical field evidence.

Coastal Vulnerability Index (CVI)

Coastal vulnerability was assessed using the Smartline methodology of Sharples et al. (2009), comprising indicative mapping, regional assessment, and site-specific assessment of geological, geomorphological, topographic, oceanographic, and climatic conditions. The analysis considered both alongshore and cross-shore coastal characteristics and was adapted to local conditions.

Nine parameters were included in the Coastal Vulnerability Index (CVI): coastal relief, geomorphology, mean tidal range, shoreline change rate, relative sea-level change, mean wave height, coastal slope, land subsidence, and land use. Vulnerability scores were calculated using the CVI approach of Gornitz (1990), with parameter values ranging from 1 (low) to 3 (high). The integrated Smartline–CVI approach enabled the production of coastal vulnerability maps classified into five categories: very low, low, moderate, and high vulnerability.

SWOT Analysis

To complement the Coastal Vulnerability Index (CVI), a SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis was conducted to evaluate the relationships among physical vulnerability, community perceptions, and coastal governance (Table 2). The analysis integrated CVI results, shoreline change and land subsidence data, field observations, interviews, FGDs, and community perception surveys into a strategic coastal management framework.

Physical vulnerability factors, including shoreline retreat, tidal flooding, mangrove degradation, and land subsidence, were identified from spatial and CVI analyses, while qualitative data were used to assess socioeconomic impacts, public awareness, participation, and perceptions of the Semarang–Demak Toll Road. These variables were classified into internal (strengths and weaknesses) and external (opportunities and threats) factors.

The SWOT assessment involved five experts and stakeholders representing coastal engineering, environmental science, spatial planning, local government, and coastal communities. By integrating physical and social dimensions, the SWOT framework was used to identify management priorities and develop adaptive, ecosystem-based coastal management strategies that enhance resilience, community participation, and governance sustainability.

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Table 2. Indicators Used in the SWOT Analysis.

SWOT Component	Number of Indicators	Indicators
Strengths (S)	5	Presence of mangrove vegetation cover, existence of tidal flats as natural buffers, protective function of the toll road/sea dike infrastructure, existing community-based adaptation practices, availability of coastal monitoring data
Weaknesses (W)	5	High land subsidence rate, shoreline retreat intensity, dependence on groundwater extraction, degradation of mangrove ecosystems, limited drainage and sediment management capacity
Opportunities (O)	5	Potential for mangrove restoration programs, implementation of integrated coastal zone management, policy support for climate adaptation, availability of ecosystem-based adaptation funding, opportunities for sediment nourishment and hybrid engineering
Threats (T)	5	Accelerated sea-level rise, increasing frequency of tidal flooding, continued urban expansion in coastal zones, coastal erosion intensification, risk of maladaptation due to excessive dependence on hard infrastructure

Source: Modified from Chen and Qiu, 2024.

RESULTS AND DISCUSSION

Local Community Perceptions of the Semarang–Demak Toll Road Development

An analysis of local community perceptions regarding the development of the Semarang–Demak Toll Road indicates a complex interaction between economic expectations, environmental concerns, and public participation in coastal management (Figure 2 and Table 3). Based on interviews with 88 respondents, most local residents perceive the coastal area as having high economic potential, as reflected by the relatively high average score for Question 1 (Q1 = 4.11 out of 5). This result indicates that coastal communities still consider fisheries, aquaculture, transportation access, and coastal-based economic activities as important sources of livelihood and regional development opportunities.

Simultaneously, respondents also expressed strong concern regarding the environmental degradation of the coastal area. Question 2 (Q2) regarding declining environmental quality obtained an average score of 4.11, indicating that most respondents perceive significant environmental deterioration in recent years. Field observations and interview responses suggest that this perception is associated with increasing coastal erosion, tidal flooding (rob), shoreline retreat, and changes in coastal ecosystems following intensive coastal development and land-use changes.

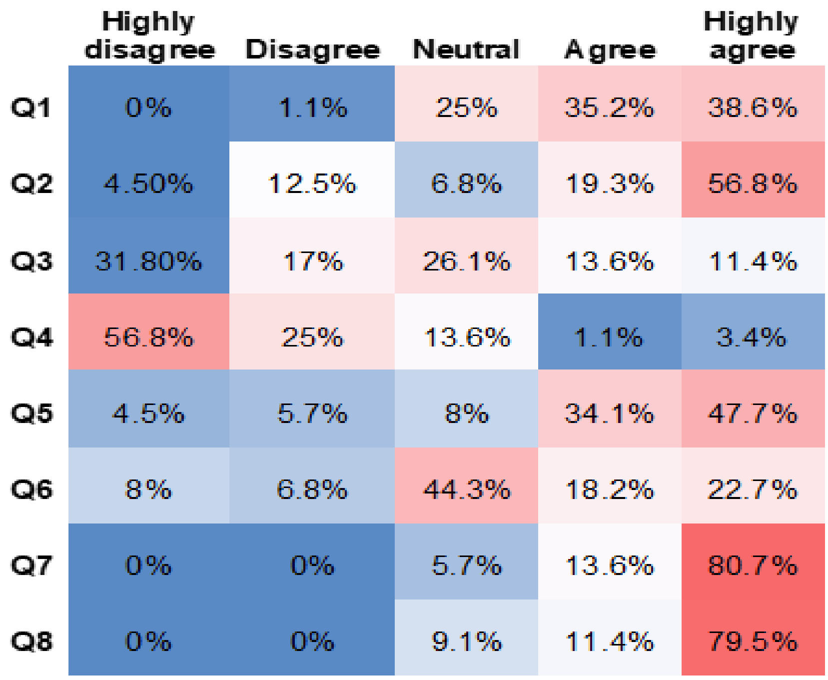

Figure 2. Heatmap Chart of Local Society's Perception Regarding the Development of Semarang–Demak Toll Road.
Source: Data analysis, 2025.

Table 3. Descriptive Statistical Results of Local Community Perceptions Regarding the Development of the Semarang–Demak Toll Road Based on Responses From 88 Respondents Using A 5-Point Likert Scale.

Question Code	Perception Indicator	Mean	Std. Dev.	Min	Max
Q1	The coastal area has high economic potential	4.11	0.82	2	5
Q2	The quality of the coastal environment has declined in recent years	4.11	1.25	1	5
Q3	Awareness of government policies/programs related to coastal management	2.56	1.36	1	5
Q4	Community involvement in coastal management decision-making	1.69	0.99	1	5
Q5	The area is vulnerable to coastal erosion and tidal flooding	4.15	1.09	1	5
Q6	Current government programs are effective in addressing environmental vulnerability	3.41	1.15	1	5
Q7	Strengthening community participation is important in coastal management	4.75	0.55	3	5
Q8	Support for new policies based on local potential	4.70	0.63	3	5

Note: Likert scale: 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, and 5 = strongly agree. Total respondents (n) = 88.

Source: Data analysis, 2025.

Community awareness of government policies and coastal management programs remains relatively limited. The average score for Question 3 (Q3) was only 2.56, indicating that many respondents have insufficient knowledge regarding existing coastal governance policies or adaptation programs. Perceptions of community involvement in coastal management decision-making processes were even lower, with Question 4 (Q4) obtaining the lowest average score among all indicators (1.69). This result shows that local communities generally feel excluded from coastal development and environmental management planning and management processes.

In contrast, the awareness of coastal vulnerability is relatively high. Respondents strongly agreed that their area was vulnerable to abrasion and tidal flooding, as evidenced by the high average score for Question 5 (Q5 = 4.15). This perception is consistent with the physical conditions observed along the Semarang–Demak coastline, which has experienced severe land subsidence, recurrent tidal inundation, and shoreline changes over recent decades.

Perceptions regarding the effectiveness of current government programs in addressing environmental vulnerability were moderate, with an average score of 3.41 for Question 6. Although some respondents acknowledge the presence of government interventions, many still consider the implemented measures insufficient to significantly reduce environmental risks and improve coastal resilience.

The strongest responses were recorded for community participation and locally based policy support. Question 7 (Q7), concerning the importance of strengthening community roles in coastal management, achieved the highest average score (4.75), while Question 8 (Q8), regarding support for policies based on local potential, also showed high agreement (4.70). These results demonstrate strong public support for participatory, community-based, and locally adaptive coastal management approaches.

Coastal Vulnerability assessments

The vulnerability assessment indicates that the Semarang–Demak coast is a highly stressed socio-ecological system affected by shoreline retreat, land subsidence, tidal flooding, and environmental degradation. High vulnerability is concentrated along the eastern Semarang and Sayung coastlines, while moderate vulnerability occurs in Genuk and lower vulnerability in more protected inland areas (Figure 3). Notably, several planned sections of the Semarang–Demak Toll Road overlap with moderate- to high-vulnerability zones, highlighting potential risks to coastal dynamics.

The CVI results reveal a clear eastward increase in vulnerability. North Semarang and Gayamsari exhibit relatively low vulnerability, whereas Genuk shows a more heterogeneous pattern. Sayung is the most critical hotspot, with nearly half of its coastline (48.87%) classified as highly vulnerable. This pattern is closely linked to severe land subsidence, rapid shoreline retreat, persistent tidal inundation, and ecosystem degradation.

Field observations (Figure 4) support these findings, documenting widespread flooding, housing damage, and settlement abandonment. These impacts are compounded by limited infrastructure, restricted access to services, and low community participation in coastal governance, resulting in elevated social vulnerability and reduced adaptive capacity.

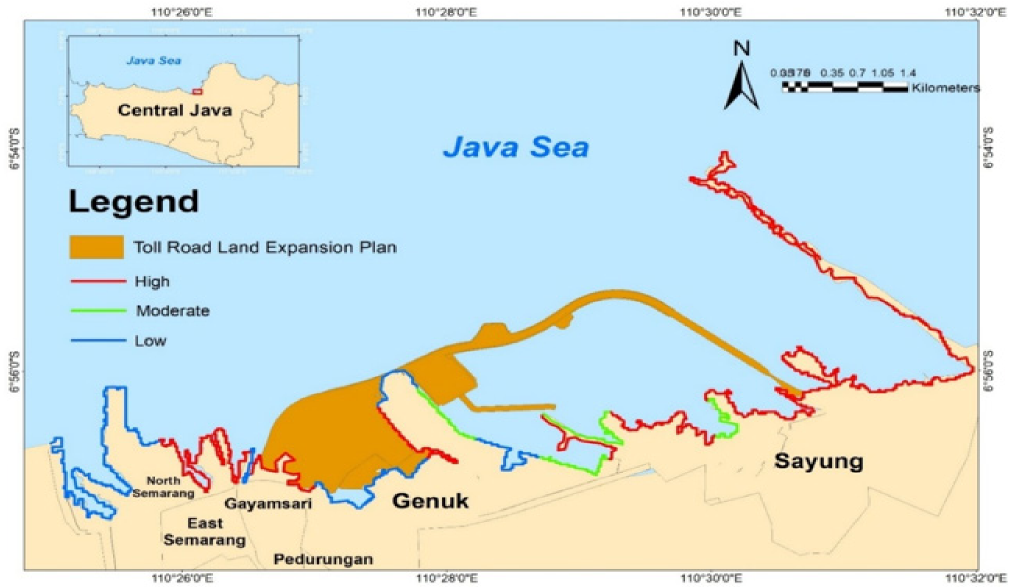

Figure 3. Coastal Vulnerability Analysis Result.
Source: Data analysis, 2025.

Figure 4. The Documentation of Eroded Coastal Areas and Toll Road Project in Semarang and Demak.
Source: Kompas, 2026.

Policy Analysis Results

The SWOT analysis was conducted to evaluate the interactions among physical coastal vulnerability, infrastructure development, socioeconomic conditions, and governance capacity along the Semarang–Demak Coastal Area. To strengthen the analytical rigor of the policy assessment, the SWOT framework was quantitatively supported using the Internal Factor Analysis Summary (IFAS) and External Factor Analysis Summary (EFAS) matrices. The analysis integrated results from the Coastal Vulnerability Index (CVI), shoreline change and land subsidence mapping, community perception surveys, interviews, and Focus Group Discussions (FGDs).

Each SWOT indicator was assigned a weight ranging from 0.00 to 1.00 according to its relative importance, based on expert judgment, field observations, and stakeholder discussions. The total weights for internal factors (strengths and weaknesses) and external factors (opportunities and threats) were each standardized to 1.00. Subsequently, each variable was assigned a rating from 1 to 4, where higher values represented stronger positive influence for strengths and opportunities, or greater severity for weaknesses and threats. The weighted score for each factor was calculated by multiplying the assigned weight by its corresponding rating. The quantitative results of the internal factors are presented in the IFAS matrix (Table 4), while the external factors are summarized in the EFAS matrix (Table 5).

As shown in Table 4, the IFAS analysis identified several dominant strengths, including the strategic economic role of the Semarang–Demak Toll Road corridor, the partial flood protection function of the toll road embankment, and the adaptive capacity of local communities through housing elevation and aquaculture adjustments. High public awareness of coastal hazards observed during surveys and FGDs also contributed positively to local resilience. However, these strengths were offset by significant weaknesses, including severe land subsidence, shoreline retreat, mangrove degradation, concentration of settlements within flood-prone zones, and continued dependence

Table 4. Internal Factor Analysis Summary (IFAS) Matrix.

Internal Factors	Weight	Rating	Weighted Score
Strengths (S)			
Presence of the Semarang–Demak Toll Road as both transport corridor and partial sea-dike protection	0.14	4	0.56
Strategic Pantura economic corridor supporting regional logistics and trade	0.11	4	0.44
Existing community adaptation practices (house elevation, aquaculture adjustments)	0.10	3	0.30
Localized accretion indicating ongoing natural sediment deposition processes	0.07	3	0.21
High public awareness of coastal hazards from surveys and FGDs	0.08	3	0.24
Total Strength Score	**0.50**		**1.75**
Weaknesses (W)			
High land subsidence rates due to groundwater extraction	0.14	4	0.56
Severe shoreline erosion in Sayung coastal sectors	0.12	4	0.48
Loss of mangroves and tidal flats reducing ecosystem services	0.09	3	0.27
Settlements and industries concentrated in flood-prone zones	0.08	3	0.24
Dependence on hard infrastructure with limited ecosystem-based adaptation	0.07	3	0.21
Limited public participation and policy dissemination	0.05	2	0.10
Total Weakness Score	**0.55**		**1.86**

Source: Data analysis, 2025.

Table 5. External Factor Analysis Summary (EFAS) Matrix.

External Factors	Weight	Rating	Weighted Score
Opportunities (O)			
Potential for mangrove rehabilitation and ecosystem restoration	0.14	4	0.56
Integrated sediment management strategies	0.11	3	0.33
Strong national policy support for climate adaptation and coastal resilience	0.10	4	0.40
Community-based monitoring and participatory governance initiatives	0.08	3	0.24
Opportunity to transfer lessons to other subsiding delta regions	0.07	3	0.21
Total Opportunity Score	**0.50**		**1.74**
Threats (T)			
Accelerating sea-level rise and climate change impacts	0.15	4	0.60
Maladaptive impacts from altered sediment transport processes	0.11	4	0.44
Continued urban and industrial expansion in flood-prone areas	0.10	3	0.30
Declining fisheries and aquaculture productivity	0.08	3	0.24
Increasing frequency of extreme weather events and storm surges	0.06	3	0.18
Total Threat Score	**0.50**		**1.76**

Source: Data analysis, 2025.

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on hard engineering approaches with limited ecosystem-based adaptation integration. The IFAS calculation produced a total strength score of 1.75 and a total weakness score of 1.86, resulting in an internal factor score of –0.11, indicating that existing weaknesses slightly outweigh the current strengths of the coastal system.

Meanwhile, the EFAS matrix presented in Table 5 demonstrates that significant opportunities remain available to improve long-term coastal resilience. These opportunities include mangrove rehabilitation programs, integrated sediment management strategies, increasing national support for climate adaptation, and the development of participatory coastal governance initiatives. Nevertheless, the coastal region also faces severe external threats, such as accelerating sea-level rise, maladaptive impacts associated with altered sediment transport processes, continued industrial expansion in flood-prone areas, declining fisheries productivity, and increasing storm intensity. The EFAS analysis generated a total opportunity score of 1.74 and a total threat score of 1.76, resulting in an external factor score of –0.02, suggesting that environmental and climate-related threats remain slightly more dominant than the available adaptive opportunities.

The combined IFAS and EFAS scores were subsequently plotted into the SWOT quadrant matrix to determine the strategic position of the Semarang–Demak coastal system. The results indicate that the study area is positioned within the Defensive/Adaptive Quadrant (WT-oriented condition), reflecting a coastal system characterized by high environmental pressure and institutional limitations. Consequently, strategic priorities should emphasize minimizing vulnerabilities while strengthening adaptive governance and ecosystem-based coastal management.

Based on the SWOT strategic matrix (Table 6), four strategic policy directions were formulated. The SO (Strength–Opportunity) strategies focus on optimizing existing infrastructure and community adaptive capacity to support mangrove rehabilitation and ecosystem-based coastal protection. The ST (Strength–Threat) strategies emphasize strengthening infrastructure management and hazard preparedness to reduce risks from sea-level rise, erosion, and storm surges. The WO (Weakness–Opportunity) strategies prioritize improvements in participatory governance, sediment management, and ecological restoration to address environmental degradation and institutional weaknesses. Finally, the WT (Weakness–Threat) strategies highlight the importance of reducing dependence on hard engineering approaches, strengthening groundwater extraction regulation, and implementing Integrated Coastal Zone Management (ICZM) to minimize maladaptive risks and long-term socioeconomic vulnerability.

Discussion

The integrated results of the descriptive analysis, Coastal Vulnerability Index (CVI), and SWOT assessment reveal that the Semarang–Demak coastal region faces interconnected environmental, socioeconomic, and governance challenges. While the Semarang–Demak Toll Road supports regional economic growth, its benefits are unevenly distributed, and highly vulnerable areas such as Sayung continue to experience severe tidal flooding, shoreline retreat, and livelihood disruption.

The CVI analysis identified Sayung as the most vulnerable coastal sector, with 48.87% of its coastline classified as highly vulnerable. This vulnerability is closely linked to land subsidence, ecosystem degradation, and the dependence of local communities on fisheries and aquaculture, making environmental change a direct threat to

Table 6. Strategic SWOT Matrix.

Strategy Type	Strategic Direction
SO (Strength–Opportunity)	Utilize the Semarang–Demak Toll Road and existing community adaptive capacity to support ecosystem-based coastal protection and mangrove rehabilitation programs.
ST (Strength–Threat)	Strengthen coastal infrastructure management and hazard awareness programs to reduce risks from sea-level rise, storm surges, and erosion.
WO (Weakness–Opportunity)	Improve participatory governance, mangrove restoration, and integrated sediment management to address environmental degradation and institutional weaknesses.
WT (Weakness–Threat)	Reduce dependence on hard engineering approaches, strengthen groundwater regulation, and implement integrated coastal zone management (ICZM) to minimize maladaptive risks and long-term socioeconomic vulnerability.

Source: Data analysis, 2025.

livelihoods and adaptive capacity (Ngo et al., 2023; Bagstad et al., 2007).

Survey and interview results also revealed a governance gap: although public awareness of coastal hazards is high, participation in planning and decision-making remains limited. Respondents generally supported coastal management initiatives but reported low involvement and limited awareness of government programs. In addition, some communities perceived that infrastructure development improved connectivity while failing to adequately address local environmental impacts, including flooding, erosion, and declining fishpond productivity.

The findings highlight the strong linkage between physical degradation and social vulnerability. Mangrove loss, tidal-flat degradation, and disrupted sediment dynamics reduce natural coastal protection, increase flood exposure, and undermine fisheries productivity. Consistent with the SWOT results, structural weaknesses and environmental threats outweigh existing strengths and opportunities, placing the region within a Defensive/Adaptive management position.

These results demonstrate that long-term coastal resilience depends not only on engineering solutions but also on effective governance, community participation, and ecosystem restoration. Therefore, adaptation strategies should integrate mangrove rehabilitation, sediment management, groundwater extraction control, adaptive infrastructure, and inclusive coastal governance to enhance both environmental and social resilience (Handayani et al., 2021; Yadav, 2025; Bridges et al., 2015).

CONCLUSIONS AND POLICY RECOMMENDATION

Conclusions

This study shows that the Semarang–Demak coast faces high vulnerability driven by land subsidence, tidal flooding, shoreline erosion, environmental degradation, and socioeconomic pressures. The CVI identified Sayung District as the most vulnerable area, while descriptive and SWOT analyses highlighted governance challenges, including limited community participation, weak policy outreach, and reliance on engineering-based protection measures. Although the Semarang–Demak Toll Road improves connectivity and provides some flood protection, it may also create unintended environmental impacts if not accompanied by integrated, ecosystem-based management. The findings demonstrate that coastal vulnerability is shaped not only by physical exposure but also by socioeconomic conditions, institutional capacity, and community resilience.

The main contribution of this study is the integration of CVI, community perceptions, and SWOT-based governance analysis within a socio-ecological framework. This approach provides a comprehensive understanding of the interactions among infrastructure development, environmental change, and social vulnerability, highlighting the need for adaptive governance, participatory planning, ecosystem restoration, and a balanced approach to development and environmental protection.

Policy Recommendation

Short-term (1–3 years)

Lead institutions: Ministry of Public Works, Semarang City Government, and Demak Regency Government.

- Prioritize mangrove rehabilitation, groundwater extraction control, and drainage system improvements.
- Implement hybrid coastal protection combining seawalls, breakwaters, and nature-based solutions.
- Strengthen community participation through climate literacy, disaster preparedness, and community-based coastal monitoring programs.

Medium-term (3–10 years)

Lead institutions: Regional Development Planning Agencies (Bappeda) of Central Java, Semarang, and Demak.

- Integrate Coastal Vulnerability Index (CVI) results into spatial planning and infrastructure development policies.
- Implement integrated sediment management and large-scale ecosystem restoration programs.
- Strengthen cross-jurisdictional coordination between Semarang and Demak to improve adaptive coastal governance.

Long-term (>10 years)

Lead institutions: Ministry of National Development Planning (Bappenas), Ministry of Environment (KLH), and Ministry of Public Works.

- Institutionalize Integrated Coastal Zone Management (ICZM) as the foundation of coastal development planning.

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- Establish long-term monitoring systems using remote sensing, UAVs, and InSAR, supported by coastal early warning systems.
- Promote sustainable livelihood diversification and climate-resilient economic development for coastal communities.

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AUTHORS CONTRIBUTION STATEMENT

We hereby declare that all authors equally contributed to this article.

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