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Policy Recommendation for Industrial Area Development based on Environment Carrying Capacity in The Northern Coast of Tuban, Indonesia

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Abstract: The development of industrial areas is one of the main strategies in supporting national economic growth but also has various impacts that need to be managed carefully. This study focuses on the analysis of the development of industrial areas on the coast of Tuban and its impacts on the environment, infrastructure, and local economy. This study also explores the harmony of land and coastal land use, which is an important factor in ensuring sustainable and integrated development. This study analyzes the development of coastal industrial areas in Tuban and its impacts on the environment, infrastructure, and local economy. The focus is the integration of land and coastal land use to support sustainable development. Through a spatial analysis approach, literature review, and stakeholder interviews, it was found that coastal area development has the potential to cause ecosystem degradation, increased disaster risk, and pollution. Other challenges include infrastructure needs, minimal local economic growth (PAD) and limited skills of the local workforce. This study recommends spatial planning policies, environmental management, and inclusive economic programs to ensure equitable and sustainable development in the coastal area of Tuban.

Keywords: Coastal industry; Land–sea interaction; Environmental impact; Infrastructure development; Spatial planning.

1. Introduction

1.1. Industrial Expansion and Spatial Policy in Tuban

Tuban Regency is located on the north coast of East Java and has experienced rapid development in the industrial sector in recent years (Priambodo & Chabibi, n.d.). In 2023, the manufacturing industry sector in Tuban Regency contributed 30.69% of the Gross Regional Domestic Product (GRDP) of Tuban Regency (Susilowati & Hartono, 2021). In addition, Tuban Regency is also one of the regencies with strategic access to the sea which has the potential for industrial development. Industrial development planning in Tuban Regency is also in line with the Tuban Regency Regional Regulation (PERDA) Number 17 of 2020 concerning the Tuban Regency Spatial Plan for 2020-2040 and Tuban Regency Regional Regulation Number 2 of 2023 concerning the Regency Industrial Development Plan for 2023-2043 where later Tuban Regency will be directed as a Resilient and Sustainable Inclusive Industry.

Industrial Development on the North Coast of Tuban is also stated in Presidential Regulation No. 109 of 2020 concerning the Third Amendment to Presidential Regulation Number 3 of 2016 concerning the Acceleration of the Implementation of National Strategic Projects. Where in Jenu District itself there is the Tuban Oil Refinery (Expansion) This oil refinery expansion is part of an effort to increase the capacity and efficiency of oil production in the region, as well as strengthen Indonesia's position as one of the main energy producers. This oil refinery is planned to become a larger processing and production center, with the target of meeting the growing domestic energy needs and supporting local economic growth (Fransisco Pascalino Adriana, 2021). The existence of an industrial development plan on the North Coast of Tuban will certainly have an impact on the environment, infrastructure, and local economy(Susilowati & Hartono, 2021). Therefore, recommendations are needed for spatial planning policies and environmental management.

1.2. Identification Industrial Development in Coastal Areas

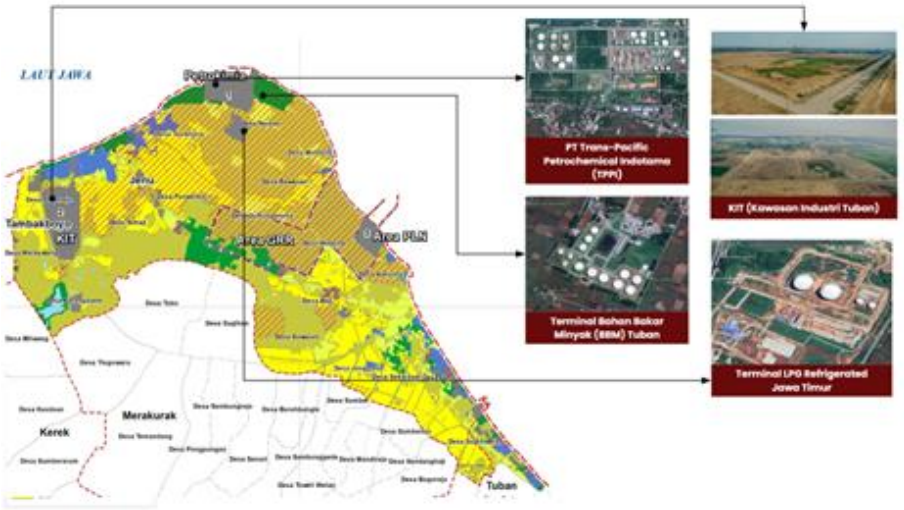

Figure 1 The Distribution of Industrial Areas on the North Coast of Tuban

Based on the results of industrial identification in the North Coastal Area of Tuban, 4 industrial areas were found. First, PT Trans-Pacific Petrochemical Indotama (TPPI) is one of the leading companies engaged in the petroleum refining industry, chemicals, and wholesale trade. This company produces various main products, such as aromatic products, petroleum, and various types of fuel, including light naphtha, gas oil, and other fuels. Its production capacity covers around 600,000 tons of Paraxylene and 300,000 tons of Benzene per year, as well as other energy products such as 275,000 tons of diesel, 66,000 barrels of Premium per day, and 59,000 barrels of Pertamax per day. Second, Tuban Fuel Terminal (BBM) has been operating since 2009 with a total investment of around IDR 2 trillion. This terminal has a large capacity, namely 350,000 kiloliters (kl), consisting of 150,000 kl of diesel and 250,000 kl of premium gasoline. The fuel received by the Tuban Terminal mostly

comes from the Bojonegoro Refinery as well as direct imports from Singapore and Malaysia for premium fuel, and diesel from Kuwait. This terminal is a distribution center in meeting fuel needs in various regions of Indonesia (Nankeni et al., 2022). Third, the East Java Refrigerated LPG Terminal is one of the largest energy terminals in Indonesia, serving 35% of national LPG needs, including for East Java, Bali, Nusa Tenggara, parts of Kalimantan, and Sulawesi. This terminal has a large storage capacity, reaching 93,000 MT. The role of this terminal is very crucial in supporting domestic energy supplies, especially LPG (Fransisco Pascalino Adriana, 2021). Fourth, the Tuban Industrial Area (KIT) is a strategic area located in Tuban Regency, East Java. This area is designed to support economic growth and investment through the development of modern and sustainable industrial infrastructure. KIT has various supporting facilities such as water supply, energy, waste management, telecommunications systems, and adequate transportation networks. This area is home to various major industrial sectors, including petrochemicals, oil and gas, and renewable energy (Susilowati & Hartono, 2021). In addition, it is also based on Presidential Regulation No. 109 of 2020 concerning the Third Amendment to Presidential Regulation Number 3 of 2016 concerning the Acceleration of the Implementation of National Strategic Projects in Jenu District on the North Coast of Tuban itself, there is the development of the Tuban Oil Refinery or commonly known as the PSN Grass Root Refinery (GRR Tuban) (Government of Tuban, 2020).

2. Method

The research methodology is structured into three interrelated components. The first component, Impact Analysis of Industrial Development in Coastal Areas, is conducted through in-depth interviews with key informants and spatial data collection. This stage employs both qualitative and quantitative descriptive methods, along with spatial analysis, to provide a comprehensive understanding of the impacts of industrial development on coastal environments. This stage also includes the development of the Environmental Risk Impact Map, which follows the environmental risk assessment approach from the Strategic Environmental Assessment (KLHS) of Tuban Regency. The map construction consists of four analytical steps; identifying industrial stressors, mapping vulnerable ecological and socio-economic components and generating spatial risk zonation through weighted overlay analysis.

The second component, Policy Evaluation of Industrial Development Impacts in Coastal Areas, involves a review of relevant literature and existing policies. A gap analysis is applied to identify deficiencies or gaps in current policy frameworks (Mutmainah et al., 2022), to assess policy effectiveness in environmental management. The final component, Policy Recommendations for Spatial Planning and Environmental Management, is formulated based on literature and policy reviews, as well as the findings from the previous analyses. In this stage, qualitative descriptive methods and a triangulation method are applied to ensure data validity and the relevance of the proposed strategies (Vera Nurfajriani et al., 2024).

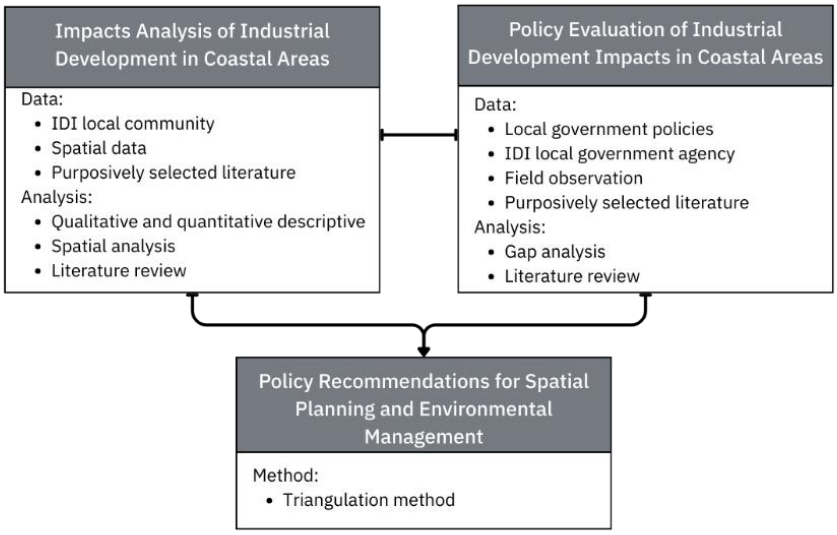

Figure 2 Research Framework Diagram

3. Results and Discussion

3.1. Impact Analysis of Industrial Development in Coastal Area

The impact of industrial area development on the coastal zone will be discussed in various aspects, such as its effects on the coastal environment (including physical changes and habitats), on the land area, and on the local community. Before delving into the details of the impacts of industrial area development in coastal zones, a literature review will be conducted from several selected articles/journals that are relevant to the advantages and disadvantages/risks of developing industrial zones along the coast.

This is done because the development of industrial zones in coastal areas can have complex environmental, social, and economic consequences(Pratiwi & Gunawan, 2019). It is essential to understand both the potential benefits and challenges before implementing such projects. Some of the potential disadvantages and risks include environmental degradation, land use conflict, and socio-economic disruption (Nankeni et al., 2022; Susilowati & Hartono, 2021).

Table 1 Weaknesses and Strengths of Industrial Development in Coastal Area

Strengths	Weaknesses
The development of industry, especially in the fuel oil sector, has the potential to reduce imports of fuel oil products. So that it will provide foreign exchange savings and increase the National GRDP.	Ecosystem Degradation, Industrial development often leads to the destruction of natural habitats such as mangroves and coral reefs, which are crucial for the coastal ecosystem's balance.
Increase employment opportunities both in the project phase and industrial operations	Erosion and Shoreline Changes. Activities like land reclamation and infrastructure development can alter the shoreline, increasing erosion risks and reducing the natural protective capabilities of the coast.
The development of a new petrochemical industry has the potential to grow the downstream petrochemical industry (processing of more varied derivative products)	Displacement and Livelihood Loss: Industrial development frequently results in the displacement of coastal communities and the loss of traditional livelihoods such as fishing.
Stimulate the growth of supporting economic activities around the industrial area (such as direct refinery supporting industries, worker investment, f&b, automotive, etc.)	Biodiversity Loss: Industrial activities can endanger already vulnerable species, reducing biodiversity in coastal areas.
In addition to the growth of the National GRDP, the increase in GRDP will certainly occur both in Tuban Regency and East Java Province	

The presence of industry also allows for the transfer of knowledge and technology to the public.

3.1.1. Coastal Environmental Impacts

Industrial development in coastal areas brings considerable environmental changes. Physical and habitat alterations occur due to excavation, dredging, and construction, reshaping coastlines and disrupting marine habitats (Nankeni et al., 2022). Industrial waste pollution is a major threat, as waste discharge contaminates coastal waters, degrades soil and water quality, and endangers marine life. Erosion and sedimentation from construction also impact the area, with sediment covering vital ecosystems like coral reefs and seagrass beds, damaging these habitats.

Moreover, altered drainage and flooding risks arise as industrial water use disrupts freshwater flows, affecting salinity levels essential to specific species and increasing coastal vulnerability to flooding (Sugiyanto & Joni Setiyono, 2022). These impacts highlight the need for environmentally mindful planning in coastal industrial zones.

3.1.2. Physical and Habitat Changes

The TPPI industrial area and the Tanjung Awar-Awar power plant have already contributed to noticeable physical and ecological alterations along Tuban's coastline. These areas have led to coastal erosion, sedimentation, and shallow water zones, disrupting natural processes and local ecosystems (Mahfudz et al., 2023; Pratiwi & Gunawan, 2019). Sediment buildup has been observed in regions around the power plant, causing water shallowing and changes in sediment dynamics like that seen in areas like JIIPE.

(a) *(b)*

Figure 3 (a) Industrial Area Existing, (b) Industria Area Plan

The future GRR Industrial Estate (Planned Industrial Area in Tuban) is expected to bring further modifications, specifically through land reclamation and infrastructure development, which could exacerbate existing issues:

- Shoreline Changes: Industrial development in Tuban's coastal areas is expected to increase coastal erosion and reduce natural barriers like mangroves and wetlands, weakening coastal resilience and raising risks from storms and flooding.
- Increased Sedimentation: Construction activities will likely lead to higher sediment levels, degrading water quality and smothering vital habitats such as coral reefs and seagrass beds, threatening local biodiversity.

- Shallowing: Sediment buildup may cause shallow waters, obstructing shipping routes and impacting local fishing activities, which are crucial for the local economy.
- Flooding Risks: Drainage changes from reclamation could increase flooding risks, especially during high tides or storm surges, posing challenges to nearby settlements and infrastructure

3.1.3. Impacts of Land Environment

Based on the analysis that has been carried out, where there is the development of New Industry in the coastal area of Tuban, namely the GRR project, the affected areas have been determined, which are divided into Ring 1 and Ring 2. Ring 1 and Ring 2 were delineated using a distance–decay approach based on GIS buffering around the GRR industrial footprint. Ring 1 represents the zone within approximately 1 km of the industrial boundary, where direct physical and environmental disturbances (noise, air emissions, vibration during construction, and potential groundwater quality changes) are expected to be the most intense. Ring 2 covers the area between 1 and 2 km from the site, where impacts are still present but are expected to be of moderate intensity. The choice of a 1 km and 2 km radius follows previous impact-zone studies around large industrial plants, which identify 0–1 km as a serious impact zone and 1–2 km as a sub-serious impact zone for industrial heat and pollution effects (Gao et al., 2022).

Figure 4. Impact of Land Environment: Affected Area

Ring 1, The directly affected area with strong potential is in a range of approximately 1 km from the location. The area of the affected settlement is 173,134 Ha. The affected areas are in Desa Wadung, Desa Sumurgeneng, Desa Kaliuntu, Desa Rawasan, and Desa Mentoso. Ring 2, The area directly affected but with moderate potential is approximately 2 km from the GRR location. The area of the affected settlement is 151,262 Ha. The area of the affected settlement is Desa Beji, Desa Remen, Desa Tasik and Desa Purworejo.

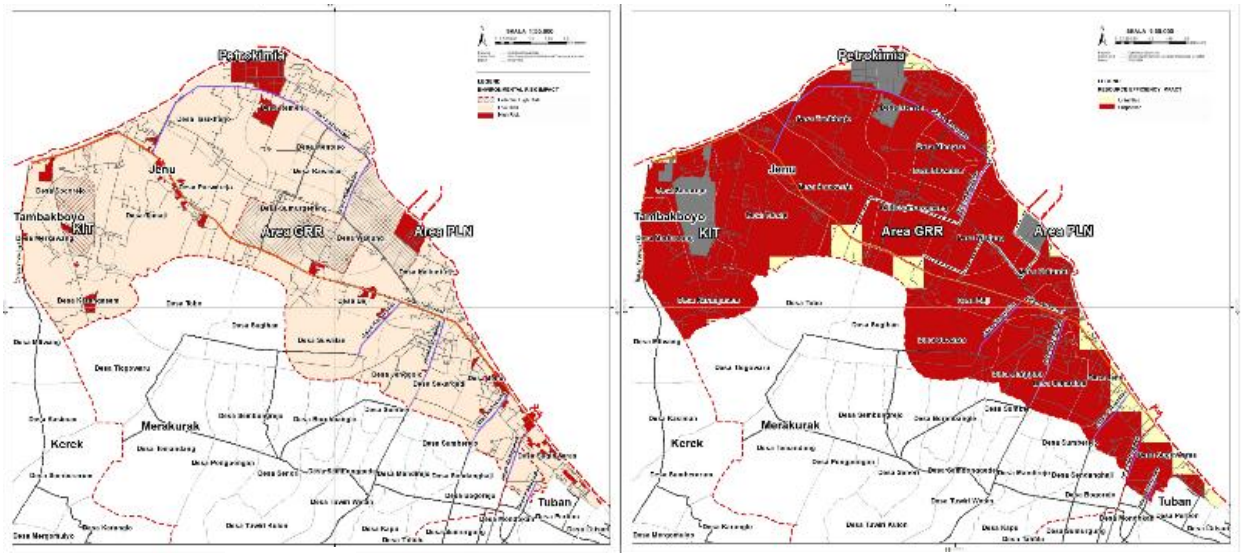

Figure 5. (a) Environmental Risk Impact Map, (b) Resource Efficiency Impact Map

The Environmental Risk Impact Map provides a detailed overview of ecological risks related to the relocation project and the expansion of the GRR industrial zone, including soil degradation, water pollution, biodiversity loss, air quality decline, and vulnerability to natural disasters (Fransisco Pascalino Adriana, 2021; Mahfudz et al., 2023). The map follows the environmental risk assessment approach from the Strategic Environmental Assessment (KLHS) of Tuban Regency, consisting of four analytical steps: (1) identifying industrial stressors, (2) mapping vulnerable components, (3) assessing risk magnitude using a likelihood–consequence matrix, and (4) spatially classifying risk zones through weighted overlay. As illustrated in Figure 5(a), High Potential areas (red) are concentrated exactly at the locations of existing industrial activities, demonstrating that industrial development is the main driver of environmental pressure—a pattern consistent with evidence of ecosystem degradation and pollution in petrochemical-based coastal areas (Susilowati & Hartono, 2021). Conversely, Low Potential areas (beige) are found in inland zones farther from industrial exposure, where biodiversity disturbance and pollution intensity remain relatively low. The spatial distribution also shows overlaps between high-risk zones and planned settlement or infrastructure expansion, indicating potential development–environment conflicts that require equitable mitigation to protect vulnerable communities (Susilowati & Hartono, 2021). Predictive modeling embedded in the map strengthens proactive and resilience-focused planning for sustainable post-relocation environmental management (Pratiwi & Gunawan, 2019).

In parallel, the Resource Efficiency Impact Map in Figure 5(b) evaluates the spatial balance between resource availability and demand specifically for land resources and water supply. The map retains the classification scheme — Unfulfilled areas (red) indicate zones where demand for land and water exceeds ecological capacity, while Surpassed areas (yellow) represent zones where availability still exceeds demand. Methodologically, this map is built upon the framework of environmental carrying capacity, where resource supply is compared with demand to assess sustainability thresholds (Hastoyuando et al., 2020). In this approach, land suitability and water supply are quantified, and the spatial distribution of overshoot (exceeding capacity) is modelled using grid-based overlay techniques. The spatial pattern reveals that the northern coastal industrial belt has reached a resource-critical condition, whereas a limited area in the southeast still retains surplus land and water capacity. The overlap of (i) high environmental risk and (ii) unfulfilled land and water capacity underscores the requirement for stringent resource governance and capacity-based spatial planning to prevent cumulative ecological and socioeconomic impacts.

3.1.4. Impact on Local Community

The social dynamics within communities affected by relocation due to land acquisition reveal significant disparities between anticipated outcomes and the lived experiences of residents. Local inhabitants, many of whom once thrived in their original communities, now face profound challenges in adapting to their new environments. This transition, intended to elevate their quality of life, has instead exposed inadequacies in housing provisions, especially when benchmarked against their initial expectations. As depicted in the perception analysis, village heads, community leaders, and village apparatus share a unified vision of an ideal outcome that encapsulates adequate infrastructure and the assurance of sustainable living conditions. However, reality falls short, with relocated residents voicing concerns over the inadequacy of fundamental amenities necessary to support their daily needs. The prevailing sentiment among the displaced is a call for enhanced housing solutions that genuinely address their socioeconomic and emotional requirements, facilitating a smoother adjustment and fostering an overall improvement in post-relocation life quality (Wahyuni & Ardiansyah, 2023).

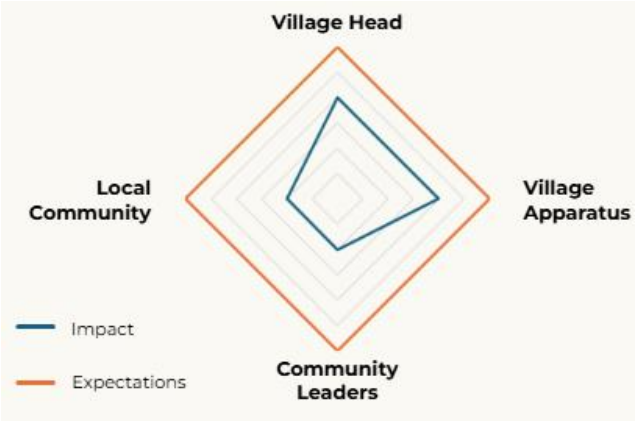

Figure 6. The radar chart depicts the perceived impact alongside the community's envisioned ideal conditions

Source: Author

The radar chart visualizes a clear gap between the community's expectations and the actual impacts of the relocation project, as perceived by four key stakeholder groups: village head, community leaders, local community, and village apparatus. The village head and apparatus show a relatively close alignment between expectations and outcomes, suggesting partial satisfaction or adaptation. In contrast, the local community and community leaders demonstrate a significant disparity, indicating unmet needs and dissatisfaction with current conditions.

The findings reveal a clear discrepancy between community expectations and the actual impacts of relocation. Although the program aimed to improve living conditions through new housing, many residents experienced greater economic hardship due to increased distance from coastal-based workplaces, resulting in higher transportation costs, reduced job access, and loss of income. This dissatisfaction is further intensified by environmental issues, particularly the neglected industrial green spaces that have deteriorated into dry, fire-prone areas, creating safety risks and prompting demands for improved disaster mitigation and ecological management. In contrast, local government officials view the relocation as successful because it was implemented according to administrative plans, including land preparation, housing construction, and the smooth transfer of residents. This administrative orientation overlooks the socio-economic and environmental challenges faced by the community, producing a significant perception gap, as also reflected in the radar chart. The findings highlight the urgency of addressing these concerns through tangible reforms and support systems, to align relocation outcomes with community aspirations for safety, sustainability, and improved quality of life (Wahyuni & Ardiansyah, 2023).

3.1.5. Accumulation Impacts

Industrial development along the coast of Tuban has resulted in cumulative impacts across economic, social, and governmental dimensions since its early stages. Economically, there has been a significant shift in land use and value. Socially, the development has disrupted community structures through land conversion and relocation. From a governance perspective, it has increased pressure on institutional capacity and highlighted the need for cross-sectoral coordination to manage emerging challenges. The study identified the accumulation impacts in the phase of industrial development through a qualitative approach. Data were collected using in-depth interviews with community members and stakeholders, which were then validated through direct field observations to ensure accuracy and contextual relevance. All interview materials were fully transcribed and analyzed using descriptive narrative techniques.

Table 2. Accumulation Impacts in Phase of Development industry

Activities	Environment	Social-Economics	Governance
Pre-Development			
Land Acquisition	-	**Loss of livelihoods** of residents (farmers, fishermen)	**Suboptimal society empowerment** (government assistance to communities experiencing difficulties due to land acquisition)
Land Preparation	**Pollution** due to building and construction renovation	**Providing a positive impact on society,** because it employs residents to clear the land	-
Development			
Recruitment and Mobilization of Workforce	**Air pollution** due to increased mobility and increasingly dense traffic	**Increasing population density** (this will be a problem if it is not accompanied by the fulfillment of housing) > benchmark from JIIPE which provides housing rentals	**Fulfillment of residents capacity according to company qualifications**
		Fulfillment of the basic needs of the population (because of the increasing population, an increase in infrastructure service capacity is required)	
Construction Implementation	**Degradation of the land, water and air environment** due to construction activities	**Noise and odor disturbance** due to construction activities	**Control of environmental quality to ensure** it meets quality standards
Dredging, Reclamation, Construction in Coastal Areas. Development plans on reclaimed land, namely special terminals, jetties, SPM, breakwaters	**Coastal area pollution** due to dredging activities	**Disruption of fishing activities** resulting in a decrease in fishermen's income	**Control of the quality of the coastal environment** to ensure it meets quality standards and does not damage the ecosystem.
	Disturbance of coastal ecosystems due to dredging activities	**Disruption of basic community needs** (dredging causes disruption of drainage, pollution of water sources, etc.)	
	Changes in drainage patterns due to dredging activities		
Post-Development			
Procurement of operational manpower	**Air pollution and increased noise** due to increased mobility and increasingly dense traffic	**Loss of livelihood resulting in increased unemployment** (because operational labor is not needed as much as during construction, and operational qualifications are different from construction)	**Efforts to address increasing unemployment**
		The termination of construction workers resulted in the loss of income for residents who rent out boarding houses/lodgings.	**Fulfillment of HR capacity** according to the qualifications required by the company

Activities	Environment	Social-Economics	Governance
Industrial operational activities	**Environmental degradation** due to industrial operational activities	**Disruption of basic society needs** due to industry (pollution of water sources, blocked drainage, etc.)	**Control of environmental quality** to ensure it meets quality standards and does not damage the ecosystem.
	Disasters occur due to errors in industrial activities (fires, gas leaks, etc.)	**Increase in building tax** due to increase in land value	**Synergy of cooperation** between regional apparatus and companies
	The occurrence of cumulative disasters due to industrial areas (floods, landslides, abrasion, accretion, extreme weather, etc.)		**Reduced budget burden** due to assistance in fulfilling infrastructure and welfare from company CSR
	The decreasing carrying capacity and environmental capacity due to increasing needs that are not balanced with the ability to provide them.		**Increased investment and local revenue** from increases in land values have an impact on increasing building taxes.

The strategic issues surrounding industrial development on the coast of Tuban emphasize the need for strict environmental policies and close monitoring to prevent pollution and ecosystem degradation, ensuring environmental quality control throughout all stages of development and operation. It is crucial to sustain community empowerment programs that integrate local society into the economic chain of the project, helping them adapt to environmental changes and new economic patterns. Strengthening synergy between local government officials and companies is necessary to address community needs and support sustainable development, including controlling environmental impacts.

Additionally, infrastructure development must accompany project implementation, with provisions for worker housing and essential public services to prevent social and environmental crises. Comprehensive disaster risk mitigation in industrial areas is also a priority, involving effective planning, ongoing monitoring, and education for workers and nearby communities about the associated risks of industrial activities. From an economic perspective, the development of new industries in Tuban is expected to boost local revenue (PAD) and gross regional domestic product (GRDP) for both Tuban Regency and the broader East Java Province. Finally, industrial development is anticipated to create employment opportunities for the community, both during construction and in ongoing operations

3.2. Policy Evaluation of Industrial Development Impacts in Coastal Area

In conducting an evaluation of the development of industry in coastal areas, review of related regulatory documents is carried out. The review of aspects is carried out from the environmental, socio-economic and government aspects.

Table 3. Policies Gap Analysis

Aspects	Policies	Evaluation
Environment	**Environmental quality** Determining the points and locations for environmental quality trial samples that represent land use activities.	The industrial area on the north coast of Jenu is not included as a sample point in the calculation of the environmental quality index, thereby failing to represent the environmental quality policies of the district
	Buffer Zone Green spaces in industrial areas are strategically designed to include buffer zones covering approximately 30% of the total industrial area	The vegetation selection for green belts serving as industrial buffer zones is suboptimal and inadequate (Takwim, 2020)
	Development of nonpolluting industries The development of environmentally conscious industrial processing activities focuses on supporting environmental sustainability, equitable distribution, and the provision of essential infrastructure to foster balanced regional development.	Industrial development has led to an increase in cases of acute respiratory infections (ARI) among local populations

Aspects	Policies	Evaluation
	Disaster mitigation Securing the region against potential disaster risks	The current early warning system for disasters is not fully effective as it fails to accommodate the risks associated with industrial spills (Takwim, 2020)
Social and Economic	**New Resident location** Preparation of new residential locations around industrial areas to anticipate the needs of new organizations along with the development of the number of workers in each industrial sector	**Preparation of new settlement sites is planned only for worker (dormitories)**. For residents affected by the industry, there's no plan for the relocation area. Housing development also requires the development of supporting infrastructure (road networks, clean water, electricity networks, telecommunications networks, and others) (Linda Fitriani et al., 2024).
	Employment Recruitment Every company is required to make maximum efforts and prioritize so that open job vacancies are filled by local workers. Filling job vacancies is done by prioritizing people who are domiciled in the area and have a local Population Identity Card	**The recruitment of workers where there must be local workers needs to be considered by the institutional labor affairs that coordinate with the industry**. Where the number/percentage of recruitment has not been determined, there needs to be supervision in the process so that the involvement of the local community is truly realized (Linda Fitriani et al., 2024).
	Development of industrial promotion center Government policy introducing industry in Tuban Regency, both through promotional activities to introduce industrial activities in Tuban Regency to attract investors	**The policy of introducing industry in Tuban Regency, both through promotional activities, hasn't been fully optimal**. This is indicated by the still less than optimal investment in KIT Tuban.
Goverment	**Institutional Strengthening** Strengthening linkages/institutions with other sectors in industrial development	**The suboptimal institutional coordination in the development of industries in Tuban Regency, particularly in the northern area,** is evident. For instance, in addressing the leakage incident at the TBBM (Fuel Terminal), the parties involved should not be limited to environmental affairs alone (Takwim, 2020).
	Development of reclamation activities as support for the construction of oil refineries (expansion) Development of reclamation activities requires supervision and control from various sectors according to the respective departmental affairs	**The existence of reclamation development for industrial areas is not yet fully known by all related institutions**, which of course requires further socialization.

3.3. Policy Recommendations: Spatial Planning and Environmental Management

3.3.1. Spatial Strategies (Buffer Zone)

The proposed spatial strategy involves creating buffer zones between industrial areas and sensitive locations like residential neighborhoods and protected zones, divided into two main rings.

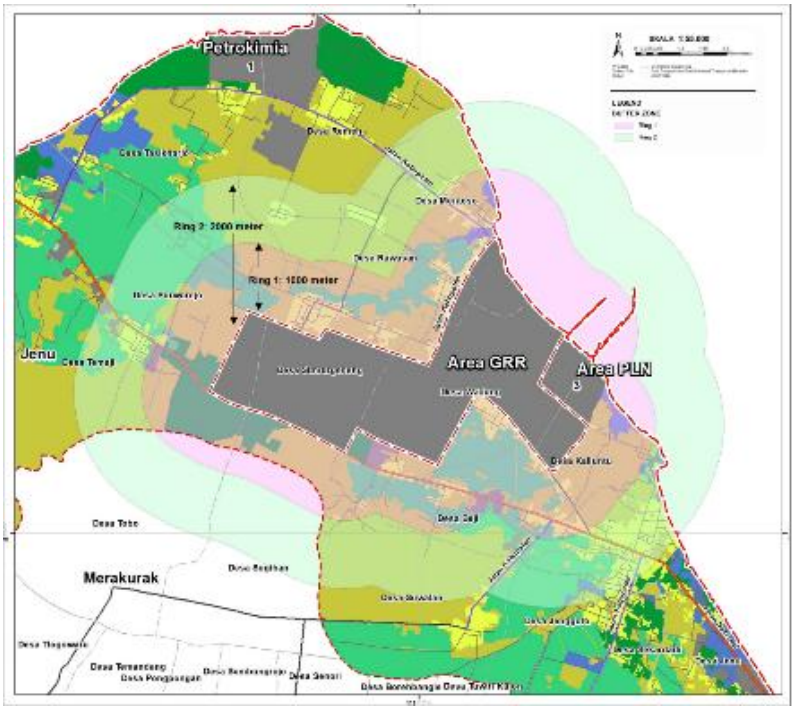

Figure 7. Buffer Zone Strategies

Environmental Control Zone (Ring 1): This zone is closest to the industrial area and prohibits permanent structures like housing and schools. It serves as a green belt to mitigate noise, air pollution, and fire hazards. Access roads must incorporate safety measures, such as evacuation routes and speed restrictions. Transition Zone (Ring 2): This area allows non-residential commercial activities supporting industrial operations, such as logistics centers and small services like restaurants. It can also include urban agriculture and green spaces to further buffer industrial activities.

Relocating existing residential settlements from these zones is essential, along with providing basic infrastructure and quality housing for displaced communities. This layered approach enhances coexistence between industrial development and nearby communities by managing environmental and social impacts through strategic land use planning.

3.3.2. Environmental and Management Strategies

1. **Environmental Quality Monitoring and Management**
   - **Adding More Representative Environmental Quality Monitoring**
     This strategy focuses on enhancing the accuracy and spatial coverage of environmental monitoring within the industrial area. Additional sampling points will be established in zones that were previously unrepresented to ensure that variations in air, water, and soil quality are adequately captured. Furthermore, continuous monitoring technologies will be integrated to generate real-time data, thereby strengthening regulatory responsiveness to environmental fluctuations and improving the reliability of environmental governance mechanisms
   - **Increasing Vegetation in Buffer Zones and Green Open Spaces**
     Enhancing vegetation in buffer zones and green open spaces is a key strategy for mitigating the environmental impacts arising from industrial activities. A comprehensive vegetation audit will be carried out to assess existing conditions and identify ecological gaps that require reinforcement. Recommended species include Samanea saman (Rain Tree / Pohon Trembesi), which is known for its exceptional carbon absorption capacity and ability to reduce airborne dust. Terminalia mantaly (Madagascar Almond / Ketapang Kencana) is proposed due to its effectiveness in moderating micro-

climate temperatures and improving shading. Tabebuia species (Tabebuya) are suggested because of their resilience to pollution and stable root systems suitable for buffer planting. Bamboo varieties such as Bambusa vulgaris (Bambu Kuning) and Bambusa wulung (Bambu Wulung) are recommended for their ability to filter particulate matter and function as natural wind barriers. Additionally, Acacia mangium (Akasia Mangium) is included for its rapid growth, canopy expansion, and ability to improve soil structure. The integration of these species is expected to strengthen the ecological performance of green buffers and contribute significantly to reducing industrial emission impacts around the site.

- **Managing Environmentally Friendly Industries**
  The strategy for managing environmentally friendly industries emphasizes the implementation of stricter zoning regulations and more rigorous emission standards. Industrial actors are encouraged to adopt advanced pollution-control technologies, including scrubbers, electrostatic precipitators, and closed-loop wastewater treatment systems. These interventions aim to reinforce compliance with environmental regulations, minimize industrial pollutants, and support the transition toward cleaner production processes.

2. **Disaster Risk Prevention and Mitigation**
   Improving the Early Warning System for Industrial Disaster Risks: Strengthening early warning infrastructure to detect hazardous material spills and integrating with community communication networks and related agencies for rapid disaster response.
   - **Development and Settlement: Developing New Settlement Locations**
     The development of new settlement areas seeks to accommodate communities affected by industrial activities while ensuring access to essential infrastructure such as transportation networks, clean water supply, electricity, telecommunications, and public services. Given the social sensitivities associated with relocation policies, conflict-mitigation measures are incorporated. These include participatory planning processes involving community consultations, transparent and equitable compensation schemes, livelihood protection programs through job prioritization and skill enhancement, group-based relocation to maintain social cohesion, and post-relocation support to assist community adaptation. These measures are intended to reduce social tension and ensure that relocation outcomes are socially just and sustainable.
   - **Human Resource Development: Recruiting Local Workforce**
     To strengthen local economic inclusion, industries operating in the area are required to employ a minimum proportion of local workers. Strict monitoring mechanisms will be implemented to ensure compliance with this requirement. Additionally, training programs will be developed to enhance the competencies of local residents in areas such as industrial machinery operation, occupational safety, waste management, and administrative skills. This strategy is expected to improve community participation in the industrial economy and foster more equitable development outcomes.
   - **Industry Promotion and Investment: Developing Industrial Promotion Centers**
     Industrial promotion and investment development will be advanced through targeted initiatives such as exhibitions, digital marketing, and investment outreach activities. Incentives including streamlined licensing procedures and tax benefits—will be offered to attract investors to the Tuban Industrial Estate (KIT). The establishment of an Industrial Promotion Center will function as a platform for information dissemination, product showcasing, and business matching. This initiative aims to strengthen the competitive positioning of the industrial area and facilitate sustainable industrial growth.

4. Conclusion

The development of the coastal industrial area in northern Tuban presents significant potential for both local and national economic growth, but it also brings serious challenges to environmental carrying capacity, infrastructure resilience, and local community engagement. This study highlights critical issues such as coastal ecosystem degradation, increased disaster risk, pollution, and development inequality that demand immediate

and integrated policy responses. Furthermore, the lack of skilled local labor and minimal contribution to local government revenue reinforce the urgency for more inclusive and sustainable policy frameworks.

Through spatial analysis, policy evaluation, and stakeholder input, this paper proposes three key policy directions: (1) integration of land and marine spatial planning; (2) strengthening environmental management instruments based on carrying capacity and ecological thresholds; and (3) empowering the local economy by enhancing skills and integrating communities into industrial value chains. Achieving alignment between industrial development and environmental protection should become a fundamental principle in building a resilient, inclusive, and sustainable coastal region in Tuban.

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