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Risk-Based Governance for Trans-Island Hub Development: A Blue Economy Framework for Sustainable Food and Service Exchange in Archipelagic Regions

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Abstract- ***This study examines risk mitigation governance in maritime infrastructure development as a strategic input for the development of trans-island hubs supporting sustainable food systems and the exchange of goods and services in archipelagic regions. Using a qualitative meta-analysis approach, data were collected through documentary analysis of 40 scientific publications and four comparative case studies of port and airport development in Bali, Central Java, Yogyakarta, and Kulon Progo. The findings identify five interrelated strategies for sustainable hub development: (1) harmonization of sectoral regulations to integrate risk reduction into regional planning; (2) participatory and multi-stakeholder governance arrangements; (3) early risk detection supported by systematic assessment tools; (4) institutional preparedness strengthened through inter-agency coordination; and (5) adaptive, risk-oriented leadership that enhances the capacity of local service providers and communities. In addition, the study highlights the importance of a phased checklist-based approach to addressing technical, human, environmental, and institutional risks. Drawing on experiences from Java and illustrative archipelagic contexts such as South Halmahera, the study proposes a governance-oriented model for trans-island hub development aligned with blue economy principles, emphasizing resilience, inclusivity, and ecological sustainability. The findings contribute policy-relevant insights for regional governments seeking to operationalize sustainable risk mitigation in archipelagic development.***

Keywords: Port Planning, Risk Mitigation, Stakeholder Participation

I. INTRODUCTION

Risk management has increasingly been recognized as an essential discipline in both public and private sector governance. Its growing prominence is reflected in the expanding body of scholarly literature and the incorporation of risk management frameworks into organizational and policy handbooks. The importance of risk management lies in its capacity to reduce performance variability, integrate diverse perspectives on uncertainty, enhance stakeholder trust, strengthen the relationship between governance mechanisms and decision-making, and improve organizational responsiveness to dynamic environmental changes [1]. These benefits underline the relevance of risk mitigation as a core component of sustainable development strategies.

Risk mitigation refers to a systematic process aimed at reducing exposure to risk and/or minimizing the likelihood and impact of adverse events. As part of the broader risk management cycle, mitigation focuses on identifying vulnerabilities through qualitative and quantitative assessments and selecting appropriate response strategies to reduce potential losses [2]. Rather than eliminating risk entirely, risk mitigation emphasizes preparedness and impact reduction, particularly in contexts where risks are unavoidable, such as natural hazards and socio-environmental disruptions [3].

From a governance perspective, risk mitigation encompasses a range of strategic options, including risk avoidance, risk acceptance, risk transfer (e.g., insurance mechanisms), and risk reduction through technical, institutional, and behavioral interventions [4]. In the public sector, effective risk mitigation

requires a holistic and integrated framework that aligns regulatory instruments, institutional capacity, and community participation, particularly in disaster-prone and infrastructure-dependent regions [5].

In recent years, risk mitigation approaches have been widely applied in large-scale infrastructure projects, including airports and ports. The airport city concept, for example, highlights the need for comprehensive risk management to address uncertainties beyond the control of governments and market actors [6]. Similarly, port development projects face diverse risks arising from environmental dynamics, institutional fragmentation, and socio-economic vulnerabilities, which can result in project delays and service disruptions if not properly managed [7].

For archipelagic regions, these challenges are compounded by geographical dispersion, high logistics costs, climate change impacts, and limited connectivity between islands. In such contexts, ports and related infrastructure play a strategic role not only as transportation nodes but also as trans-island hubs that facilitate food distribution, economic exchange, and public service delivery. Risk mitigation therefore becomes a critical governance instrument for ensuring that hub development supports sustainable food systems, community resilience, and blue economy objectives.

South Halmahera Regency in North Maluku Province represents an illustrative example of an archipelagic region characterized by abundant natural resources, high dependency on maritime connectivity, and significant exposure to environmental and logistical risks. Similar to other island regions in Indonesia, South Halmahera faces challenges related to fleet availability, human resources, energy supply, cold chain infrastructure, and market integration. While this study draws on empirical insights from South Halmahera, its primary objective is not to present a localized case study but to extract transferable risk mitigation strategies that can inform the development of trans-island hubs in archipelagic regions more broadly.

Accordingly, this study aims to identify and synthesize risk mitigation strategies derived from comparative infrastructure cases and existing literature.

II. METHOD

This study employed a qualitative manalysis approach using documentary as the primary method of data collection. The research was designed to identify and compare risk mitigation strategies relevant to maritime infrastructure and public service development. Data were collected from peer-reviewed journal articles published in both English and Bahasa Indonesia. Sources were retrieved through systematic keyword searches on academic databases, including Google Scholar and ScienceDirect, using search terms such as “maritime hub,” “risk mitigation,” “port development,” and “public service governance.” Inclusion criteria emphasized relevance to infrastructure risk management, governance mechanisms, and contextual similarity to developing or archipelagic regions. A total of 40 scholarly publications were selected, including four comparative case studies of infrastructure development located in Bali (Sanur Port), Central Java (Tanjung Emas Port), the Special Region of Yogyakarta (Gesing Coastal Fisheries Port), and the Yogyakarta International Airport area. Each document was subjected to content analysis to identify dominant risk types, mitigation measures, institutional arrangements, and stakeholder engagement practices.

To ensure analytical consistency, the selected studies were coded according to thematic categories aligned with the research objectives: (1) types of risk and vulnerability, (2) mitigation strategies, (3) governance and institutional frameworks, and (4) relevance for trans-island hub development. Through comparative analysis, the study develops a conceptual understanding of risk mitigation governance that can be operationalized in diverse archipelagic settings.

III. RESULTS AND DISCUSSION

The comparative analysis of risk mitigation governance across infrastructure projects and port operations highlights findings that are directly relevant to strengthening trans-island (hub–spoke) logistics as a foundation for blue-economy development. At Yogyakarta International Airport, risk mitigation is integrated into public service policies and regulations, which strengthens compliance, stakeholder coordination, and adaptive governance conditions that increase the reliability of service continuity and reduce disruption uncertainty in interlinked transport systems. In contrast, the Sanur Port project applies the Lookup Method for risk identification by generating checklists from previous projects, and the tidal wave emerges as the primary risk parameter with delays of up to 98 days recorded [8]. These differences indicate that technical identification must be converted into operational controls (contingency scheduling, routing flexibility, and buffer capacity) to protect logistics performance, not only to document construction-phase hazards [9].

This governance–operations linkage is consistent with wider blue-economy and maritime risk scholarship that argues risk in ocean development must be assessed as an interconnected social–ecological–economic system rather than treated in disciplinary silos. Integrated risk assessment approaches emphasize that blue-economy expansion introduces "new and complex risks" and therefore requires cross-disciplinary engagement, inclusion of diverse expertise, multi-scale analysis, and an explicit understanding of feedbacks within systems principles that align with trans-island hub planning where port performance, community livelihoods, and ecosystem stability co-determine logistics reliability [10]. In addition, recent evidence from climate-resilient ports research reinforces that resilience planning often over-focuses on physical infrastructure while under-addressing supply-chain and network interdependencies, and that advanced tools (e.g., digital twins, AI, satellite monitoring) remain underutilized despite their potential for predictive and adaptive risk management in ports and waterborne transport systems [11]. This supports the implication that hazard identification methods such as checklists must be operationalized through systems-based governance that connects infrastructure, operations, and supply chains particularly critical for archipelagic hub networks exposed to compound climate events.

The comparison between Tanjung Emas Port and PPP Gesing further clarifies how each mitigation approach provides a different "potential" to support trans-logistics. Tanjung Emas faces recurring tidal flooding linked to land subsidence and relies on engineered solutions such as polder systems, embankments, and retention ponds, supported by technology and early digitalization of port services. This configuration indicates strong potential for scaling and modernizing logistics throughput, but it also implies continuing dependence on institutional capacity, financing, and maintenance governance to prevent chronic disruption, particularly as environmental pressures intensify. Meanwhile, PPP Gesing benefits from a naturally strategic coastal setting where limestone cliffs, green belts, and coral reefs provide ecosystem-based protection, and this natural buffering supports operational continuity for coastal and fisheries-related services. The port's resilience is reinforced by social capital through community cooperatives and MSMEs that help sustain day-to-day operations and livelihoods, including a portable ice factory (2 tons/day) managed by the Panjolo Karto Mukti Gesing Cooperative and a rest area that accommodates 15 MSMEs [12]. These features show that ecosystem services and community-based economic institutions can function as risk-reducing logistics assets especially for cold-chain dependent commodities rather than being treated only as "social programs" [12]. At the port-governance level, this logic is strengthened by cooperative risk management perspectives which underline that seaports face diverse risk sources and complex stakeholder environments, and therefore require standardized cooperative processes spanning stakeholder analysis, risk governance, risk management, and knowledge management to coordinate prevention and response across actors [13].

The SWOT-based comparison also reinforces that neither engineered mitigation nor ecosystem-based protection is sufficient in isolation. Tanjung Emas demonstrates technological advancement and industrial positioning but remains vulnerable to

environmental degradation and external competition, while PPP Gesing benefits from strong social capital and natural protection but faces weaker institutional support and exposure to natural hazards. For trans-island hub development, this implies the need for a dual mitigation pathway: engineered infrastructure for service stability and capacity, paired with ecosystem-based measures that reduce hazard intensity and protect coastal functionality, all supported by coordinated governance and risk-focused leadership to reduce vulnerabilities in personnel, equipment, and construction methodologies. Community participation strengthens this dual approach by building ownership and oversight, as reflected in the Kampung Bahari Program in Tambaklorok, where the fishing port is positioned as a fisheries economy center and local residents are given roles to oversee development to cultivate responsibility for infrastructure protection and maintenance [14]. In this way, community empowerment becomes an operational mechanism for continuity, not merely stakeholder engagement [14]. At the same time, the broader governance literature cautions that "blue economy" is often enacted through collaborative governance expectations that can "responsibilise" states to cooperate in marine management, yet implementation commonly faces counter-pressures such as limited technical capacities/resources and community resistance to development priorities; therefore, hub governance must explicitly invest in governmental capacity-building and legitimacy mechanisms, not only physical infrastructure [15].

When these comparative lessons are repositioned to South Halmahera, the "potential" becomes more concrete for trans-logistics and blue economy pathways. South Halmahera has several large ports, including Kupai Harbor (Kupal Port) on Bacan Island, which is prioritized because it facilitates inter-island access and mobility to the regency capital and connects Labuha City with other areas in the regency [16]. Bacan Island's geographic setting and the regency's sea-dominant area structure (78% sea area) further underline the strategic importance of maritime connectivity for trans-island exchange and distribution systems. Kupal Port also serves as an entry point for people and goods into Labuha City and supports modal switching to land transport, with reported average passenger movement of 428 boarding and descending activities per day. However, the indication that dock expansion may be comparatively unnecessary until 2039 because facility performance (BOR) remains below potential suggests that strengthening hub performance should prioritize service reliability, operational systems, and supporting infrastructure (including cold-chain readiness) rather than berth expansion alone.

In parallel, forecasts indicate that container operational service performance at Babang Port is rated as good for the next ten years or until 2031 [17], yet operational governance issues remain, including limited container storage/stacking yard capacity and port activities not aligning with established procedures. These gaps are not marginal, because yard constraints and procedural non-compliance directly shape dwell time, scheduling reliability, and logistics costs key determinants for sustaining commodity flows that support blue economy sectors [12]. Therefore, assessing service levels through container operational performance, including determining stacking yard capacity and wharf installed capacity for present and future needs, becomes essential to ensure that port utilization aligns with established protocols and supports reliable trans-island logistics. At the same time, the South Halmahera context also shows that trans-logistics potential is inseparable from environmental and basic-service risks, including abrasion, ecosystem damage, and clean water needs, alongside constraints in energy availability across settlements and islands [18]. The existence of information services pertaining to ports and maritime transportation indicates that baseline public services already exist in the maritime domain, and this can be leveraged to strengthen operational governance through better coordination, standardized procedures, and risk-informed decision-making. In operational terms, the sustainability of inter-island passenger and service flows also depends on safety governance maturity in the domestic ferry sector; governance frameworks that integrate ESG principles, socio-technical systems thinking, and climate-resilient safety practices supported by measurable principles, criteria, and indicators provide a relevant reference for strengthening hub–ferry interfaces in archipelagic settings [19]. Finally, because trans-island hubs

function within wider supply chains, risk governance should also account for the security–cost tradeoffs in port and maritime operations; risk-based cost assessment approaches highlight the need for integrated and effective risk and cost assessment frameworks (including supply-chain security) so that security and regulatory measures do not unintentionally undermine efficiency and service reliability [20].

Overall, the results imply that sustainable trans-island hub development in South Halmahera should apply dual mitigation (engineered and ecosystem-based), reinforced by institutional strengthening, service-standard enforcement, and community-based cooperative/MSME participation as embedded components of logistics.

IV. CONCLUSION

This study confirms that resilient maritime and port development requires integrated risk mitigation that combines adaptive infrastructure, institutional coordination, and community participation. Comparative insights from ports in Java demonstrate that resilience is strongest when engineered solutions are complemented by ecosystem-based and spatial approaches, while the illustrative case of South Halmahera highlights persistent gaps in regulatory coherence, stakeholder integration, and climate-responsive governance.

The findings reinforce the need to position risk mitigation as a core element of public service governance in archipelagic regions. From a policy perspective, strengthening regulatory frameworks, embedding risk mitigation into service delivery, and aligning maritime development with blue economy principles are essential to ensuring socio-economic resilience while safeguarding marine ecosystems.

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