INTEGRATING CIRCULAR ECONOMY PRINCIPLES IN SMALL-PERIPHERAL PORTS: A CASE STUDY OF BADAS PORT

Bahana Wiradanti[1*], Yusuf Ferdian Umar[1], Tri Wahyunita[1], Jumhari Nasrun[1], Stephen Pettit[2]

[1]Pelabuhan Indonesia (Pelindo), Jakarta, Indonesia

[2]Logistics & Operations Management Section, Cardiff Business School, Cardiff, United Kingdom

Abstract

The Circular Economy (CE) concept is gaining global importance, particularly in the maritime industry due to its significant resource consumption and environmental impact. Ports, as critical nodes in supply chains, are increasingly viewed as hubs for sustainability efforts. However, limited research exists on adopting CE principles in small peripheral ports. This paper examines how CE principles can be implemented in Badas Port, in West Nusa Tenggara, Indonesia, which predominantly handles corn, livestock and containers under 10,000 TEUs annually. Badas Port's challenges include dependency on limited shipping routes and fluctuating cargo volumes. This study employs a mixed-methods approach, including field observations and interviews with stakeholders like port operators, cargo owners and local businesses. The output describes a proposed plan for development of Badas Port. Findings indicate that implementing CE activities in small peripheral ports is feasible. Unlike larger hub ports that benefit from consolidation and higher volumes, small ports should prioritize increasing cargo volumes and attract businesses through CE initiatives, which can drive economic growth and sustainability simultaneously. Fostering stakeholder collaboration and leveraging port's role as sustainability hubs are also essential. This study provides practical recommendations and highlights the transformative potential of CE principles in small peripheral ports worldwide.

Keywords

Circular economy, small peripheral port, sustainability, collaboration, Indonesia

1 Introduction

The terminology "circular economy" has its roots in various conceptual frameworks that emerged in the late 20th century, but its formal introduction is often attributed to the work of Kenneth Boulding in 1966. Boulding's seminal paper, "The Economics of the Coming Spaceship Earth," proposed a system where resources are reused and recycled, contrasting sharply with the traditional linear economy model that follows a "take-make-dispose" approach (Boulding, 1966 in Jarrett, 1966). This foundational idea laid the groundwork for the development of the circular economy (CE) concept in various sectors, including in maritime transport and economics. The role of ports in promoting sustainability efforts within their ecosystems has garnered increasing attention in recent years. Ports are uniquely positioned as critical nodes in global supply chains, and their operations significantly impact local and regional environments. Several studies have explored how ports can become hubs for sustainability initiatives, particularly through the adoption of CE principles and green practices.

Ports have the potential to create local economic benefits and achieve long-term sustainability goals by adopting CE principles, by transforming waste into resources, thereby contributing to sustainable development at multiple levels (Roberts et al., 2021). Ports play a critical role as hubs for sustainability, with their strategic position in supply chains enabling them to influence green practices such as integrating sustainable logistics practices, enhancing waste management systems, emission reduction and other various green practices (Notteboom et al., 2020; Loizidou, 2024; Karagkouni, 2024). Ideally, ports which are integrated with their hinterland and industrial clusters develop a sustainable industrial symbiosis or promote sustainable industrial ecosystems, which lead into ecologies of scale (Notteboom et al., 2022). The by-products of a port's industrial area such as oxygen, heat, or water could be recycled and reused locally, using supporting infrastructures such as pipelines and storage tanks. Notteboom et al. (2022) states that a competitive cluster requires good inter-company infrastructure (e.g. pipelines), product diversity, shared utility services and infrastructure, also strong cluster governance.

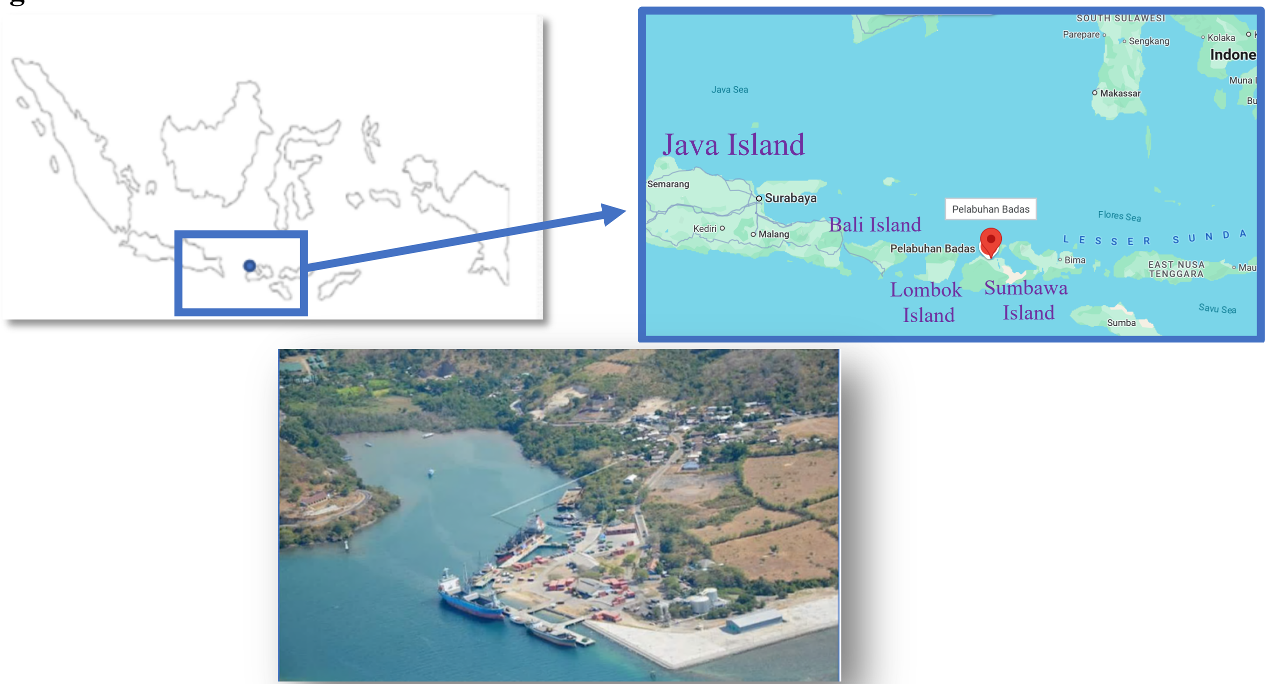
Meanwhile, many ports' struggle to survive financially or economically, and are also further pressured to become more sustainable. Small-peripheral ports experiencing this are typically smaller in size and located in less favorable geographical or economic locations compared to major hub ports. Their characteristics are often similar. They may lack the advanced infrastructure and facilities found in larger ports, which can hinder their ability to accommodate larger vessels and handle significant cargo volumes (Wiradanti et al., 2020) Many are situated in remote locations, making them less accessible and less attractive to shipping companies. The smaller volumes of cargo coming in and out of the port, in addition to their isolated locations lead to reduced shipping traffic and limited economic opportunities (Wiradanti et al., 2020). They typically depend on nearby hub ports for access to global markets which can limit their operational autonomy and economic growth potential (Wiradanti et al., 2020; Wiradanti et al., 2018).

According to Roberts et al. (2021), smaller ports may struggle to implement CE practices due to their limited resources and lower volumes of traffic, which restrict their access to a diverse pool of waste products and potential consumers. Moreover, due to their smaller scale, these ports often face financial and operational constraints, making it challenging to invest in modernization or sustainability initiatives (Roberts et al., 2023). This suggests that while the potential for adopting CE principles exists, smaller ports may require targeted support and innovative strategies to overcome these barriers

(Roberts et al., 2021). Latest research on the implementation of CE principles in secondary ports has been conducted such as by Mańkowska et al. (2020) and Gurning & Tangkau (2022). Research by Mańkowska et al (2020) identified opportunities, challenges and key action for secondary ports to adopt CE principles, with Szczecin Port in Poland as their case study. They identified 5 circular supply chains at Szczecin Port, which are as follows: 1) steel products-scrap metal; 2) copper concentrate-sulphuric acid; 3) limestone-gypsum; 4) tyres-oil, soot, scrap metal; 5) wood waste-ground wood waste. Meanwhile, research by Gurning & Tangkau (2022) used a Fishing Terminal in Bali, Indonesia as their case study. They explored CE activities to process waste generated from Benoa Fishing Terminal area such as oily sludge treatment, domestic solid waste treatment, wastewater treatment, fish solid waste treatment and squid solid waste treatment.

This paper further explores how CE principles can be implemented in small-peripheral ports, by using a single case study in Badas Port. This research differs from previous studies since the object of the study is smaller in size and handles different cargoes compared to previous research. Location of Badas Port, a small port located in West Nusa Tenggara Province, Sumbawa Island, Indonesia, as seen in Figure 1.

Figure 1. Location of Badas Port



Source: Authors

Besides exploring potential circular economic activities, this study also investigates stakeholders involved in port operations and sustainability efforts, stakeholder's awareness to sustainability issues and circular economy, examines influencing factors or motivation to conduct CE principles, propose planning for potential infrastructure, collaboration/partnerships and supporting policies to be developed. Furthermore, it identifies the benefits for the local economy as well as benefits for the environment.

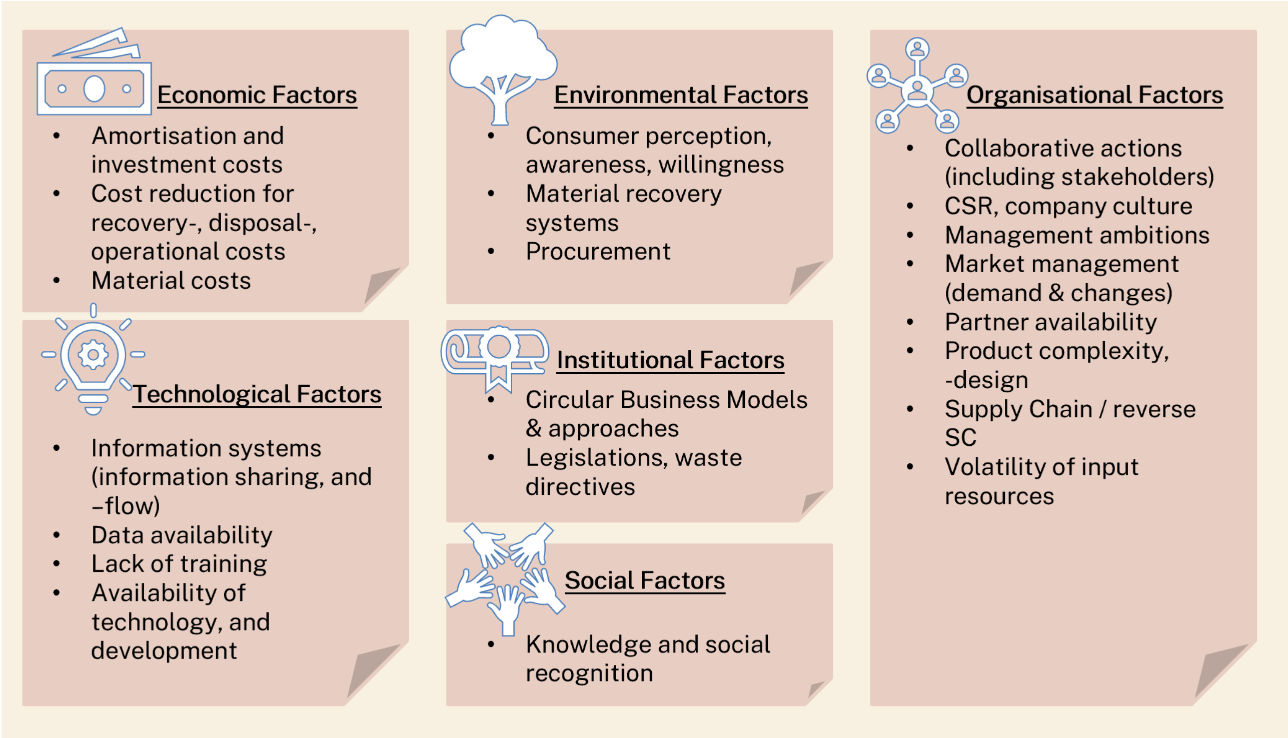
2 Literature Review

2.1 CE in Port and Maritime Economics Literature

The concept of the CE represents a transformative approach to economic development that emphasizes sustainability, resource efficiency, and the minimization of waste. It is characterized by principles such as reducing resource consumption, reusing materials, recycling products, and recovering energy from waste (Antón & Alonso-Almeida, 2019; Okorie et al., 2018).

Notteboom et al. (2022) defined 'Circularity' in four key principles as follows. First is 'Maintenance', which involves servicing and upgrading products to extend their lifecycle. Second is 'Reuse', where products are transferred between users through leasing or sharing systems. Third is 'Remanufacture', the process of creating new products by refurbishing and replacing parts from non-functional items. Lastly is 'Recycle', which repurposes discarded products as raw materials for manufacturing new goods. These principles ensure products retain value and reduce waste throughout their lifecycle. Meanwhile, Leder et al. (2023) compiled 'influencing factors', which are factors influencing the use of the circular economy or to achieve circularity from various studies in the literature and identified these factors in a multiple case study, consisting of 25 case organizations from 9 industry sectors. There are 6 categories of influencing factors, with each detailed in Figure 2.

Figure 2. Influencing Factors to achieve circularity



Source: Compiled by Leder et al. (2023) from various studies

In the context of the maritime industry, the CE is particularly relevant due to the sector's significant resource consumption and environmental footprint. The maritime industry is a critical component of global trade, accounting for over 90% of international cargo volume, which underscores the need for sustainable practices within this sector (Park et al., 2019). However, the transition to a CE in maritime contexts faces several barriers, including inadequate reverse supply chain practices and the lack of effective take-back strategies for end-of-life products (Okumus, 2024; Okumus, 2023). These challenges necessitate a strategic approach to operationalizing circular principles, particularly in port operations and logistics, where the integration of CE practices can yield substantial economic and environmental benefits (Roberts et al., 2021; Mańkowska et al., 2020).

Recent literature has begun to explore the application of CE principles specifically within port and maritime economics. For instance, ports are increasingly recognized as pivotal nodes in circular supply chains, facilitating the movement of goods while also serving as platforms for recycling and resource recovery (Mańkowska et al., 2020; Razmjooei et al., 2023). The implementation of CE strategies in ports can enhance local economic benefits, reduce negative environmental impacts, and foster sustainable urban development (Roberts et al., 2021; Stanković et al., 2021). However, the diversity of port types—primary, secondary, and tertiary—suggests that a one-size-fits-all approach is inadequate; tailored strategies are essential for effective transition (Mańkowska et al., 2020). While the potential for CE practices in the maritime sector is considerable, actual implementation is currently limited, hence, further studies are needed to identify best practices or frameworks that can guide ports in adopting CE principles effectively (Roberts et al., 2021; Razmjooei et al., 2023). The use of digital technologies, data analytics and innovative business models are also beneficial to enhance sustainability in maritime operations, enabling better resource management and operational efficiency (Koilo, 2024; Wagner & Wiśnicki, 2022; Fenisa, 2024).

2.2 Ecologies of Scale in Port Ecosystem

Ecologies of scale in port operations refer to the benefits and efficiencies that arise from the concentration of activities and resources within a port environment. This concept is particularly relevant in the context of the CE, as larger ports can leverage their scale to implement more effective circular practices. The relationship between ecologies of scale and CE principles is multifaceted, encompassing resource management, waste reduction, and economic opportunities. Larger ports, such as those in Rotterdam and Antwerp, benefit from high volumes of traffic and diverse operations, which create a substantial pool of resources, waste products, and potential consumers (Roberts et al., 2021). This concentration allows for more efficient waste management systems and resource recovery processes. For instance, the Port of Rotterdam has implemented advanced waste management strategies that transform waste into valuable resources, effectively turning a pollution issue into an economic opportunity (Roberts et al., 2023). The scale of operations enables these ports to invest in infrastructure that supports CE initiatives, such as recycling facilities and sustainable logistics systems.

Moreover, the concept of ecologies of scale suggests that larger ports are more likely to adopt CE practices due to their ability to integrate various stakeholders and resources within a single operational framework. This integration fosters collaboration among businesses, local governments, and research institutions, which is essential for developing innovative solutions to waste management and resource recovery (Cerreta et al., 2020). For example, the Port of Antwerp has established partnerships that facilitate the exchange of materials and energy among different industries, enhancing the circularity of the local economy (Mańkowska et al., 2020). In contrast, smaller ports often face challenges in implementing CE practices due to limited resources and lower traffic volumes. These ports may struggle to achieve the same level of efficiency and collaboration as their larger counterparts, making it difficult to realize the benefits of CE principles (Roberts et al., 2021; Mańkowska et al., 2020). The literature highlights the need for tailored strategies that can help smaller ports overcome these barriers and engage in CE initiatives effectively (Haezendonck & Berghe, 2020).

Additionally, the integration of digital technologies plays a crucial role in enhancing the CE within port operations. Larger ports can leverage data analytics and smart technologies to optimize resource management and waste reduction efforts, further reinforcing the advantages of scale (Jugović et al., 2022). For instance, the Copenhagen-Malmö Port has adopted a CE approach that emphasizes energy efficiency and renewable energy integration, showcasing how digital solutions can facilitate sustainable practices (Karimpour et al., 2019). Ecologies of scale in port operations are closely linked to the successful implementation of CE principles. Larger ports can capitalize on their scale to foster collaboration, optimize resource management, and invest in sustainable infrastructure, thereby enhancing their economic viability and environmental performance. Conversely, smaller ports may require targeted support to navigate the challenges associated with adopting CE practices.

2.3 Circular Economy Adopted in Global Hub Ports and in Small Peripheral Ports

The implementation of CE practices in advanced global hub ports is increasingly recognized as a vital strategy for enhancing sustainability and operational efficiency. These ports are adopting various best practices that not only minimize waste but also create economic opportunities by transforming waste into resources. This response synthesizes current best practices observed in several leading ports around the world. Implementation in global hub ports are summarized in Table 1.

On the other hand, research on small peripheral ports adopting CE principles is limited but growing, as these ports face unique challenges and opportunities in their transition to more sustainable practices. The literature suggests that while larger ports may have more resources and traffic to implement CE initiatives effectively, smaller ports can also adopt CE principles tailored to their specific contexts. One significant study by Roberts et al. (2021) highlights that smaller ports may struggle to implement CE practices due to their limited resources and lower volumes of traffic, which restrict their access to a diverse pool of waste products and potential consumers. This suggests that while the potential for adopting CE principles exists, smaller ports may require targeted support and innovative strategies to overcome these barriers. In a comparative analysis, Mańkowska et al. (2020) discuss the challenges and opportunities for secondary ports in the context of circular supply chains. They emphasize that there is no universal plan for transitioning to a CE, as the diversity of port types necessitates tailored approaches (Mańkowska et al., 2020). This indicates that while smaller ports may face challenges, they also have the potential to develop unique CE strategies that leverage their local contexts and resources.

Table 1. Circular Economy Principles Implemented in Global Hub Ports

Global Hub Ports	Circular Economy Principles Implemented	Source
Port of Amsterdam	• Comprehensive waste management system that encourages waste minimization and resource recovery. • Fit-for-purpose reception facilities that incentivize shipping companies to manage waste effectively, thereby aligning with CE principles	(Loizidou, 2024).
Port of Hamburg	• Optimizing waste management processes, which include recycling and reusing materials generated during port operations • Enhance the economic viability of the ports by creating new revenue streams from recycled materials.	(Loizidou, 2024)
The Port of Gävle (Sweden)	• CE principles have been integrated into its operational framework. • Making use of contaminated dredged materials to create new land. • Fostering innovation and reducing environmental impacts through collaborative projects with local industries, ensures the port's competitiveness and contributes to regional sustainability goals • Enhance operational resilience and economic performance.	(Carpenter et al., 2018).
Port of Antwerp	• Establishing a CE model that emphasizes the importance of collaboration among stakeholders such as partnerships with local businesses and research institutions to develop innovative solutions for waste management and resource recovery. • Collaborative approach is essential for overcoming the barriers to CE implementation, such as high costs and land use challenges and act as catalysts for regional CE initiatives.	(Lukman et al., 2022), Roberts et al., 2021).
Copenhagen-Malmö Port	• Adopted a CE approach aimed at transitioning into a self-sustainable energy port. • Focuses on integrating renewable energy sources and optimizing energy efficiency within port operations • Highlights the potential for ports to not only reduce their carbon footprint but also to serve as models for sustainable energy practices in the maritime sector.	(Karimpour et al., 2019

Source: compiled by Authors

A study by Gurning and Tangkau explores the application of CE principles in public and fishing terminals in Indonesia, demonstrating how collaborative management of waste across different port activities can promote sustainability (Gurning & Tangkau, 2022). This case illustrates that even smaller ports can implement CE practices through cooperation among various stakeholders, thereby enhancing their operational efficiency and environmental performance. Moreover, research by Argyriou (2023) emphasizes the importance of sustainability in small and medium-sized ports (SMSPs), noting that these ports play a crucial role in regional economies. The study suggests that by adopting CE principles, SMSPs can mitigate environmental impacts while enhancing their economic viability (Argyriou, 2023). This aligns with the broader understanding that CE can provide economic opportunities even for smaller entities within the maritime sector. Furthermore, the work by Opferkuch et al. (2021) reviews organizational approaches to CE implementation, indicating that smaller ports can benefit from adopting frameworks that align with CE principles, even if they operate on a smaller scale. This highlights the potential for smaller ports to engage in CE practices by leveraging existing frameworks and adapting them to their specific needs.

While research on small peripheral ports adopting CE principles is still developing, existing studies indicate that these ports can indeed implement CE practices tailored to their unique contexts. By focusing on collaboration, resource optimization, and innovative strategies, smaller ports can enhance their sustainability and contribute to the broader circular economy.

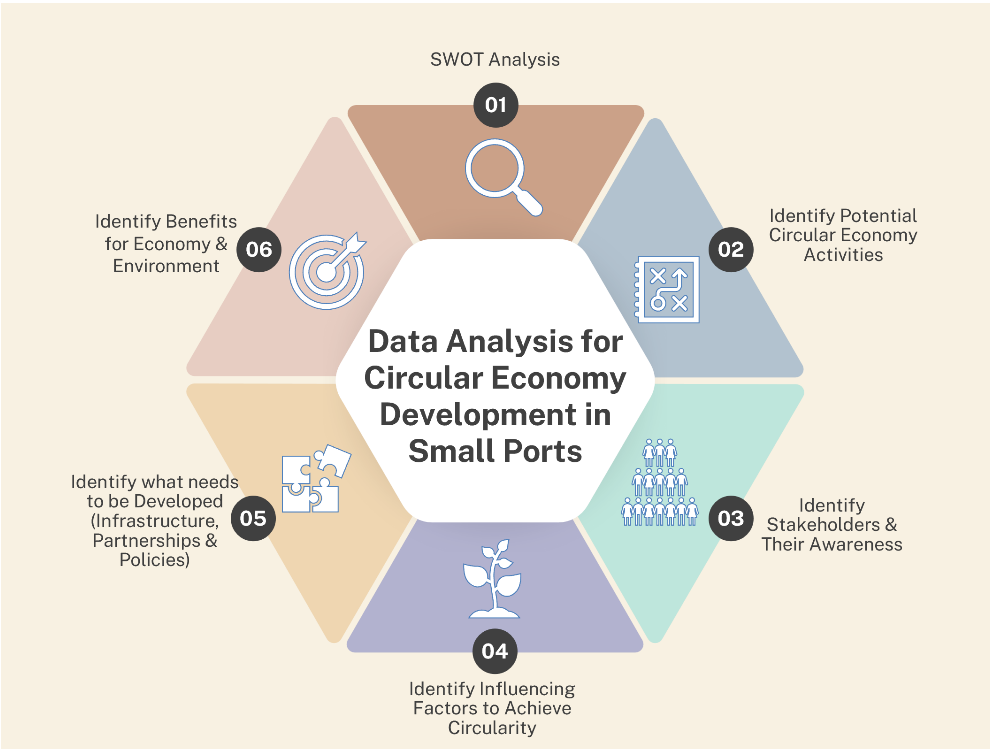
3 Methodology

In order to achieve the research objectives, especially to develop a framework for integrating CE principles into the operations of small peripheral ports, Badas Port in Sumbawa is used as case study. It is chosen because of its unique cargo handled and since its existence is critical for the island. The study employs a mixed-methods approach, integrating qualitative and quantitative data collection and analysis techniques. This approach allows for a deeper understanding of the contextual, operational, and stakeholder-driven factors influencing the adoption of CE principles at Badas Port.

Observation and interviews were conducted in July 2024. A five-day observational study was conducted at Badas Port to assess its current operations, infrastructure, and environmental practices. This hands-on approach provided direct insights into the port’s workflows, resource usage, and waste management practices, forming the foundation for identifying areas with CE potential. Meanwhile, semi-structured interviews were carried out with 15 key stakeholders. First, key stakeholders are port operators and managers with the purpose to understand current operational processes and challenges. Second are cargo owners and logistics service providers, mainly with the purpose to identify their needs and expectation from the port, including their role in promoting sustainable practices. Third are local businesses and community members, to explore the socio-economic impact of port operations. Lastly are policy makers and representatives from relevant government agencies, in order to assess the alignment of port operations with regional and national sustainability goals. The interviews focused on uncovering awareness and knowledge gaps, perceptions of CE principles, and potential barriers to and enablers of CE implementation.

In parallel with observation and interviews, secondary data analysis was conducted. Operational data from the port, such as cargo volumes, types of goods handled, and waste management records, were analyzed to quantify the port's material flow and identify inefficiencies. Additionally, relevant government policies and reports were reviewed to understand the regulatory environment and support mechanisms available for CE implementation. Afterwards, the collected data were analyzed using a 6 step framework (Figure 3), which is an improvement from the methods applied by Leder (2023) in their multiple case study on CE implementation. First, a SWOT Analysis was conducted to evaluate the strengths, weaknesses, opportunities, and threats at Badas Port. Second, potential CE activities in Badas Port were identified. Third, stakeholders and their awareness on CE and sustainability issues were identified. Fourth, influencing factors needed to achieve circularity in Badas Port were identified. Fifth, infrastructure, partnerships and policies needed for a successful implementation of CE in Badas Port were identified. Lastly, the benefits for economy and environment were identified.

Figure 3. Data Analysis Framework for Circular Economy Development in Small Ports



Source: Authors, improved from Leder (2023)

4 Findings

4.1 Port of Badas Profile

Located in Sumbawa Regency, facing the northern open sea of Sumbawa Island, Badas Port is well-protected by natural breakwaters. Badas Port supports trade of agricultural products from Sumbawa Island, with dominant commodities including corn, pearls, fish, honey, and livestock (cattle). Imported cargo includes cement, fertilizers, MFO (marine fuel oil), and asphalt. The port infrastructure currently consists of 4 piers, 1 beaching pier, 3 warehouses, and a container yard. Its equipment includes 1 reach stacker and 2 grain pumps. The largest revenue for Badas Port comes from dry bulk corn loading activities and container handling (loading/unloading). Badas Port is managed and part of a port operating company named *PT Pelabuhan Indonesia (Persero)*, which is Indonesia's largest state-owned company providing port services or also well known as *Pelindo* or Indonesian Ports.

Within the Pelindo Group, Badas Port operates under the Pelindo Multi Terminal sub-holding and the Bali-Nusra Subregion (Regional 3). Corn production and the volume of corn handled by Badas Port generally exhibit a long-term upward trend, although production levels occasionally fluctuate. The potential for exporting corn abroad exists, as demonstrated by a previous export to Vietnam in early 2023, when Badas Port loaded 13,000 tons of corn onto two vessels. However, this has currently halted due to a decline in corn production. The development of corn storage facilities, such as silos within the port area, presents an attractive business opportunity. Respondents, particularly corn cargo owners, highlighted that such facilities would simplify logistics for cargo owners given the large volume of corn shipments.

Additionally, there is potential for establishing a livestock handling hub, particularly for cattle, given the significant production of cattle in Sumbawa, which is shipped to Java Island, Lombok Island, and Makassar. Respondents also noted that the port area still has ample space to accommodate additional facilities, such as livestock shelter and warehouses. Most cattle are transported by truck via ferry and traditional wooden ships through Badas Port. An incident occurred in 2024 where livestock died due to inadequate shelter during the logistics process via ferry. Therefore, developing a facility to provide temporary housing for livestock, particularly during transit or while awaiting transport is critical. Not only for business expansion of the port but also for the animals and for the continuity of business for cargo owners. The following Table 2 outlines throughput data in Badas Port.

Table 2. Badas Port Throughput Data

Type of Cargoes Handled in Badas Port	Units	Throughput 2023	Throughput 2024	Additional Information
General Cargo	Tons	259,165	267,742	
Bag Cargo	Tons	-	-	
Liquid Bulk	Tons	43,723	32,014	
Dry Bulk	Tons	384,312	228,871	All dry bulks handled are corn
Gas	Tons	-	-	
Vehicles	Unit	-	-	
Livestock	Animals	6,454	5,658	Cattles and goats
Containers	Boxes	6,992	6,558	
	TEUs	7,112	6,693	

Source: Authors from Pelindo data

4.2 SWOT Analysis

A SWOT analysis of Badas Port was developed using secondary data collection, interviews, and on-site observations. The identified strengths, such as the port's strategic location and key hinterland commodities, serve as the primary input for pinpointing potential CE activities. The analysis results are next utilized to identify key influencing factors, which effectively supporting the implemention of CE initiatives at the port. The SWOT analysis results are described in Figure 4.

4.3 Identification of Potential CE Activities, Stakeholder Awareness and Influencing Factors

The interviews conducted with key stakeholders in the implementation of circular economy (CE) principles at Badas Port revealed valuable insights. Stakeholders included port operators and managers, cargo owners and logistics service providers, local businesses and community members, and policy makers.

Port Operators and Managers highlighted challenges related to fluctuating cargo volumes. They identified the potential use of silos near the port to store corn as a significant opportunity to enhance operational efficiency. This infrastructure would not only streamline the transportation of corn but also enable its use as feed for livestock, creating a closed-loop system that aligns with CE principles. However, they expressed uncertainty about how to initiate and manage such initiatives and emphasized the need for collaboration with other stakeholders. The need for partnerships to gain funding such as from financial institutions, donor countries or green financing is also needed for infrastructure upgrades. Investment budget from Pelindo Headquarters or Regional Office are mostly prioritized for hub ports which generates revenue for the company. Being a small port is a challenge because not much revenue could be generated although supports local economy.

Figure 4. SWOT Analysis of Badas Port

Source: Authors

Cargo Owners and Logistics Service Providers showed interest in sustainable practices, particularly in improving cargo handling efficiency and resource utilization. They supported the idea of silos for corn storage, which would reduce transportation costs and improve the quality of the commodity. They acknowledged their role in supporting CE initiatives but felt that leadership from the port operator was essential to guide collaborative efforts and integrate these practices into their operations.

Local Businesses and Community Members expressed concerns about the socio-economic impact of port operations, including limited employment opportunities and environmental degradation. They viewed the potential integration of silos and livestock feeding systems as a way to create economic opportunities, such as increased agricultural productivity and livestock industry development. However, they noted a lack of engagement and collaboration between the community and port authorities. Meanwhile, respondents from Policy Makers and Government Representatives underscored the alignment of CE initiatives with national sustainability goals. They recognized the strategic value of silos in supporting the local agricultural economy and fostering synergies between corn and livestock industries. They also mentioned how such strategies could further bring induced economic activities such as initiation of related industries (e.g biofertilizer, biogas, biofuel industry). However, they identified gaps in coordination and policy enforcement, which hinder the effective implementation of such infrastructure projects.

Moreover, most interview respondents, particularly port customers such as shipping companies and cargo owners, emphasized the need for infrastructure development, including corn silos and livestock warehouses. There is a growing awareness of environmental and sustainability issues, as well as the importance of addressing climate change through improvements and investments. However, efforts toward sustainability are not yet well-coordinated for collaborative action. For example, one respondent suggested, "It would be better if there were a livestock warehouse so that livestock cargo would be safer, healthier, and the waste could be utilized." Additionally, involving the local community in CE initiatives and CSR activities is crucial, particularly for resolving land-related issues in a way that ensures a win-win outcome. However, current CSR efforts have yet to focus on addressing the needs related to corn and livestock and involvement of local community are still limited.

Overall, the interview results indicate that while stakeholders are aware of CE principles and see the potential for implementing related activities at Badas Port, there is confusion regarding leadership roles, planning, and execution. The integration of silos near the port is highlighted as a key opportunity to enhance efficiency, promote circular practices, and drive socio-economic benefits. Stakeholders collectively emphasized the need for coordinated efforts, clear guidelines, and capacity-building programs to enable successful CE adoption. Influencing factors to adopt circular economy in Badas Port's case is described in Figure 5.

Figure 5. Influencing Factors to Adopt Circular Economy Badas Port

Influential Factors compiled from the literature by Leder (2023)		Influencing Factors in the Case of Badas Port	
Category	**Factors**	**Positive/ Negative**	**Explanation**
Economic Factors	Amortisation and investment costs	-	Cargo owners are aware of potential CE activities. However, they are unwilling to invest in infrastructure to provide ideal services for them because the return on investment would take a long term which is not appealing for their business.
	Cost reduction for recovery-, disposal-, operational costs	+	There are business potential to process waste or disposal from port operations to local industries. However, stakeholders currently appear to be prioritizing their individual interests, which has hindered the exploration of collaborative opportunities to establish cost reduction or cost recovery for consolidated port waste disposal.
	Material costs	+	Material cost for producing organic fertilizers from manure is cheaper in terms of raw materials and energy costs, compared to materials to produce chemical fertilizers. However, logistical challenges (transportation, handling) and lower economies of scale can increase expenses. In the long term, organic fertilizers are more sustainable and environmentally friendly, while chemical fertilizers may face increasing costs due to resource depletion and regulatory pressures.
Technological Factors	Information systems (information sharing, and –flow)	+	So far information sharing between stakeholders has been limited. Furthermore, it must be initiated by the port to get related stakeholders involved in planning, development and operations of livestock warehouse, fertilizer industry and corn cargo owners.
	Data availability	+	Similar to information sharing, data availability from each stakeholders has been limited and there is a need to improve data management. It could be initiated by the port to get related stakeholders collaborating on this.
	Lack of training	-	Trainning conducted so far has been focused on port operations and productivity and not yet concerning strategic planning and sustainability issues.
	Availability of technology, and development	+	Cattle manure can produce energy for electricity generation, primarily through biogas production which is renewable energy. The process involves using the manure in an anaerobic digester to produce biogas, which can then be converted into electricity. However, to develop this technology, Badas Port ecosystem needs to be supported by universities or research institution and related Ministries such as the Ministry of Energy and Mineral Resources, Ministry of Environment and Forestry, Ministry of Agriculture, Ministry of Industry, and Ministry of Villages, Development of Disadvantaged Regions, and Transmigration.
Environmental Factors	Consumer perception, awareness, willingness	+	There are awareness on sustainability and potential CE activities. However, still unclear in what roles must each stakeholder do, who initiates the investments to develop infrastructure and uncertain of the feasibility of the project.
	Material recovery systems	+	There has not been a structured program or dedicated human resources to focus on material recovery systems and implement them routinely; so far, efforts have only been reactive responses to incidental waste.
	Procurement	+	There has not been collaboration between cargo owners to support sustainable procurement and create green supply chain from the cargoes produced by the hinterland.
Institutional Factors	Circular Business Models & approaches	+	In Indonesia's context, there has been regulation on environment and alignment with global sustainability goals such as those outlined in the Paris Agreement. However, regulations specifically on CBM and CE activities in transport has not been established well and still on progress.
	Legislations, waste directives	+	In Indonesia's context, there has been regulation on environment and alignment with global sustainability goals such as those outlined in the Paris Agreement. However, regulations specifically on waste directives in transport has not been established well and still on progress.
Social Factors	Knowledge and social recognition	+	There has been awareness on ESG in general and at high level. However, no involvement from society or stakeholders around the port for sustainability and CE activities in port environment. More socialization is needed and campaign for port stakeholders.
Organisational Factors	Collaborative actions (including stakeholders)	+	Exploration of collaborative opportunities needs to be improved. Initial steps could be done through CSR, port customer hearing, coordination meetings with local governments or morning breakfast meetings between Badas Port Stakeholders.
	CSR, company culture	+	Port company CSR has been doing CSR which could actually participate in giving solution go sustainability issues. However, the CSR programs done so far are focused to reduce carbon emission through greening of port area and mangrove planting. CSR programs has not touched CE principles.
	Management ambitions	+	Pelindo management has ambitions for ESG implementation and continuous improvement for increasing port productivity. However, for CE activities in each port or terminals are not well defined in its strategic initiatives.
	Market management (demand & changes)	-	Seasonal demands for products going through the port needs to be managed better through infrastructure such as silos or warehouses, moreover because of the low volume of cargo, and this makes implementing CE even more challenging.
	Partner availability	+	The port has not met partners with the same willingness to implement CE activities, either from cargo owners, local business or NGOs to support CE initiatives.
	Product complexity, -design, Supply Chain / reverse SC, Volatility of input resources	-	The potential ideas for CE activities seems simple related to corn and cattle/livestock, however, practical and processes to establish circularity is complex and needs detailed designs, moreover with volatile nature of the resources.

Source: Authors

4.4 Proposed Infrastructure, Partnerships and Policies to be Developed

Based on stakeholder interviews in the Badas Port environment, it can be concluded that nearly all of them recognize the importance of implementing a circular economy (CE). The successful practices implemented by major hub ports can serve as a model for adoption in Badas Port, with adjustments made to align with its specific scope and needs. By tailoring these approaches to local conditions, Badas Port has the potential to effectively integrate CE principles, driving sustainable development and enhancing its operational efficiency. Implementing a CE in Badas port for managing corn and cattle manure involves creating a closed-loop system where resources are reused, waste is minimized, and sustainability is prioritized. To support CE activities at Badas Port, a comprehensive approach involving infrastructure development, strategic partnerships, and supportive policies is essential. These efforts will enable the port to become a model for sustainability and efficiency in Indonesia.

Infrastructure Developments

Significant infrastructure enhancements are necessary for CE implementation. For corn-related activities, constructing efficient grain storage silos with transportation systems, such as conveyors and trucks, will streamline distribution. Developing climate-controlled livestock shelters and warehouses for feed storage will improve animal care and welfare during transit. To integrate a corn industry for livestock feeding, processing facilities for feed production, along with quality control and storage infrastructure, are required. Biogas production from livestock manure necessitates biogas digesters, processing units, and gas distribution systems, while biofertilizer production will benefit from composting facilities and packaging infrastructure.

Additionally, the establishment of facilities to convert corn into biofuels, alongside renewable energy technologies like solar and wind power, can further reduce the environmental impact. Finally, supporting side industries such as food processing, agricultural R&D, and logistics centers will enhance economic opportunities around the port.

Partnerships to be Established

Collaboration is critical for success. Partnerships with agricultural cooperatives will ensure a consistent supply of corn and livestock. Universities and research institutions can drive innovation in sustainable practices and technologies. Engagement with local governments and regulatory bodies will facilitate planning, permitting, and compliance. The private sector can contribute expertise and resources for biogas and biofertilizer production, while NGOs and environmental organizations can raise community awareness and support sustainability initiatives.

In addition, establishing partnerships with financial institutions—whether local or international—is essential. These institutions can provide loans, grants, or even CSR support for green development projects. Such financial backing is not only necessary for infrastructure upgrades but also for funding research and development related to the potential circular economic activities that can be implemented at Badas Port.

Technology plays a crucial role in the establishment of industries based on CE principles (Leder et al., 2023) such as biofertilizers, biogas, and biofuel, as mentioned in Figure 5 on Technological Factors. For these sectors to thrive, the support of financial institutions is equally important for universities and research centers, ensuring that technological innovations are adequately funded and effectively integrated into circular economy initiatives. These partnerships create a collaborative ecosystem that integrates multiple stakeholders into CE activities. Learning from the Port of Antwerp, which has established partnerships that facilitate the exchange of materials and energy among different industries—thereby enhancing the circularity of the local economy—Badas Port has the potential to build collaborations with existing stakeholders or seek out new partners to develop and implement circular economy principles.

Policies to Support Circular Economy Activities

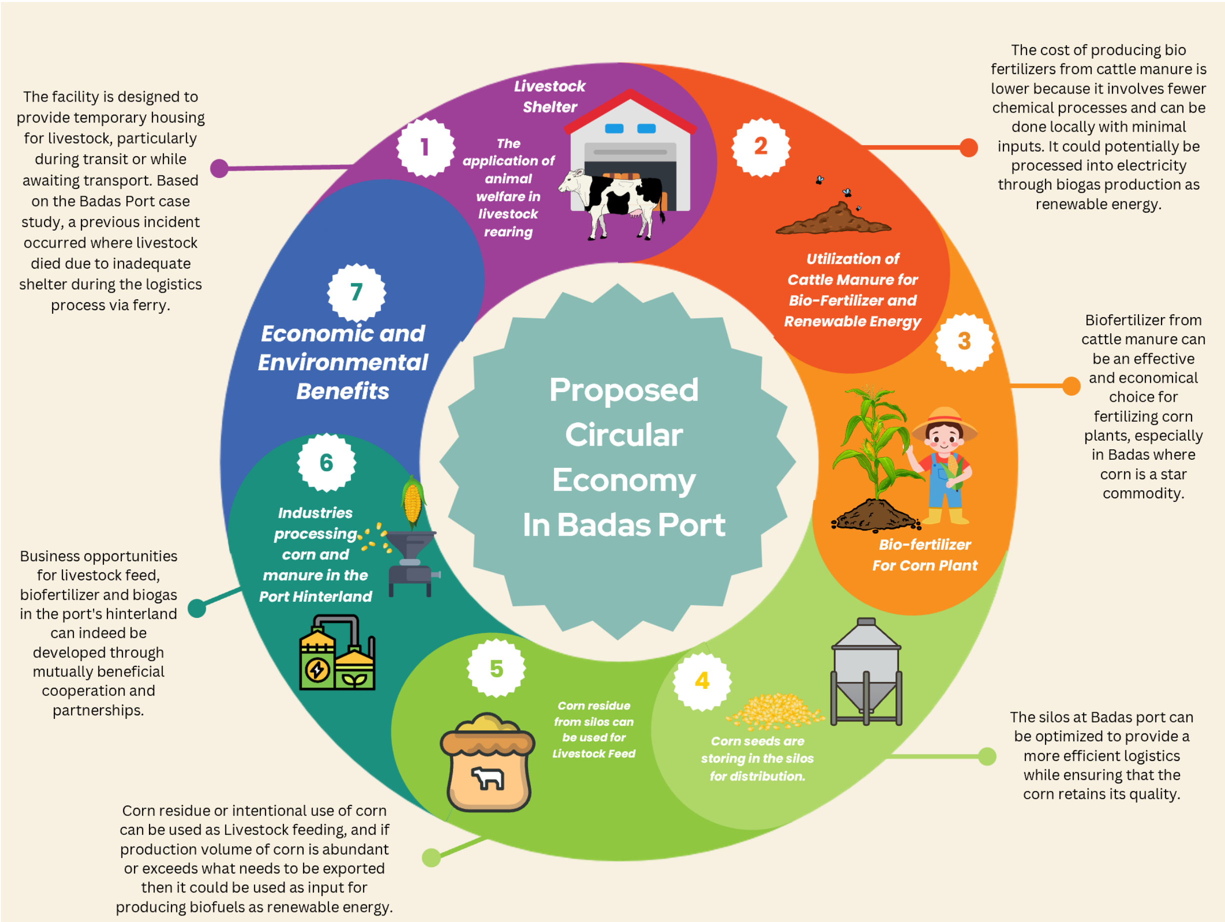
Supportive policies will drive the adoption of CE practices. Incentives such as tax breaks or grants can encourage businesses to implement sustainable models. A regulatory framework for waste management will ensure effective recycling and manure treatment. Government funding for infrastructure projects will accelerate development efforts, while education and training programs will prepare the workforce to engage in sustainable agriculture and CE principles. Policies promoting innovation in renewable energy and consumer awareness campaigns about the benefits of circular practices will further solidify Badas Port’s commitment to sustainability.

5 Discussion

5.1 Circular Economy in Badas Port

Circular economy activities at Badas Port are highly feasible, provided the input and output of processing for the port's most dominant cargo are effectively mapped. Key activities include developing livestock warehouses and corn silos to enhance operational efficiency and sustainability. Livestock warehouses ensure cattle comfort, proper healthcare, and the conversion of manure into renewable energy and fertilizer, which can then be used for corn cultivation. Corn silos support efficient storage, while nearby processing industries transform corn into livestock feed or renewable biofuels such as ethanol. This closed-loop system, illustrated in Figure 6, demonstrates how these activities can create synergies between agriculture and renewable energy, aligning with CE principles.

Figure 6. Proposed Circular Economy in Badas Port



Source: Authors

In addition to business development and environmental benefits, this CE scheme also bring benefits to address safety issues. The welfare of the cattle during transportation is also compromised. The absence of adequate and comfortable facilities exposes the animals to significant stress during their journey, which can lead to deteriorated health and a decline in meat quality. The primary function of the livestock shelter is to ensure the welfare of the animals while meeting the standards for health, safety, and biosecurity. These shelters are typically designed with features such as climate control, proper ventilation, and designated feeding and watering stations to maintain the animals' health during their stay. In addition to providing shelter, they facilitate the smooth transfer of livestock from one mode of transportation to another—whether by ship or truck, while minimizing stress on the animals.

The infrastructure of such shelters includes specialized loading and unloading ramps to ensure humane handling, quarantine zones for veterinary inspections, and holding areas segregated by species or health status to prevent cross-contamination and disease spread.

5.2 Economic and Environmental Benefit for Small Peripheral Ports

The planned CE activities at Badas Port have the potential to simultaneously deliver economic and environmental benefits. By integrating initiatives such as livestock warehouses and corn silos into the port's operations, these activities not only enhance operational efficiency but also create opportunities for broader economic impacts through induced activities.

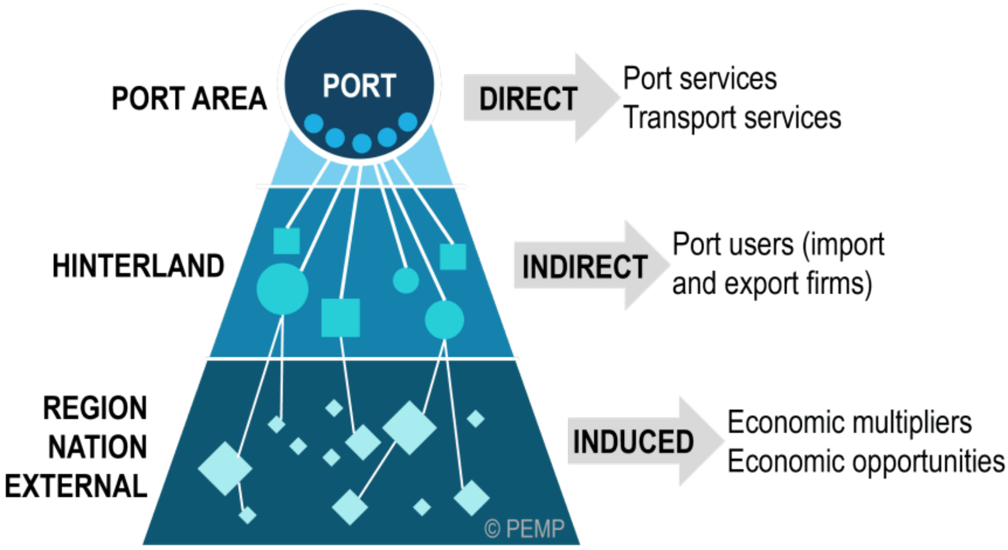
One major impact is on local consumer spending. Workers employed at the livestock warehouse and corn silos, along with employees of related industries, will spend their incomes on housing, food, healthcare, education, and leisure. This spending stimulates the local economy, benefiting retail businesses, service providers, and the hospitality sector. Additionally, the demand for agricultural support services is expected to grow, as the facilities will drive increased need for livestock feed, fertilizers, and associated supplies like agricultural equipment, seeds, and irrigation systems.

The renewable energy sector will also see growth. Biogas production from livestock manure and bioethanol from corn will boost industries involved in energy distribution, maintenance, and renewable energy technologies. Similarly, enhanced storage and processing facilities will require expanded logistics services for transporting livestock, corn, biofertilizers, and biofuels, creating jobs in trucking, warehousing, and freight handling. Moreover, the establishment of food processing industries near the port becomes a feasible prospect. Corn silos can attract companies to produce corn-based snacks or beverages, generating additional employment and economic activity. The improved port infrastructure could also indirectly boost the tourism and hospitality sectors, as regional trade increases and spending in local businesses grows.

Research and development activities may also emerge as institutions collaborate on innovations in sustainable farming, livestock care, and waste management. This not only supports economic growth but also positions Badas Port as a hub for advancing sustainable practices. Even though ecologies of scale might not be reached in a short period, at least all these efforts could increase the small port's throughput in the early phase and continue to grow to reach the profitable and significant scale. Overall, the induced activities driven by the livestock warehouse and corn silos will create a multiplier effect, where new income circulates through the local economy, leading to job creation, higher regional output, and improved living standards. These developments align with CE principles while fostering long-term economic resilience and sustainability in the region.

Notteboom et al. (2022) describes that ports can serve as catalysts for economic growth by generating a cascade of positive effects. These benefits are categorized into three, which are direct benefits through port services, indirect benefits through port users' activities and induced benefit becoming multiplier effect for the regional and national economy, as shown in Figure 7. Through this research, an argument is put forward that small-peripheral ports could bring economic and environmental benefits in each of these three layers simultaneously. Furthermore, not only stakeholders in the port area could adopt CE activities, stakeholders in the hinterland and inter-island of Indonesia could also adopt CE activities, where they share their waste as commodities and as resources for other industries, at other port locations. This highlights the role of small ports could play as orchestrators in CE activities.

Figure 7. Three Categories of Port's Economic Benefits



Source: Notteboom et al. (2022)

5.3 Increasing Awareness of Stakeholders and Establishing Development through Investment and Partnership

To emphasize the importance of CE and sustainability efforts in small peripheral ports like Badas Port, a strategic approach is essential. The first priority is to meet customer expectations by addressing their basic operational needs, ensuring efficient and reliable port services. This builds trust and sets a foundation for introducing CE initiatives. Next to push forward CE activities, key influencing factors must be established: institutional, organizational, and social factors. These act as the core framework enabling other factors, such as economic, environmental, and technological considerations, to function effectively. Digital technology platforms for communication, data sharing and collaboration of stakeholders would also bring benefits for the implementation of CE. A well-structured foundation ensures alignment and collaboration among stakeholders in driving sustainability efforts.

Additionally, small ports must position themselves as orchestrators within the surrounding industrial ecosystem and green financing. This involves synchronizing partnerships and investments to create a cohesive network of stakeholders who are aware of and willing to participate in CE initiatives. For example, planning infrastructure development requires forecasting data for corn and cattle throughput over the next 10 years and determining acceptable investment levels for potential partners. By taking a proactive role in coordinating these efforts, small ports can enhance stakeholder engagement and foster long-term sustainability in the port ecosystem.

6 Conclusion

This research contributes to the ongoing debate whether small-peripheral ports, which are challenged by their small volume and limited infrastructure, could play the role in creating a more sustainable ecosystem by implementing CE principles. A case study is conducted at Badas Port, located in West Nusa Tenggara, Indonesia, which is a small port handling less than 10,000 TEUs containers per year. Cargoes that are currently dominant handled at Badas Port are dry bulk corn and livestock cattle. Data from direct observation and interviews conducted were analyzed using mixed methods approach. Critical aspects from the port are identified which are the potential circular economic activities that could be initiated, related stakeholders and their awareness on CE, influencing factors to achieve circularity, what needs to be developed including port and warehouse infrastructure, relevant industries, policies to support the ecosystem, etc. Lastly benefits for local economy and environment are also identified.

Badas Port has potential to become pilot and inspiration for other small-peripheral ports in adopting CE. It could be concluded from the findings and discussion as follows. Firstly, identifying CE-based activities in small peripheral ports is feasible, supporting previous research on CE in secondary ports by Mankowska et al (2020) and Gurning & Tangkau (2022). However, more detailed quantitative calculations are necessary to determine whether these activities are economically viable (feasible or not) and whether they fit within ecologies of scale (beneficial or not). In Badas Port, certainly various new infrastructure must be developed beforehand. However, this research could become guideline for the port's long-term planning and roadmap to green and sustainable port ecosystem.

Secondly, significant strategies are needed by small ports in comparison to the CE activities at larger hub ports with the focus on increasing cargo volume in parallel to becoming more sustainable. In larger hub ports, circular economic activities are supported by significant consolidation, resulting in more efficient waste management, enhanced stakeholder collaboration, and integration of renewable energy sources. However, the primary challenge in small ports is the low volume of cargo. Therefore, planned CE activities in these ports should initially aim to increase cargo volumes, which would subsequently allow them to achieve economies of scale and ecologies of scale. For instance, in Badas Port's case, utilizing waste from cattle as renewable energy, developing a corn-based feed industry for cattle, and initiating a fertilizer industry could potentially stimulate the emergence of entrepreneurs and new businesses on the island. This, in turn, would lead to cargo growth, eventually reaching a profitable scale.

Lastly, on Stakeholder Awareness and Collaboration. While small port stakeholders have some awareness of CE principles, they remain uncertain about how to implement them. The solution lies in initiating stakeholder collaboration, which should be led by the small port operator. This aligns with the literature review, emphasizing that ports play a critical role as hubs for sustainability efforts.

7 Research Implications and Future Study

The findings of this study have significant implications for both practice and policy. They provide a framework that can serve as a best-practice example for the development of other small peripheral ports based on CE principles. The initial steps involve identifying the primary cargo handled by the port, assessing the port's strengths and potential, and determining the types of CE initiatives that can be implemented. These steps should be accompanied by fostering collaboration among stakeholders and clearly outlining the economic and environmental benefits of such initiatives. Additionally, the study highlights the need for future research with more rigorous quantitative analysis to identify other innovative ways for small peripheral ports to stimulate growth while contributing to global sustainability efforts. Other possible research includes the exploration and quantification of direct benefit, indirect benefit and induced benefit of CE implementation in small ports. By doing so, these ports can align economic development with environmental stewardship in a unique way, ensuring their role in supporting a sustainable future.

Acknowledgments

We would like to thank respondents and Management of Pelindo for their support in this research.

References

Antón, J. and Alonso-Almeida, M. (2019). The circular economy strategy in hospitality: a multicase approach. Sustainability, 11(20), 5665. https://doi.org/10.3390/su11205665.

Argyriou, I. (2023). Sustainable solutions for small/medium ports a guide to efficient and effective planning. Journal of Marine Science and Engineering, 11(9), 1763. https://doi.org/10.3390/jmse11091763.

Carpenter, A., Lozano, R., Sammalisto, K., & Astner, L. (2018). Securing a port's future through circular economy: experiences from the port of gävle in contributing to sustainability. Marine Pollution Bulletin, 128, 539-547. https://doi.org/10.1016/j.marpolbul.2018.01.065.

Cerreta, M., Muccio, E., Poli, G., Regalbuto, S., & Romano, F. (2020). City-port circular model: towards a methodological framework for indicators selection., 855-868. https://doi.org/10.1007/978-3-030-58808-3_61.

Fenisa, D. (2024). The role of big data in circular supply chain practices and corporate sustainability performance. Widya Cipta - Jurnal Sekretari Dan Manajemen, 8(1), 40-45. https://doi.org/10.31294/widyacipta.v8i1.16568.

Gurning, R. and Tangkau, D. (2022). The analysis of the conceptual framework of green port implementation in indonesia using circular economy: the case study of benoa public and fishing terminals. Sustainability, 14(10), 6083. https://doi.org/10.3390/su14106083.

Haezendonck, E. and Berghe, K. (2020). Patterns of circular transition: what is the circular economy maturity of belgian ports?. Sustainability, 12(21), 9269. https://doi.org/10.3390/su12219269.

Jarrett, H. 1966. Environmental Quality in a Growing Economy, pp. 3-14. Baltimore, MD: Resources for the Future/Johns Hopkins University Press.

Jugović, A., Sirotić, M., Žgaljić, D., & Oblak, R. (2022). Assessing the possibilities of integrating ports into the circular economy. Tehnicki Vjesnik - Technical Gazette, 29(2). https://doi.org/10.17559/tv-20200327221233.

Karagkouni, K. (2024). Classification of green practices implemented in ports: the application of green technologies, tools, and strategies. Journal of Marine Science and Engineering, 12(4), 571. https://doi.org/10.3390/jmse12040571.

Karimpour, R., Ballini, F., & Ölçer, A. (2019). Circular economy approach to facilitate the transition of the port cities into self-sustainable energy ports—a case study in copenhagen-malmö port (cmp). Wmu Journal of Maritime Affairs, 18(2), 225-247. https://doi.org/10.1007/s13437-019-00170-2.

Koilo, V. (2024). Unlocking the sustainable value with digitalization: views of maritime stakeholders on business opportunities. Problems and Perspectives in Management, 22(1), 401-417. https://doi.org/10.21511/ppm.22(1).2024.33.

Leder, N., Kumar, M. & Rodrigues, V.S. (2023). Influencing factors driving collaboration in circular business models, International Journal of Logistics Research and Applications, https://doi.org/10.1080/13675567.2023.2254258.

Loizidou, X. (2024). Optimizing waste management for green shipping: industry commitment through participatory processes in cyprus. Journal of Shipping and Trade, 9(1). https://doi.org/10.1186/s41072-024-00168-x.

Lukman, R., Brglez, K., & Krajnc, D. (2022). A conceptual model for measuring a circular economy of seaports: a case study on antwerp and koper ports. Sustainability, 14(6), 3467. https://doi.org/10.3390/su14063467.

Mańkowska, M., Kotowska, I., & Pluciński, M. (2020). Seaports as nodal points of circular supply chains: opportunities and challenges for secondary ports. Sustainability, 12(9), 3926. https://doi.org/10.3390/su12093926.

Notteboom, T., Pallis, A., & Rodrigue, J. P. (2022). Port economics, management and policy. New York: Routledge. https://porteconomicsmanagement.org/

Notteboom, T., Lugt, L., Saase, N., Sel, S., & Neyens, K. (2020). The role of seaports in green supply chain management: initiatives, attitudes, and perspectives in rotterdam, antwerp, north sea port, and zeebrugge. Sustainability, 12(4), 1688. https://doi.org/10.3390/su12041688.

Okorie, O., Salonitis, K., Charnley, F., Moreno, M., Turner, C., & Tiwari, A. (2018). Digitisation and the circular economy: a review of current research and future trends. Energies, 11(11), 3009. https://doi.org/10.3390/en11113009.

Okumus, D. (2023). Circular economy approach in the maritime industry: barriers and the path to sustainability. Transportation Research Procedia, 72, 2157-2164. https://doi.org/10.1016/j.trpro.2023.11.701.

Okumus, D. (2024). An approach to advance circular practices in the maritime industry through a database as a bridging solution. Sustainability, 16(1), 453. https://doi.org/10.3390/su16010453.

Opferkuch, K., Caeiro, S., Salomone, R., & Ramos, T. (2021). Circular economy in corporate sustainability reporting: a review of organisational approaches. Business Strategy and the Environment, 30(8), 4015-4036. https://doi.org/10.1002/bse.2854

Park, J., Seo, Y., & Ha, M. (2019). The role of maritime, land, and air transportation in economic growth: panel evidence from oecd and non-oecd countries. Research in Transportation Economics, 78, 100765. https://doi.org/10.1016/j.retrec.2019.100765.

Razmjooei, D., Alimohammadlou, M., Kordshouli, H., & Askarifar, K. (2023). A bibliometric analysis of the literature on circular economy and sustainability in maritime studies. Environment Development and Sustainability, 26(3), 5509-5536. https://doi.org/10.1007/s10668-023-02942-6.

Roberts, T., Williams, I., Preston, J., Clarke, N., Odum, M., & O'Gorman, S. (2023). Ports in a storm: port-city environmental challenges and solutions. Sustainability, 15(12), 9722. https://doi.org/10.3390/su15129722.

Roberts, T., Williams, I., Preston, J., Clarke, N., Odum, M., & O'Gorman, S. (2021). A virtuous circle? increasing local benefits from ports by adopting circular economy principles. Sustainability, 13(13), 7079. https://doi.org/10.3390/su13137079.

Stanković, J., Marjanović, I., Papathanasiou, J., & Drezgić, S. (2021). Social, economic and environmental sustainability of port regions: mcdm approach in composite index creation. Journal of Marine Science and Engineering, 9(1), 74. https://doi.org/10.3390/jmse9010074.

Wagner, N. and Wiśnicki, B. (2022). The importance of emerging technologies to the increasing of corporate sustainability in shipping companies. Sustainability, 14(19), 12475. https://doi.org/10.3390/su141912475

Wiradanti, B., Pettit, S., Potter, A., & Abouarghoub, W. (2018). Ports, peripherality and concentration – deconcentration factors: a review. Maritime Business Review, 3(4), 375-393. https://doi.org/10.1108/mabr-09-2018-0040.

Wiradanti, B., Pettit, S., Potter, A., & Abouarghoub, W. (2020). Willingness to invest in peripheral ports: perceptions of indonesian port and maritime industry stakeholders. Maritime Economics & Logistics, 22(4), 699-714. https://doi.org/10.1057/s41278-020-00147-6.