Adaptive Dynamic Collaboration Model Innovation In Multimodal Green Logistics Transportation As An Effort To Strengthen Business Sustainability Towards Indonesia Emas 2045

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Abstract
Indonesia's logistics sector faces significant challenges in efficiency and sustainability, evidenced by high logistics costs (23.5% of GDP) and the environmental impact of multimodal transportation. This research develops an innovative adaptive dynamic collaboration model to address operational fragmentation and promote effective green logistics practices, which are vital for achieving the Indonesia Emas 2045 vision. Employing a qualitative approach through in-depth interviews, observations, and document analysis involving three major logistics companies in Surabaya (PT Bintang Laut Platinum, CMA CGM, PT Yusen Logistics Indonesia) and other stakeholders, this study identifies collaborative mechanisms that enhance operational efficiency and reduce environmental impact. Key findings indicate that this model holds significant potential in reducing logistics costs, decreasing greenhouse gas (GHG) emissions, improving intermodal connectivity, and elevating Indonesia's Logistics Performance Index (LPI) ranking. The novelty of this research lies in the integration of Green Supply Chain Management, Triple Bottom Line, Green Logistics, and Open Innovation theories within an adaptive collaborative framework tailored for developing countries. This model offers a strategic roadmap for a more efficient and sustainable logistics transformation, thereby strengthening business sustainability and supporting Indonesia's ambition to become a global economic power with a green and efficient logistics sector.
Keywords: *Dynamic Collaboration; Green Logistics; Business Sustainability; Multimodal Transportation; Logistics Efficiency; Logistics Performance Index (LPI); Indonesia.*

INTRODUCTION

The Indonesian logistics sector faces a dual pressure: the imperative for efficiency and the demands of sustainability. The nation's high logistics costs, reaching 23.5% of its Gross Domestic Product (GDP), significantly hinder economic competitiveness, far exceeding the global average of 10-15%. Furthermore, logistics transportation is a major contributor to greenhouse gas (GHG) emissions and air pollution, raising serious environmental and public health concerns. Despite an increase in container volume in cities like Surabaya, the lack of effective intermodal integration and slow adoption of green technologies exacerbate these challenges. This situation is reflected in Indonesia's Logistics Performance Index (LPI), which ranked 63rd out of 139 countries in 2023.

This research aims to address these challenges by proposing an innovative adaptive dynamic collaboration model for multimodal green logistics. The model is specifically designed to contribute to four key performance indicators crucial for achieving the Indonesia Emas 2045 vision: 1) The reduction of national logistics costs as a percentage of GDP; 2) A decrease in GHG and air pollutant emissions from the logistics sector; 3) An improvement in intermodal connectivity and efficiency; and 4) An increase in Indonesia's LPI ranking. As such, this study seeks to provide a concrete strategic framework for transforming Indonesia's logistics sector

into a more efficient, sustainable, and globally competitive one, which will directly strengthen long-term business sustainability.

LITERATURE REVIEW

This research integrates several key theories to build the conceptual framework for an innovative adaptive dynamic collaboration model in green logistics:

1. *Green Logistics* and *Green Supply Chain Management* (GSCM): These concepts emphasize the minimization of the environmental impact of all supply chain activities, including transportation, warehousing, and waste management.
2. Dynamic Collaboration Theory: Highlights the importance of flexible partnerships and organizations' ability to adapt to rapid changes in the business environment. In logistics, this translates to synergy among various parties to achieve common goals.
3. *Open Innovation* Theory: Supports the idea that innovation can be accelerated by integrating ideas and knowledge from both internal and external sources of an organization. This is crucial for the adoption of green technologies and sustainable practices.
4. *Triple Bottom Line* (TBL): A sustainability framework that measures business performance based on three pillars: economic, social, and environmental, ensuring a holistic balance in green logistics practices.
5. General Systems Theory and Contingency Theory: Views logistics as a complex system that requires adaptive strategies based on specific contexts and conditions.

While the literature extensively discusses GSCM and collaboration, there remains a gap in understanding how an explicitly dynamic and adaptive collaborative model can be implemented in the context of multimodal green logistics in a developing country like Indonesia. This research aims to bridge this gap by directly linking specific collaboration mechanisms to macro-performance indicators, thereby contributing to business sustainability and the national vision.

Conceptual Framework

The core of this research is an adaptive dynamic collaboration model, built upon a clear conceptual framework. The framework, illustrated in Figure 1 (Thinking Framework) and Figure 2 (Conceptual Framework), begins with an identification of the core problem: high logistics costs, increasing environmental pressure, and a lack of multimodal integration and regulation in Indonesia. The proposed solution model and effective implementation strategies are then developed, focusing on the core components of the model. The research design and methodology, as described previously, are intended to validate and refine this framework.

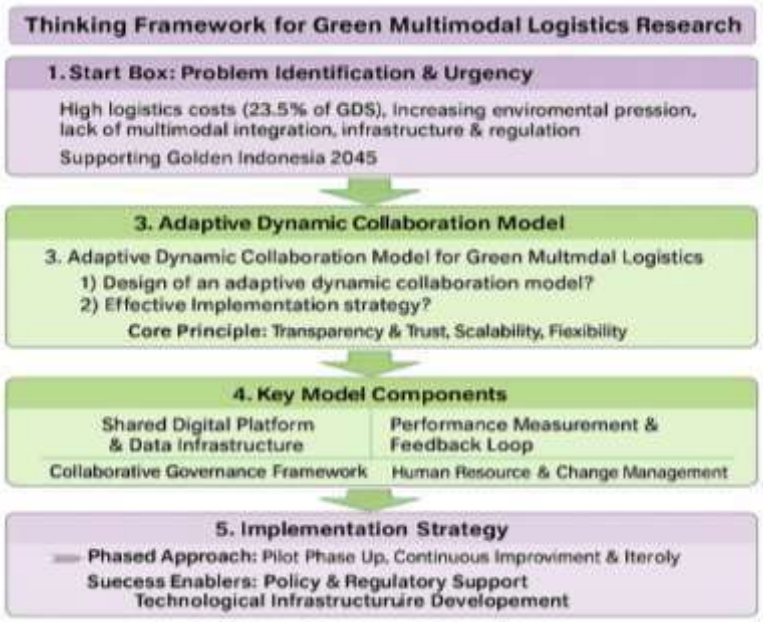

Figure 1: Research Thinking Framework

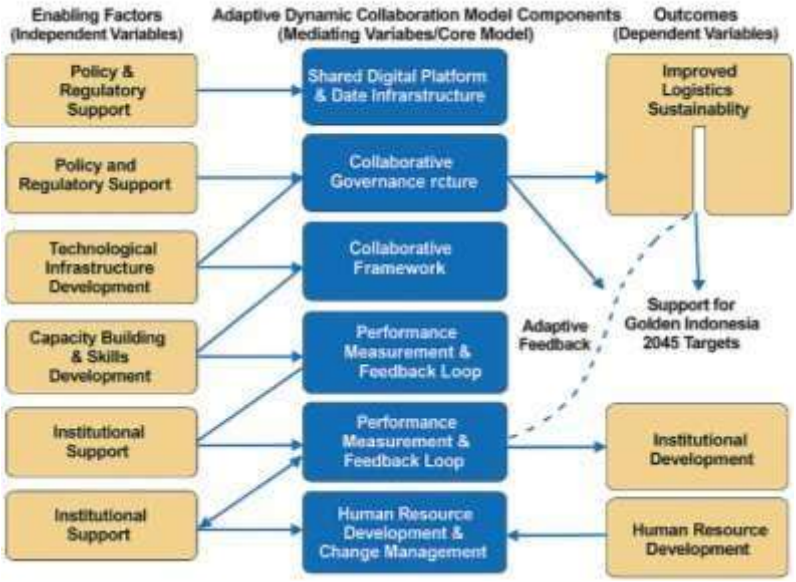

Figure 2: Research Conceptual Framework

RESEARCH METHOD

1. Research design and setting

This study adopts an exploratory qualitative approach with a multiple case study design. The choice of a qualitative approach enables a rich understanding of the complex dynamics of collaboration and the contextual factors influencing it. Surabaya was selected as the study location due to its role as a major logistics hub in Eastern Indonesia, offering a relevant context for multimodal transportation.

2. Participants

The study involved 8 key informants purposefully selected to represent diverse perspectives within the multimodal logistics ecosystem: 1) Senior managers from three leading logistics companies in Surabaya: PT

Bintang Laut Platinum (BLP), CMA CGM, and PT Yusen Logistics Indonesia (YLID). These companies were chosen for their significant multimodal operations and involvement in sustainability initiatives; 2) Officials from the East Java Provincial Transportation Agency, representing regulatory and policy aspects; 3) Academics with expertise in green logistics and sustainability; 4) Chairs of industry associations, such as ALFI-ILFA (Association Indonesian Logistics and Forwarders)East Java and ASDEKI (Association Depo Kontainer Indonesia)East Java, representing industry voices and facilitating collaboration.

3. Data Collection

Employed data triangulation to enhance the validity of findings:1) In-Depth Interviews: Semi-structured interviews were conducted with managers/executives from logistics companies, government officials, and academics to explore their perceptions, experiences, and strategies for green logistics and collaborative challenges; 2) Field Observations: Direct observation of logistics operations at the facilities of the subject companies, particularly at multimodal transshipment points, to understand process flows and potential inefficiencies; 3) Document Analysis: Review of company sustainability reports, government policies related to logistics and the environment, and operational data (e.g., fuel consumption reports, transportation volumes).

4. Data Analysis

Qualitative data were analyzed thematically using a systematic framework, starting from transcription, coding, categorization, to theme identification and pattern interpretation. This analysis was interpreted based on GSCM, TBL, Green Logistics, and Open Innovation theories to construct a comprehensive collaborative model. The validity of findings was strengthened through member checking with key informants.

FINDING AND DISCUSSION

The research findings indicate that the Adaptive Dynamic Collaboration Model Innovation in Multimodal Green Logistics Transportation as an Effort to Strengthen Business Sustainability Towards Indonesia Emas 2045 is built upon three main pillars: Integrated Digital Platforms, Multi-Stakeholder Engagement (Quadruple Helix), and Adaptive & Continuous Learning Mechanisms. The implementation of this model shows significant contributions to the targeted performance indicators. Key Components of the Innovative Adaptive Dynamic Collaboration Model:

1. Integrated Digital Platforms: Interview findings with managers from PT Bintang Laut Platinum, CMA CGM, and PT Yusen Logistics Indonesia consistently highlight digital technology as a fundamental element of collaboration. The use of cloud-based *Transportation Management Systems* (TMS), IoT-enabled asset tracking, and AI-driven route optimization algorithms is crucial. These platforms enhance end-to-end supply chain visibility, enabling real-time data exchange on transport capacity, optimal routes, and shipment status. This data integration directly supports improved intermodal connectivity and efficiency.
2. Multi-Stakeholder Engagement (Quadruple Helix): Effective collaboration extends beyond logistics companies to include government bodies, academia, and industry associations/communities. The government's role is to act as a facilitator through pro-environmental policies and incentives, such as for electric vehicles or low-emission fuels, and regulations that promote cargo consolidation.
3. Adaptive & Continuous Learning Mechanisms: The model includes a feedback loop that allows for strategic and operational adjustments based on performance data and changes in market conditions or regulations. Real-time information sharing and regular performance analysis are essential for organizational learning and adaptation.

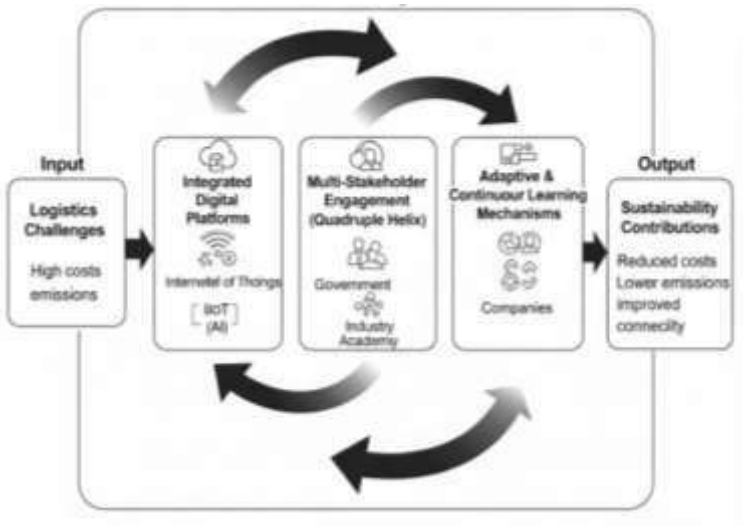

Figure 3: Adaptive Dynamic Collaboration Model Innovation in Multimodal Green Logistics Transportation

Impact of the Model on Performance Indicators

The application of this innovative adaptive dynamic collaboration model shows a strong correlation with potential improvements in the four key indicators:

1. Reduction of Logistics Costs as a Percentage of GDP: Through better route optimization and cargo consolidation via intermodal collaboration, operational costs can be significantly reduced. If applied nationally, these efficiencies could potentially lower the percentage of logistics costs to GDP, aligning with the Indonesia Emas 2045 target, which is an integral part of corporate business sustainability.
2. Decrease in GHG and Air Pollutant Emissions: Route optimization, reduced vehicle idle time, and the shift to more efficient transport modes (e.g., rail for long distances) directly lower the logistics sector's carbon footprint. This demonstrates a commitment to environmental sustainability.
3. Improvement in Intermodal Connectivity and Efficiency: Technology-supported collaboration facilitates smoother transitions between different modes of transport, such as road, sea, and rail. Coordinated scheduling at Surabaya's container terminals has reduced waiting times, improved port capacity, and enhanced overall multimodal supply chain efficiency. This supports Indonesia's vision as a "maritime nation" with integrated logistics, which is the foundation of long-term business sustainability.
4. Increase in Logistics Performance Index (LPI) Ranking: The collective enhancements in operational efficiency, cost reduction, improved digital infrastructure, and the adoption of green practices collectively contribute to the improvement of various LPI components. This national logistics improvement positively affects the global perception of Indonesia's logistics performance, ultimately leading to a higher LPI ranking.

Novelty and Theoretical Implications

This research offers theoretical novelty by comprehensively integrating Dynamic Collaboration, Green Logistics, and Open Innovation theories into a concrete adaptive model, specifically for the multimodal logistics context in developing countries such as Indonesia with Surabaya as the research city. This contribution enriches the understanding of the Triple Bottom Line by showing how technological synergy and collaboration can simultaneously achieve economic, environmental, and social goals in multimodal transportation. Furthermore, this research advances Green Logistics Theory by emphasizing real-time digitalization and ecosystem collaboration, while extending Open Innovation Theory by focusing on selective information risk management in the context of green logistics.

Conclusion and Implication

This study concludes that the proposed adaptive dynamic collaboration model for multimodal green logistics holds substantial potential to significantly enhance business sustainability and national logistics performance in Indonesia, particularly within the multimodal transport context in Surabaya. The model directly contributes to achieving the strategic targets of Indonesia Gold 2045, especially concerning logistics cost reduction, GHG emission decrease, intermodal connectivity improvement, and LPI ranking enhancement.
Some iimplications of this research are:

1. Address to logistics business players: Strongly advised to further invest in digital collaboration platforms and develop human resource capabilities to manage and leverage these technologies. Forming strong, transparent strategic partnerships with various stakeholders is crucial. Companies should also develop clear reporting mechanisms based on TBL principles;
2. Address to government: The government needs to strengthen policy and regulatory frameworks that provide clear incentives for adopting green logistics practices and facilitate the development of national interoperable collaboration platforms across transport modes. Regulations supporting data sharing and interoperability standards will accelerate the adoption of this model.

Limitation and Future Reseach

This study is qualitative and focused on the context of Surabaya, which limits direct generalization. Therefore, future research could include:

1. Large-scale quantitative studies to statistically validate the model and measure its quantitative impact on performance indicators across various regions;
2. Cross-country comparisons to understand contextual differences;
3. Exploration of the role of specific technologies, such as Blockchain for enhanced transparency and data security, or Artificial Intelligence (AI) for demand forecasting and network optimization, in strengthening green logistics collaboration.

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