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Environmental Process Maturity of Logistics Operators: Theoretical Aspects

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Abstract:

Purpose: *The study aims to present a reference model for assessing the environmental process maturity of logistics operators, thereby providing a systematic framework for evaluating and enhancing sustainability practices within the logistics sector.*
Design/Methodology/Approach: *The model is developed based on a comprehensive review of existing literature and best practices in environmental management, logistics, and organizational maturity models. The framework delineates maturity levels across six key dimensions: Environmental Policy, Operational Practices, Performance Measurement, Stakeholder Engagement, Digital Integration, and Continuous Improvement. Each maturity level represents a progressive stage of integration and sophistication in environmental management practices.*
Findings: *The proposed model offers a diagnostic tool for logistics operators to assess their current environmental maturity levels and identify specific areas for improvement. By following a structured approach, operators can systematically enhance their environmental process maturity. The model emphasizes the importance of adopting best practices, leveraging advanced technologies, and fostering stakeholder engagement to achieve higher levels of sustainability.*
Practical implications: *Logistics operators can use the model to develop targeted action plans, track progress, and make data-driven decisions to improve environmental performance. The framework provides a roadmap for progressive development, guiding operators from initial ad hoc practices to optimized, continuously improving processes. The adoption of this model can lead to significant improvements in operational efficiency, regulatory compliance, and brand reputation, as well as cost savings through resource optimization and waste reduction.*
Originality: *This paper addresses a gap in the literature by proposing a specialized reference model tailored specifically to the logistics sector. The model integrates various dimensions of environmental process maturity, providing a holistic approach to sustainability in logistics operations. The inclusion of digital integration and continuous improvement as key dimensions highlights the model's relevance in the context of technological advancements and the dynamic nature of logistics operations.*

Keywords: *Inland transport, process management, environmental process maturity.*
JEL classification: *L15, M10, M16, R49.*
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1. Introduction

The contemporary global economy's evolution has precipitated an increased focus on sustainability, with logistics operators emerging as pivotal entities in mitigating environmental impact. Environmental process maturity within logistics operations has become a subject of critical importance, warranting comprehensive theoretical and empirical exploration (Bai *et al.*, 2018).

Environmental process maturity, in the context of logistics, refers to the extent to which logistics operators have integrated and institutionalized environmental management practices into their operational processes. This concept is rooted in the broader discipline of environmental management systems (EMS), which encompasses structured frameworks for managing environmental responsibilities (Barón Dorado *et al.*, 2022).

The assessment of environmental process maturity involves evaluating various dimensions, including policy formulation, process implementation, performance measurement, and continuous improvement mechanisms.

Logistics operations inherently impact the environment through activities such as transportation, warehousing, and packaging (Mckinnon *et al.*, 2010). These activities contribute to greenhouse gas emissions, resource consumption, and waste generation, among other environmental challenges.

Consequently, logistics operators are under increasing pressure from stakeholders, including regulatory bodies, customers, and investors, to adopt sustainable practices (Rossi *et al.*, 2013). The adoption of such practices not only mitigates environmental impact but also enhances operational efficiency, brand reputation, and compliance with legal requirements.

The concept of process maturity models, initially developed in the field of software engineering, has been adapted to various domains, including environmental management. Maturity models provide a structured approach to assess and enhance organizational capabilities by delineating stages of development from initial ad hoc practices to optimized, continuously improving processes (van Looy *et al.*, 2011).

In the context of environmental management, such models facilitate the identification of strengths, weaknesses, and areas for improvement, thereby enabling organizations to systematically advance their environmental performance (Bai *et al.*, 2018).

Several models and frameworks have been proposed to assess environmental maturity in organizations. Notable among these is the Capability Maturity Model Integration (CMMI), which has been adapted to environmental management contexts to evaluate the maturity of environmental practices (Khanzadi *et al.*, 2024).

Additionally, the ISO 14001 standard provides guidelines for establishing effective environmental management systems, which can be leveraged to assess environmental process maturity (Corbett and Pan, 2002). However, specific models tailored to the logistics sector are relatively scarce, underscoring the need for a specialized framework.

This paper proposes a reference model specifically designed to assess the environmental process maturity of logistics operators. The model is constructed based on a comprehensive review of existing literature and best practices in environmental management and logistics. It delineates maturity levels across several dimensions, including environmental policy, operational practices, performance metrics, stakeholder engagement, and continuous improvement. Each maturity level represents a progressive stage of integration and sophistication in environmental management practices.

2. Literature Review

The assessment of environmental process maturity in logistics operations intersects multiple fields, including environmental management systems, logistics and supply chain management, and organizational maturity models (Bai *et al.*, 2018; Doss *et al.*, 2017; Liu *et al.*, 2018; Ormazabal *et al.*, 2017).

The foundation of environmental process maturity lies in the principles and practices of EMS. EMS frameworks, such as ISO 14001, provide organizations with structured methodologies for managing their environmental impacts (Latan *et al.*, 2018). The ISO 14001 standard emphasizes the integration of environmental considerations into organizational processes, encompassing policy development, planning, implementation, monitoring, and continuous improvement (Latan *et al.*, 2018).

Numerous studies have demonstrated the positive impact of ISO 14001 certification on environmental performance and operational efficiency (Melnyk *et al.*, 2003). These frameworks serve as a basis for assessing environmental process maturity by establishing benchmarks for best practices.

Logistics operations significantly contribute to environmental degradation through activities such as transportation, warehousing, and packaging. The environmental impacts of logistics have been well-documented, with transportation alone accounting for a substantial proportion of global greenhouse gas emissions (European Environment Agency, 2022; Mckinnon *et al.*, 2010). Consequently, the logistics industry has been the focus of various sustainability initiatives aimed at reducing emissions, improving resource efficiency, and minimizing waste.

Green logistics, which integrates environmental considerations into logistics and supply chain management, has emerged as a critical area of research (Prokop, 2011).

Studies have explored strategies such as optimizing transportation routes, adopting energy-efficient technologies, and implementing reverse logistics to enhance environmental sustainability (Marcilio *et al.*, 2018; Martí *et al.*, 2015).

The concept of organizational maturity models, originally developed in software engineering, has been adapted to assess the maturity of various organizational processes, including environmental management. Maturity models provide a systematic approach to evaluate and enhance organizational capabilities by identifying current maturity levels and outlining pathways for improvement (Charłampowicz *et al.*, 2024; Lee *et al.*, 2019).

In the context of environmental management, maturity models facilitate the assessment of an organization's progress in integrating environmental practices into its operations (Bai *et al.*, 2018; Kadlubek *et al.*, 2022a; 2022b).

Several models and frameworks have been proposed to specifically assess environmental process maturity in organizations. Azevedo *et al.* (2017) introduced the LARG index, a benchmarking tool that evaluates the leanness, agility, resilience, and greenness of supply chains, emphasizing the integration of environmental considerations. Similarly, the Environmental Performance Index (EPI) provides a comprehensive framework for assessing and comparing the environmental performance of countries, which can be adapted to organizational contexts (Block *et al.*, 2024).

These models highlight the importance of adopting a multi-dimensional approach to assess environmental process maturity, considering factors such as policy development, operational practices, performance measurement, and stakeholder engagement.

Empirical research has explored the implementation and outcomes of environmental maturity models in logistics. For instance, Evangelista *et al.* (2017) examined the adoption of green supply chain practices among logistics service providers in Italy, identifying key drivers and barriers to implementation.

Their findings underscore the role of organizational culture, regulatory pressures, and customer demands in shaping environmental practices. Similarly, a study by Colicchia *et al.* (2013) investigated the eco-efficiency of logistics service providers, highlighting the impact of green innovations on performance outcomes. These studies provide valuable insights into the practical application of environmental maturity models in the logistics sector, informing the development of tailored frameworks.

Despite the progress in developing environmental maturity models, several challenges remain. One significant challenge is the lack of standardized metrics and indicators for assessing environmental process maturity, leading to inconsistencies

in evaluation and benchmarking (Zhu *et al.*, 2005). Additionally, the dynamic nature of logistics operations, characterized by complex supply chains and diverse activities, poses difficulties in applying uniform assessment frameworks.

Organizational maturity models, such as CMMI, offer structured approaches to assess and enhance maturity levels. Empirical research on green logistics practices provides practical insights into the implementation and outcomes of environmental maturity initiatives. While challenges remain, ongoing research and technological advancements hold promise for refining and standardizing maturity assessment frameworks.

This paper builds on these foundations to propose a reference model specifically tailored to assess the environmental process maturity of logistics operators, aiming to contribute to the broader goal of sustainable development in the logistics sector.

3. Model of the Environmental Process Maturity for Logistics Operators

The proposed reference model for assessing the environmental process maturity of logistics operators is designed to provide a structured and comprehensive framework that evaluates and enhances sustainability practices. This model is grounded in established principles of environmental management, logistics, and organizational maturity models, aiming to contribute to the broader goal of sustainable development in the logistics sector (Charłampowicz and Grzelakowski, 2022; Evangelista *et al.*, 2017; Moutchnik, 2015; Zhu *et al.*, 2005).

The model comprises five maturity levels (Table 1) and evaluates logistics operators across six key dimensions (Table 2), Environmental Policy, Operational Practices, Performance Measurement, Stakeholder Engagement, Digital Integration, and Continuous Improvement.

Table 1. *Environmental process maturity levels for logistics operators*

Maturity level	**Characteristics**
Level 1 - Initial	At this level, environmental practices are ad hoc and unstructured. There is minimal awareness of environmental issues, and no formal policies or procedures are in place.
Level 2 – Identification	Environmental practices are recognized, and some basic policies and procedures are established. However, implementation is inconsistent, and efforts are primarily reactive, driven by regulatory compliance.
Level 3 – Defined	Environmental practices are formalized and documented. There is a systematic approach to managing environmental impacts, with defined processes and responsibilities. Stakeholder engagement begins to take shape.
Level 4 - Quantitatively Managed	Environmental performance is measured and analyzed. Quantitative goals are set, and data-driven decision-making is employed. There is active engagement with stakeholders, and

	digital technologies are utilized to enhance environmental management.
Level 5 – Optimizing	Continuous improvement mechanisms are in place, fostering innovation and excellence in environmental management. Best practices are shared across the organization, and there is proactive engagement with stakeholders. Digital integration is fully realized, enabling real-time monitoring and optimization.

Source: *Own elaboration.*

Table 2. *Key dimensions of environment process maturity assessment*

Dimension	**Level of maturity**	**Characteristics**
Environmental policy	Initial	No formal environmental policy exists.
	Identification	Basic environmental policy developed, focusing on regulatory compliance.
	Defined	Comprehensive environmental policy established, aligned with organizational goals.
	Quantitatively Managed	Policy includes quantitative targets and is regularly reviewed and updated.
	Optimizing	Policy drives continuous improvement and innovation, with active stakeholder involvement.
Operational Practices	Initial	Environmental practices are sporadic and not integrated into operations.
	Identification	Basic practices in place, such as waste management and energy conservation.
	Defined	Systematic integration of environmental practices into operational processes.
	Quantitatively Managed	Practices are optimized using performance data; sustainable technologies are adopted.
	Optimizing	Practices are continuously improved, leveraging advanced technologies and best practices.
Performance Measurement	Initial	No performance measurement; environmental impact is not quantified.
	Identification	Basic metrics established, primarily for compliance reporting.
	Defined	Comprehensive set of metrics covering key environmental aspects.
	Quantitatively Managed	Performance is quantitatively measured, and data is used for decision-making.
	Optimizing	Advanced analytics and real-time monitoring used to continuously improve performance.
Stakeholder Engagement	Initial	Minimal or no engagement with stakeholders on environmental issues.
	Identification	Basic engagement with regulatory bodies; limited interaction with other stakeholders.
	Defined	Active engagement with key stakeholders, including customers and suppliers.
	Quantitatively	Stakeholder feedback is systematically collected and

	Managed	used to inform practices.
	Optimizing	Proactive and collaborative engagement with stakeholders to drive sustainability initiatives.
Digital Integration	Initial	Limited or no use of digital technologies for environmental management.
	Identification	Basic digital tools used for data collection and reporting.
	Defined	Digital systems integrated into environmental management processes.
	Quantitatively Managed	Advanced digital technologies (IoT, big data) used for performance optimization.
	Optimizing	Full digital integration, enabling real-time monitoring, predictive analytics, and continuous optimization.
Continuous Improvement	Initial	No formal mechanisms for continuous improvement.
	Identification	Basic improvement initiatives driven by regulatory requirements.
	Defined	Structured continuous improvement processes in place.
	Quantitatively Managed	Continuous improvement driven by data analysis and performance feedback.
	Optimizing	Culture of continuous improvement, with innovation and excellence in environmental management.

Source: *Own elaboration.*

The proposed reference model serves as a diagnostic tool for logistics operators to evaluate their current level of environmental process maturity. By assessing each dimension across the five maturity levels, operators can identify strengths, weaknesses, and areas for improvement. The model also provides a roadmap for progressive development, guiding operators through incremental stages of maturity.

To implement the model, logistics operators should follow a structured approach comprising several key steps. First, they should conduct a thorough self-assessment using the model's criteria to determine the current maturity level for each dimension. Next, they need to identify gaps between the current state and the desired maturity levels through a gap analysis, which will highlight specific areas requiring improvement.

Following this, they should develop and implement action plans to address the identified gaps, incorporating specific initiatives, timelines, and resource allocations. Regular monitoring and evaluation mechanisms should be established to track progress, using performance data to make necessary adjustments to the action plans.

Finally, fostering a culture of continuous improvement is essential, encouraging innovation, knowledge sharing, and stakeholder engagement. By adhering to this structured approach, logistics operators can systematically enhance their environmental process maturity, thereby contributing to the broader goals of sustainability and sustainable development in the logistics sector.

4. Discussion

The proposed reference model for assessing the environmental process maturity of logistics operators represents a significant advancement in the field of environmental management within logistics. By providing a structured framework that evaluates multiple dimensions of environmental performance, the model offers a comprehensive approach to understanding and improving sustainability practices in logistics operations.

The adoption of structured environmental policies, as delineated in the model, is fundamental to achieving higher levels of environmental process maturity (Latan *et al.*, 2018; Ormazabal *et al.*, 2017). The proposed model emphasizes the progression from initial ad hoc practices to sophisticated, continuously improving policies that drive innovation and stakeholder engagement.

This progression is critical in ensuring that logistics operators not only comply with regulatory requirements but also proactively address environmental challenges (Charłampowicz *et al.*, 2024; Saha *et al.*, 2023).

Operational practices form another critical dimension of the model. The integration of sustainable practices into daily logistics operations, such as optimizing transportation routes, adopting energy-efficient technologies, and implementing reverse logistics, can significantly reduce environmental impacts (Marcilio *et al.*, 2018; Prokop, 2011).

The model's emphasis on continuously improving these practices aligns with the broader goals of green logistics, which aim to enhance environmental sustainability while maintaining operational efficiency (Liu *et al.*, 2018). By adopting best practices and leveraging advanced technologies, logistics operators can achieve substantial improvements in their environmental performance (Liu *et al.*, 2018; Van den Berg and De Langen, 2017).

Performance measurement is an essential component of the model, enabling logistics operators to quantify their environmental impacts and track progress over time. The use of comprehensive metrics and advanced analytics, as suggested in the model, allows for data-driven decision-making and continuous improvement (Evangelista *et al.*, 2017).

This approach is supported by existing research, which highlights the importance of performance measurement in driving environmental sustainability (Colicchia *et al.*, 2013). By systematically measuring and analyzing environmental performance, logistics operators can identify areas for improvement, set realistic goals, and monitor the effectiveness of implemented strategies.

Stakeholder engagement is also a crucial dimension of the model. The active involvement of stakeholders, including customers, suppliers, regulatory bodies, and the community, is essential for achieving environmental sustainability (Khanzadi *et al.*, 2024). The model encourages logistics operators to move from minimal engagement to proactive and collaborative interactions with stakeholders.

This approach not only enhances transparency and accountability but also fosters a culture of sustainability within the organization. Stakeholder engagement can drive innovation, as diverse perspectives and feedback contribute to the development of more effective environmental practices.

Digital integration represents a significant opportunity for enhancing environmental process maturity in logistics. The incorporation of digital technologies, such as the Internet of Things (IoT), big data analytics, and blockchain, can revolutionize environmental management by providing real-time monitoring, predictive analytics, and enhanced transparency (Kamilaris *et al.*, 2019).

The model underscores the importance of leveraging these technologies to optimize environmental performance and facilitate continuous improvement. By integrating digital solutions, logistics operators can achieve higher levels of efficiency, accuracy, and responsiveness in their environmental management practices.

Continuous improvement is the final dimension of the model, emphasizing the need for logistics operators to foster a culture of innovation and excellence (Agmoni, 2015). This dimension aligns with the principles of organizational maturity models, which advocate for systematic and ongoing enhancements to organizational processes (Bai *et al.*, 2018; Moutchnik, 2015).

By adopting continuous improvement mechanisms, logistics operators can ensure that their environmental practices remain relevant, effective, and aligned with evolving sustainability goals. This approach is critical for maintaining a competitive edge in the increasingly sustainability-conscious logistics industry.

5. Conclusions

The proposed reference model for assessing the environmental process maturity of logistics operators offers a comprehensive and structured framework that addresses the unique challenges and opportunities within the logistics sector. By evaluating multiple dimensions - Environmental Policy, Operational Practices, Performance Measurement, Stakeholder Engagement, Digital Integration, and Continuous Improvement, the model provides a holistic approach to understanding and enhancing environmental sustainability in logistics operations.

The implementation of this model has several implications for logistics operators. First, it provides a diagnostic tool that enables operators to assess their current

maturity levels and identify specific areas for improvement. This self-assessment process is crucial for developing targeted action plans that address identified gaps and drive incremental progress towards higher maturity levels.

Second, the model offers a roadmap for progressive development, guiding operators through the stages of maturity from initial, ad hoc practices to optimized, continuously improving processes. This roadmap facilitates systematic and strategic advancements in environmental performance.

The benefits of adopting this model are multifaceted. By enhancing their environmental process maturity, logistics operators can achieve significant improvements in operational efficiency, regulatory compliance, and brand reputation. Moreover, the adoption of sustainable practices can lead to cost savings through resource optimization and waste reduction. The proactive engagement with stakeholders and the integration of digital technologies further enhance the effectiveness and transparency of environmental management practices.

However, several challenges must be addressed to ensure the successful implementation of the model. The lack of standardized metrics and indicators for assessing environmental process maturity poses a significant challenge, leading to inconsistencies in evaluation and benchmarking.

Additionally, the dynamic and complex nature of logistics operations requires adaptable and flexible assessment frameworks that can accommodate diverse activities and supply chain configurations. Future research should focus on refining and standardizing assessment metrics, developing sector-specific models, and exploring the integration of emerging digital technologies to address these challenges.

In conclusion, the proposed reference model represents a significant advancement in the field of environmental management within logistics. By providing a structured and comprehensive framework for assessing and enhancing environmental process maturity, the model contributes to the broader goal of sustainable development in the logistics sector.

The implementation of this model can drive substantial improvements in environmental performance, operational efficiency, and stakeholder engagement, ultimately supporting the transition towards a more sustainable and resilient logistics industry.

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