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PORT MANAGEMENT ORIENTED TOWARDS ESG: THE LARGES APPROACH FOR PORT TERMINALS

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Abstract
The port operations demands management tools integrating operational efficiency, sustainability, and organizational resilience. This article presents the LARGES paradigm (Lean, Agile, Resilience, Governance, Environment, Social), developed as an integrative model for port management that combines management principles with governance and social responsibility, offering a theoretical and practical framework to increase the competitiveness and sustainability of ports. A systematic literature review was done focusing on supply chains of port and were analyzed and systematized according to the dimensions of the LARGES, allowing the identification of trends, gaps, and imbalances. Based on the LARG (Lean, Agile, Resilience, Green), the LARGES is proposed, incorporating the Governance and Social dimensions, shifting the focus from “green” to “environment,” in order to reflect a more systemic environmental approach. The applicability to the port context is discussed. The results indicate the LARGES contributes to the integration between operational efficiency and sustainable development, offering a holistic perspective.

Keywords: Paradigm. LARGES. Port terminals. Governance. Sustainability.

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1. Introduction

The port sector plays a structuring role in international trade, being responsible for the movement of more than 90% of the total volume of goods in the world. In this context, port terminals assume a strategic position by enabling intermodal flows and integrating increasingly complex global logistics chains. However, the intensification of competitive demands, associated with environmental, social, and regulatory pressures, has revealed the need for new management models capable of reconciling operational efficiency, sustainability, and organizational resilience.

The contemporary dynamics of port logistics has driven the transition from the concept of Port Supply Chain (PSC), centered on the internal efficiency of port operations, to the Integrated Port Supply Chain (IPSC), which broadens the scope of analysis by integrating public and private actors, logistics operators, and land and maritime chains. More recently, the paradigm of the Sustainable Integrated Port Supply Chain (SIPSC) has emerged, which adds to the dimensions of integration and efficiency a strategic orientation focused on environmental sustainability, responsible governance, and social inclusion. This conceptual evolution highlights the maturity of port management but also reveals the need for more comprehensive approaches that can articulate competitiveness, innovation, and sustainability within a single theoretical and operational framework.

Although the Sustainable Integrated Port Supply Chain (SIPSC) represents a significant advance by incorporating the environmental and social dimensions into the logic of port integration, it still presents significant limitations. Governance in port chains remains fragmented, since the various stakeholders — port authorities, logistics operators, shipping companies, private terminals, and local communities — often have objectives that are distinct and even competitive with each other. This heterogeneity of interests hinders the implementation of joint and coordinated strategies, resulting in environmental and social actions with limited reach and impact. Thus, even under the SIPSC paradigm, a gap persists for management models that promote collaborative and integrated governance, capable of aligning efficiency, sustainability, and interorganizational cohesion.

In view of this scenario, the LARGES paradigm is proposed, an integrated conceptual model that encompasses six fundamental dimensions of contemporary port management: Lean, focused on operational efficiency, waste elimination, and process optimization; Agile, related to adaptability in the face of market and demand variations; Resilience, which emphasizes the capacity to maintain and recover operations in the face of crises, shocks, or disruptions; Governance, which incorporates compliance, transparency, and control mechanisms; Environment, aimed at mitigating environmental impacts and aligning with the global green agenda; and Social, which considers corporate social responsibility and positive effects on local communities.

The development of the LARGES paradigm arose from the identification of gaps in existing approaches, which, for the most part, neglect the Governance and Social dimensions. It is observed that when seeking to improve internal processes such as cargo

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handling or the reorganization of operational flows, an emphasis on financial efficiency often prevails, frequently dissociated from social and environmental implications. This fragmentation reduces ports' ability to establish sustainable links with surrounding communities and compromises the implementation of integrated socio-environmental responsibility practices. In addition, the absence of integrated governance mechanisms tends to accentuate conflicts of interest among actors in the logistics chain, such as operators, suppliers, and customers, weakening the cohesion necessary for the systemic sustainability of the port complex.

From a theoretical point of view, the proposal of the LARGES paradigm dialogues with contemporary approaches to integrated management, such as the Agile Supply Chain and Resilient Logistics models (Christopher, 2000; Ivanov and Dolgui, 2020). Furthermore, it aligns with international corporate sustainability guidelines outlined by the Global Reporting Initiative (GRI) and the principles of the UN Global Compact, by explicitly incorporating the environmental, social, and governance dimensions. The originality of the paradigm lies in the synergistic articulation of these six dimensions in a single framework, applicable to the port context, offering a holistic and operationalizable perspective of sustainable and competitive management.

The purpose of the research is to propose and develop the LARGES framework (Lean, Agile, Resilience, Governance, Environment, Social) as a new integrative paradigm for port management, with emphasis on the crucial role of governance. It aims to investigate how efficient governance, based on transparency, compliance, and integration among all stakeholders in the supply chain, can enhance the effectiveness of the other dimensions of the LARGES paradigm, promoting more efficient, sustainable, and resilient port operations. This objective highlights the importance of governance as a central axis that can amplify or compromise the other dimensions, introducing an integrated and innovative perspective that has not yet been sufficiently explored in port literature. The study seeks to show that governance failures can generate disruptions in key areas such as operational efficiency, adaptability, environmental and social responsibility, directly affecting the competitiveness and long-term sustainability of port terminals.

2. Theoretical Framework

Due to the quantitative growth of commercial activities and consequently the increased use of the port, concern with efficiency in cargo operations also increased, and from the 2000s the term integrated port supply chains (Hussein and Song, 2023) emerged.

The evolution to the Integrated Port Supply Chain (IPSC) expands this perspective by incorporating integration among the different logistics links, connecting the port to land and maritime modes and encouraging cooperation among the various stakeholders. IPSC introduces a systemic management vision, in which port competitiveness depends on the synergy among the chain's actors, real-time information exchange, and strategic coordination of operations throughout the entire logistics corridor. While there was an effective flow of products and processes optimizing the relationship between customer

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needs and the supplier, on the other hand it generated detriment in port-city relations with increased negative environmental and social impacts, pressuring attention toward the concept of sustainability.

More recently, the Sustainable Integrated Port Supply Chain (SIPSC) has added to the dimensions of integration and efficiency an orientation toward environmental, social, and governance sustainability. This model seeks to align ports with global sustainable development agendas, promoting low environmental impact practices, corporate social responsibility, and greater transparency in relations among logistics chain agents. Thus, SIPSC represents a conceptual advancement by associating competitiveness and sustainability in an integrated port management structure. Although each stakeholder may adopt the SIPSC paradigm internally within the company, when looking at the entire chain, they are often conflicting or generate disruptions because governance is not integrated.

Publications and literature on systematic review research of the port supply chain were mapped with the intent of examining efficiency improvements and technological innovations; analysis of integrated and sustainable practices; green chains and mitigation of environmental impact. The methodology used in the articles varied from bibliometric analysis; systematic review; and case study. Using the SciSpace database, 927 articles were found and 80 were added from parallel research also in SciSpace with additional relevant articles, totaling 1007 articles, of which 13 were discarded by exclusion criteria, leaving 994 articles.

From this initial approach five questions were opened: one was a systematic review of the port supply chain focusing on efficiency improvements and technological innovations; the second question was to explore the role of smart technologies in increasing efficiency and sustainability, focusing on innovations and best practices for integrated and environmentally correct operations. The third question was to explore the intersection of digital transformation and sustainable practices emphasizing the role of smart technologies, digital twins, and AI in improving efficiency and environmental impact. The fourth question was to investigate the relationship between digital transformation technologies and their impact on increasing sustainability and efficiency, focusing on innovative solutions and best practices for integrated operations. And the fifth question was to explore advanced technological advances and their impact on integrated and sustainable practices with a focus on digital transformation, blockchain applications, and comparative case studies of efficiency improvement. Addressing the five questions, 100 articles remained, of which 7 were duplicates and were discarded, as shown in Figure 1.

The inclusion criteria choosen were articles in English, Portuguese, and Spanish; articles from the last 6 years.

The exclusion criteria adopted were news and websites.

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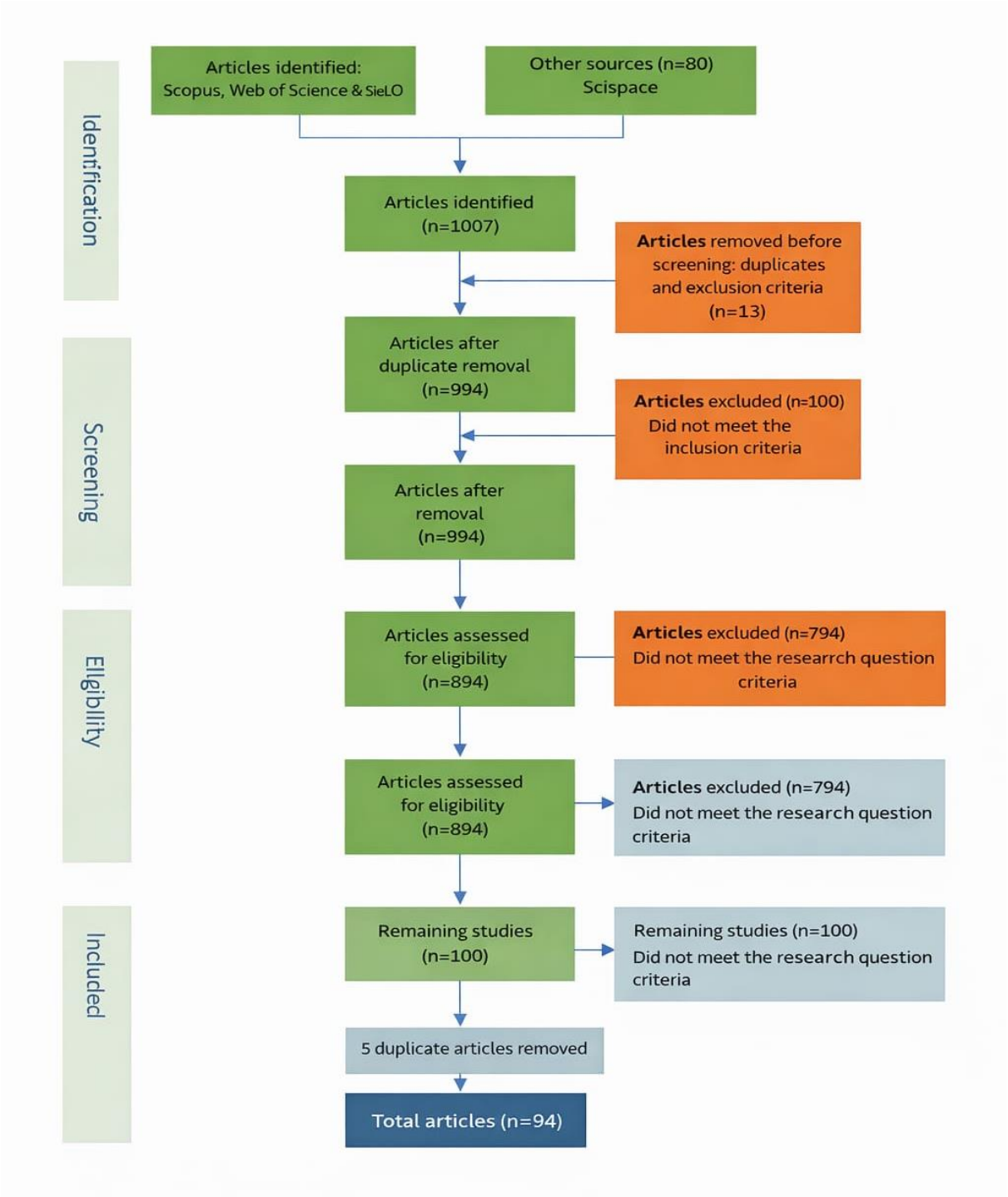
Figure 1. Research results from the database



Source: Own elaboration

Table 1 shows the researched articles, identified by: a) author and year of publication; b) research focus (efficiency, environmental or social); c) research method, i.e., quantitative (Quanti) when the research results have a numerical value derived from modeling or

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calculations, qualitative (Quali) when the research result describes non-numerical changes, case study (Case) or review (Review); d) existence of mathematical modeling or not; e) country, whether it is developed (D), developing (ING) or not applicable (n/a); and f) the sector, whether it is public, private or not applicable.

Table 1 – Researched authors, separated by focus and year of publishing

	Author	Focus Efficiency	Environment	Social	Research	Modeling	Country	Sector
1.	(Iris e Lam, 2019)	x	x		Review	n	n/a	n/a
2.	(Lim *et al.*, 2019)	x	x		Review	n	n/a	n/a
3.	(Hussein e Song, 2021)	x	x		Quali	n	n/a	n/a
4.	(Kon *et al.*, 2021)	x	x		Review	n	n/a	n/a
5.	*(Balić et al., 2022)*	x	x		Review	n	n/a	n/a
6.	*(Cortes-Murcia, Guerrero e Montoya-Torres, 2022)*	x	x		Review	n	n/a	n/a
7.	(Ahang, Seljom e Tomasgard, 2023)	x	x		Quanti	ok	D	n/a
8.	(Belmoukari, Audy e Forget, 2023)	x	x		Review	n	n/a	n/a
9.	(Clemente et al., 2023)	x	x		Quali	n	n/a	n/a
10.	(Du *et al.*, 2023)	x	x		Quali	n	n/a	private
11.	*(Hussein e Song, 2023)*	x	x		Quanti	ok	D	public
12.	(Liao, Lo e Pan, 2023)	x	x		Review	n	n/a	n/a
13.	(Nguyen, 2023)	x	x		Quanti/Quali	ok	ING	n/a
14.	(Resende et al., 2023)	x	x		Quali	n	ING	pub/priv
15.	(Sakita, Helgheim e Bråthen, 2023)	x	x		Review	n	n/a	n/a
16.	(Al Azzani *et al.*, 2024)	x	x		Quanti	ok	ING	n/a
17.	(Alzate *et al.*, 2024)	x	x		Quali	n	n/a	n/a
18.	(Azisah, Paotonan e Asdar, 2024)	x	x		Review	n		n/a
19.	(Basulo-Ribeiro e Teixeira, 2024)	x	x		Review	n	n/a	n/a
20.	(Catherine, Samuel e Monday, 2024)	x	x		Review	n	ING	n/a
21.	(Dahlan *et al.*, 2024)	x	x		Quali	n	D	n/a
22.	(Diniz *et al.*, 2024)	x	x		Review	n	n/a	n/a
23.	(Durán, Derpich, et al., 2024)	x	x		Quanti	ok	D	private
24.	(Durán, Yazdi, et al., 2024)	x	x		Quali	ok	ING	public
25.	(Fernandes *et al.*, 2024)	x	x		Quanti	n	n/a	n/a
26.	(Guan *et al.*, 2024)	x	x		Review	n	n/a	n/a
27.	(Heebkhoksung, 2024)	x	x		Quali	n	n/a	n/a
28.	(Huang e Li, 2024)	x	x		Quali	n	n/a	n/a
29.	(Karagkouni e Boile, 2024)	x	x		Quali	n	n/a	n/a
30.	(Karjono *et al.*, 2024)	x	x		Quanti/quali	ok	D	pub/priv
31.	(Kishore *et al.*, 2024)	x	x		Review	n	n/a	n/a
32.	(Kurniawan, 2024)	x	x		Review	n	D/ING	n/a
33.	(Marinova e Zeneli, 2024)	x	x		Quali	n	ING	public
34.	(Mba, 2024)	x	x		Quali	n	n/a	n/a
35.	(Mohiuddin *et al.*, 2024)	x	x		Review	n	n/a	n/a
36.	(Nurrosyidah e Rachmannullah, 2024)	x	x		Quali	n	ING	public
37.	(Paraskevas *et al.*, 2024)	x	x		Review	n	n/a	n/a

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38.	(Resende *et al.*, 2024)	x	x	Review	n	n/a	n/a
39.	(Sepehri *et al.*, 2024)	x	x	Review	n	n/a	n/a
40.	(Silva e Ensslin, 2024)	x	x	Review	n	n/a	n/a
41.	(Song, 2024)	x	x	Review	n	n/a	n/a
42.	(Su *et al.*, 2024)	x	x	Quanti	ok	D/ING	pub/priv
43.	(Tang, 2024)	x	x	Quali	ok	ING	pub/priv
44.	(Toygar, 2024)	x	x	Quali	n	n/a	n/a
45.	*(Tsvetkova et al., 2024)*	x	x	Quali	n	n/a	pub/priv
46.	(Xie, 2024)	x	x	Quali	n/a	n/a	n/
47.	(Yu *et al.*, 2024)	x	x	Quanti	ok	n/a	n/a
48.	(Zeneli e Marinova, 2024)	x	x	Quali	n	n/a	n/a
49.	(Zhang et al., 2024)	x	x	Review	n	n/a	n/a
50.	(Zhang, Zeng e Wang, 2024)	x	x	Review	n	n/a	n/a
51.	(Akhter, 2025a)	x	x	Quali	n	n/a	n/a
52.	(Akhter, 2025b)	x	x	Quali	n	n/a	n/a
53.	(Alavi-Borazjani *et al.*, 2025)	x	x	Quali	n	n/a	n/a
54.	(Amditis *et al.*, 2025)	x	x	Quali	n	n/a	n/a
55.	(Avşar e PeliT, 2025)	x	x	Review	n	n/a	n/a
56.	(Casimiro, Mesia e Cuaresma, 2025)	x	x	Quanti/Quali	ok	ING	pub/priv
57.	(Chen e Biancardo, 2025)	x	x	Quali	n	n/a	n/a
58.	(Chen *et al.*, 2025)	x	x	Quali	n	D	private
59.	(Cheng *et al.*, 2025)	x	x	Quanti/Case	ok	D/ING	pub/priv
60.	(Cocuzza *et al.*, 2025)	x	x	Quali	n	n/a	n/a
61.	(Elhussieny e Cicine, 2025)	x	x	Quali	n	ING	public
62.	(Hossain, 2025)	x	x	Quali	n	n/a	n/a
63.	(Ibrahim, Jalil e Rasam, 2025)	x	x	Quali	n	ING	pub/priv
64.	(Jain, Mitra e Paul, 2025)	x	x	Quali	n	n/a	n/a
65.	(Jaya, 2025)	x	x	Quali	n	ING	pub/priv
66.	(Jiang, Xu e Xu, 2025)	x	x	Quanti	ok	n/a	n/a
67.	(Jugović *et al.*, 2025)	x	x	review	n	n/a	n/a
68.	(Korostin, 2025)	x	x	Quali	n	n/a	n/a
69.	(Kumaran e Nagalingam V, 2025)	x	x	Quali	n	n/a	n/a
70.	(Li e Sun, 2025)	x	x	Case	n	D	private
71.	(Li, 2025)	x	x	Quanti	ok	n/a	n/a
72.	(Limi *et al.*, 2025)	x	x	Quanti	ok	n/a	n/a
73.	(Liu *et al.*, 2025)	x	x	Review	n	n/a	n/a
74.	(Mohamed, Salah e ELgarhy, 2025)	x	x	Quali	n	ING	public
75.	(Mohammad *et al.*, 2025)	x	x	Quanti	ok	D	pub/priv
76.	(Moldoveanu e Titu, 2025)	x	x	Quanti	ok	n/a	n/a
77.	(Pedersen, 2025)	x	x	Quali	n	n/a	n/a
78.	(Pereira *et al.*, 2025)	x	x	Quanti	ok	D	public
79.	(Pozo, Machado e Lopes, 2025)	x	x	Quali	n	ING	public
80.	(Rafaat e Elsmsar, 2025)	x	x	Quali	n	n/a	n/a
81.	(Riyadh e Syaifullah, 2025)	x	x	Review	n	n/a	n/a
82.	(Samatov, 2025)	x	x	Quali	n	ING	n/a
83.	(Song, 2025)	x	x	Case	ok	D	private
84.	(Sun *et al.*, 2025)	x	x	Quanti/Case	ok	n/a	n/a
85.	(Twrdy *et al.*, 2025)	x	x	Review	n	D	pub/priv
86.	(Vaca Cabrero, 2025)	x	x	Quanti/Quali	ok	D	pub/priv
87.	(Vakili *et al.*, 2025)	x	x	Review	n	ING	n/a
88.	(Wafaa e Abdessamad, 2025)	x	x	Quali/Review	n	n/a	n/a

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89. (Weda, 2025a)	x	x	Quali	n	D	pub/priv
90. (Weda, 2025b)	x	x	Quali	n	D	pub/priv
91. (Xie e Zhou, 2025)	x	x	Quanti	ok	D	public
92. (Yang, Liao e He, 2025)	x	x	Quant	ok	n/a	n/a
93. (Zevallos *et al.*, 2025)	x	x	Quali/Review/ Case	n	D	pub/priv
94. (Zhu *et al.*, 2025)	x	x	Quanti	ok	D/ING	pub/priv

Source: Own elaboration

Regarding efficiency improvements, the articles with author numbers 1, 4, and 17, according to Table 1, found in more than 40 publications surveyed the idea that technological innovations such as automation, digital twins, blockchain, and Industry 4.0 technologies significantly increase operational efficiency in ports and terminals. Authors 16, 20, and 32 state that several studies emphasize the role of integrated supply chain management and digitization in improving cargo handling, scheduling, and logistics coordination, leading to measurable efficiency gains. Authors 24, 38, and 43 argue that empirical analyses using methods such as DEA (Data Envelopment Analysis) and econometric modeling confirm efficiency improvements linked to smart port projects and digital maturity assessments. Authors 9, 13, and 25 believe that automation and digital transformation are consistently associated with cost reductions and productivity enhancements in various port contexts.

Regarding the adoption of sustainability practices, authors 2, 29, and 49 found in their research that approximately 35 studies highlight the growing adoption of ecological and integrated sustainability practices, including the use of renewable energy, pollution control, and circular economy initiatives. Authors 21 and 80 state that institutional readiness, political support, and organizational culture are identified as critical facilitators for the adoption of sustainability in ports. Authors 5, 8, and 23 argue that sustainability is frequently incorporated into smart port frameworks, with a growing focus on balancing environmental, social, and economic dimensions. Authors 39 and 40 contend that collaborative and multi-stakeholder approaches are emphasized to promote the maintenance of sustainable port operations.

Regarding technology integration, authors 12, 26, and 49 reported that more than 30 studies have high levels of integration of advanced digital technologies such as IoT, blockchain, digital twins, AI, and big data analysis in port supply chains. Authors 24 and 30 state that the adoption of blockchain is increasingly recognized for enhancing transparency, security, and sustainability in maritime logistics. Authors 25, 44, and 48 argue that digital twin technology is emerging as a transformative tool for real-time decision-making and predictive maintenance in ports. Authors 19 and 37 describe that Industry 4.0 technologies support the development of smart ports, although some studies note gaps in addressing human and urban impacts.

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Regarding the reduction of environmental impact, authors 1, 41, and 49 found in their bibliographic research that more than 30 studies document measurable reductions in emissions, energy consumption, and pollution through technological and operational innovations. Authors 29, 33, and 49 argue that green ports employing shore power, alternative fuels, and energy management systems achieve significant environmental benefits. Authors 9, 14, and 42 state that digital technologies facilitate environmental monitoring, tracking of carbon emissions, and optimized resource use. Authors 41 and 49 believe that decarbonization roadmaps and emission reduction strategies are increasingly integrated into port sustainability structures.

Regarding comparative performance analysis, authors 2, 3, and 11 in their research concluded that numerous studies demonstrate that sustainable integrated port supply chains outperform traditional models in economic, environmental, and operational terms. Authors 8, 17, and 37 argue that smart ports leveraging digitization and sustainability practices exhibit superior performance in efficiency, cost-benefit, and environmental management. Authors 26 and 30 say that blockchain-enabled and digitally mature ports exhibit greater supply chain transparency and sustainability compared to conventional ports. Authors 31, 32, and 47 believe that empirical evidence supports the superior resilience and competitiveness of ports that adopt integrated smart and green supply chain strategies.

Regarding papers published in 2025, it is noticeable that the green approach in port supply chains is prioritized, especially about paper saving, as a result of digital technology used to provide transparency in the process, credibility in service, and speed; what is often described as “sustainability.” The social dimension, when addressed, is mentioned not as resulting from a direct action but rather as a consequence of environmental sustainability measures that end up impacting the social sphere in terms of wellbeing.

The reviewed articles this year discuss the importance of the level of integration among port stakeholders, including authorities, operators, and regulators to achieve sustainability outcomes, with approaches ranging from collaborative governance to system dynamics (according to Table 1, authors 59, 79, and 94). Authors 61, 85, and 86 emphasize the importance of multidimensional integration combining environmental, social, and economic factors, as well as digital and operational processes to increase port resilience and green innovation. Authors 61 and 77 highlight the challenges to achieving full integration due to regulatory gaps, fragmented governance, and coordination difficulties, especially in emerging regions.

Many works have discussed the issue between the integrated port supply chain and the concept of sustainability. Hussein and Song (2023) broadly discuss the concept of sustainability uniquely from the supply chain perspective, which involves cooperation, coordination, and collaboration among chain members with the aim of achieving sustainable development. However, the environmental and social concepts are cited as important but not discussed.

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The study on efficiency, sustainability, and resilience in port terminals has gained strength in recent decades, accompanying the exponential growth of international trade. Since the 1990s, research has highlighted the need to reduce operational bottlenecks, optimize logistic flows, and align ports with sustainable practices. In this context, approaches inspired by Lean have emerged, applied to eliminate waste and increase port productivity.

In this sense, ports began to adopt productivity-oriented management models, incorporating terminal automation, computerization of customs processes, and the implementation of performance indicators (KPIs).

At the beginning of the 21st century, the view of the port as a strategic link in the supply chain was consolidated, giving rise to the concept of Port Supply Chain and, subsequently, the Integrated Port Supply Chain. The main actions involved improving land and rail connectivity, implementing inland terminals, integration with logistics operators, and collaborative management with shipping lines and land carriers. The objective was to reduce dwell times, improve predictability, and increase the fluidity of intermodal flows.

In the 2010s, with the advancement of global sustainability agendas (such as the UN SDGs and the IMO 2050 agenda), ports began to incorporate environmental, social, and governance (ESG) sustainability practices. The most relevant actions included reducing atmospheric emissions, adopting alternative fuels (LNG, biofuels), monitoring water and air quality, waste management, community relationship plans, and transparency and compliance policies. Green Ports and EcoPorts programs also emerged, consolidating international standards of environmental performance.

In parallel, the concept LARG (Lean, Agile, Resilience, Green) emerged, which broadens the focus of operational efficiency — characteristic of Lean — by incorporating agility, resilience, and environmental sustainability dimensions. The Agile perspective emphasizes the capacity to adapt to uncertainties of the globalized market, while the Resilience component highlights maintaining and recovering operations in the face of crises, logistical interruptions, and extreme climatic events. This theoretical and practical movement expanded the scope of research on port terminals, promoting the integration of sustainability indicators and corporate responsibility into port management and performance evaluation models.

In this scenario of theoretical and practical evolution, this article proposes and defends the LARGES paradigm (Lean, Agile, Resilience, Governance, Environment, and Social), conceived as an integrative proposal for port management that explicitly incorporates the Governance and Social dimensions. It reflects the need for multidimensional models capable of uniting operational efficiency, governance, and socioenvironmental commitment, recognizing that collaborative governance and corporate social responsibility are structural elements for long-term sustainability. The paradigm stands out by bringing together in a single model dimensions that were previously analyzed in a segmented way and consolidates itself as an integrated conceptual model capable of

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aligning operational efficiency, organizational adaptation, systemic resilience, institutional transparency, environmental responsibility, and social engagement within the same sustainable port management structure.

The Lean dimension refers to principles of waste elimination, inventory reduction, continuous improvement, and value flow enhancement. In supply chain and operations literature, the Lean model has been widely studied for its ability to improve performance, reduce costs, and increase operational efficiency. For example, a systematic study (revision circuit) shows that implementations of Lean Supply Chain Management (LSCM) are positively related to operational performance, although there are gaps regarding measuring their impacts in unstable environments (Garcia-Buendia, Moyano-Fuentes, and Maqueira-Marín, 2021).

The agile approach responds to uncertainties of international trade, such as demand variations, logistical crises, and regulatory changes. The Agile dimension emphasizes adaptability, quick response to demand changes, flexibility in operations, and the ability to deal with volatile markets. Christopher (2000) is a classic work that introduces the concept of "The Agile Supply Chain," distinguishing it from the Lean paradigm, showing how supply chains need to become more responsive in uncertain environments. Additionally, Christopher and Towill (2001) propose an integrated model for designing agile chains that combines lean with agility, adapting manufacturing and logistics strategies for markets where availability and speed are competitive factors.

Ports are vulnerable to crises such as strikes, pandemics, or environmental disasters. Resilience consists of preparing and adapting operations to minimize impacts and ensure logistical continuity.

Resilience in supply chains deals with the ability to resist, adapt, and recover in the face of shocks, interruptions, and adverse conditions. Ivanov and Dolgui (2020) have produced a robust line of research on this topic, especially mobilized by recent crises (e.g., the COVID-19 pandemic). Castillo (2023) explores how interconnected networks demand strategies that go beyond merely resisting but also surviving and adapting to new normals. Another relevant work is "Supply chain resilience and its interplay with digital technologies: making innovations work in emergency situations," which addresses how digital technologies (e.g., digital twins, IoT) can strengthen operational resilience (Ivanov, Blackhurst, and Das, 2021).

Governance involves transparency, regulation, integrity, and alignment with international compliance standards, reducing institutional risks and strengthening competitiveness. Although references to control structures, institutional alignment, and transparency exist in Lean, Agile, and Resilience literature, the Governance dimension in ESG management models has gained strength more recently. Corporate governance, compliance, accountability, and internal control mechanisms are fundamental to ensuring that efficient and sustainable practices are maintained and legitimized before stakeholders.

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Authors in resilient supply chain literature also highlight that governance failures exacerbate shock impacts and reduce institutional response capacity.

Port terminals have high environmental impact (emissions, noise, waste). Environmental and social programs strengthen institutional image and reduce negative externalities, promoting integration with the port community.

The environmental dimension, environment, is present in ESG (Environment, Social, Governance) and in international sustainability frameworks. Practices include emission mitigation, efficient resource use, waste management, adaptation to climate norms, and environmental regulation. In the logistics and operations context, recent works analyze the trade-off between efficiency and environmental impact, as well as the integration of environmental metrics into operational performance.

The social dimension refers to corporate social responsibility, impacts on local communities, working conditions, social justice, relations with stakeholders external to direct business, and aspects of inclusion, health, and safety. Although this dimension is less studied than the others in operations/logistics literature, it has grown significantly in the ESG context, and there are studies investigating how social practices affect legitimacy, social license to operate, institutional image, and even financial performance.

3. Methodology

This is a theoretical-conceptual study that does not involve a practical case study.

First, a systematic review was conducted with primary and secondary data focused on supply chains of port terminals.

Thus, the following were sought:

a) To find and systematize academic articles on the subject;
b) How the works are distributed regarding the dimensions of LARGES;
c) Identify gaps in the use of the LARGES dimensions;
d) Verify the geographical location of the research; and
e) Identify gaps and opportunities for future research.

A scoping review design with conceptual development was adopted, following the PRISMA-ScR recommendations, identifying gaps, trends, and asymmetries in the literature, offering a comprehensive view of the state of knowledge. Subsequently, the LARGES model was proposed, with a conceptual and bibliographic mapping approach, structuring the publications according to six dimensions in order to highlight the existing epistemological fragmentation and justify the proposition of an integrative model for port governance. Searches were conducted in the Scopus, Web of Science, and SciELO databases, with support from Google Scholar for supplementary literature.

Search strings were defined (port, lean, agile, resilience, governance, environment, social), open period, languages English, Spanish, and Portuguese, and filters by engineering and management areas.

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Records were exported; screening occurred in two stages (title/abstract and full text). Coding classified each study according to the primary LARGES dimension (L, A, R, G, E, S) and, when applicable, secondary dimensions, analyzing the keywords.

Two evaluators proceeded independently the classification; disagreements were resolved by consensus.

Extracted data included: study type, method, terminal context, reported KPIs (, and main findings.

The synthesis combined descriptive statistics and narrative analysis, with sensitivity analyses (reclassification and removal of grey sources).

The quantities in which each dimension is addressed in the research were identified.

This made it possible to identify gaps. A table was made with the various supply chain acronyms, then the LARGES proposition was built with the inclusion of governance and social dimensions and the shift of emphasis from green to environment. Finally, the applicability of the LARGES framework in the port system was discussed.

4. Results and Discussion

4.1 Identifying gaps in the literature

The high operational demand that characterizes contemporary ports requires these structures to be simultaneously agile and lean, capable of responding efficiently to variations in cargo flows and the logistical demands of global trade. The port, as a dynamic system of product movement and process flows, acts as a central element of the supply chain and, therefore, its operations directly impact the environment and society. Thus, understanding its transformations through the lens of the LARGES paradigm becomes essential to align operational efficiency, environmental sustainability, and social responsibility within a single conceptual framework.

The commercial relationship between suppliers and customers established in the port environment involves not only products, services, and information, but also people, processes, knowledge, strategies, and technologies.

This integrated view reinforces the need to treat the port as a complex organizational ecosystem in which the dimensions of the LARGES paradigm must act in a complementary and synergistic manner. A bibliographic research was conducted, collecting 94 scientific articles and classifying them according to the dimension addressed: L for lean, A for agile, R for resilience, G for governance, E for environment, and S for social. The distribution is illustrated in Figure 2. There is a predominance of works focused on the L, A, and E dimensions, with R, G, and S being the least addressed.

The analysis of the researched material, aimed at port changes and improvements under the LARGES paradigm lens, revealed an unequal distribution of publications among

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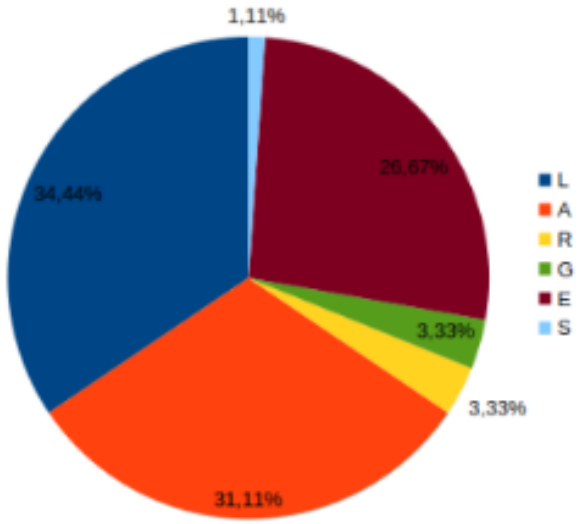
the proposed dimensions, as illustrated in Figure 2. It is observed that both in the Brazilian and international contexts, significant gaps persist in the Governance and Social dimensions, indicating the need for deeper scientific study in these areas.

Figure 2. Percentage of articles by dimension



Source: Own elaboration

The Lean dimension appears as one of the most addressed, especially due to its direct association with port operational efficiency and consequent economic return. The studies analyzed highlight that the application of Lean enables the reduction of times and costs, in addition to the elimination of redundant steps in logistics processes. The commercial relationship between company and customer involves the dynamics of product, service, and information, encompassing people, processes, knowledge, strategies, and technologies — which directly reflects cost and competitiveness (Hussein & Song, 2023).

It was also found that the adoption of digital technologies, such as blockchain, the Internet of Things (IoT), and automation systems, has been widely discussed in the studies analyzed. These innovations reinforce Lean and Agile principles by promoting leaner and more agile processes, with waste reduction, decreased paper use, and greater traceability of information throughout the logistics chain. Thus, it is observed that digital transformation contributes not only to operational efficiency but also to environmental sustainability, shaping a trend of integration between productivity, innovation, and environmental responsibility in contemporary ports.

Among the tools analyzed, Agile, alone or in combination with Lean, stands out as the most recurrent in the studies. This combination proves coherent, since both approaches share methodological affinity and process focus. While Lean seeks to optimize flows by eliminating waste, Agile focuses on dynamic adaptation to demand variations and intermodal flexibility — critical factors for port performance in highly uncertain environments.

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In the case of the port that involves various actors, efficiency arises from organizational cooperation, that is, governance (Hussein & Song, 2023). The authors state that all companies must be integrated. They found that this integration is generally done with communication systems and value-added services, multimodal systems and operations, and supply chain integration practices.

In port systems, which involve multiple actors and operational interfaces, efficiency strongly depends on organizational cooperation, a central element of port governance (Hussein & Song, 2023). This cooperation manifests through integration among terminals, logistics operators, land carriers, port authorities, and users, with the objective of ensuring continuous and coordinated flows throughout the logistics chain.

According to the authors, all companies inserted in the port ecosystem must operate in an integrated manner. This integration is operationalized through efficient communication systems, value-added services, multimodal operations, and collaborative supply chain management practices. Such mechanisms strengthen connectivity among agents and contribute to the systemic competitiveness of ports.

Hussein and Song (2023) add that long-term relationships between clients and suppliers favor commercial reliability and the economic sustainability of operations. However, they emphasize that such relationships must be accompanied by continuous investments in technologies and innovative processes, since the absence of modernization can lead to operational obsolescence and compromise system efficiency. In such cases, companies that do not keep up with technological evolution tend to be replaced by those better adapted to contemporary port market demands.

However, a recurring limitation was identified: the low integration of Lean and Agile with the Governance and Social dimensions, which compromises the systemic vision proposed by the LARGES paradigm.

In contrast, the Resilience dimension proved to be little explored and difficult to quantify, limiting the perception of its practical effects. Still, its relevance is undeniable, as it deals with the capacity to recover from unforeseen events, encompassing aspects such as contingency plans, responses to climatic and energy crises, and team training. The scarcity of objective indicators to measure operational resilience may explain the low incidence of studies dedicated exclusively to this dimension, in addition to the lack of control over information from partner companies regarding the services used or shared. For example, it is essential to know the decision-making procedures of the contracted transport company when resolving an unavailability of its services due to an accident or other reason.

Governance, although recognized as fundamental for decision-making and stakeholder alignment, appears as the least addressed dimension in research. The literature suggests that its intangible nature — linked to institutional structure, compliance, transparency, regulation, and public policies — hinders its measurement and, consequently, its empirical advancement. However, governance constitutes the articulating axis of the

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LARGES paradigm, being responsible for ensuring that all stakeholders share the same strategic objectives, whether they are direct actors in the port, subcontracted companies, or external organizations whose products, services, or information are connected to port operation. This integrated perspective extends the reach of governance beyond the physical boundaries of the port, incorporating the entire logistical and institutional network that underpins its efficiency and legitimacy.

The Environment dimension shows broad diffusion, often in association with other dimensions, especially Lean and Social. Studies concentrate on CO□ emissions, electrification of equipment, use of renewable energies, energy efficiency, and waste management, reflecting the growing environmental concern on the global port agenda. Although there are studies dedicated exclusively to the topic, treating the environment as a transversal dimension is more common, reinforcing its interconnection with the other variables of the paradigm. Adopting an “environment” policy instead of a “green” one broadens the supply chain focus: from internal ecological efficiency practices to systemic environmental governance. In a supply chain policy with multiple stakeholders, “green” refers to the adoption of technological and operational practices aimed at reducing direct environmental impacts such as emissions and waste, whereas “environment” encompasses a systemic approach to environmental governance, considering ecosystemic relations, regulation, conservation, and socioenvironmental sustainability across the entire logistics network.

Finally, the Social dimension also shows low representativeness in the literature, although it addresses essential aspects such as job creation, worker training, community relations, and social sustainability. The difficulty in quantifying subjective results — such as social impacts and community perception — partially explains the scarcity of works on the topic. However, such elements are crucial for strengthening the port-city relationship and promoting corporate socioenvironmental responsibility, indispensable components of a sustainable and integrated port model.

It is also observed that many ports have been carrying out structural works and urban interventions to improve their relationship with the city and society, promoting greater spatial and social integration with the urban surroundings. These actions, although relevant, are not always accompanied by internal changes in logistics and management practices. Thus, it is essential that companies operating in the port incorporate the LARGES paradigm into their transformation strategies, so that any logistical modification — whether in cargo flows, infrastructure, mooring processes, or intermodal transport systems — is conceived in light of the six dimensions of the paradigm: Lean, Agile, Resilient, Governance, Environment, and Social. Such integration enhances operational efficiency while simultaneously reinforcing the sustainability and social legitimacy of the port system.

LARGES differs from previous paradigms by integrating organizational, environmental, and social dimensions within the same port governance framework. While

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traditional models focus on operational efficiency and flexibility or superficially address sustainability, LARGES introduces a multidimensional vision in which governance acts as a coordinating axis among the different actors in the chain and the social dimension ensures the acceptance and public value of port activities.

In summary, the results show that scientific production on the LARGES paradigm is still fragmented and asymmetric. There is a predominance of Lean, Agile, and Environment dimensions, to the detriment of Governance, Resilience, and Social, which indicates the need for interdisciplinary approaches that integrate the six dimensions in a balanced manner, aiming for more efficient, resilient, and socially responsible port management.

4.2 Example of application in a port scenario

In the Port Supply Chain paradigm, the focus is on operational efficiency and reduction of logistic costs. Relationships are linear among agents (supplier → carrier → terminal → customer). Decisions are predominantly internal and institutional, with little integration. Indicators prioritize operation time, storage costs, and quay productivity.

In the Integrated Port Supply Chain paradigm, the links in the chain are connected, sharing information, planning, and resources. There is emphasis on horizontal and vertical coordination to reduce inefficiencies, with the use of digital platforms and collaborative logistics to avoid bottlenecks.

In the Sustainably Integrated Port Supply Chain paradigm, logistic integration is expanded to include environmental and social dimensions. Social and environmental indicators are adopted, such as carbon footprint, waste management, and impacts on the local community.

Table 2 synthesizes the nuances between the paradigms presented.

Table 2 – Port Management Models

Dimension	Port Supply Chain (PSC)	Integrated Port Supply Chain (IPSC)	Sustainably Integrated Port Supply Chain (SIPSC)	LARGES
Main Focus	Operational efficiency	Inter-organizational coordination	Sustentability and port governance	Balance between dimensions. Governance aligned with the stakeholders through social and environmental actions
Integration	Linear and limited	Comprehensive linear	Logistics + green + society	Multilevel (economic, environmental, institutional and social)
Stakeholders	Companies and carriers	Logistics operators, interface terminals and port	Port community and strictly civil society	All of the above, including governance with broad deliberative

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Dimension	Port Supply Chain (PSC)	Integrated Port Supply Chain (IPSC)	Sustainably Integrated Port Supply Chain (SIPSC)	LARGES
				participation
Indicators	Productivity, costs, time	Integration level, total lead time	The previous one + environmental and social indicators, even if restricted	Composite performance indicators (Lean, Agile, Resilience, Governance, Environment and Social)
Examples in port scenario	Individual terminal cargo handling	Port management system integrating cargo companies, transport companies, port terminals and carriers	Port Authority environmental and social programs	Implementation of the LARGES paradigm as a systemic port policy

Source: Own elaboration

The evolution of port paradigms reflects the development of the supply chain from a functional and competitive model (Supply Chain) to a systemic and adaptive model (LARGES).

We can cite an example of three operators, each adopting their own governance models, ESG, but whose joint operations result in conflicting governance and disruptions. For example, a river transport company that practices intermodality with rail, with the final destination being a seaport. Within the PSC model, each operator focuses only on its respective processes. In the IPSC model, companies work together on operational efficiency, i.e., only Lean and Agile. In the SISC model, operators use the green agenda, small actions that mitigate environmental and social conflicts. In the LARGES paradigm, the dimensions of sustainability, governance, and resilience are introduced, transforming the port into a strategic agent of sustainable development and social inclusion in national and international logistics.

However, the Larges paradigm will only work when stakeholder governance is integrated.

Governance involves public authorities, port operators, port workers, and users of port services, as well as the community. The actions of all these actors need to occur harmoniously. The breakdown of the chain happens precisely when this harmony is lacking.

As noted by several authors, KPIs involve economic efficiency, financial situation and investments, high-quality services, operational efficiency, environmental and social issues such as job creation, safety, training, and social equality.

As noted by several authors, KPIs involve economic efficiency (service rate for waterborne and land-based cargo handling, berthing rate), financial situation and investments (external investment, cost of operations, return on investment and revenue),

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high-quality services (speed of cargo handling and traceability of information), operational efficiency (expected task times), pollution control (control of ballast water, wastewater, cargo leaks, hazardous cargo and waste), air (particles, vapors, gases, noise and vibration reduction) and soil, energy source used (renewable), and social sustainability (job creation, health, safety, training, social equality, work environment and port-city relationship). Governance, regulatory and institutional structure; alignment and collaboration, decision-making and accountability.

5. Conclusion

The LARGES paradigm proved applicable to the port context, offering an integrated and multidimensional view of port terminal management. Its adoption can reduce operational bottlenecks, increase resilience in the face of crises, and align port practices with ESG agenda requirements.

Figure 3 illustrates the LARGES paradigm based on six interdependent dimensions articulated by a central axis of coordination. At the core of the representation is governance as a structuring element, responsible for aligning strategies, processes, institutional actors, and control mechanisms, ensuring systemic coherence between operational performance, sustainability, and social responsibility among all stakeholders.

The circular and interconnected graphic layout highlights the systemic and multidimensional nature of the paradigm, indicating that no dimension operates in isolation. On the contrary, the sustainable performance of the port emerges from the dynamic interaction between efficiency, innovation, governance, resilience, and social responsibility. The base of the figure, by highlighting sustainable development and port-city integration, reinforces the strategic repositioning of the port as an agent of territorial cohesion and sustainable economic development.

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Figure 3 - Schematic representation of the LARGES paradigm in governance.

Source: AI-generated – ChatGPT

Future researches may be done to develop concepts and validate the paradigm through applied studies in terminals at different ports and regions, as well as quantify gains in efficiency and sustainability.

Despite advances in the literature on efficiency, agility, resilience, governance, and sustainability in the port sector, it is observed that these elements are still analyzed in a fragmented way, without an integrative model that enables joint management of these dimensions, as shown in Figure 2. Most studies focus on isolated aspects such as operational productivity, environmental impacts, or governance practices, leaving in the background the need for a holistic approach that unites economic efficiency, social responsibility, and resilience in the face of crises, ignoring that all dimensions directly or indirectly depend on governance. The social dimension does not even have a representative study, either in quantity or content.

Some studies on efficiency simply address the environmental issue. Compared to the number of research on increases in gains, those exclusively on port environmental issues are much smaller, and as shown in Figure 2, approximately 27%, while works focused on efficiency, dimensions L+A, correspond to approximately 66%. This gap highlights the relevance of the present research, which proposes the LARGES paradigm as a multidimensional framework capable of consolidating these different axes into a single model of analysis and practical application.

The application of LARGES for port terminals can evolve simultaneously in efficiency and sustainability when the six dimensions are worked on in an integrated manner. The

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traditional emphasis solely on productivity was expanded to a model that incorporates resilience, governance, and socioenvironmental impacts. The paradigm contributes to meeting ESG standards, attracting investments, and improving institutional reputation.

It is concluded that governance is fundamental to the achievement of all other dimensions, as all are derived from it. Resilience depends on the understanding of governance, that is, the policies and modus operandi knowledge of all partners involved. Likewise, the Lean and Agile dimensions also depend on governance, because the result of the investment in equipment, whether to increase production and/or reduce turnaround time, will be null if in the next process, or in a partner company, there is a rupture in the production chain, just as decision-making about social and environmental dimensions results from the economic return of the company linked to the Lean and Agile dimensions and the commitment that investment must not compromise the company's resilience.

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