LEAN 4.0 AND INNOVATION IN THE MARITIME SERVICE MANAGEMENT:
AN AGENDA FOR FUTURE STUDIES

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The maritime economy has a significant impact on the global economy and its strength continues to grow as new methods and technologies are integrated. Aiming to contribute to this process, this study carried out a literature review according to the Systematic Search Flow (SSF) method and content analysis based on Bardin (2011), with this review aiming to propose an agenda for future studies on the management of the maritime service, aligning innovation in the perspective of Lean 4.0. Lean 4.0 demonstrates itself as a strategy for innovation in the maritime economy, from the perspective of technologies arising from Industry 4.0, the Lean Thinking approach, the complementarity of resources via value co-creation, and management focused on sustainability. However, it was possible to identify that innovations have been sought only as a way to get pregnant, while the social side has been relegated. Aiming to improve this scenario, the article contributes to both public and private sector organizations, in order to guide actions to reduce environmental impacts and encourage innovation based on Lean 4.0. Related to the exposed technologies, new services, and experiences can be provided to actors in the sector and society in general. The research findings present guidelines for future studies from the perspective of the maritime service from the perspective of the Lean 4.0 concept, in addition to the adopted method has proved to be an aggregator, and can be replicated in other areas of knowledge.

Keywords: Lean 4.0, Industry 4.0; Innovation; Maritime economy; Value co-creation.
1. Introduction

The maritime service economy represents 2.5% of world GDP (OECD, 2016), and this figure is growing rapidly (FÁTIMA AND JAMSHED, 2020), as the ocean is a primary source of food and resources, in addition to being the main means of transport service which global trade takes place (RAYNER et al., 2019). The oceans are increasingly seen as a new frontier for economic development (BENNETT et al., 2021; SUN et al., 2022), as human needs for food, energy, transport, recreation, and other services are growing rapidly (WINHER et al., 2020).

The adoption of more efficient production chains automated, efficient, and will promotion faster and more sustainable services are necessary (KON et al., 2021; MARTÍNEZ-JURADO AND MOYANO-FUENTES, 2014). However, with the expansion of the maritime economy, sustainable development has become a concern (KUMAR AND BARUA, 2021), as anthropogenic activities and the increasing exploitation of natural resources are causing a loss of biodiversity and irreparable damage to the environment (LEDOUX AND TURNER, 2002; SUMAILA et al., 2021).

Lean 4.0 has been used for the adoption of green and sustainable production chains (NADEEM, 2019). The joint implementation of its techniques with the fundamentals of the economy of the sea promotes economic and environmental benefits (LANZOLLA et al., 2021). In the B2B scenario, companies that invest in sustainable methodologies gain competitive advantages in the market and better supply chain management (LAVISSIÈRE et al., 2019). From this perspective, Lean 4.0 is used to remove processes that do not add value, aiming at continuous improvement in production (CALDERA et al., 2017). The fusion of Lean concepts with the maritime service is harmonious and promotes the reduction of worthless activities, and market leadership through high-quality products with less production time and costs (SADIQ et al., 2021).

According to Kon et al. (2021), the development of the maritime economy will happen through the adoption of technologies that promote the automation of the production line. Lean 4.0, it is possible to make digital process flows more simplified and intelligent, through Lean 4.0 technologies, such as Big data, IoT, and AI, it is possible to track, in real-time, the product throughout its life cycle, including post-consumption; plan the production chain, promote the digitization and automation of production (BASTOS et al., 2022). This study aims to propose an agenda for future studies on the management of the maritime service, aligning innovation in the perspective of Lean 4.0. Via findings, it is expected to support research on the subject,
contributing to the promotion of the maritime service in a sustainable and orchestrated way through 4.0 technologies and the value co-creation among the players of the maritime sector.

2.1. Lean 4.0

Lean thinking aims to reduce the time between customer order and product delivery, by eliminating waste (LIKER, 2021). Currently, Lean Thinking has been applied in conjunction with Industry 4.0 technologies, providing agility and automation of the chain (CIFONE AND STAUDACHER, 2021). The integration of Lean Thinking and Industry 4.0 (I4.0) concepts form Lean 4.0 (VALAMEDE AND AKKARI, 2020).

In the maritime service scenario, Lean 4.0 can promote the optimization of services, and the elimination of costs and time (KON et al., 2021). Lean 4.0 is used in supply chains bringing agility and resilience, maximizing profit, and managing production sustainability (CARVALHO AND CRUZ-MACHADO, 2011). The investments in I4.0 technologies conduct to process innovation, with the advantage of using smart tools and the latest technology developments, focusing on 3D printing, Robotics, smart sensors, industrial Internet of Things, and advanced human-machine interface (DE GIOVANNI AND CARIOLA, 2021). In this sense, Lean 4.0 helps industries to remove non-value-added processes and achieve operational excellence (LOH AND LAU, 2018).

2.2. Value co-creation in B2B services

Value co-creation emphasizes the integration of resources and makes it possible to bring together actors within an ecosystem (MAGLIO AND SPOHRER, 2007; VARGO AND LUSCH, 2004). In this way, each actor must contribute with value to other components of the network (POMBINHO, 2015). Value co-creation has gained notability in the current scenario, due to its importance in adding value between consumers and companies (B2C) and between companies, known as business-to-business (B2B) (LIBRELATO et al., 2011).

In the B2B scenario, value co-creation is created through the mutual commitment generated in the relationships among partners located in business networks in the B2B market (TROCCOLI, 2010). B2B relationships promote the exchange of knowledge and values, aiming to achieve the individual and joint goals of companies (ARICA AND OLIVEIRA, 2019). Successful innovation ecosystem is a good supporting environment created by the complementary cooperation of all parties involved in the system (CHEN et al., 2021; SPIGEL, 2017). The value co-creation among multiple actors is a basic strategy to connect actors and provide
infrastructure, knowledge, information, and access to new technologies for the integrated management of the chain (BONAMIGO et al., 2021; BONAMIGO et al., 2023).

Lean 4.0 allows for value co-creation in an orchestrated way, that is, as a strategy to bring players together where collaboration makes it possible to overcome the obstacles of lack of interaction, as well as leverage competitiveness (KUMAR et al., 2022). This statement is especially true in the case of small and medium-sized enterprises, since innovation ecosystems allow them to integrate resources and cocreate Industry 4.0 solutions (BENITEZ et al., 2020). In this way, co-creation through 4.0 technologies contributes significantly to the B2B scenario, generating an improvement in industrial performance (TRISTE et al., 2018).

3. Methodological procedures

This study aims to present a future studies agenda on innovation with Lean 4.0 for the sustainable maritime service. To achieve the aim of this work, we followed the method Systematic Search Flow (SSF) proposed by Ferenhof and Fernandes (2016). The SSF Method consists of four phases, broken down into a set of eight steps. Figure 1.

First, we established a research plan embracing the research questions we were interested in answering. This also involved the keywords and a set of inclusion and exclusion criteria. Second, we decided to use the research query ((“Lean 4.0” OR “Lean management” OR “Lean production” OR “Toyota Production System” OR “Lean thinking” OR “Lean manufacturing”) AND (“Ocean Economy” OR “Blue Economy” OR “maritime economy” OR “marine ecosystems” OR “sea economy”) AND (“industry 4.0” OR “digital transformation” OR “smart manufacturing” OR “digital technologies”)).

The inclusion criteria were: empirical papers, peer-reviewed, English, Portuguese language, and indexed in the databases: Compendex, Scopus, EBSCO, Emerald, Scielo, Science Direct, and Web of Science. We excluded gray literature such as reports, conference papers, nonacademic research, and other languages.

Then, we accessed the databases and searched them using keyword set combinations. We analyzed for this combination in the title, keywords, and abstract. The search on the databases was made on August 2nd, 2022. A total of 281 documents were found. Third, we managed the documents, importing the references to reference manager software, later we excluded the duplicates, resulting in 275 documents. Table 1.
Table 1 – Resulting SLR papers

<table>
<thead>
<tr>
<th>Database</th>
<th>Number of publications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ebsco</td>
<td>156</td>
</tr>
<tr>
<td>Emerald</td>
<td>83</td>
</tr>
<tr>
<td>Science Direct</td>
<td>14</td>
</tr>
<tr>
<td>Scopus</td>
<td>6</td>
</tr>
<tr>
<td>Compendex</td>
<td>18</td>
</tr>
<tr>
<td>Web of Science</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td>281</td>
</tr>
<tr>
<td>Duplicates</td>
<td>6</td>
</tr>
<tr>
<td>Resulting SLR total</td>
<td>275</td>
</tr>
</tbody>
</table>

Source: the authors

Fourth, each one of us manually scanned the respective documents’ abstracts and, if pertinent, read parts of the full text to make sure if it fits in the scope of interest. This was reduced to 13 documents that fulfilled our criteria. Fifth, we composed the bibliographic portfolio for analysis, exporting from the reference manager software, the author (year), title, and journal information to a spreadsheet. Sixth, the content analysis was conducted based on Bardin (2011). Substantiated with the document’s portfolio from the literature, these were read in full by all the authors. At this stage, the following questions were considered as inclusion or exclusion criteria from the portfolio: (a) The work presents some insight or implications towards Lean 4.0 in the maritime service? (b) How can Lean 4.0 impact the maritime service? (c) The paper presents a strong or weakness related to the Lean 4.0 application?

Seventh, following the Synthesis stage, the data of each author were brought together in one spreadsheet. This revision enabled us to organize the findings into connection themes, then, the analysis categories were defined as "a posteriori". Eighth, the final stage of our review process was devoted to the write-up of the findings.

4. Results

Based on the SSF, the resulting bibliographic portfolio displays 13 articles, as can be seen in Table 2, which are the basis for the analysis.

Table 2 – Resultant portfolio from the literature

<table>
<thead>
<tr>
<th>Cod</th>
<th>Author(year)</th>
<th>Title</th>
<th>Journal</th>
</tr>
</thead>
</table>
Critical Factors for Introducing Lean Product Development to Small and Medium sized Enterprises in Italy.

Implementation of industry 4.0 and lean production in Brazilian manufacturing companies.

Trajectory of research on maritime transportation in the era of digitization.

Six sigma with the blue economy fundamentals to assess the economic and environmental performance in the aircraft refueling process.

Data-Driven Fleet Monitoring and Circular Economy.

Sustainability of operations through disruptive technologies in the petroleum supply chain.

The global trends of automated container terminal: a systematic literature review.

Sustainable Marine Ecosystems: Deep Learning for Water Quality Assessment and Forecasting.

Sustainability indicators for the yachting industry: Empirical conceptualization

From the content analysis based on Bardin (2011), four topics were defined to direct future research for the management of the maritime economy based on Lean 4.0, namely: Lean, Industry 4.0, value co-creation, and Sustainability.

Table 3 – Content Analysis

<table>
<thead>
<tr>
<th>Cat.</th>
<th>Context unit</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>A3 - The ports(se) are an exemplary network-based business-to-business (B2B) industry</td>
<td>A3 - The multi-agency coordinated approach and the port authorities of San Pedro Bay, is obviously one of the key success factors of the CAAP.</td>
<td>7</td>
</tr>
<tr>
<td>A3 - A wide range of different business and non-business actors are the basis for the existence of a seaport.</td>
<td>A3 - The actors of the port start to involve both local and international actors to build the project of a port network that would contribute to everyone.</td>
<td>5</td>
</tr>
<tr>
<td>A3 - sustainable port, can only be achieved through the port community and, thus, through the activities of the port community</td>
<td>A3 - Horizontal partnerships between ports would imply the sharing of resources, which would result in an increase in quality</td>
<td></td>
</tr>
<tr>
<td>A4 - The reduction of transport costs has led container shipping companies to form shipping alliances or even go through merger and acquisition (M&amp;A) processes</td>
<td>A4 - A lean port is a business unit, which makes effective use of its available resources, achieving superior customer service in the provision of transport solutions</td>
<td></td>
</tr>
<tr>
<td>A4 - horizontal partnerships between ports would imply the sharing of resources, which would result in an increase in quality</td>
<td>A4 - JIT in a port environment means better use of the scarce space, increasing productivity, and eliminating waste</td>
<td>14</td>
</tr>
<tr>
<td>A6 - In general, LP can be implemented in a part or at the entire company, as well as at the whole supply chain, including product development, procurement.</td>
<td>A6 - In general, LP can be implemented in a part or at the entire company, as well as at the whole supply chain, including product development, procurement.</td>
<td></td>
</tr>
<tr>
<td>A8 - Increased economic and environmental benefits, such as CO2 reduction, after implementing Lean in conjunction with the blue economy</td>
<td>A11 - Increase in productivity, after the implementation of Lean in the container terminal.</td>
<td></td>
</tr>
<tr>
<td>A2 - the implementation of private cloud and network management, can give a possibility to predict the oil field and reserves based on these data, which helps in easy exploration</td>
<td>A2 - Using the new technologies in these sectors, we can have real-time operations which can be highly reliable and of higher quality in the oil and gas industry</td>
<td></td>
</tr>
</tbody>
</table>
A2 - Big Data can be used in analyzing the current trend and predicting the future aspects, and the political and climatic conditions which is an important factor that affects the logistic
A7 - Data analysis techniques are used to solve challenges related to circular and sustainable maritime logistics and supply chain
A9 - The use of IoT in the maritime domain aims to prevent unpredicted downtime, energy efficiency monitoring, reduction in maintenance costs, and complex event detection or trajectory classification
A10 - AI helps to manage petrographic data using data mining and intelligent data analysis.
A10 - In the oil and gas industry, Big data analysis allows for understanding the particular drilling site before starting drilling.
A10 - IoT can reduce non-productive time by using real-time data to predict schedule preventive maintenance and breakdown
A11 - the adoption of ACT technology would increase productivity, would lower the cost of the container terminal, and would render the container terminal environmentally sustainable
A12 - Use of industry 4.0 technologies to assess water quality, contributes to sustainable management of marine environments
A12 - the combination of IoT and WSNs, poses a perfect candidate to be used for sensing and monitoring purposes in marine environments
A12 - DL offers important breakthroughs in the implementation of smart fish farming. DL is expected to expand into new application areas such as fish disease diagnosis
A3 - the model of sustainable ports with “zero emissions” allowed port development to continue, favoring job creation and economic activity
A3 - sustainable port, can only be achieved through the port community and, thus, through the activities of the port community
A3 - Green actions aiming to mitigate air pollution are progressively taken by ports
A8 - the adoption of circular economy practices for the recovery of energy and materials
A8 - the Blue Economy is a strategy to promote sustainable development
A10 - Carbon emission is the most difficult challenge in the petroleum industry that needs to address effectively
A10 - Protected areas and companies have to improve their operations to conserve biodiversity
A11 - The replacement of diesel engine vehicles with electric-powered equipment could realize minimize the effect of climate change and environmental sustainability of green port
A11 - The ACT technology application in a container terminal is necessary to sustain the environment and the practice of a green port.
A12 - The development of a sustainable coastal ecosystem represents an urgent short-term.
A12 - Water quality assessment has become one of the key pillars to guarantee a sustainable society.
A13 - Yachting industry tourism may highly affect environmental sustainability, given the impact of improper boat operations, garbage and oil disposals, emissions, and anchoring on near-shore marine ecosystems.

5. Discussion and research agenda

The maritime service, in general, is still little explored by researchers, which leaves room for a series of future studies for development and improvement in this sector (MARTINEZ VASQUES et al., 2021). From the perspective of the maritime service, new firms and types of businesses seek to adapt to the new productive composition to increase their productivity, ensure strength in the markets and maintain their growth potential (WINIWARTER et al., 2016). However, there are some challenges that these industries face when seeking to improve processes, these challenges open a window of opportunity for future studies.

5.1. Innovation
A problem identified in the literature on the innovation ecosystem is that current studies only focus on economic aspects and ignore environmental, cultural and social aspects (DOS SANTOS AND ZEN, 2022). An opportunity for study is the result of using ISO 56002:2019, as it is the rule that seeks to standardize methods, terminologies and interactions between the parties involved in innovation (DA SILVA, 2021).

The use of Lean 4.0 aiming at innovations in ports, aligning co-creation and sustainability is a little explored fertile ground, but worthy of attention. An example of demand for innovation would be the digitization of the sector, as according to Heikkilä et al. (2022), 80% of port operations are still carried out manually. Lean 4.0 in this digitization process, can be an important tool for its successful implementation.

The implementation of shore-power to supply ships has been an alternative to mitigate the impacts of emissions while ships are berthed in ports (WANG et al, 2023). The proposition of new fuels such as ammonia, green hydrogen, liquefied natural gas (LNG), methanol and the use of batteries has been shown to be innovative alternatives incorporated into the maritime industry (ZOU AND YANG, 2023). The issue of reducing the speed of ships during navigation is discussed as an alternative to reduce fuel consumption and consequently emissions. In addition, automation processes have been employed with the entry into operation of autonomous ships already reported by the industry (STĘPIEŃ, 2023).

5.2. Industry 4.0 (I4.0)

The lack of knowledge about I4.0 and the benefits of its devices is considered one of the barriers to the adoption of I4.0 (MOUEUF et al., 2018). This opens an opportunity for future studies seeking to elucidate the quantitative benefits that the adoption of I4.0 would bring to the maritime and port terminal service. Other limitations found in the literature state that the requirement of high financial values for I4.0 implementation makes it impossible to adopt technologies (TURKYILMAZ et al., 2021). Another challenge concerns the lack of qualified labor, because to implement advanced technologies, employees must have to develop additional skills and competencies (LAM et al., 2016).

In this sense, the innovation through Lean 4.0 in ports can be guided by the 9 pillars of Industry 4.0 development (RÜBmann et al., 2015). They are: i) robots and autonomous systems, ii) Internet of Things (IoT), iii) Cybersecurity, iv) Horizontal and Vertical System Integration (HVSI) through new standards, v) Cloud Computing (CC), vi) 3D Printing (3DP) and Additive Manufacturing (AM), vii) Big Data (BD) and Business Analytics, viii) Augmented Reality.
Simulation and Modeling (S&M), it is valid to add the possible tenth pillar proposed by Rodič (2017), Green Information Technology ("Green IT"). Which pillar listed allows direct strategies to deal with problems in the port sector via technological innovation. The problem in this sector, the technologies adoption, and culture for continuous improvement based on the Lean perspective (BONAMIGO et al., 2022; DE LA PEÑA ZARZUELO et al., 2020).

The challenge posed is to identify possible combinations of these listed pillars, allowing directing strategies to deal with problems in the port sector via technological innovation, since this sector problem, the adoption of technologies and culture for continuous improvement based on the Lean perspective (BONAMIGO et al., 2022; LA PEÑA ZARZUELO et al., 2020)

5.3. Value co-creation

The port sector is based on cooperation between actors, being a collective process of ships, containers, information, system operators, regulators, manufacturers, and consumers (SARKAR AND SHANKAR, 2021). Thus, adequate coordination of the actors increases the performance of ports (HU et al., 2019). Port terminal activity impacts several stakeholders, and the complex and uncertain environment causes conflicting interests among actors (ALMUTAIRI et al., 2019; SARKAR AND SHANKAR, 2021).

In this context, trust is necessary for these actors to work together, ensuring innovation through the co-creation of value (AQUILANI et al., 2020). As value co-creation is formed by social interactions, the consequence is that each actor adopts a certain position in this interaction with the aim of achieving mutual gain through sharing innovation (EDVARDSSON et al., 2021).

Laamanen and Skålén, (2015), argued that co-creation is not free of conflicts among the actors involved, but if the actors are aware of their positions and the right balance of power between them, good results can come from such interaction. With regard to the adoption in ports, Gjerding and Kringelum (2018) emphasize that its implementation should not be taken lightly, as although it brings benefits, it is complex and can be harmful to port administrators by value co-destruction (BONAMIGO et al., 2020).

Based on what has been exposed, innovation can be stimulated in ports through the adoption of technologies, based on the assumptions of industry 4.0 as a way to protect and boost the sharing of information between partners (AQUILANI et al., 2020). For example, to deal with the waste problem and environmental impacts, initiatives, and innovation can be performed through co-development processes among suppliers. In this way, risks and/or benefits from innovation can be shared among the players (BONAMIGO et al., 2021).
5.4. Sustainability challenges and limitations

According to Gadekar et al. (2022), Industry 4.0 technologies promote innovation and production efficiency, influencing sustainable development. However, for industry 4.0 to be the key factor for sustainability in the maritime economy, more studies on the area are needed (NASCIMENTO et al., 2018). Still on the perspective of sustainability, another point for studies is the lack of governmental and public policies that play key roles in raising awareness and protecting the environment (ALAMOUSH et al., 2022). The absence of co-creation between companies and government is detrimental to sustainable promotion (BHATIA et al., 2020).

The Lean 4.0 encourages improvement of sustainable ports, in the perspective of eco-ports, or green ports, once the Lean stimulates the training, people develop for continuous improvement. In this sense, once the workers are qualified and sensitized for the green perspective, the innovation can be maximized in this sector (ESMEMR AND TUNA, 2010). New strategies that the ports are adopting are the creation of innovation environments, with the presence of startups, financing of innovative projects and ideation, with the objective of developing sustainable projects. Examples of this nature have been identified mainly in European ports, such as Port of Rotterdam, with the creation of innovative processes and products with an emphasis on reducing environmental impacts (KARÁS, 2020).

6. Conclusions

Based on the results of this research, it is evident that L4.0 is an alternative that allows dealing with use of natural resources and proposing a sustainable methodology within the maritime economy. Although the origin of the Lean concept is in manufacturing, in this work it has been presented as a solution for the mitigation of, and as a way to promote the environmental footprint of organizations.

Lean, linked to I4.0 technologies, makes it possible to overcome problems related to the inefficient use of resources through the adoption of digital technologies and allows to integrate the multiple players of sector. From the analysis of Lean 4.0, it was possible to observe that the theme is recent and incipient in relation to sustainability within the maritime players.

From the Lean 4.0 perspective, it is possible to overcome the lack of interaction for the value co-creation among the actors, through Lean management technologies and practices. Through management techniques, such as Lean Thinking in line with I4.0, it is possible to promote the reduction of harmful gas emissions and pollution, ensuring the sustainability of the marine and
port terminal ecosystems. Based on this, the incorporation of Lean 4.0 and the value co-creation among actors in the port terminal sectors focused on logistics chains is responsible for reducing costs and minimizing waste, elucidating the economic benefits of sustainable development.

In addition to the contributions of innovation with Lean 4.0 in the oil and gas sector, we seek to emphasize the environmental impacts caused mainly by this sector due to spills, as well as the harmful impacts on the marine ecosystem caused by the tourism and fishing industry that mainly harm coastal communities. Therefore, due to the potential growth in the maritime service, the unsustainability of these sectors needs to be evidenced for future studies in order to achieve sustainable development in all ocean-based industries and the assets, goods, and services of marine ecosystems.

References


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