

Article

Lean Thinking to Foster the Transition from Traditional Logistics to the Physical Internet

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Abstract: This paper studies the relationship between Lean paradigms and the Physical Internet (PI). Lean thinking is a philosophy that allows one to obtain the right amount of the right items in the right place at the right time; it seeks to minimize waste and is flexible to change. In fact, applying Lean not only helps to reduce costs, but it also adds value and improves results across the supply chain. By using a value stream map, we can map the process from the supply chain to the customer, while trying not to add value activities. Such activities include excessive production, overstorage, waiting times poorly adjusted to needs, defects and rejects that require reprocessing, and, finally, unnecessary transport and movements. Storage, waiting times, and unnecessary transport and movements are at the core of the PI. A value stream map can also help to identify empty transport and unnecessary CO₂ emissions. This study analyzes value stream mapping as a tool that can enable the objectives of the different Alliance for Logistics Innovation through Collaboration (ALICE) roadmaps for logistics innovation to be achieved, and can also allow PI principles to be reached on the established dates.

Keywords: physical internet; lean thinking; value stream map; supply chain

1. Introduction

The COVID-19 crisis has shown that today's world is multiconnected, as demonstrated by the rapid transmission of the virus, but it has also shown that it is multiconnected to deliver products. This hyperconnection in logistics is only expected to continue to increase in the future [1].

Connections extend to everywhere, every organization, and every person, and it will become increasingly difficult for them to advance if we remain impassive to this situation [1]. This need for total and permanent connection highlights the importance of a comprehensive global perspective in logistics and supply chain management and the need to maximize its efficiency.

It is within this context that the concept of the Physical Internet (PI) arises, which develops the metaphor of the Digital Internet by applying it to physical objects [2]. The intention is that PI will achieve optimized logistics, including various entities through new business models within a more sustainable logistics networks, where the roles of technology and professional skills related to flexibility and adaptability are key [3].

To achieve this, a company must be flexible to adapt itself to the ever-changing market situation. This means putting into practice a continuous improvement strategy in all areas of the company, an objective that will be achieved with the application of Lean, which is a system designed to optimize production by optimizing its parts, eliminating tasks that do not add value to production,

and optimizing the organization's resources through waste management. It is an innovative, effective, and inexpensive alternative to obtain the benefits it creates.

In addition, the Lean paradigm is based on the principle of cost reduction and waste elimination. According to Womack et al. [4], the basic concept of Lean is to do more with less; for example, less human effort, less equipment, less time, and less space, while focusing on client needs.

A value stream map (VSM) is a Lean tool that shows both the flow of materials and the flow of information from the supplier to the customer, which allows for the simple and visual identification of all of the activities that are carried out to realize products and the identification of the value chain.

By using a VSM, one can identify activities that do not add value, such as a large amount of stock produced in excess of market requirements, waiting longer than necessary or waiting unnecessarily, product rejections and reprocesses, as well as transport and unnecessary movements.

Avoiding excessive storage, time wasting, transportation, and unnecessary movement is the first priority of Lean theories, as it is in the PI. Other wastage that one can include and search using Lean are empty containers and excess carbon dioxide emissions, for which, a VSM can be used to achieve the objectives of the roadmap that the Alliance for Logistics Innovation through Collaboration (ALICE) has prepared to achieve the PI, which, in turn, facilitates the achievement of each established roadmap. Indeed, the VSM tool has been used to determine process problems and waste, which, when applied, results in a comprehensive analysis of the logistics chain and a proposal of how it will be after carrying out the necessary improvements for the implementation of an action plan [5–7]

More specifically, the objective of this work was to analyze the interconnections between the principles of the PI and Lean, as well as the potential of their integrated use to create value in logistics networks using the VSM tool. To achieve this objective, we analyzed the concept of the PI and its fundamental pillars, as well as the concept of Lean manufacturing and the tools it offers to achieve continuous improvement by focusing on the VSM tool, which can reveal the reality of the current situation. The search for the future and ideal situation allows for detecting problems and waste, which can improve the economic, social, and environmental variables of the PI.

2. Physical Internet

The PI is a concept that has been created to revolutionize the underpinnings of logistics, the handling of materials, and the design of installations. This new paradigm is motivated by the affirmation that the ways in which products are transported, processed, laid up, produced, delivered, and utilized across countries are not ecofriendly or economically and socially responsible [8].

Montreuil [7] found 13 causes that make logistics unsustainable and inefficient, as presented in Table 1. To solve these problem areas, he considered important developments that could enable new infrastructure to be transposed to the logistics world in the long term. Therefore, the PI can be defined as the mode by which physical objects are manipulated, moved, stored, realized, supplied, and used, oriented toward global logistical efficiency and sustainability, as well as organizing the transport of goods in a similar way to which data packets flow on the Digital Internet [9].

The PI is based on physical, digital, operational, business, and legal global interconnectivity achieved through open standard protocols, encapsulation, interfaces, certification, evaluation, and performance control [10].

To achieve these objectives, the PI relies on a logistics web, global interconnection, and innovation. The logistics web is conceptualized as a website, the objective of which is to facilitate logistics activities for people and organizations, as well as society. It is an open and global logistics website that is divided into five websites, namely, the mobility, distribution, realization, supply, and service websites, which, together, lead to global interconnection that allows efficient and sustainable logistics.

Actually, it can be found that some companies are already applying some of these principles, especially software solutions, to optimize the supply chain management. An example of this is MixMoveMatch.com, the creator (Marlo company) of which describes it as a software as a service

(SaaS) solution for supply chain collaboration that integrates multiple suppliers and logistics service providers into an open cooperation network already used by companies [11].

Table 1. Inefficiency and unsustainability symptoms.

Inefficiency and Unsustainability Symptoms	Economic	Environmental	Societal
1. We are shipping air and packaging.	•	•	
2. Empty travel is the norm rather than the exception.	•	•	
3. Truckers have become the modern cowboys.	•		•
4. Products mostly sit idle, stored where unneeded, and yet are so often quickly unavailable where needed.	•		•
5. Production and storage facilities are poorly used.	•	•	•
6. So many products are never sold or used.	•	•	•
7. Products do not reach those who need them the most.	•		
8. Products move unnecessarily, crisscrossing the world.	•	•	•
9. Fast and reliable multimodal transport is a dream.	•	•	•
10. Getting products in and out of cities is a nightmare.	•	•	•
11. Logistics networks and supply chains are neither secure nor robust.	•		•
12. Smart automation and technology are hard to justify.	•		•
13. Innovation is strangled.	•	•	•

The Physical Internet (PI) Manifesto: Globally transforming the way physical objects are handled, moved, stored, realized, supplied, and used [10].

As can be seen in Table 2, the PI vision was designed using 13 characteristics.

Table 2. The characteristics of the physical Internet.

1. Encapsulate goods in standard, ecological, and smart containers.
2. Global interconnectivity.
3. Evolve toward π - containers handling and loading systems.
4. Develop smart container networks that contain smart products.
5. Evolve toward distributed and multisegmented intermodal transport.
6. Adopt a unified conceptual multitier framework.
7. Create an open global web of suppliers.
8. Design products for containers with minimal space consumption.
9. Minimize physical movements and storage, digitally transmitting knowledge to materialize the object in the local area where a used one goes.
10. Deploy performance monitoring and certification of capabilities.
11. Prioritize network security and trust.
12. Stimulate innovative business models.
13. Allow open innovation infrastructures.

Source: Towards a Physical Internet: Meeting the Global Logistics Sustainability Grand Challenge [7].

In order for efficient and sustainable logistics to exist, logistics must be global; therefore, logistics must be designed under the same conceptual framework, integrating local networks into ever more extensive and global networks according to the physical principles, regulations, and protocols designed by the PI, and must not be an open system as in the case of private networks. This universal interconnectivity in the PI will be achieved through integrated exploitation, encapsulation, interfaces, and protocols designed specifically for it. However, in order to design these, new business models, technologies, and infrastructures are necessary.

When the term Physical Internet was initially conceived, we observed that it was not only scarcely found in the literature, but, generally, it came from the efforts of the Center for Excellence in Logistics and Distribution (CELDi), an applied research and education entity formed by five universities (i.e., University of Arkansas, Clemson University, Virginia Tech University, University of Missouri, and University of California at Berkeley), various private organizations, the U.S. military, and the National Science Foundation. The most common topics that we found in our literature review are shown in Table 3 [12].

Table 3. The PI topics.

Element	Authors
Modular containers (i.e., transport containers, container handling, and packaging containers)	[13–19]
Achievement of full vehicle loading, shared by different providers	[20–22]
Design of open transport centers with fully functional, efficient, and effective handling of cargo	[23–26]
Creation of integrated, secure protocols in terms of confidential information and exchange mechanisms with restricted data access	[20,27,28]
Analysis of the legal framework and regulations on the topic	[29]
Models of cooperation with an equitable distribution of income	[19,21,30–34]
Innovative business models built under the pillars of the PI	[13,22,35]

Source [12].

The PI is of particular interest in Europe, where the European Technology Platform ALICE established a comprehensive innovation research strategy for supply chain management based on the PI concept, which should be completely implemented by 2050. ALICE has identified five different roadmaps that are interconnected (Figure 1) and shows what needs to be analyzed and managed in order to achieve their objectives. These five roadmaps are as follows [36]:

- **Sustainable, Safe, and Secure Supply Chains:** This roadmap has the goals of reduced transportation (percentage of total value), improved carrier/(volume/weight), reduced emissions, increased reuse, reduced supply chain costs, and improved supply chain service (quality and reliability of expiration date).
- **Corridors, Hubs, and Synchromodality:** The goal of this roadmap is to achieve efficiency by reducing CO₂ emissions using large modes of transport to load packages (i.e., barges and freight trains). Therefore, networks such as Ten-T and, ultimately, the PI can contribute significantly to more sustainable transport.
- **Information Systems for Interconnected Logistics:** The objective of this third roadmap is the use of information to achieve greater security through the use of information transparency and the design of less intrusive inspection methods.
- **Global Supply Network Coordination and Collaboration:** The coordination of the forward and backward flows allows the increase of sustainability and more efficient transport by higher transport loads, applying both collaboration and horizontal and vertical coordination.
- **Urban Logistics:** To achieve an increase in efficiency, as well as the reduction of emissions and cost, it is essential to analyze the logistics of the first and last miles, with a reduction in the number of cargo vehicles in urban areas, for which coordinated and intelligent collaboration between the actors involved is fundamental.

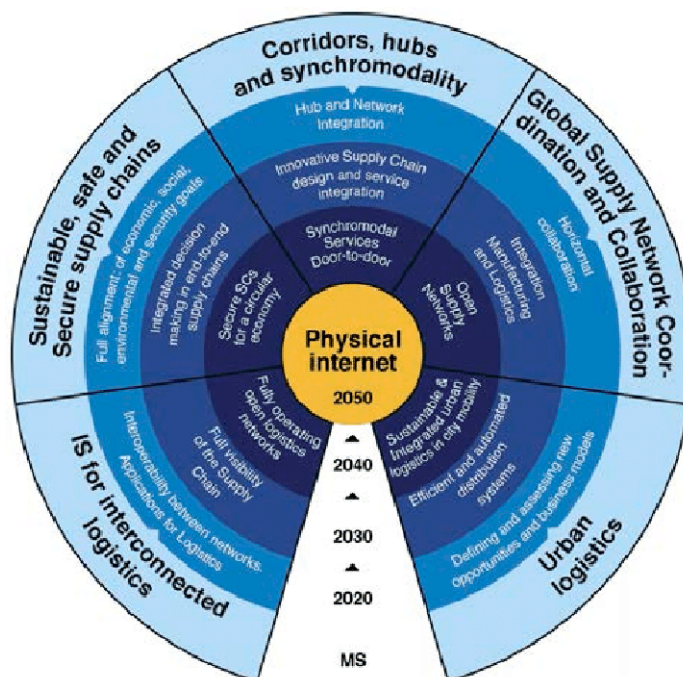


Figure 1. Interconnection between the roadmaps established by Alliance for Logistics Innovation through Collaboration (ALICE) [36].

As we can see in the roadmaps, one of the main concerns is to achieve an efficient and sustainable value chain that allows for the reduction of emissions. Thus, it is essential to analyze the concept of synchronomodality, which was defined by Giusti [37] as the provision of efficient, reliable, flexible, and sustainable services through the coordination and cooperation of stakeholders and the synchronization of operations within one or more supply chains. It is driven by information technology and communication (ICT) and intelligent transport system (ITS) technologies. The concept involves understanding low load factors and idle operation, which are the main causes of inefficiencies in transportation [38], in addition to collaboration networks that can lead to reducing these problems and increasing sustainability with fewer limitations and lower costs [39]. Authors such as Ambra, Caris, and Machadi [40] have analyzed the effectiveness of uniting both concepts under the premises set by the Urban Logistics roadmap of the ALICE platform to achieve the established objectives of sustainability and cost reduction with logistical efficiency.

These energy efficiency problems derived from logistics activities are especially relevant in the first mile (i.e., the first delivery point) and the last mile (i.e., final delivery), where deliveries are made up of individual orders, and each order must be collected in and delivered to different places [41], which implies high costs. For this reason, this topic and the search for tools to measure and reduce costs have been discussed in the literature [42]. The last mile represents a serious problem for the logistics industry due to the strong impact it has on cities, not only in terms of pollution, but also in terms of noise, traffic, and so forth [43].

Since delivery in the last mile is essential for the development of urban logistics, it is not surprising that studies and projects that focus on restricted home distribution in urban areas (e.g., [9,44,45]) include new models and case studies where solutions to this problem are implemented based on the PI principles.

This effort to evolve and improve delivery in the last mile is also included in ALICE's roadmaps (2016), named Urban Logistics. In addition, delivery in the last mile is one of the most expensive and least efficient processes, as well as the most polluting part of the entire logistics chain, and is therefore one of the processes with the best chance of reducing costs and negative environmental impacts, thus fulfilling two of the fundamental objectives of the PI [43].

One of the most relevant aspects in this regard is urban freight transport, since it contributes to the well-being of cities and their sustainability while generating high social costs [46]. The peculiarities of each city regarding legislation, regulations, infrastructure, networks, urban configuration, social habits, and interest groups that participate in urban cargo transportation require specific measures depending on the context in which the process is established [47]. These specific measures go through collective and shared solutions, which, most likely, will be achieved by designing a policy package that incorporates a commitment capable of balancing conflicting interests between the different heterogeneous parties participating in the process—namely, supplier transport (TP), retailers (RE), public administrations (PA), and citizens (CZ)—instead of a single policy that tries to satisfy all interested parties [48,49].

In search of solutions to the logistical problems analyzed, this work focuses on various elements of the roadmaps, since our objective was to analyze the coincidences between the principles of the PI and Lean that allow us to achieve sustainable, efficient, and safe supply chains and to reduce emissions, as well as the amount of transport by improving the volume/weight ratio for transport.

3. Lean Manufacturing

Lean manufacturing seeks to optimize the production system by having all parts contribute toward a whole. The objective is to optimize any or all of the activities of the production system, eliminating all tasks that do not add value within the production process and focusing on optimizing a company's resources by controlling waste [50].

Waste does not add value to merchandise from the point of view of the customers and, as such, there is a set of productive practices to achieve the objective of waste minimization [51,52]. The focus is on supporting and stimulating workers to continuously improve the process where they work, as well as on eliminating any waste that may occur in the development of their activities. The initial focus was on production plants, but the principles are quite broad and applicable to engineering, business, and service operations.

Lean manufacturing originated in Japan with the Toyota Production System (TPS). It is grounded in the continuous improvement of processes based on three basic pillars: Philosophy, Management, and Techniques (Figure 2).

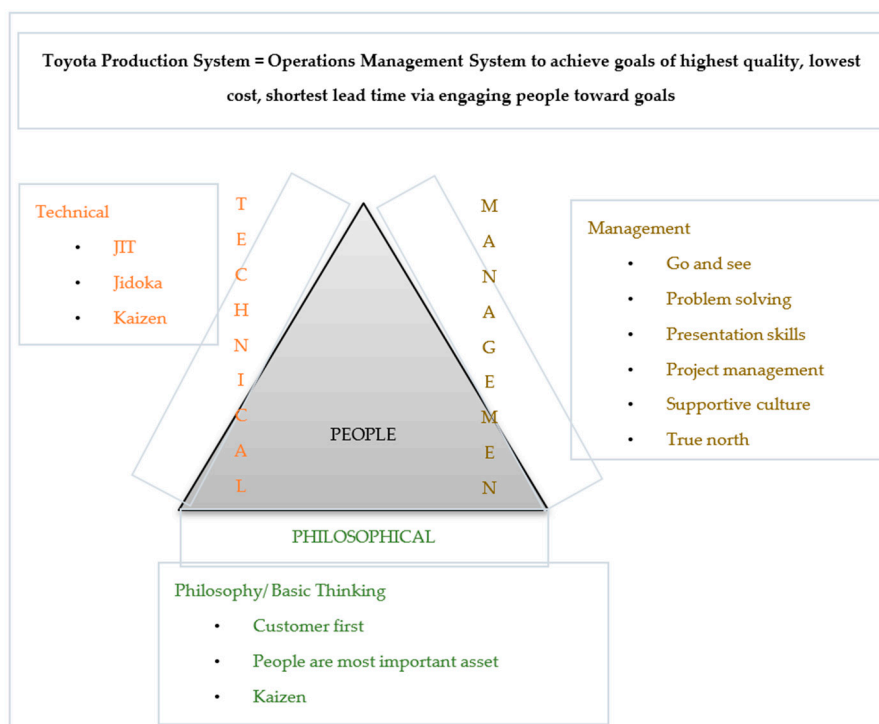


Figure 2. Toyota Production System (TPS) [53].

Based on these three pillars, it can be observed that the final objective of Lean manufacturing is that the product or service and its attributes must be based on customer requirements, through small and frequent improvements using techniques that make this possible by achieving a rate of improvement and increased competitiveness that is optimal and sustained over time, in addition to achieving a reduction in overall costs while meeting quality standards and reducing the manufacturing cycle time [51].

One criticism of Lean thinking is the way in which “value” is determined. Value can only be defined at the end point by the customer. It is only significant when it is expressed in terms of a specific product (a good or service and often both at once) that brings together customer needs at a certain time and price. Value is created by the manufacturer, from the point of view of the customer, but many times it is difficult for manufacturers to define the precise value [52].

When the TPS is applied, it begins by examining the manufacturing process from the customer’s perspective. The first question in the TPS is always “What does the customer want from this process?” and there are two types of clients, namely, the internal clients in the following stages of the production line and the external client (i.e., the final consumer) [51].

Lean works to eliminate waste (“Muda” in Japanese). Eliminating Muda is the main aim of most of the efforts in this philosophy. The seven waste areas are waiting, overproduction, defects, excessive movement, excessive processing, excessive inventory, and excessive transport. There is also another type of waste that interconnects with those mentioned above, namely, human talent, in not using the work force’s creativity and intelligence or in not utilizing everyone in the organization that is involved in eliminating the seven areas of waste previously mentioned.

If we focus on the 7 + 1 areas of waste, at least four of them are related to logistics (internal and/or external): waiting, excessive movement, excessive inventory, and excessive transport (Figure 3).

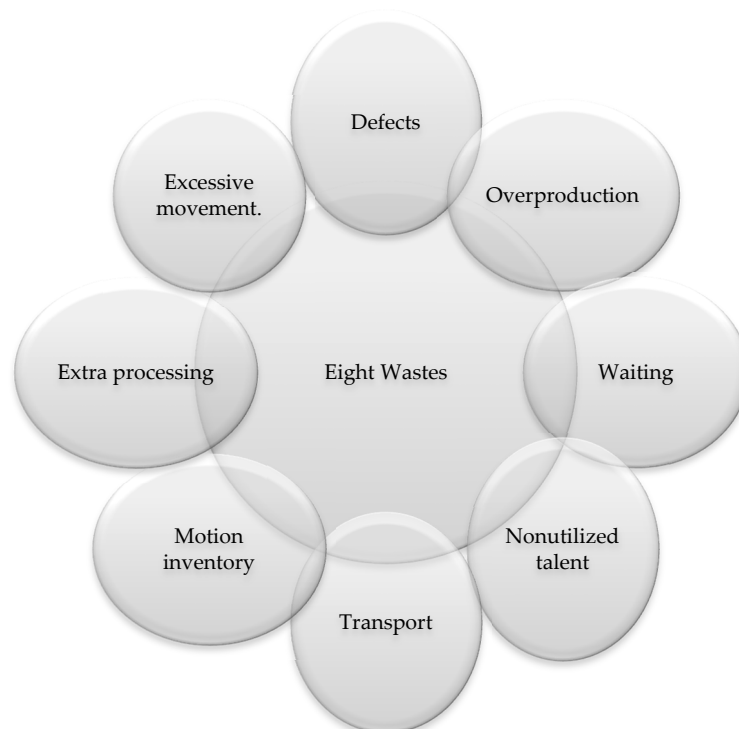


Figure 3. Eight areas of waste [53].

Therefore, Lean is a set of “tools” that helps to identify and eliminate waste (Muda), improve quality, and reduce the time and cost of production [54]. León [55] presented a summary of the main tools used by this philosophy, which is outlined in Table 4.

Table 4. Main Lean manufacturing tools.

	Name/Font	Description
Lean Pillars	Six Sigma (6σ) [56,57]	Identification and correction of the causes of errors, which, in doing so, reduces the rate to a level of 3.4 defects per million opportunities (DPMO) or 6σ . Committed top-down leadership.
	Just in Time [58,59]	Synchronization of suppliers and processes to reduce a good amount of waste, based on luxury, quality, and employee intervention. Reduction in delivery times and inventory levels, as well as improvement in quality. Provision of smooth operations and immediate feedback. Deliver to the customer what they want, in the amount they want, and exactly how they want it.
	Jidoka [60,61]	Incorporation of systems and devices that provide to machines the ability to detect the errors that are occurring. Manual or automatic stop of the production process, based on error detection, to prevent waste. Automation, taking into account human beings. Relationship between people and machinery in charge.
	Kaizen [61,62]	Culture of continuous sustainable improvement, involving the entire organizational structure, which has relatively low costs. Train leaders to propose improvements in the long term.
Tracking Tool	Visual Management [60,63]	Set of communication measures that capture, in an obvious and simple way, the situation of the production system, especially in terms of anomalies and waste. Empowers and generates a sense of belonging in employees. Demarcates areas, materials, products, equipment, and production programs. Uses indicators.
Operational Tools	5Ss [61,64]	Consisting of Seiri (Classification), Seiton (Order), Seiso (Cleaning), Seiketsu (Standardization) and Shitsuke (Discipline). Avoid problems caused by clutter and lack of instructions. Provide well-being, discipline, and a harmonious environment.
	Single-Minute Exchange of Dies (SMED) [60,61]	Set of techniques that seek to reduce machine set-up times. Standardization by installing new mechanisms, templates, and functional anchors. Eliminates dead-time adjustments.
	Total Productive Maintenance (TPM) [60,61]	Set of techniques aimed at eliminating breakdowns through the participation and motivation of all employees. Prevents losses in all of the operations of the company. Maximizes effectiveness and extends equipment life.
	Kanban [65]	Synchronized programming and control system of card-based production, which communicates information about product flow.
	Manufacturing cells [60,66]	Work cells that are designed to produce a family of parts or a limited number of families of parts, allowing a continuous flow to transform several processes, which work independently, into a joint work cell. Improve communication and use of people and equipment. Consider the formation, arrangement, and sequence of the machines.
	Poka-Yoke [60,61]	Installation of devices to detect errors, stop production, and alert the operator. Error proof, respecting the intelligence of the workers. Prevents defect production through early error detection.
Diagnostic Tool	Value Stream Map [67,68]	Map in which the organization's value chain is specified, both in productive and managerial areas. Identifies process flow and waste. Responds to communication problems, personnel, material, equipment, and processes.

4. Results

To achieve full implementation of the PI by 2050, the first step proposed by ALICE is to achieve the roadmap “sustainable and secure supply chains.” The objectives defined in this roadmap can be found in Table 5.

Table 5. Expected impacts from the implementation of ALICE roadmaps’ proposed actions.

	IMPACTS
SOCIETAL	+ Customer satisfaction. + Product availability. + Secure societies.
ENVIRONMENTAL	–Energy consumption (kWh Logistics/GDP). + Renewable energy resources share. – CO ₂ emissions (kg CO ₂ /tkm).
ECONOMIC	+ Return on assets and working capital. – Cargo lost to theft or damage. – Total supply chain costs.

Source: Adapted ALICE, 2015 [47].

As we analyzed, in Figure 1, the PI aims to make the logistics value chain more economically, environmentally, and socially efficient by applying the logistics web through innovations in technology, business models, and infrastructure.

The fundamental objective of Lean is the elimination of waste, which includes defects, overproduction, waiting time, lack of use, excess transportation, excess inventory, excess movements, and extra processing. We found that at least four of these have to do with the logistics (internal and/or external) of the organization, namely, waiting, excess movements, excess inventory, and excess transportation. By reducing these four wastes, it would be possible to reduce the costs of the supply chain (economic objective), increase customer satisfaction and the availability of products (objectives for society), and allow reducing energy consumption, sharing renewable energy sources, and reducing CO₂ emissions (environmental targets). Some ways in which to achieve these reductions are as follows:

- Distribute the necessary products, in the right quantity and appropriately presented, looking back on the supply chain.
- Be proactive in achieving efficiency by looking at the next links in the value chain.
- All types of waste must be eliminated at each link in the chain to improve the effectiveness of operations.
- Delivery times must be reduced at each link in the chain to reach customers as sooner as possible.

Upon reaching these four objectives, in order to reduce waste in the logistics sector, it would be possible to analyze the value flow of a process and to eliminate waste, as well as to analyze what really creates value for the client, with the aim of giving it to them, thus creating a new flow of value based on customer needs. The previous stages would be cyclically continued in a process of continuous improvement [52], which would achieve the objectives set by ALICE in the first roadmaps, the purpose of which is to implement the PI.

At its core, employing Lean would put the right things in the right place at the right time and in the right quantity, thus reducing waste and being flexible and open to change. As a consequence, the application of Lean helps to reduce costs, to create more value for the company, and to improve results, making itself applicable to the supply chain from the point of manufacture up until it has been delivered to the customer.

The Lean approach insists that the organization must focus its efforts on the horizontal processes that generate the greatest value, since all of the value generated is the result of these processes, but taking into account at all times the actors that participate in said processes, the clients, the final

objective of the processes, as well as the employees and managers who make their execution possible. The five principles of Lean thinking are shown in Figure 4.

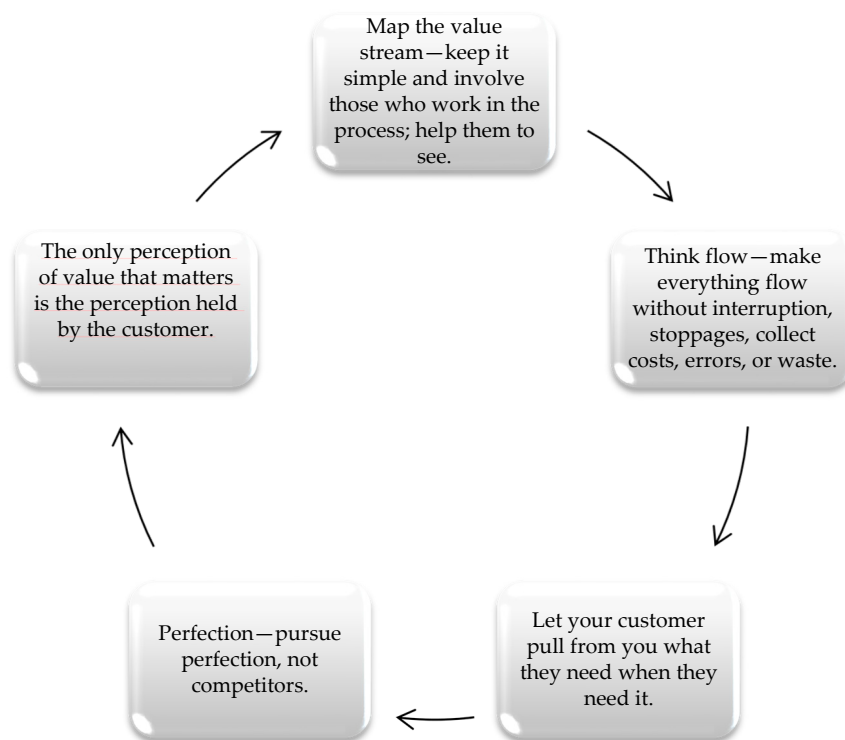


Figure 4. The five principles of Lean thinking [52].

A VSM allows us to see, in a single document, the map of the logistics process from the first supply activity through to the final activity of delivery to the customer. It can be used to find those activities that do not add value to the process, such as excessive storage; overproduction; excessive or unnecessary waiting times; defects, rejections, and reprocesses; and transportation and unnecessary movements.

As we can see, several of these unnecessary activities detected by a VSM are the basis of the PI and the objectives to be reduced by the roadmaps previously analyzed. In addition, other issues that can be detected by a VSM are empty transport and unnecessary CO₂ emissions, which would complement the objectives to be reduced by the PI to achieve sustainability by reducing emissions and costs. Therefore, this proposal offers a tool to achieve the objectives of the roadmaps.

Therefore, using a VSM encourages an improvement of the processes by allowing the detection and elimination of those activities that do not add value, thus reducing unnecessary resources [6], as can be seen in Figure 5.

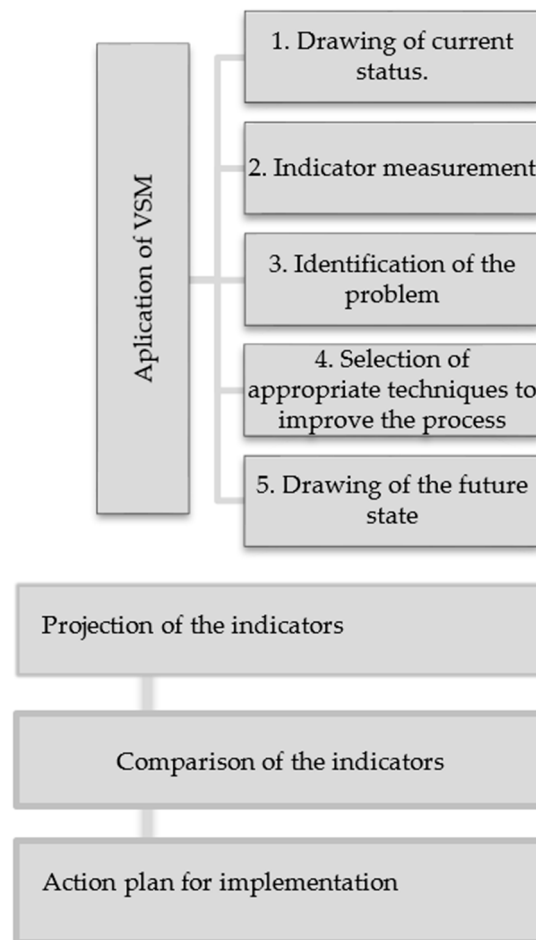


Figure 5. Process of a value stream map (VSM) [6].

First, it is necessary to define the current VSM tool, which allows us to identify the problems and individual processes that exist in the logistics chain, as well as to assign the waste generated by each of these detected problems. The following processes offer a way of getting closer to the working practice needed to produce a VSM [60]:

- Draw different icons for clients, suppliers, and control manufacturing.
- Identify customer needs for months and days.
- Calculate daily production and container requirements.
- Draw logistics icons for the frequency of delivery.
- Add process boxes in sequence, from left to right.
- Add data boxes below each process and a timeline below the boxes.
- Add the communication arrows and observe the methods and frequencies.
- Obtain process data and add them to the data tables.
- Add symbols and number of operators.
- Add locations and inventory levels on demand days.
- Add flow arrows and other information that may be useful.
- Add data on time, day shifts, rest times, and available time.
- Add hours of work, added value, and delivery times at the bottom of the processes.
- Calculate cycle time, total value added, and total processing time.

This procedure is usually carried out for three different statuses, namely, current status, future status, and ideal status. Here, it is necessary to establish how the process works in the short term.

It is necessary to analyze and answer the questions “What processes are integrated?”, “How many operators does the line require?”, “How much equipment?”, “What amount of space?”, and “How long is the stock in process?”.

The application of the VSM tool to the logistics process is developed through the graphic monitoring of the logistics process and by taking note of each phase; thus, it helps to have a global vision of the flow and of each individual stage or activity, allowing the individualization of waste and its causes. It also allows visualizing the effects of the improvements to be implemented in the flow, which forms the basis of the action plan, when preparing a future VSM from the identification both of activities that do not add value and of waste and poorly managed resources.

Therefore, the VSM tool allows to determine the interconnections between the PI principles and the Lean principles, as well as the potential for integrating them to create value in logistics networks.

This process can allow to achieve the objectives of the roadmaps previously analyzed. The use of the information obtained in the analysis of the initial situation allows for increasing the security of the process and for designing less intrusive inspection methods (i.e., route maps and information systems for interconnected logistics). A VSM, by focusing its efforts on horizontal processes and vertical relationships, can allow greater transport loads and synchronomodality, global route map supply network coordination and collaboration, and corridors, hubs, and synchronomodality. In addition, it affords the analysis of supplier relationships and customers and allows the inclusion of improvements in the first and last miles (i.e., Urban Logistics).

For all of the above, the application of the VSM tool would lead to avoiding empty transport and unnecessary CO₂ emissions, as well as reducing costs, which would allow more efficient and sustainable transport (roadmap for Sustainable, Safe, and Secure Supply Chains). Therefore, this proposal offers a tool to achieve the objectives of the roadmaps and to establish the pillars of the PI (Figure 6).

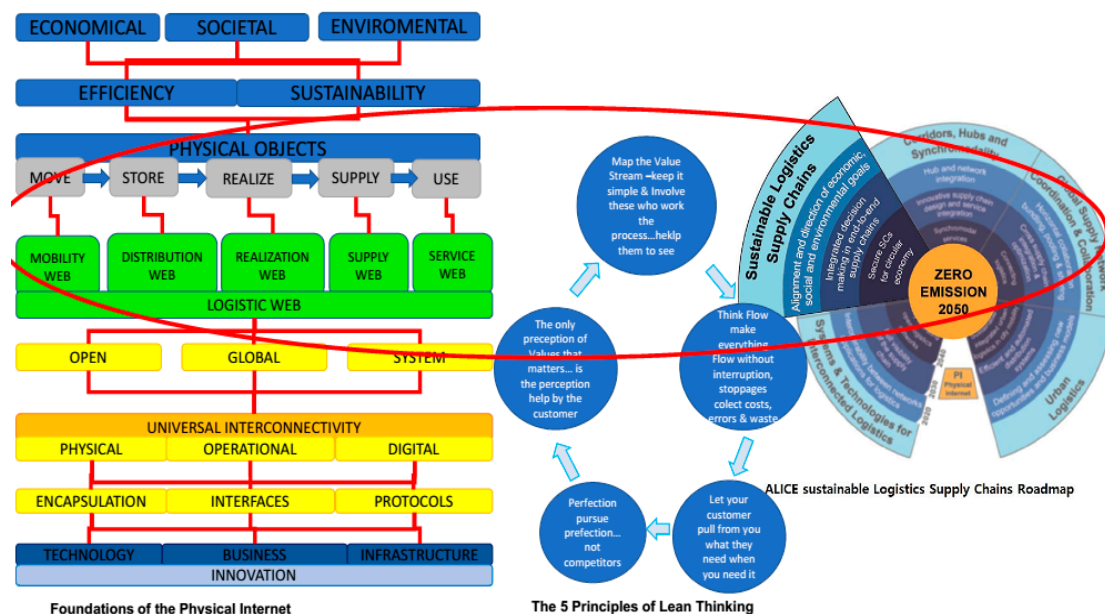


Figure 6. Interaction between Lean and the PI [36,52,69].

5. Discussion

There is a close relationship between the PI paradigms and the Lean philosophy; the value chain can be analyzed using both visions simultaneously.

In essence, using Lean would get the right things in the right place at the right time and in the right amount, thus minimizing waste and being flexible and open to change. Consequently, the application of Lean helps to reduce costs, creating more value for the company and improving its

results, which makes it applicable to the supply chain from the point of manufacture to the end point with the customer, achieving the objectives of the PI.

Lean approaches emphasize processes, urging the organization to focus its efforts on those that generate more value, since all generated value is the result of a process. However, they do not neglect the people involved or the clients (either internal or external) for whom a certain process works, nor the employees and managers who make possible the process and the generation of value.

To achieve the objective of this work and to analyze if there are interconnections between the principles of the PI and Lean, and to determine if it is possible to apply them to logistics companies, it is necessary to determine which of the PI and Lean tools should be applied to achieve its objectives.

The VSM tool comprises the actions and activities that add value and those that do not in a value chain, that is, the production flow from the provider to the customer or consumer. This tool has shown itself to be effective in generating greater visibility of processes [70], and in reducing lead time and inventories [71]. The main benefits of its application are as follows [72]:

- Better understanding of the cost of the product.
- Clear picture of the process.
- Reduction in work in progress.
- Inventory reduction.
- Reduction in production cycle time.
- Flexibility—faster response to changing demand.
- Faster response to quality issues.
- An emphasis on pulling from the client.
- An increase in the contribution of added value and the standardization of production processes.

The use of a VSM allows an organization to implement actions that eliminate waste, as well as to meet other objectives pursued by the PI and established by ALICE (Figure 2). As can be seen when analyzing the literature on the design and application of a VSM in logistics, it allows one to identify energy consumption that does not add value in order to establish ways to save it [73–75], since it identifies the level of energy used in each step and the subsequent waste. This gives rise to defining opportunities for energy conservation, either through modifications to machine tools or changes to these for different designs [76]. It also allows a reduction of the carbon footprint of the production of metal parts to improve sustainability [77,78].

6. Conclusions

There is a close relationship between the PI paradigms and the Lean philosophy; the value chain can be analyzed using both visions simultaneously. This study reveals the close relationship between the PI and Lean paradigms, as well as the added value that they jointly contribute to analyzing and enhancing logistical networks.

The information society has opened thousands of doors to obtain improvements in the management of companies individually and in the relationships between them, their suppliers, and their customers. This poses new challenges and paradigms for organizations. With the introduction of the PI as a model, logistics will act as a driver of change and will result in new management challenges, such as reducing costs, reducing emissions to the atmosphere, reducing the number of trucks on roads, and improving the quality of life of customers and the workers in the logistics sector.

The VSM tool should be specifically highlighted, as it identifies activities that do not add value and that generate excessive production, overstorage, waiting times poorly adjusted to needs, defects and rejects that require reprocessing, and, finally, unnecessary transport and movements.

The application of the VSM tool in logistics processes allows one to carry out an examination of the current situation, thus making it an important tool to detect and analyze the problems that the processes present and the waste originating from those problems. This will have an impact on society (i.e., increasing the availability of the product and customer satisfaction), on the economy (i.e., reducing

costs for the loss or deterioration of products and the costs of the process), and on the environment (i.e., allowing the reduction of energy consumption and decreasing CO₂ emissions). All these advantages presented by the VSM tool are the objectives to be achieved by the PI.

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