

## THE CURRENT CONTEXT OF LEAN AND SIX SIGMA LOGISTICS APPLICATIONS IN LITERATURE: A SYSTEMATIC REVIEW

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### ABSTRACT

Originated in the Toyota Production System, the concept of lean production has become widely disseminated and broadly applied in the industry. When considering lean and six sigma principles in logistics, companies have obtained advantages in terms of cost and quality, which encouraged scientific researches for improvements in the topic. To study the current state of the art on Lean Logistics (LL) and Six Sigma Logistics (SSL), in the national and international level, a systematic review of lean and six sigma logistics were performed, aiming to evaluate theoretical and practical applications, in order to classify the current literature and propose studies to address research opportunities. For this purpose, a review protocol was created to guide and structure the review. As results, it was identified that Transportation has been the main logistic operational drive component in which LL has being applied. The most frequent type of waste considered was Motion and most of the studies were practical applications. Finally, this study found considerable research opportunities for future studies.

**Keywords:** Systematic Review; Lean Manufacturing; Lean Logistics; Six Sigma.

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## 1. INTRODUCTION

Based on the Toyota Production System (TPS), Lean Manufacturing had its origin after World War II, when Toyota, in order to outstand from its competitors in terms of quality, reinvented the mass production model, focusing on eliminating time and material waste in its production process. Consequently, Toyota could obtain fast and flexible processes, allowing it to offer customers what they want, when they want it, with high quality and at a reasonable price (Liker, 2005).

In the economic context, companies have been searching for the development of continuous improvement habits, waste elimination and improvement of the skills in their human resources, and those practices were related to Lean thinking (Gonçalves Filho *et al.*, 2014). The concept of Lean has been widely applied in production process, with a considerable number of studies in this field (Dennis, 2008). However, there have been difficulties in adapting Lean concepts and assumptions to Logistics, although lean philosophy can potentially provide benefits for this field (Zylstra, 2008). Therefore, there are opportunities for the development of studies that map and generate information on the current literature state in the Lean and Six Sigma Logistics area, such as systematic reviews.

In this sense, the review in Gonçalves Filho *et al.* (2014) comprehended the strategy in Lean manufacturing in different industry segments. As a result, it was observed the Processing Industry was the most representative, followed by the Automobile and Service Industries. Furthermore, the authors identified opportunities for studies on specific Industries such as Sugarcane-based Energy, which represented a high potential of application.

Similarly, Khorasani *et al.* (2015) performed a systematic review on Lean Supply Chain Management applied to the Healthcare context. The papers were categorized according to their relevance, scope, methodology, type of industry and year of publication, and results demonstrated that the selected papers focused on the application of Lean methodology to reduce costs, increase time efficiency and quality. In addition, the most studied topics were identified as being technology in the Supply Chain and its implementation factors, and the main methodologies were data mining, surveys, simulation, optimization models and Value Stream Mapping. The authors suggest future studies on practical application of theoretical articles.

In this context, considering the research opportunities for connecting Lean, Six Sigma and Logistic concepts in the literature, this study aimed to characterize the current state of the literature on Lean Logistics (LL) and Six Sigma Logistics (SSL), using a systematic review approach for analyzing pa-

pers published from 2012 to 2016. For this purpose, along with the review protocol, research questions were provided to guide data collection from the selected papers in terms of theory, application, Lean tools, Six Sigma concepts, methodology and Logistic concepts. Therefore, the contribution of this study comprehends the identification of the main topics covered in literature of LL and SSL as well as new research opportunities for the practices.

This study is organized as follows: Section 1 provides a brief introduction to the study, justifying its contribution and objectives; Section 2 presents a detailed description of the systematic review methodology; Section 3 contains the analysis of data collected from the selected papers and the discussion on the LL and SSL current context. Finally, in Section 4, conclusions and final thoughts on the results achieved are exposed.

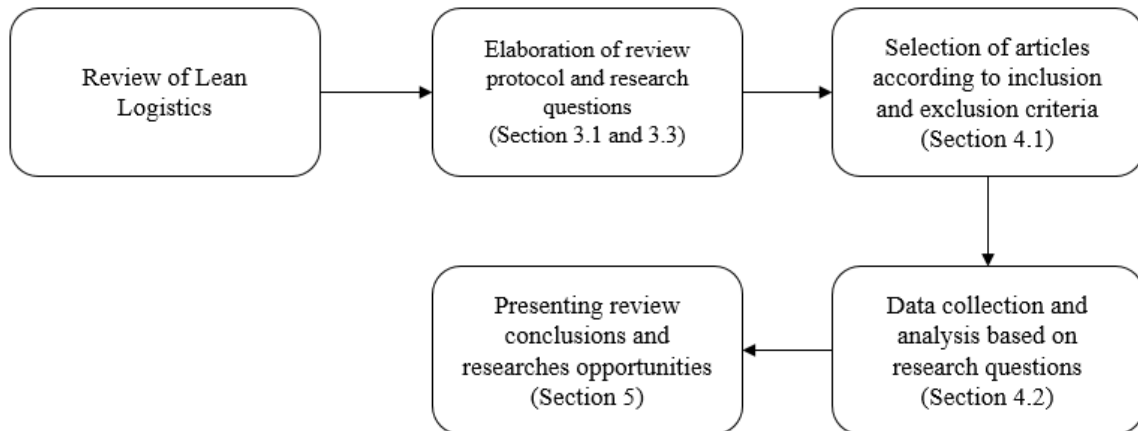
## 2. METHODOLOGY

It is important to follow proper guidelines to conduct a systematic review to ensure a valid and unbiased analysis. Therefore, a systematic review protocol was elaborated with guidelines for the entire review process. Afterwards, following the inclusion and exclusion criteria, papers were selected to compose the final analysis. Finally, a complete reading and analysis on those papers was performed to collect information to answer a set of research questions and describe the current panorama of LL e SSL studies. These methodology steps are systematically illustrated in Figure 1.

The research protocol that led this systematic review is summarized in Table 1. In order to clarify the criteria adopted in the protocol, it is important to comment the connection between lean and six sigma considered in the review.

The combination of lean and six sigma concepts results in a powerful combination of tools, techniques and methods for management and control analysis. According to Goldsby *et Martichenko* (2005), combining lean concepts and techniques with six sigma methods from logistics perspective results in waste reduction caused by regulated efforts to understand and decrease variation, simultaneously increasing velocity and material flow performance in the logistics and supply chain.

The papers resulted from the search using keywords and the Boolean operators were matched with the protocol guidelines, and those aligned with the inclusion criteria were selected for this review. It is worth mentioning the necessity of a subjective analysis in this phase: the sensibility and knowledge of the authors about the subject, since some articles did not directly state the approach of LL or SSL,



**Figure 1.** Methodology steps for the proposed systematic review

Source: Adapted from Negrão et al. (2016)

making necessary to analyze carefully the published studies' content. Papers were selected with full accordance between the authors, and duplicates were removed.

**Table 1.** Review protocol parameters for the systematic review on LL and SSL

RESEARCH PROTOCOL			
Main Research Question: "What is the current literature state of Lean Logistics (LL) and Six Sigma Logistics (SSL)?"			
Keywords	Period	Inclusion criteria	Databases
"Logística Enxuta"	2012 - 2016	Papers in journals and conferences	Science Direct CAPES Journals Web of Science SCOPUS Google Scholar
"Logística Lean"		Papers that precisely state LL and SSL in its content or that relate lean thinking or six sigma with at least one logistics driver, being able to identify this information in the title, abstract or keywords	
"Lean Logistics"			
"Logística Seis Sigma"			
"Logística Six Sigma"		Papers in Portuguese, English or Spanish	
"Six Sigma Logistics"		<b>Exclusion criteria</b> Articles on Lean only	

Source: The author(s)' own

The next step was to perform a detailed reading on the selected papers to extract their respective information based on a set of research questions (RQ), as shown in Table 2, along with their respective objectives. These RQ aimed to identify trends and gaps in the current literature.

For RQ-1, it was proposed a set of multiple-choice alternatives: a) Logistics and Lean or six sigma concepts are linked (when both concepts are connected, presenting lean or six sigma logistics integrated theories). b) The concepts are not linked (when it presents either only concepts of logistics, or lean thinking, or six sigma or both, but not relating them clearly in the literature review). c) It does not contain specific literature review topics (when none of the concepts is presented in a specific theoretical topic or the literature review section could not be identified in the paper).

In RQ-2, the answer could be one or more logistics operational drivers, since it is possible to approach more than one simultaneously. Therefore, the answer options were: a) Transportation; b) Inventory; c) Facility; d) Information; and e) Not defined, in cases where there was not a clear definition or the study was not restricted to these drivers.

RQ-3 allowed the classification of the selected papers according its applicability. The answer was "applied" when the paper's results were composed of purely practical content application in some sector or organization - although the sector was not clearly defined in some cases. On the other hand, when results were composed of only theoretical content, without practical application, the paper was considered theoretical.

For RQ-4, it could be identified more than one tool/principle in each paper. For the cases when there was no application of a certain tool or it was not explicitly specified, the question was not applicable. The range of tools was adapted from Negrão *et al.* (2016).

RQ-5 intended to gather the paper's application sectors within the articles. The range of economic and industrial activity sector was defined according to the National Economic Activity Code (CNAE 2.0) of the Brazilian Institute of Geography and Statistics (IBGE, 2017). If a sector was not clearly



specified, then the answer for this was “not defined”. If the paper was theoretical and not applied in any sector, the answer was “not applicable”.

**Table 2.** Research questions and their objectives

ID	Research Question	Objective
RQ-1	In the paper’s literature review, was there connection between logistics and lean thinking concepts?	Verify the level of integration between the logistics and lean thinking concepts
RQ-2	Which logistics operational driver is the lean logistics principle applied in?	Identify which logistics operational drivers (facility, inventory, transportation and information) the lean philosophy has been applied more frequently.
RQ-3	Is the paper a theoretical research or an application in some productive/ industrial sector?	Define what is more common: theoretical studies on lean logistics application and impacts, or effective establishment of lean philosophy in the proposition of specific logistics results
RQ-4	What lean logistics tools and/or principles does the article address?	Identify how logistics has been applied in organizations based on the lean tools utilized and if there is a trend on its utilization
RQ-5	What productive/industrial/economic sector the article focuses on?	Identify in which productive, industrial or economy sectors the lean logistics approach has been more commonly applied.
RQ-6	What wastes tackled by lean logistics does the article address?	Define the main problems and wastes that motivate proposal of studies and application of lean logistics

Source: The author(s)’ own

Finally, in RQ-6, the alternatives for answer were based on the seven wastes defined by Goldsby *et Martichenko* (2005), which are: Inventory; Transportation; Space and Facilities; Time; Packaging; Administration; and Knowledge. When it was not clear what waste was being tackled, the answer would be “not defined”. It was possible to select more than one alternative, since it is common to tackle more than one type of waste simultaneously in lean systems.

### 3. RESULTS AND ANALYSIS

The results of the systematic review were presented in this section, which comprises the information obtained from collection and analysis of the selected papers based on the proposed protocol and research questions, aiming to verify the current scenario of the LL and SSL literature. A set of parameters was created for analysis (research question’s answers) for each research question (RQ), thus, for the systematic review. In Figure 2 all sets of criteria and their respective code are described.

Based on the review protocol, it was obtained a sample of 67 papers, varying in terms of language, country of publication and lean or six sigma logistics approach. In Table 3, a summary about those papers is presented, along with each RQ analysis.

In terms of language, one can verify the majority of papers were written in English, representing 64%, followed by 28% in Portuguese, and 8% in Spanish, as illustrated in Figure 3.

<p><b>RQ-1</b>  <b>Connection between logistics and lean thinking concepts in the literature review</b></p> <table border="1"> <thead> <tr> <th></th> <th>Code</th> </tr> </thead> <tbody> <tr> <td>Logistics and Lean concepts are linked</td> <td>link</td> </tr> <tr> <td>Logistics and Lean concepts are not linked</td> <td>nolink</td> </tr> <tr> <td>Does not contain literature review topics</td> <td>noliterat</td> </tr> </tbody> </table>		Code	Logistics and Lean concepts are linked	link	Logistics and Lean concepts are not linked	nolink	Does not contain literature review topics	noliterat	<p><b>RQ-4</b>  <b>Lean logistics tools and principles</b></p> <table border="1"> <thead> <tr> <th></th> <th>Code</th> <th>Lean logistics tools and principles</th> <th>Code</th> </tr> </thead> <tbody> <tr> <td>Kanban</td> <td>Kan</td> <td>Radio Frequency Identification</td> <td>RFID</td> </tr> <tr> <td>5S</td> <td>5S</td> <td>Single Minute Exchange of Die</td> <td>SMED</td> </tr> <tr> <td>5W2H</td> <td>5W2H</td> <td>SIPOC</td> <td>SIPOC</td> </tr> <tr> <td>A3 Problem Solving</td> <td>A3</td> <td>Six Sigma</td> <td>SS</td> </tr> <tr> <td>Batch size reduction</td> <td>Batch</td> <td>Spaghetti Diagram</td> <td>Spagh</td> </tr> <tr> <td>Constant Work in Progress</td> <td>Cwip</td> <td>Standardization</td> <td>Standz</td> </tr> <tr> <td>Continuous flow</td> <td>ContFlw</td> <td>Takt Time</td> <td>Tkt</td> </tr> <tr> <td>Electronic Data Interchange</td> <td>EDI</td> <td>Teamwork</td> <td>Team</td> </tr> <tr> <td>Enterprise Resource Planning</td> <td>ERP</td> <td>Total Productive Maintenance</td> <td>TPM</td> </tr> <tr> <td>Global Operating Income Index</td> <td>IROG</td> <td>Total Quality Management</td> <td>TQM</td> </tr> <tr> <td>Kaizen</td> <td>Kai</td> <td>Value Stream Mapping</td> <td>VSM</td> </tr> <tr> <td>Layout</td> <td>Lyt</td> <td>Variation Control</td> <td>Vari</td> </tr> <tr> <td>Logistics Personal Excellence</td> <td>Lopez</td> <td>Vendor Managed Inventory</td> <td>VMI</td> </tr> <tr> <td>Milk-Run</td> <td>Mlk</td> <td>Visual Management System</td> <td>Visu</td> </tr> <tr> <td>Overall Equipment Effectiveness</td> <td>OEE</td> <td>Water Spider</td> <td>WS</td> </tr> <tr> <td>Performance Measure System</td> <td>PMS</td> <td>Workplace Management</td> <td>WorkM</td> </tr> <tr> <td>Plan for every part</td> <td>PPEP</td> <td>None/not defined</td> <td>n/a</td> </tr> <tr> <td>Pull Systems and Just in Time</td> <td>JIT</td> <td></td> <td></td> </tr> </tbody> </table>		Code	Lean logistics tools and principles	Code	Kanban	Kan	Radio Frequency Identification	RFID	5S	5S	Single Minute Exchange of Die	SMED	5W2H	5W2H	SIPOC	SIPOC	A3 Problem Solving	A3	Six Sigma	SS	Batch size reduction	Batch	Spaghetti Diagram	Spagh	Constant Work in Progress	Cwip	Standardization	Standz	Continuous flow	ContFlw	Takt Time	Tkt	Electronic Data Interchange	EDI	Teamwork	Team	Enterprise Resource Planning	ERP	Total Productive Maintenance	TPM	Global Operating Income Index	IROG	Total Quality Management	TQM	Kaizen	Kai	Value Stream Mapping	VSM	Layout	Lyt	Variation Control	Vari	Logistics Personal Excellence	Lopez	Vendor Managed Inventory	VMI	Milk-Run	Mlk	Visual Management System	Visu	Overall Equipment Effectiveness	OEE	Water Spider	WS	Performance Measure System	PMS	Workplace Management	WorkM	Plan for every part	PPEP	None/not defined	n/a	Pull Systems and Just in Time	JIT			<p><b>RQ-5</b>  <b>Industrial/economic sector</b></p> <table border="1"> <thead> <tr> <th>Industrial/economic sector</th> <th>Code*</th> </tr> </thead> <tbody> <tr> <td>Automotive</td> <td>29</td> </tr> <tr> <td>Metallurgical</td> <td>24</td> </tr> <tr> <td>Equipment and Machinery</td> <td>28</td> </tr> <tr> <td>Health</td> <td>86</td> </tr> <tr> <td>Food</td> <td>10</td> </tr> <tr> <td>Electronics</td> <td>26</td> </tr> <tr> <td>Air Transportation</td> <td>51</td> </tr> <tr> <td>Others</td> <td>Other</td> </tr> <tr> <td>Not defined</td> <td>ND</td> </tr> <tr> <td>Not applicable</td> <td>n/a</td> </tr> </tbody> </table>	Industrial/economic sector	Code*	Automotive	29	Metallurgical	24	Equipment and Machinery	28	Health	86	Food	10	Electronics	26	Air Transportation	51	Others	Other	Not defined	ND	Not applicable	n/a
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**Figure 2.** Criteria and coding for each research question

Source: The author(s)’ own

**Table 3.** Classification and summary of the lean logistics papers

Main results	RQ-6	RQ-5	RQ-4	RQ-3	RQ-2	RQ-1	Country	Authors
Development of a tool for quantifying value-added shares in material supply as a main task of logistics. The value-added shares of commissioning are identified and reasons for losses are discussed	Time	ND	OEE	A	ND	Nolink	Germany	Adolph et al., 2016
The implementation of the comprehensive plan has reduced inventory, decreased lead time and improved service quality, enhanced employee satisfaction and increased staff productivity, both dedicated to health and logistics	Time, Inv, Adm	86	Kan	A	Inv, Fac, Inf	Noliterat	Spain	Aguilar-Escobar et Garrido-Vega, 2013
Reduction in logistics costs and increase in the satisfaction level of the internal hospital users with the new logistics system. Some differences in the degree of satisfaction by different groups of users were detected	Inv, Time, Adm	86	n/a	A	Fac	Noliterat	Spain	Aguilar-Escobar et al., 2013
Through improving service time, lean caused positive impact towards Tam Cargo clients. A layout change allowed better cargo organization in operational processes. The company has been adjusting its costs according to demand, practice that is aligned with lean philosophy	SpcFac	51	5S, Kan, SS, Lyt	A	Fac	Link	Brazil	Almeida Filho et Lobosco, 2015
There is a lack of studies regarding in-plant milk run system as a whole, and in certain areas of the system, such as manual feeding. There is also a tendency to deviate from lean manufacturing philosophy, looking for optimality based on restrictive objectives	Tra	ND	Mlk, JIT	T	Tra	Link	Germany	Alnahhal et al., 2014
Reduced number of stock out incidents by applying the DMAIC methodology in the healthcare logistics management	n/a	86	SS	A	Inv	Link	Jordan	Al-Qatawneh et al., 2013
Proposed ideas for a lean logistics system to prevent problems caused by failure on demand, sales and production forecast, which were proven unstable and inaccurate	Inv, Time	10	Kan	A	Inv, Fac	Link	Brazil	Alves et Santos, 2013
Applied the four phases of the DMAIC methodology, which showed the necessity to pay attention and focus on personal capacity, job rotation, usage of trucks with an hydraulic system and sample size	SpcFac	28	SS	A	Inv	Noliterat	Peru	Ángeles, 2013
Reduction of defects in 80%, improvements in the customer service and increase in productivity in supermarket and repacking areas	Tra	29	Kan, Mlk, TQM, SS, JIT	A	Tra	Nolink	England	Antunes et al., 2013
Discusses milk run logistics in the line feeding system with a special emphasis on the automobile industry, which leads to the enhancement of logistics indices	SpcFac, Inv, Tra, Adm, Time	29	5S, Mlk, Standz	A	Tra, Fac, Inf	Nolink	-	Bagheri et al., 2016
A survey conducted in the 126 organizations showed the use the lean in logistics process regardless of the type of production, which is related to the complexity of the logistics system. The order of methods frequently used is Teamwork, 5S, KAIZEN, TPM, KANBAN and VSM.	n/a	ND	5S, Kai, Kan, VSM, TPM, Team	A	ND	Noliterat	Slovakia	Bednár et al., 2013b

The article showed how logistics is responsible for how fast and efficiently the customer will receive their product and the benefits of lean techniques applied directly and indirectly in logistics processes	Inv, Adm, Time	29	5S, Visu, Kai, Kan, VSM, Tkt, TPM, Team	A	Tra, Fac	Nolink	Slovakia	Bednár et al., 2012a
Proposed lean logistics concepts focusing on customer services and visibility of wastes in the metallurgical sector in order to achieve global efficiency	Tra, Inv, Time	24	VSM, Kan, JIT, Standz, Lyt	T	Tra, Inv, Inf	Link	Brazil	Belli, 2012
Implemented Kaizen and a RFID system to control 100% of product movement. Resulted in the reduction of human error, increasing in logistics processes' informatization and automation, and reduction of time in expedition processes and inventory	Inv, Adm, Time	29	5S, Kai, SS, RFID	A	Inv	Nolink	Brazil	Benevides et al., 2013
Taught the adequate application of Industry 4.0 technology in production logistics and evaluated the specific problems of logistics planning in the field of "intelligent production logistics" with a survey	n/a	Other	JIT	A	Inf	Noliterat	Germany	Blöchl et Schneider, 2016
Applied lean techniques towards improvements in a company's internal logistics. a shipping and receiving window, internal supply routes, flexible storage and a milk-run system were planned. The projected annual earnings in labor and equipment are R\$ 316.718 and R\$ 27.886, respectively.	Inv, Tra, Pack, Time	24	5S, A3, Mlk, JIT, SMED, ContFlw	A	Tra, Inv	Nolink	Brazil	Carreira et Sobrinho, 2012
The use of DMADV methodology allows to systematically establish a model. Created an online community (Be One Logistics) whose membership fee increased to 71% of the target population	n/a	29	SS	A	Inf	Nolink	Portugal	Carvalho et al., 2016
Reduction in production costs and improvements in the quality of products were consequences of the lean implementation. It was observed that lean inventory depends on a series of activities, whether related with inventory management or not.	Inv, Time, Tra	24	Visu, Kai, Kan, Mlk, TQM, Batch, Tkt, Standz, PFEP, EDI	A	Tra, Inv, Inf, Fac	Nolink	Brazil	Catapan et al., 2013
Proposed a logistics project approach using the DMAIC methodology to eliminate waste from flows and operations, lower delivery times, reduce process variance, and increase value in companies	Time, Tra, SpcFac	n/a	VSM, TQM, SS, Standz TPM, Visu, 5S, Vari, Batch	T	Inf	Link	Colombia and Mexico	Celis et García, 2012
Reduction of 61% in the logistics operator's idle waiting time and of 26% in the total duration of a material supply route. Improved the system efficiency and material handling.	Time, Pack	29	A3, Visu, Tkt, Lyt	A	Tra, Fac	Noliterat	Brazil	Costa and Costa, 2016
Applied a kanban system in equipment and machinery industry, reducing extra storage space on the shelves, leaning in the entire process and facilitating the stock replenishment	Inv	28	Visu, Kan, Lyt	A	Inv	Nolink	Brazil	Domingos et al., 2013

Provides practitioners with answers to the question about which performance indicators to use in today's automotive logistics chain and which indicators serve as a base for continuous improvement	Inv, Time, Tra	29	PMS	A	Tra	Link	Germany	Dornhofer et al., 2016
Affirms that lean logistics can be applied in any distribution company, which will possibly reduce costs and wasted time, making logistics processes more efficient and effective	Time, Tra	Other	n/a	A	Tra, Fac	Link	Brazil	Ferreira et Magno, 2013
Introduces a learning methodology through lean logistics projects, in which the worker effectively contributes with theory and practices	Time	Other	n/a	A	Tra	Link	Brazil	Ferreira et al., 2014
The concurrent deployment of the green and lean paradigms is an effective approach to improve both operational efficiency and environmental performance of road transport operations	Tra	ND	VSM	A	Tra	Nolink	England and Mexico	Garza-Reyes, et al., 2016
Identified patterns in publications on lean logistics and supply from 2005 to 2014, such as publication platform and business segment in which the concepts were applied	n/a	n/a	n/a	T	ND	Link	Brazil	Gonçales Filho et al., 2014
Identify important implementation aspects when applying Lean Six Sigma to logistics services, such as continuous improvement structure, strategic analysis and process management	n/a	26	Visu, VSM, SS, SIPOC	A	ND	Nolink	Netherlands	Gutierrez-Gutierrez et al., 2016
Results from fit hypothesis tests in two logistics service providers indicated that challenging and enabling workers to creatively use their talents and skills in daily work will most likely lead to positive results	Know	ND	n/a	A	ND	Nolink	Netherlands	Haan et al., 2012
Logistics Personal Excellence will provide training modules for post-secondary education in the area of lean logistics, required basic skills and transparency of personal excellence with a personal self-assessment software solution, regarding the personal maturity level of hard and soft skills at any time	Know	n/a	Lopec	T	Inf	Noliterat	Austria	Jäger et al., 2014
Implemented a kanban system for a production line, thus reducing warehouse inventory and people/material motion. There were improvements associated with material availability in the logistic process	Adm, Inv	28	5S, Kan, VSM	A	Inv	Nolink	Brazil	Kach et al., 2015
The results of this study revealed that despite the management style, 88% of managers believe Six Sigma is compatible with logistics managers' roles and responsibilities. Furthermore, adaptation of logistics processes to Six Sigma requirements proved more compatible than otherwise.	n/a	ND	n/a	A	ND	Link	US, Canada, Turkey	Khoury et al., 2013
The milk-run distribution problem is Categorized and explained in the plants, based on observations in real manufacturing environment. Modeling is performed to minimize the number of vehicles and the distance traveled	Tra, SpcFac	n/a	Mlk	T	Tra	Nolink	Turkey	Kilic et al., 2012



Strategies for handling delivery peaks on milk-run systems and evaluation regarding delivery cost, lead time and service level, using real material consumption data from two large companies from the automotive industry	Time, Tra	29	Kan, Mlk, Vari	A	Tra	Nolink	Germany	Klenk et al., 2015
Analyzed the various kinds of disturbances occurring in the production and management decision on the production stability and performance by developing a discrete-event simulation model	n/a	ND	Mlk, Tkt	A	Tra	Nolink	Poland	Korytkowski et Karkoszka, 2016
The results of design using Lean and RFID showed that the Germinated Brow Rice (GBR) logistics operations significantly reduced time from 3,731.5 to 617 minutes, accounting for 16.53%	Tra, SpcFac	Other	VSM	A	Inf	Nolink	Thailand	Kravenkit et Arch-int, 2013
Presented the benefits of lean production and distribution, together with statistics in percentage of road, rail, air, and water transport, used today in the world	Tra	n/a	Batch, Vari	T	Tra	Link	Slovakia	Kubasáková et Poliaková, 2014
Increased customer satisfaction in a logistics center by reducing the credit voucher waiting time from 14 days to 14 min and the error rate in the refund process is down to almost zero	Time	ND	SS	A	ND	Noliterat	China	Lee et al., 2013
Care pathways were the preferred approach by 43% of the hospitals in the sample, followed by business process re-engineering and lean six sigma, with 13%. Flowcharts were the most common tool, in 94% of the hospitals	n/a	86	TQM, SS	A	ND	Nolink	Netherlands	Lent et al., 2012
A lean logistics workflow was created for a pull system, describing about packing, supply logistics, receiving methods, warehouse logistics, production logistics and IT systems.	Inv, SpcFac, Pack	29	Visu, Lyt, Mlk	A	Tra, Inv, Inf, Fac	Link	China	Li et al., 2014
Built an evaluation index system covering general logistics business content. Based on rough set theory and grey theory, a lean logistics performance evaluation method is proposed	n/a	ND	n/a	A	ND	Nolink	China	Li et al., 2015
Countermeasures to implement lean supply logistics, lean production logistics, lean distribution logistics, and lean returned logistics based on the green supply chain	Inv, Time, Tra, SpcFac	29	n/a	T	Tra, Inv	Link	China	Liang et Wang, 2013
Creation of a map of publications regarding Lean Logistic Performance Measurement and a bibliographic portfolio composed of the most relevant and applicable works in the field	n/a	n/a	n/a	T	ND	Noliterat	Brazil	Loos et Rodriguez, 2015
Establishing lean principles in internal logistics caused processes improvement, cost reduction of supply logistics and workload balancing throughout routes	Tra, Time	29	Kan	A	Tra, Inf	Link	Brazil	Marodin et al., 2012

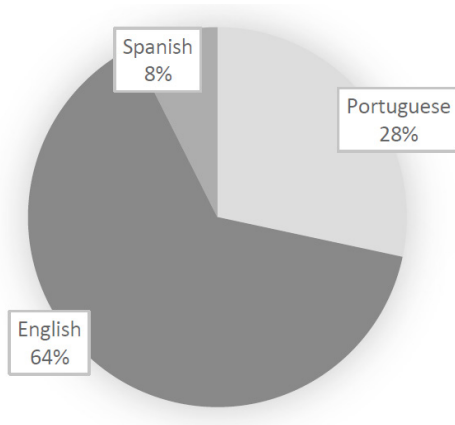


Applied lean in the redesign of a machinery manufacturing industrial company production system. Results show that it effectively led to a new flexible production system and a new industrial layout capable of responding to diverse future scenarios of products demand	SpcFac, Time, Adm	28	Kan, Lyt, VSM, Tkt, OEE, Spagh	A	Tra, Inv, Inf, Fac	Noliterat	Portugal	Marques et al., 2013
Concludes that using QLE (Queue Length Estimator) is better than conventional programming flow systems, because it improves logistics performance in lean and agile systems.	Inv	n/a	Cwip	T	Tra, Inv	Link	Germany	Mehrsai et al., 2014
States that a tightened management-labor regime in the form of lean logistic management can cause reduced earnings, minimal workplace autonomy and an unprecedented increase in the pace of work. It is vital to consider the impact of globalization on workers	Know	10	n/a	T	ND	Link	Scotland	Mulholland et Stewart, 2014
Proposes the Energy Value Stream Mapping (EVSM), an adaptation of the current VSM. It includes transportation processes and input of time and energy, which exist in production and logistics processes	Time, Tra	ND	VSM	A	Tra	Nolink	Germany	Muller et al., 2014
A comparison of the processes was executed before and after the Kaizen. Productivity increased by 30% and the extra hours for receiving, checking, planning and dispatching processes decreased by 80%. Gains of 1 million reais were estimated per year	Inv, Tra, time, SpcFac	86	Visu, Kai, VSM, Tkt, WS, Standz, Lyt	A	Tra, Inv	Nolink	Brazil	Nogueira Neto et al., 2016
Suggests solutions for handling port city congestion problems: formation of a rail linked logistics village positioned outside the city peripheries; formation of a waterfront port system logistics center linked by feeder vessels and hinterland rail connectivity	n/a	Other	n/a	T	Tra, Fac	Nolink	Nigeria	Onyemechi, 2013
Designed a mathematical model and a heuristic approach to construct the routes of a milk-run supply system based on JIT, aiming reduction of product and inventory cost, and material handling	SpcFac, Tra, Inv, Time	29	Mlk, JIT	T	Tra	Nolink	India	Patel et Patel, 2013
The implementation of lean in a metallurgical company's inventory management lead to reduction of production costs, improvements in products' quality, reduction on large safety stocks with no harm in the service level offered to the client	Inv	24	Kan, Mlk	A	Inv, Inf	Nolink	Brazil	Pinto et al., 2013
Through the developed RFID-enabled operation facilities, the materials' collection and distribution around a Supply Hub in Industrial Park are collaboratively and accurately executed in a small-lot and high frequency milk-run mode logistics	n/a	ND	Mlk, RFID, JIT	T	Tra, Inf	Nolink	China	Qu, et al., 2012
The use of JIT systems in supply activities between supplier and client is still narrow. Noted as well a lack of cooperation between them, where supplier has little involvement on process and production design and demand forecast	Inv	24	JIT	A	Inv	Link	Brazil	Rocha et al., 2013

Identified the main supportive and not supportive factors related to the nationalization of suppliers for and automotive assembler	n/a	29	n/a	A	ND	Link	Brazil	Sá et al., 2014
Provides an implementation example of Lean Six Sigma to improve a logistics supply chain. It validated the implementation and provided a description of all phases of DMAIC. An economy of 0.8 million dollars was estimated.	Inv, Time	10	SS	A	Fac	Nolink	Tunisia	Sadraoui et Fayza,
Proposed a mathematical model and a heuristic approach to construct an internal milk-run material supply system, and applied it in a TV assembly industry	Tra, Time, Adm	26	Mlk, JIT	A	Tra	Link	Turkey	Satogu et Sahin, 2013
Six Sigma is applicable and beneficial in small-to-medium-sized food distributors. Training; size of the organization; educational attainment and employees' workplace are the most effective elements to adopt Six Sigma	n/a	10	SS	A	ND	Nolink	England	Shokri et al., 2014
Created a multi-level and a multi-objective coordination optimization model for Large Equipment Service-Oriented Manufacturing, focusing on lean logistics objectives and the relationship among quality, duration and cost	n/a	28	n/a	A	Inf	Link	China	Song et al., 2013
Six sigma, quality tools and lean principles were responsible for reducing the defects in 80%, improving the customer service and increasing productivity in supermarket and repacking areas	Tra	29	Kan, Mlk, TQM, SS, JIT	A	Tra	Nolink	Portugal	Sousa et al., 2014
Developed a new warehouse and distribution layout, eliminating one of the bottlenecks in the production process that caused late delivery of the product to final customer	Tra, Time	24	5S, Standz, Lyt, 5w2h	A	Inv, Fac, Inf	Nolink	Brazil	Souza, 2015
Utilized the Balanced Scorecard tool to evaluate lean logistics practices in seven service oriented industries. One industry was classified in the first class index, four were classified in the second class index, one in the third class and one in the fourth class index	n/a	ND	n/a	A	ND	Link	China	Tong et al., 2015
The research hypotheses are empirically tested and supported, suggesting that business process improvements need to consider when operational changes can have the unintended consequence of significantly increasing emission of intensive transactions	Inv, Tra, SpcFac	29	JIT, VMI	T	Tra, Inv, Fac	Link	USA	Ugarte et al., 2015
Increases in labour discipline, cleanliness at the workplace, and the growth in productivity of assembly workplace by approx. 10 %, through application of lean methods and waste elimination	Inv, Tra, Time, Know	29	5S, Visu, Lyt, Standz	A	Tra, Fac, Inf	Link	Slovakia	Vidová et Beluský, 2013
Construction of a three-level logistic model using a lean manufacturing logistics optimization system and proposal of specific strategies for optimizing logistics system	n/a	n/a	JIT	T	Tra, Inv, Inf, Fac	Nolink	China	Wang, 2015
Proposes a multiple attribute group of decision-making framework to evaluate lean performance in logistics distribution centers (DC). Applied it in the DC of a tobacco commercial industry in China.	n/a	Other	n/a	A	ND	Nolink	China	Wu et al., 2015

All respondents in a survey reported varying degrees of cost savings and productivity improvements with Lean and Six Sigma. Large logistics companies are more likely to implement Lean and SS, and the ones with a higher service standard are more likely to implement SS	n/a	ND	SS	A	Tra, Inv	Nolink	New Zealand and Singapore	Zhang et al., 2016
Identification and elimination of the main waste sources culminated in productivity advantages, by reducing the processes of machines and minimizing production cost, which increased production and improved resources usage	Time	24	WorkM, IROG	A	Inf	Nolink	Brazil	Zismann et al., 2015

Source: The author(s)' own

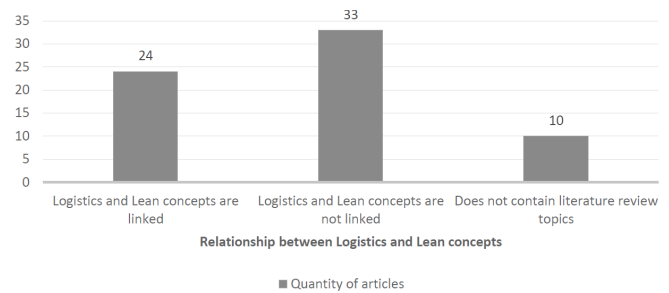


**Figure 3.** Classification of papers regarding their language  
 Source: The author(s)' own

**3.1 RQ-1: In the paper's literature review, were there connection between logistics and lean thinking or six sigma concepts?**

On this matter, this analysis considered only those concepts presented in a specific section in the articles that should be dedicated for literature review. As shown in Figure 4, most of the papers did not connect the concepts. Only 24 out of 67 effectively connected them, creating an important foundation for the lean or six sigma logistics literature. On the other hand, in 10 papers it could not be identified specific literature review sections or topics.

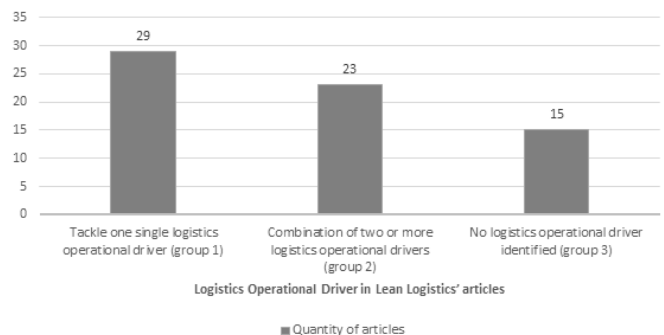
In general, there is little information on how the concepts relate, influence and assist each other. This is evidence of a weak theoretical basis about the combination between the ideas, which indicates lack of integration among the concepts that originated Lean or Six Sigma Logistics.



**Figure 4.** Relationship between logistics and lean concepts  
 Source: The author(s)' own

**3.2 RQ-2: Which logistics operational driver was the lean or six sigma logistics principle applied in?**

The papers were categorized in three different groups, regarding the presence of the logistics operational drives approach in them: 1) The paper refers to one single driver (29 papers); 2) There was a combination of two or more drivers (23 papers) and; 3) No driver was identified in the paper (15 papers). This classification is shown in Figure 5. The papers, in which any focus on logistics drivers was not identified, represented 22%, which is an expressive amount of papers, considering the importance of logistics drivers in many aspects.



**Figure 5.** Operational logistics drivers in lean logistics' articles  
 Source: The author(s)' own

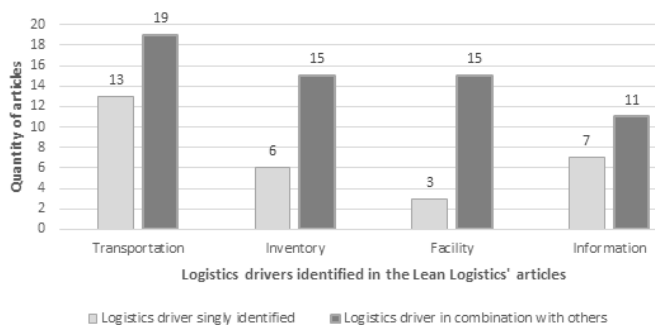


Among the papers in the second category, there was a high variation in terms of combinations of logistics drivers. The most frequent one was “Transportation and Inventory”, found in 5 papers, followed by “Transportation, Inventory, Information, and Facility” and “Transportation and Facility”, found in 4 papers each. It is notable that Transportation is the logistics operational driver present in more combinations, stating its importance by itself, and its impact and influence in a more holistic view is considered.

The classification of papers per logistics driver is shown in Figure 6. Transportation was the most frequent logistics driver addressed in lean or six sigma logistics, present in 32 papers, both individually and combined with others. This represents almost 50% of the sample of papers analyzed. Following Transportation, Inventory was the second driver most addressed. When it comes to the representativeness of the other logistics components, one can observe that Facility is present in 18 papers; and Information comprehended 18 papers.

The aggregation of the quantity of papers in each driver presents a large number of papers, when compared to the total considered in this review, since the combinations repeated for each driver are considered in the paper. Example, article “A” was counted in Information totals’ only; meanwhile article “B” was counted in both Transportation and Inventory totals.

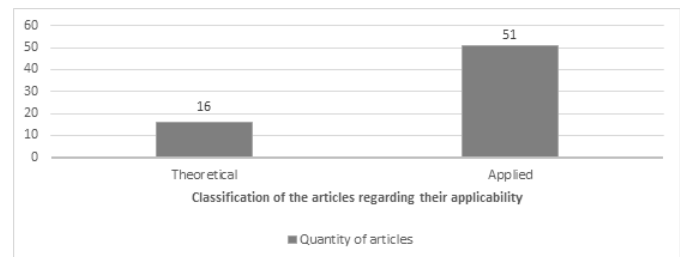
Therefore, this analysis could describe the representativeness and approach of each logistics operational drivers in the LL or SSL context. Transportation was presented as the main logistics driver, according to the current panorama of the literature. However, it is important to emphasize that combining driver allows a more systemic and integrated view of the problem to be solved, often being the most appropriate approach, even though it is more complex. Thus, the idea of more research on LL and SSL with combined approach of logistics drivers becomes interesting.



**Figure 6.** Quantity of papers per logistics components  
 Source: The author(s)' own

**3.3 RQ-3: Is the paper a theoretical research or an application in some productive/industrial sector?**

The answers in RQ-3 (Figure 7) demonstrated that most of the published research is applied: 51 out of 67 papers (76%) in the sample were essentially applied research, focusing on a specific productive or industrial sector, although, in some cases, that sector was not clearly stated. On the other hand, 16 papers (24%) were purely theoretical research. Many of the papers applied to some sector did not have theoretical studies and were fundamentally composed of practical approaches.

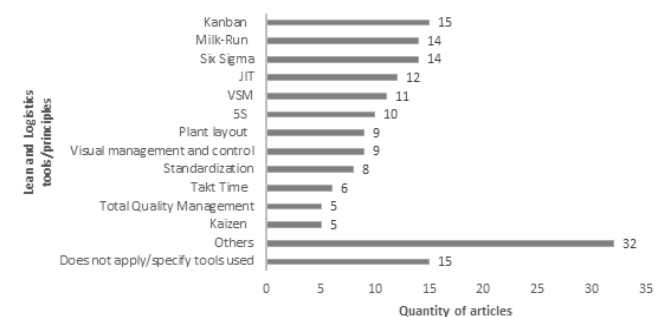


**Figure 7.** Classification of the papers regarding their applicability  
 Source: The author(s)' own

There is a lack of studies and publications on LL or SSL theory. It is valid to consider that theoretical studies are an important basis for the applied studies. The fact that most publications currently focus on the application of these concepts and philosophies demonstrates a strong trend to the practical perspective of these studies.

**3.4 RQ-4: What are logistics tools and/or the principles the article addresses?**

Within the selected papers, 33 different logistics tools/principles could be identified. The papers often addressed more than one tool at a time in their content. One can observe the distribution of papers regarding their tools in Figure 8, containing the 12 most frequently used ones.



**Figure 8.** Lean and logistics tools broached in the articles  
 Source: The author(s)' own

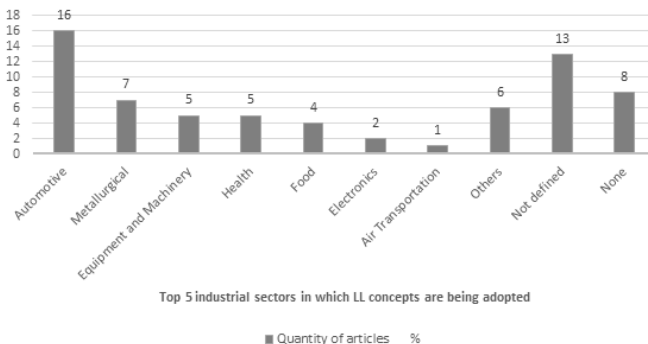
Kanban was the most used tool, presented in 15 papers, followed by Six Sigma and Milk-Run in 14 papers each, JIT in 12 papers, VSM (Value Stream Mapping) in 11 papers, 5S in 10 papers, and so on. The predominance of Kanban among the other tools is due to its high importance in the lean thinking philosophy, which clearly has been translated to the logistics scenario as well.

It was possible to notice, however, that 15 papers did not apply or specify any tools used. This is possibly due to a lack of a clearly defined range of tools. Typically, tools originally applied in a lean or six sigma production context must be adapted in their definitions so they can be correctly applied in the logistics context, addressing its particularities.

The "Others" category aggregated the less frequently used tools: A3 Problem Solving, Overall Equipment Effectiveness (OEE), Batch size reduction, Teamwork, Total Productive Maintenance (TPM), Radio Frequency Identification (RFID), Variation Control, Spaghetti Diagram, Electronic Data Interchange (EDI), Enterprise Resource Planning (ERP), Continuous flow, Workplace Management, Global Operating Income Index (IROG), Logistics Personal Excellence, Performance Measure System, Plan for Every Part, Single Minute Exchange of Die (SMED), SIPOC, Vendor Managed Inventory (VMI), Water Spider, Constant Work in Progress, 5W2H.

### 3.5 RQ-5: What is the productive/industrial/economic sector the article focuses on?

As shown in Figure 9, the most prominent economic sector was the Automotive Industry, which accounted for 24% of all papers, followed by Metallurgical, Equipment and Machinery, Health, Food, Electronics and Air Transportation. 13 papers did not clearly define the sector of application. In the "Others" category, with 6 papers, we grouped those less representative sectors.



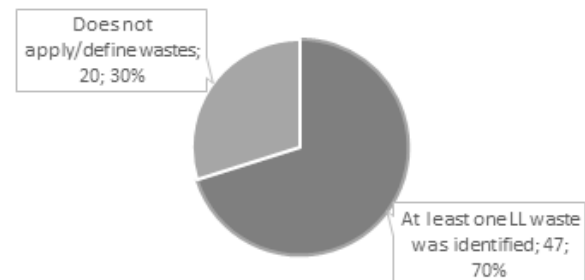
**Figure 9.** Top 5 industrial sectors in which LL concepts are being adopted

Source: The author(s)' own

The fact that the automotive industry was the birthplace of lean thinking, justifies the prominence of this sector. Moreover, the high absolute quantity in small gains, due to the high value added in automobiles, as well as the high competitiveness level of this sector, are strong reasons for such result. The results of this RQ state the flexibility of LL and SSL application, offering application opportunities and improvements in several sectors. Therefore, there is opportunity to expand studies that address LL and SSL in different sectors, such as Metallurgical, Health, Food, Equipment and Machinery, among others.

### 3.6 RQ-6: What are the wastes to be eliminated by lean or six sigma logistics addressed by the article?

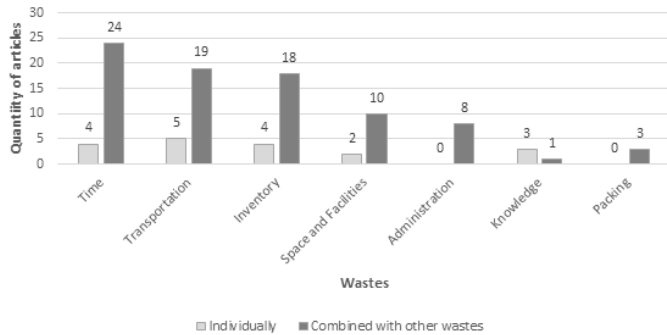
In Figure 10, the distribution of the 67 selected papers regarding wastes, agreeing with the seven wastes defined by Goldsby *et al.* Martichenko (2005), can be observed. On this matter, 47 papers considered the seven wastes approach in its analysis. However, in 20 papers it was not possible to identify which waste the paper was focused on or the waste analysis was not the paper's approach.



**Figure 10.** Distribution of papers regarding LL waste approach in their content

Source: The author(s)' own

In Figure 11, it is shown the distribution of those 47 papers in each one of the wastes: Time, Transportation, Inventory, Space and Facilities, Administration, Knowledge and Packing. Most papers addressed more than one waste at a time, i. e., combined different wastes. The waste of time was the most common, in 28 papers, followed by transportation waste, and Inventory waste. The waste caused by packing activities were the less representative, tackled in 3 papers.



**Figure 11.** Papers that reduced or eliminated wastes in their LL and SSL studies

Source: The author(s)' own

#### 4. CONCLUSION

The analysis of previously published research studies related to Lean and Six Sigma Logistics by means of systematic review denoted the increasing popularity of this topic in several productive and industrial sectors, as for example, in the Automotive industry, being the most frequently approached, as well as the current state of the art regarding theoretical and applied studies.

Despite its popularity in many areas, the relationship between Logistics and Lean Thinking or Six Sigma is still fragile: most papers do not link these concepts in their literature review.

Regarding the LL and SSL applications, we observed that practical applications were published in higher quantity than theoretical studies. The practical papers comprise mainly the implementation and impacts of the LL and SSL philosophy. Hence, this context generates opportunities for more theoretical contributions. This research gap is possibly due to the fragile integration – as mentioned previously – between the concepts that originates LL and SSL: Logistics and Lean Thinking; and Logistics and Six Sigma.

Regarding the tools, Kanban is presented as the most used, which is expected, since it is one of the main Lean tools. On the analysis of wastes, most of the papers referred to Motion and Waiting losses, which shows the relevance of the LL and SSL implementation for waste elimination and reduction. In Table 4, the results of each research question and their respective opportunities of research are described, based on the results analysis.

Through the analysis of the most recent researches published related to LL and SSL, following the systematic review methodology, it was possible to evaluate trends related to: productive and industrial sectors, logistics operational drivers, use of logistics tools, and elimination of wastes that motivate LL and SSL implementation. Moreover, research gaps that may provide opportunities for the development and improvement of research were identified. Therefore, future studies can be developed, following the lines proposed as opportunities, in order to contribute to the LL and SSL field.

**Table 4.** Achieved results and research opportunities for each research question

ID	Results	Opportunities
RQ-1	Relationship between theoretical concepts of Logistics and Lean Thinking or Six Sigma is still fragile, since they were often approached separately in the papers' literature review.	Research that effectively relate the concepts of Logistics and Lean Thinking or Six Sigma, enabling the construction of new knowledge about LL and SSL, linking the topics in an integrated way.
RQ-2	Among the logistics operational drivers considered, Transportation was approached in most of papers, both individually or combined with other drivers.	Theoretical and practical studies directed to identify and apply LL and SSL principles and concepts in other logistics drivers (Inventory, Facility and Information), individually or, specially, combined (integrated) with each other, including Transportation.
RQ-3	The majority of LL and SSL publications were applied studies (not theoretical studies), considering the implementation of the Lean or Six Sigma Philosophy.	Theoretical studies on LL and SSL and their applicability in different sectors or contexts, considering possible adaptations and the major error risks already made in order to prevent them.
RQ-4	The main tools used were: Kanban, Milk Run and combination of Six Sigma methods; there was no clear definition in terms of which tools are also LL and SSL tools.	Application of less widely used Lean tools; Studies that define the range of LL and SSL tools, considering both logistics and Lean or Six Sigma tools, with their respective adaptations
RQ-5	The automotive sector was scenario for most LL and SSL applications, demonstrating that other industries still have a certain lack of applications in this sense.	Studies and research applied to other productive and industrial sectors, for example, in healthcare, disseminating Lean Healthcare ideas within a logistic context.
RQ-6	Many publications have not defined or mentioned the wastes considered in the productive systems under study. Moreover, time was the main type of waste identified and eliminated, while waste of packing, knowledge and administration were the less identified ones.	Studies and research that clearly address the wastes of the lean philosophy and six sigma in the logistic context, as well as its importance, providing a dense theoretical basis on such wastes, so that the process of identifying wastes in practical contexts can be simplified.

Source: The author(s)' own

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