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(Article begins on next page)

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Lean, Agile, Resilient & Green paradigms: literature review and research steps towards full integration

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Abstract. In today's competitive market, the implementation and integration of Lean, Agile, Green and Resilient (LARG) practices in supply chains (SCs) are crucial for maintaining a competitive edge. Embracing the LARG paradigms enables companies to achieve key business objectives, including enhanced customer service and increased profitability. The aim of this paper is to present an updated literature review examining LARG adoption and integration strategies across diverse sectors and geographical locations. Through an analysis of 28 relevant articles encompassing the last fifteen years, the review explores the evolution of LARG paradigms. The analysis reveals various strategies, trade-offs, and methods for measuring effectiveness. Findings underscore the pivotal role of LARG integration in improving performance, sustainability, efficiency, and resilience. Furthermore, the study highlights the necessity of holistic LARG integration for effectively addressing contemporary business challenges, emphasizing the importance of ongoing research in this area. Finally, the paper identifies research gaps and provides valuable insights for practitioners and researchers striving to enhance performance and sustainability in SCs and manufacturing companies.

Keywords: Lean, Agile, Resilient, Green, supply chain, review.

1 Introduction

In the era of rapid technological advancements, evolving consumer requests, and competitive business environments, supply chain management (SCM) has emerged as a critical determinant of organizational success [1]. Among various SCM strategies, the lean, agile, resilient and green (LARG) paradigms are considered essential for enhancing the competitiveness in the complex and uncertain market landscape. Embracing the LARG paradigms represents a turning point for companies to achieve key objectives such as higher customer service and increased profitability [2, 3]. To the best of Authors' knowledge, no updated literature review in the last ten years have been published addressing specifically the LARG paradigms. Few contributions in

this field consider additional and/or different paradigms, such as “Sustainable” [4] or “Smart”[5], and analyse them jointly.

The aim of this work is to propose a renovated review on LARG paradigms that explores the evolution of the four concepts, i.e., Lean, Agile, Resilient, Green, during the last fifteen years. The study employed a comprehensive methodological approach involving bibliographic search, abstract categorization, keyword analysis, and examination of sectors and countries addressed. This process aimed to discern prevalent themes, trends, and patterns in the literature within the chosen research domain. The reminder of the paper is as follows: Section 2 presents the definitions of LARG paradigms, Section 3 is dedicated to the research methodology, Section 4 describes and critically discusses the results, lastly, Section 5 draws conclusions and insights as future research agenda.

2 Lean, Agile, Resilient, Green paradigms

In the following sub-sections, the definitions of the LARG paradigms are presented separately. Then, a brief introduction of the LARG term and a recognition of the main contributions in this field are proposed.

Lean thinking emerged as leading paradigm within both manufacturing companies and supply chains (SCs). This approach, often referred to as “lean manufacturing” (LM) has as core principles the cost minimisation, waste elimination and flexibility. Aligning industrial processes with customer requests, LM aims at producing more with less resources. Non-value-added operations are reduced to minimum, keeping only the operations that are valuable for the product or the process [6, 7]. Over the years, various tools and techniques have been implemented by companies to achieve LM, including Just in time (JIT), cellular manufacturing, Kanban, SMED, Value Stream Mapping, poka-yoke, 5S, etc [5].

To rapidly respond to unpredictable changes in the market, implementing agile practices can effectively provide support to companies. The ability to undertake actions that address the quick changes in customers’ needs and requests from the market while maintaining high level of quality and customer service, is the objective of the agile paradigm [4, 8]. Key aspects for an agile company are speed and flexibility [9]. In this context, technological innovations and the advent of Industry 4.0 plays a fundamental role by facilitating the development of adaptable and advanced production systems and ensuring rapid decision-making processes. Leveraging technologies such as hybrid prototyping software, virtual reality, and real-time data exchange, empowers stakeholders to navigate complexities effectively and enhances operational agility in dynamic environments [10, 11].

Unexpected man-made and natural disruptions now characterise the modern industrial scenario and the uncertainty of customer demand puts a strain on the stability of companies and SCs [12, 13]. Resilient practices concern the ability to maintain the continuity of operations and know-how to protect themselves against unforeseen events. The capacity to absorb or react to disruptions by recovering the desirable state is what differentiate resilient SCs [4]. The concept of resilience is quickly evolving

after the Covid-19 pandemic in 2020, which caused the bankruptcy of many companies. The achievement of resilience begins with a careful analysis of risks and related mitigation strategies. Some of the commonly adopted proactive strategies in field of resilient SC design are the flexible fulfilment, strategic stocks, multiple and backup suppliers, total SC visibility and collaborative working [2, 12, 14].

The green paradigm refers to environmental sustainability and focuses on the impact of companies and SCs on the environment. The minimisation of pollutant emissions and waste generated is one of the main goals, as well as the reduction of natural resources consumption, i.e., raw materials, water, energy [7]. Although economic profitability is not the primary goal of green paradigm, pursuing green practices in SCM can lead to long-term competitive advantage and to achieve market-share objectives [15–17]. Customers are increasingly careful and interested in companies who are oriented to environmental goals, and the same occurs to companies when choosing suppliers. Hence, green paradigm is now a fundamental requirement for SCs. Among the most used green strategies should be mentioned life cycle analysis (LCA), ecodesign, application of ISO 14001 certification, resources optimisation [18], industrial symbiosis [19], reverse logistics [2, 3].

The acronym LARG was introduced within the context of SCM in 2009 by Carvalho and Cruz-Machado [20]. Since that, the literature is continuously investigating the interrelationships among the paradigms, including synergies and divergences [8], as well as decision models and index models [1, 3, 15, 21]. Contributions in this research field deals with multiple industries, such as automotive [3, 15], seaport activities [22] and food industry [21, 23]. Furthermore, literature on LARG paradigms extends to novel research streams: Industry 4.0 [10, 11], new business models [24, 25], circular economy and reverse logistics [26, 27].

3 Research methodology

The present work proposes an updated review on LARG paradigms, investigating the evolution of these four concepts over the past fifteen years across various sectors and locations. To conduct the analysis, the authors referred to Scopus and Web of Science (WoS) databases as primary sources of scientific articles. The search string incorporated relevant keywords such as "green", "lean", "agile", "resilient", "LARG paradigms", "supply chain" and "manufacturing". The selection process included the following steps (Fig. 1): (1) identification of contributions based on Scopus (n = 4172) and WoS (n = 3679) searches; (2) elimination of the duplicates (n = 4185); (3) screening per English language and relevant document types (n = 3726); (4) identification of the final paper database (n = 28) resulting from abstracts analysis and the joint application of three criteria, i.e., relevance to the aim of the study, at least 30 Scopus citations, or more than 3 as impact factor of the source.

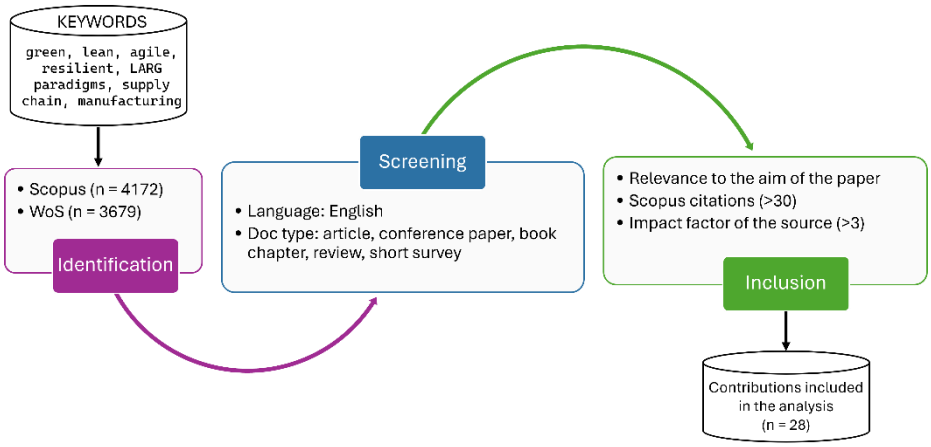

Fig. 1. Literature review strategy steps.

A comprehensive approach is applied in the following section, that involves qualitative and quantitative assessments to understand the state-of-the-art of LARG paradigms. Initially, a bibliographic analysis allowed categorizing papers based on their primary focus and content. Then, a detailed examination was conducted to ascertain the sectors and countries addressed in the papers, providing valuable contextual information. Finally, a keyword analysis was performed to discern prevalent themes and concepts across the literature. This involved extracting and analysing frequently occurring keywords to gain insights into the predominant topics within the field. Through this multifaceted approach, the study aimed to offer an understanding of the research landscape, synthesizing qualitative and quantitative data to elucidate trends and patterns in the literature.

4 Results and discussion

In this section, the findings of the review on LARG paradigms are presented and discussed. Over the total, 28 contributions address the Green paradigm (100%), 26 the Resilient (93%), 20 the Lean (70%) and 16 the Agile (57%). Also, 16 papers discuss about LARG paradigms jointly (57%), 8 refer to the combination Green-Resilient (29%), 2 focus on the triad Lean-Green-Resilient (7%), while the last 2 contributions concentrate on the Lean-Green pair (7%). Focusing on the contributions that integrate the whole set of LARG paradigms (n = 16), a tentative clustering is proposed below. Carvalho & Machado (2009) [20], Cabral et al. (2011) [6] and Carvalho et al. (2011) [8] propose reviews and conceptual analyses of LARG paradigms in SCs, examining the interactions and implications that affect performance and sustainability. Cabral et al. (2012) [1] and Azevedo et al. (2016) [3] develop and apply decision-making models and assessment tools for managing SCs according to LARG paradigms. Structured methodologies and quantitative assessment can be of help for making informed deci-

sions and benchmarking SCs. Carvalho et al. (2014) [28], Al-Refaie et al. (2020) [9], Amjad et al. (2020) [11], Salleh et al. (2020) [22] and Alvari (2021) [29] offer practical applications of LARG paradigms in the manufacturing, automotive, maritime and food sectors. In particular, the articles explore the implementation of LARG techniques into the production and SCM operations. Figueira et al. (2012) [30], do Rosário Cabrita et al. (2016) [25], Alipour et al. (2022) [31] and do Rosário Cabrita et al. (2023) [24] analyse the impact of LARG paradigms on organizational innovation and human resources performance, by also examining the influence on corporate culture, safety, engagement and success, and proposing new business models. Amjad et al. (2021) [10] and Tavana et al. (2021) [27] investigate the connections between LARG paradigms and environmental sustainability in SCs by providing strategies to reduce waste production and improve the circularity of resources. The second largest group of contributions targets the Green and Resilient paradigms (n = 8). The articles share a modelling approach for designing and managing sustainable and resilient SC networks. Mari et al. (2016) [32], Yavari et al. (2019, 2020, 2021) [12, 21, 23] and Hasani et al. (2021) [14] formulate and apply optimization models to the garment industry and to perishable products SC, with the aim of reducing total costs, carbon emissions and improving the resilience. Thomas et al. (2016) [13] and Malek et al. (2017) [33] provide useful tools for assessing resiliency and sustainability in real case studies and demonstrate how Green and Resilient practices are powerful to deal with turbulent markets. The remaining contributions focus on the triad Green-Lean-Resilient (n = 2) [2, 5] and on the combination of Green-Lean (n = 2) [7, 34]. Govindan et al. (2015) [2] develop a conceptual interpretative structural model (ISM) as synthesis addressed to automotive SC of lean, green, resilient and performance measures. Touriki et al. (2021) [5] consider also the dimension “smart” to formulate two research frameworks that underline the importance to integrate the paradigms and study their interrelationships. On the Green-Lean side, Baumer-Cardoso et al. (2020) [7] integrate green and lean principles within manufacturing systems through a discrete-event simulation (DES) model that demonstrates a positive correlation of the two paradigms in a real company case. Carvalho et al. (2017) [34] propose a mathematical model to support strategic decision-making and to find the best trade-off between green and lean practices. The model has an eco-efficiency perspective and a case study from the automotive sector is chosen for the application. In general, the absolute predominance of the Green paradigm among the 28 contributions under review is notable. This trend may reflect a heightened corporate awareness of environmental concerns and an increasing demand from consumers for sustainable processes and products. These findings underscore the imperative for businesses to prioritize environmental initiatives in response to evolving consumer expectations and global sustainability goals [9, 33].

The contributions encompass diverse sectors and industries, reflecting the broad applicability of LARG paradigms across various domains. Specifically, studies focused mainly on the automotive industry, including both case studies on the whole SC and specifically upstream SC actors. In addition, the identified articles also explored case study applications in cold SCs and several manufacturing sectors, such as the dairy industry, garment industry and many others. Regarding the geographical loca-

tions of the case studies, the countries mentioned belong to different continents, mainly Asia and Europe. The country of application of the case studies often matches the authors' affiliation. Table 1 presents the contributions ordered by year, and classified by LARG paradigm, sector and country of origin of the case studies, where present.

Table 1. Paper database classification per LARG paradigms investigated, industrial sectors, and geographical location of the case studies.

Ref.	Author(s)	Year	*Lean*	*Agile*	*Resilient*	*Green*	Sector	Country
[20]	Carvalho & Machado	2009	x	x	x	x	-	-
[6]	Cabral et al.	2011	x	x	x	x	-	-
[8]	Carvalho et al.	2011	x	x	x	x	-	-
[1]	Cabral et al.	2012	x	x	x	x	automotive	Portugal
[30]	Figueira et al.	2012	x	x	x	x	-	-
[15]	Azevedo et al.	2013			x	x	automotive	Portugal
[28]	Carvalho et al.	2014	x	x	x	x	automotive	Portugal
[2]	Govindan et al.	2015	x		x	x	automotive	Portugal
[3]	Azevedo et al.	2016	x	x	x	x	automotive	Portugal
[25]	Cabrita et al.	2016	x	x	x	x	-	-
[32]	Mari et al.	2016			x	x	garment	India
[13]	Thomas et al.	2016			x	x	manufacturing	United Kingdom
[34]	Carvalho et al.	2017	x			x	automotive	Portugal
[33]	Malek et al.	2017			x	x	automotive	Iran
[21]	Yavari et al.	2019			x	x	diary	Iran
[9]	Al-Refaie et al.	2020	x	x	x	x	cold SCs	-
[11]	Amjad et al.	2020	x	x	x	x	-	-
[7]	Baumer-Cardoso et al.	2020	x			x	construction	Portugal
[22]	Salleh et al.	2020	x	x	x	x	seaport	Malaysia
[23]	Yavari et al.	2020			x	x	diary	Iran
[10]	Amjad et al.	2021	x	x	x	x	automotive	-
[29]	Anvari	2021	x	x	x	x	petrochemical	Iran
[14]	Hasani et al.	2021			x	x	medical devices	Iran
[27]	Tavana et al.	2021	x	x	x	x	wood and paper	Iran
[5]	Touriki et al.	2021	x		x	x	-	-
[12]	Yavari et al.	2021			x	x	-	-
[31]	Alipour et al.	2022	x	x	x	x	services	Iran
[24]	Cabrita et al.	2023	x	x	x	x	-	-

Fig. 2 illustrates the authors' keywords co-occurrence network created with the VOSviewer software (version 1.6.20). The network comprises 18 nodes, i.e., items representing keywords that are at least in two articles, and 63 links, based on the co-occurrence between items. Generally, larger nodes indicate higher keyword frequency, while thicker lines between keywords signify stronger connections. At the centre, as expected, the LARG keywords predominate, with 13, 9, 10, 12 occurrences, respectively, and with the highest link strength values, i.e., the strength of connections between a specific node and others. This is predictable considering the search query used. Following LARG paradigms, the next keyword in terms of occurrences is "supply chain management", highlighting the importance of considering the entire SC in this research field [1, 2]. The figure also shows the temporal trend in which keywords are cited. The keyword with the most recent average publication year is "industry 4.0", followed by "LARG manufacturing" and "disruption". This points out the increasing predominance of technological advancements [10] and the recent necessity of facing disruptions and unexpected events [14, 23].

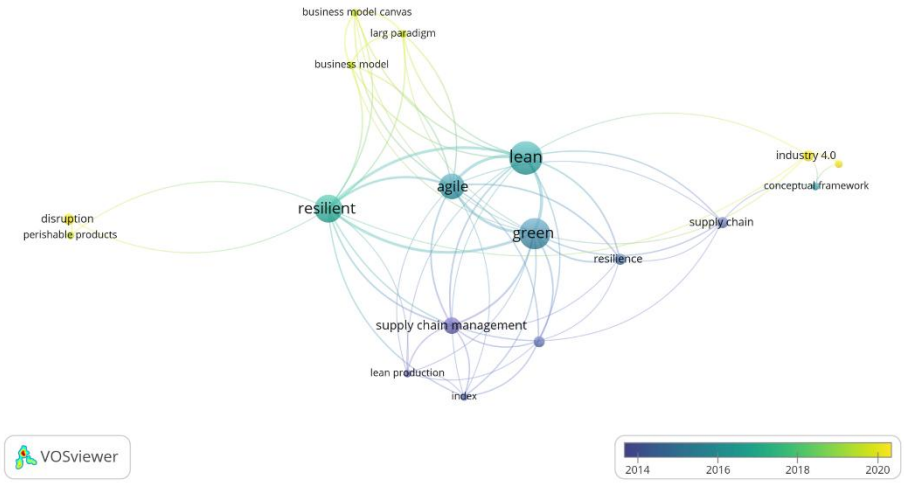

Fig. 2. Co-occurrence network of authors' keywords with temporal trend

5 Conclusions and next steps

The present review offers insights into the evolving landscape of lean, agile, resilient, and green (LARG) paradigms, especially in supply chain management (SCM), over the past fifteen years. Through a comprehensive methodological approach, including bibliographic search, abstract categorization, keyword analysis, and examination of sectors and countries addressed, the study aimed to discern prevalent themes, trends, and patterns in the literature within the chosen research domain. The findings indicate

a notable prevalence of the Green paradigm among the 28 contributions under review, reflecting an amplified awareness of environmental concerns and an increasing demand from consumers for sustainable processes and products. Despite its significance, the Agile paradigm remains the least explored. This highlights a promising avenue for future research, emphasizing the need for innovative studies that can further elucidate the integration and impact of agility in supply chains (SCs). In general, the analysed contributions encompass diverse sectors and industries, including the automotive, garment, seaport, food sectors. Geographically, the case studies spanned diverse continents, highlighting the global applicability and relevance of LARG paradigms. The keywords analysis further elucidates the predominant topics within the field, with LARG keywords featuring prominently alongside crucial concepts such as "industry 4.0" and "supply chain management". Future research should investigate new potential paradigms to include and conduct parallel analyses on the technological advancements that can enhance LARG, also enlarging the panel of contributions reviewed. Overall, this study contributes to a deeper understanding of the evolving landscape of LARG paradigms and provides valuable insights for future research endeavours in this dynamic field.

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