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School of Business and Management

Master's Programme in Supply Management

Julia Louhelainen

EXPLORING THE ROLE OF LEAN IN ENVIRONMENTALLY SUSTAINABLE SUPPLY CHAINS

Master's Thesis 2021

Examiners: Professor Katrina Lintukangas

Associate Professor Mika Immonen

ABSTRACT

Author:	Julia Louhelainen
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Today's environmental concerns are forcing firms to consider the environmental impacts of their business operations and supply chains. Environmental sustainability has become an important supplier attribute and an essential competitive factor. In order to meet customer needs while simultaneously improving the firm's green performance, efficiency and profitability, firms are implementing new business strategies. Lean thinking is a widely used customer-driven philosophy with the goal of improving efficiency by eliminating all waste. The aim of this thesis is to examine the connection between lean and green thinking and their impacts on firms' green performance, with the main focus on the environmental sustainability of supply chains. The study identifies specific lean and green practices that can have an influence on green performances of suppliers, as well as conflicting practices between lean and green.

Findings from the systematic literature review show that lean and green share a number of goals, including waste reduction, resource efficiency and a high service level. The synergy of lean and green can improve both green and operational performance by eliminating waste, improving efficiency, reducing costs and minimizing green impacts, while satisfying customer needs. Identified conflicts between lean and green include the frequency of replenishment and small batch sizes, both of which can increase efficiency, but also pollutions. In addition, lean and green have different views on end-of-life product use and costs. Despite the identified differences, sufficient overlap of lean and green practices can be identified to support the "lean is green" statement.

TIIVISTELMÄ

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Nykypäivän ympäristöongelmat pakottavat yrityksiä huomioimaan liiketoimintansa ja toimitusketjujensa ympäristövaikutuksia. Ympäristövastuullisuudesta on tullut tärkeä toimittajien ominaisuus ja olennainen kilpailutekijä. Parantaakseen yrityksen ympäristöystävällisyyttä, tehokkuutta ja kannattavuutta, yritykset ovat ottaneet käyttöönsä uusia liiketoimintastrategioita. Lean-ajattelu on laajalti käytetty asiakaslähtöinen filosofia, jonka tavoitteena on parantaa tehokkuutta poistamalla kaikki jätteet. Tämän tutkielman tarkoituksena on tutkia vihreän ajattelun ja lean-ajattelun välistä yhteyttä sekä niiden vaikutuksia yritysten vihreään suorituskykyyn keskittymällä toimitusketjujen ympäristöystävällisyyteen systemaattisen kirjallisuuskatsauksen kautta. Tutkimuksessa tunnistetaan lean- ja vihreitä käytäntöjä, joilla voidaan vaikuttaa toimittajien ympäristöystävällisyyteen sekä ristiriitaisia käytäntöjä näiden väliltä.

Tutkimus osoitti, että lean- ja vihreä ajattelu jakavat samoja tavoitteita, kuten jätteiden vähentäminen, resurssitehokkuus ja korkea palvelutaso. Yhdistämällä lean- ja vihreä ajattelu voidaan parantaa yrityksen vihreyttä sekä tehokkuutta ja vastata asiakkaiden tarpeisiin poistamalla jätteitä ja vähentämällä kustannuksia. Ristiriitoja voivat aiheuttaa täydennystiheys ja pienet eräkoot sekä eri näkemykset tuotteen loppukäytöstä ja kustannuksista. Näistä eroavaisuuksista huolimatta lean- ja vihreä ajattelu jakavat useita käytäntöjä, jotka tukevat lean-ajattelun ympäristönäkökulmaa.

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As I finalize this thesis, my five years at LUT University are finally coming to an end. These years have at times been frustrating and exhausting - but also very rewarding. After all, I am relieved and excited that this chapter of my life is now over, and I get to continue my life towards new, unknown and interesting times.

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Kerava, April 4th 2021

Julia Louhelainen

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1. INTRODUCTION

Traditionally, going green has not been a priority or a popular interest for managers. Protecting the environment has been associated with lower productivity and increased costs. Therefore, green thinking and economic performance have been viewed as two opposite sides – the firm can either protect the environment or stay successful and profitable (Gordon 2001). In the past, the main motive for green thinking has been to comply with environmental regulations (Simpson & Power 2005). Today, it is widely accepted that there can be a mutually beneficial relationship between sustainability and economic performance (Piercy & Rich 2015).

In the present global scenario, businesses must survive under complex and constantly changing business environments (Mollenkopf et al. 2010), while new competitive factors are emerging. In addition to traditional factors such as quality and price, today, environmentally friendly and socially responsible business operations are emerging as increasingly popular and important factors (Wiese et al. 2015; Engin et al. 2019). Improving resource-efficiency has become hugely important (Jakhar et al. 2018). Environmental issues, which have risen sharply in recent decades, are forcing firms to steer their business practices towards more sustainable solutions. (Gordon 2001; Caldera et al. Dawes 2017; Dieste et al. 2019). Organizations are under constant pressure from customers, government and new regulations to be aware of the impacts that their business has on the society and the environment. The growing awareness of environmental issues acts as a powerful driving force for firms to work towards greener and more responsible business practices (Zhu et al. 2008; Green et al. 2012; Jabbour et al. 2013; Martínez-Jurado & Moyano-Fuentes 2014; Al-Ghwayeen & Abdallah 2018).

Failure to engage in green thinking may increase the risk of environmentally negative outcomes, increase costs and have a negative influence on customer flows and firm reputation (Duarte & Cruz-Machado 2013). Under global competition, it is becoming increasingly difficult for firms to attract new customers and succeed in new markets while also maintaining old customer relationships and maintaining the existing market share. Adapting the business strategy to meet the responsibility and sustainability requirements as well as green values can attract environmentally conscious customers and offer important competitive advantage. (Wills 2009) For today's businesses, taking

environmental sustainability into account is an equal necessity with financial and productivity measurements (Garza-Reyes 2015). The main goal of green thinking is to reduce environmental impacts and waste and improve ecological performance (Duarte & Cruz-Machado 2013).

Firms are not only responsible for their own environmental concerns, but also for the actions of their partners (Jakhar et al. 2018). Managers are compelled to implement green thinking beyond focal firm operations (Zhu et al. 2010) and extend the green initiatives to their supply chains (Green et al. 2012; Al-Ghwayeen & Abdallah 2018). As supply chains are responsible for the entire lifecycle of products (Lambert et al. 1998), sustainable supply chain management can play an important role in the overall green performance of the firm (Jakhar et al. 2018). In general, logistics-related activities have major negative impacts on the environment with high vehicle emissions and pollutions related to climate change and the global ecosystem (Ugarte et al. 2016). In line with the green trend, the ability to deliver products in an environmentally friendly way is quickly becoming an essential supplier factor (Azevedo et al. 2011).

In order to reduce the negative environmental impacts of business activities and supply chains while also improving efficiency and financial performance, firms have begun to investigate new innovative business approaches and management strategies (Jakhar et al. 2018). During recent decades, lean thinking has emerged as one of the most influential philosophies and strategies to improve productivity and business performance (Garza-Reyes 2015; Dieste et al. 2019). Lean is a popular customer-driven initiative that offers multiple tools and practices for high efficiency and quality with no waste (Shah & Ward 2007). Lean's main goal is to eliminate all non-value-adding activities by optimizing the use of resources and continuously improving all business operations while providing superior value for customers (Florida 1996; King & Lenox 2001; Garza-Reyes 2015). Supply chains have also increasingly adopted lean principles in their operations with the aim of identifying and eliminating non-value-adding activities in supply chains to improve quality, reduce costs and respond to customer demand more effectively (Ugarte et al. 2016). Consideration of environmental issues and the inclusion of green criteria in supplier selection processes are becoming increasingly important also for lean firms (Simpson & Power 2005).

Recently, a clear link has been identified between lean and green thinking (Jakhar et al. 2018; Dieste et al. 2019). Adopting principles of lean thinking into firm and supply chain operations can serve as

a step towards greener performance (Franchetti et al. 2009; Dües et al. 2013; Pampanelli et al. 2014). A positive connection has been identified between lean and green through their naturally similar policies, operational management models and goals that allow them to work together effectively together, positively impacting both operational efficiency and the environment (Florida 1996; Yang et al. 2011; Dües et al. 2013; Huo et al. 2019; Dieste et al. 2019). A combined green-lean supply chain management strategy can provide significant improvements to firms' financial as well as environmental performance (Azevedo et al. 2012).

The positive and synergistic connection between lean and green was already observed 25 years ago in Florida's (1996) pivotal case study involving nearly 2000 firms from different industries. The study argued that by combining and implementing lean and green practices, they can together improve the firm's economic and environmental performance. Over a decade later, Azevedo et al. (2012) noticed that only few comprehensive academic studies investigating leanness and sustainability have been conducted, while Dües et al. (2013) claimed that there were only a handful of researchers who had studied the lean-green connection. (Piercy & Rich 2015) However, during recent years, the popularity of studying the relationship between lean and green has significantly grown in the academic literature (Garza-Reyes 2015; Caldera et al. 2017; Dieste et al. 2019). This suggests that the field of research on lean and green is still relatively new and evolving (Garza-Reyes 2015) but there is still no clear consensus among researchers on how lean thinking can support environmental sustainability (Caldera et al. 2017). However, due to increasingly growing demand from customers and other stakeholders for greener and more efficient business processes and production, research and academic literature on the topic of lean and green can be expected to grow in the coming years (Garza-Reyes 2015). For all these reasons, it can be said that at present, the integration of lean thinking and environmental sustainability is a very current and highly interesting topic.

1.1. The aim of the Study and research questions

This study examines the relationship between lean thinking and environmental sustainability. The objective is to improve the green performance of firms with focus on supply chains. Specifically, the aim is to find out how firms can improve their suppliers' environmental performance by implementing specific lean and green practices. The study identifies lean practices which benefit and support the green performance of supply chains, and also overlapping practices that support

the synergy of lean and green. Additionally, lean practices that can conflict with firm's green goals or create potential tradeoff situations between lean and green performance are explored.

The environmental sustainability of suppliers can be improved with green and lean practices that reduce green impacts and improve green performance. There can also be recognized some lean tools and practices that can potentially increase environmental issues and have contradicting effects on green performance. Thus, this study also examines the connection between lean and green and how the lean-green integration can help firms achieve environmentally sustainable supply chains.

Considering these aims, the following research questions are presented:

Main research question:

How can Lean improve the Sustainability of Supply Chains?

Additional sub-questions:

Which Lean practices support and overlap with Green?

Which Lean tools and practices contradict or create tradeoffs with Green?

What green benefits can Lean and Green practices have for Supply Chains?

1.2. Conceptual framework, definitions of key concepts and limitations

The main concepts of the thesis include lean thinking, green thinking, supply chain management and green supply chains. The study examines the interconnected relationships between lean and green thinking and their impacts on environmental performance of supply chains through effective supply chain management. The connections between the main themes of the thesis are illustrated in Figure 1. The purpose of the study is to explore how lean and green can improve the green performance of supply chains with particular interest in the connection between lean and green, shown with yellow arrows below in Figure 1.

Figure 1. Relationships between the main themes of the study

The thesis presents means to improve the environmental sustainability of supply chains with lean and green practices. The study explores the integration of lean and green thinking by identifying the degree of compatibility, similar motives, overlaps and synergy between the two practices. Additionally, differences, conflicts and tradeoffs between lean and green thinking are examined.

As the main focus of the study is on the environmental aspect of sustainability, the social and financial aspects of sustainability are not addressed in detail in this study. Since the study aims to identify means to enhance the environmental performance of supply chains, it focuses mainly on the environmental impacts of supplier activities. Due to the limited time and scope of the thesis, it is important to note that the results and conclusions cannot be directly integrated or widely generalized. Nevertheless, they can provide guidance for firm managers and guidelines for future research. To ensure a better understanding of the conceptual framework, a few of the main concepts of the thesis are briefly explained before moving on to more in-depth research and literature on the topic. Definitions of the key concepts are presented below.

Sustainability- A widely quoted definition for sustainable development is by the World Commission on Environment and Development (1987): *"Development that meets the needs of the present without compromising the ability of future generations to meet their needs"*. Elkington's (1997) commonly used approach to sustainability balances three dimensions, referred to as the "triple bottom line" (TBL) including the economic, the social and the environmental aspects. From a corporate perspective, sustainability can be defined as the combination of these three aspects.

Lean thinking - Lean is a widely used management approach that aims to provide superior value for customers by eliminating all activities that do not add value, commonly referred to as waste (Womack & Jones 1996).

Supply Chain – According to Lummus & Vokurka (1999), *a supply chain* refers to "all the activities involved in delivering a product from raw material through to the customer…" Lambert et al. (1998) have simply defined a supply chain as "the alignment of firms that bring products or services to market". The main aim of supply chains is to provide customers the right products at the right time and place (Azevedo et al. 2011).

Supply chain management (SCM) – SCM integrates and coordinates key supply chain functions and manages the flow of goods, services and information within and across vertically connected firms, with the aim of providing maximum value for end customers and stakeholders while generating a profit. (Lambert et al. 1998; Lummus & Vokurka 1999)

Green / Sustainable SCM - *Sustainable SCM* integrates both social and environmental impacts into supply chain management with the goal of improving environmental sustainability of all supply chain activities and partners while maintaining a high financial performance (Gimenez et al. 2012). *Green SCM* implements green thinking to SCM by considering the environmental impacts of a product's journey from product design to selecting raw materials, transportation, consumer use and the disposal process (Rajeev et al. 2017).

Green supply - *Green supply* or *environmental purchasing* refers to environmentally conscious supply chains that aim to reduce environmental impacts with efficient supply chain management activities (Corbett & Klassen 2006).

1.3. Research method

The purpose of this study is to create a review of previous work to explore the relationship between lean and green thinking with focus on supply chains. In order to achieve this, systematic literature review was chosen as a research method. The goal of the review is to identify and analyze literature related to lean management and green thinking and explore the effects that lean practices have on the environmental sustainability of supply chains.

Literature review is a research method that identifies, evaluates and analyzes existing literature and research on a specific topic (Denyer & Tranfield 2009). The aim of a literature review is to explore the diversity of knowledge related to a particular field in order to create an understanding of the existing literature from a sufficiently limited scope. This allows the researcher to increase understanding and familiarity of the chosen topic and to further develop knowledge under the guidance of defined research questions. (Tranfield et al. 2003) To find relevant literature, the search generally begins with an investigation from databases with selected keywords and various search strings specified for the topic field. Grouping keywords, using different word associations, Boolean operators and parentheses can be used to help with the search and to narrow the number of search results. (Denyer & Tranfield 2009)

According to Tranfield et al. (2003), a literature review consists of three main steps, including:

1. Planning the review

    ⇒ *identify need, prepare proposal and develop research protocol*

2. Conducing the review

    ⇒ *select studies, quality assessment, data extraction and synthesis*

3. Reporting and dissemination

    ⇒ *report and recommendations*

The literature review was carried out in accordance with this information and guidelines. For the review, literature was collected from SCOPUS and LUT University's Primo database by using different search keywords. The document type was limited to finding only articles. Other limitation criteria were that the article had open access and the language was English. In order to achieve a high-quality research analysis, the literature review focused on peer-reviewed articles.

A series of different keywords were used to find relevant literature, including *"lean management", "lean", "green management", "environmental management", "environmental sustainability", "green supply chain management", "lean and green", "lean and green OR environmental", "lean AND sustainable"," lean supply", "environmentally sustainable" AND lean, "lean and green AND "supply chain management",* were used. To find a comprehensive overview of relevant articles, different Boolean operators and parentheses were used in the searches. As most of the keywords resulted in hundreds of articles, different combinations and variations of these keywords were used to narrow down the search results. A number of the used keywords also led to finding the same articles. In the search process, the "snowball method" was also used to identify frequently repeated keywords or references to find new relevant search results.

The search for relevant articles resulted in 143 articles. Overall, the popularity of published articles on the topic of lean and green thinking and supply chains has been growing over the past years, illustrated in Figure 2. As Garza-Reyes (2015) pointed out, it can also be seen from Figure 2 that, especially after year 2010, interest towards the combination of lean and green has begun to grow more and more strongly in academic research and literature. Considering the current growing popularity and timeliness of the topic, it can also be assumed that the number of lean and green related publications will continue to grow strongly in the coming years.

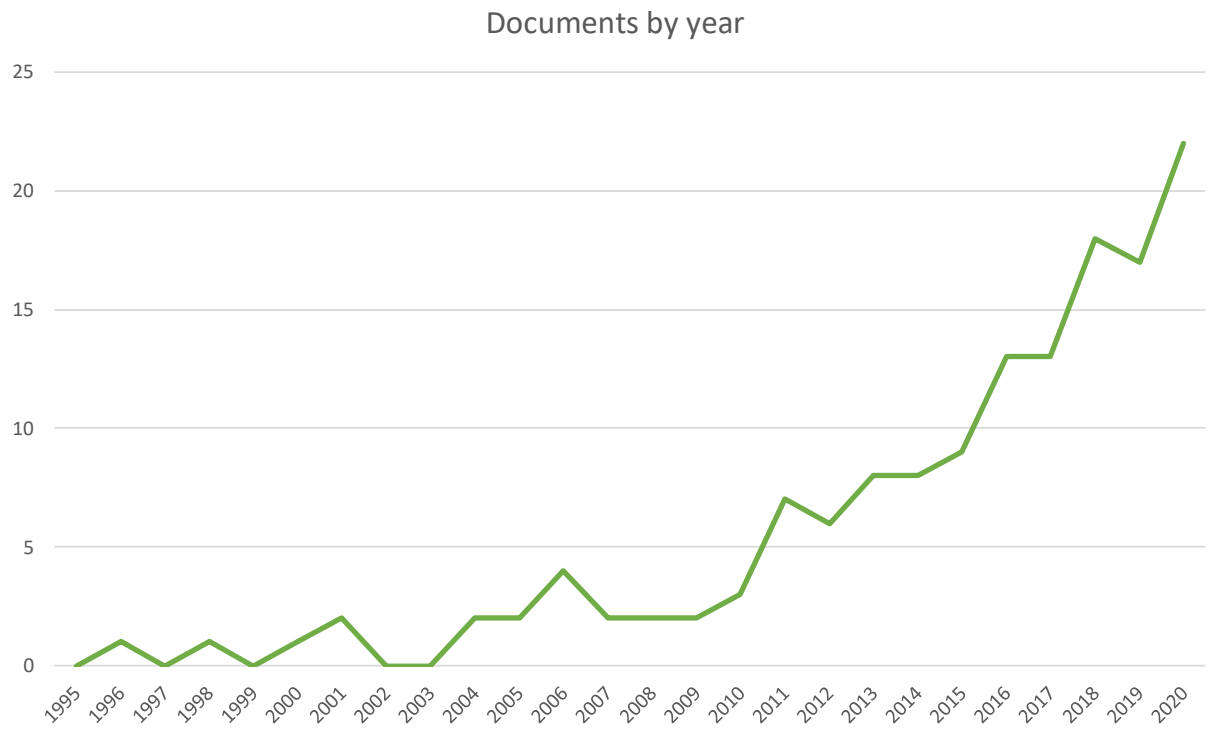

Figure 2. Published articles related to Lean and Green and Supply chains

After narrowing the results with different keyword combinations and search strings and manually scanning through the titles of the articles, 54 articles were selected for closer examination. The next process included reading through the abstracts and conclusions of the articles. At this stage, articles that were not relevant or did not specifically address lean and green, articles that were not available to access or did not fit the scope of the study were excluded from the review.

Finally, a total number of 34 articles were selected as primary sources for the literature review. To achieve a broad overview of the topic, the articles selected for the literature review represent a variety of areas of application by using different research methods in a variety of countries over the past 20 years. Specifically, the selected articles have been published between years 2001 and 2020 in ten different countries or regions. Figures 3 and 4 show the distribution of articles by year and country. A detailed list of the 34 articles can be found in Appendix 1.

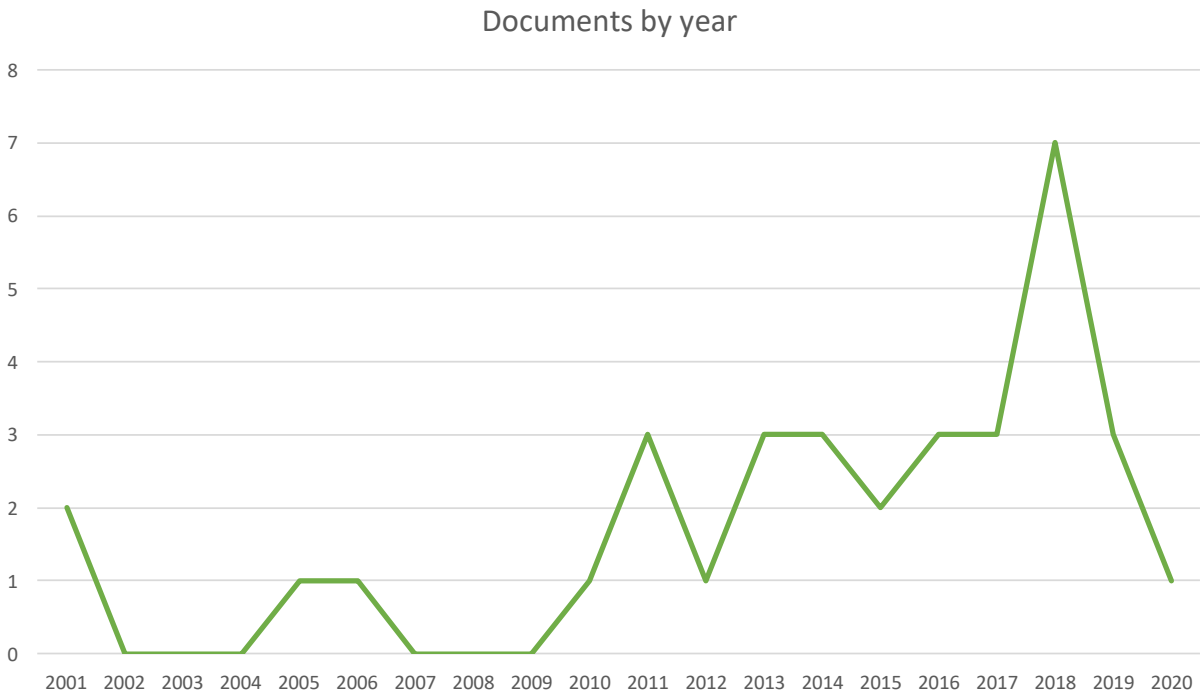

Figure 3.Publication of articles selected for the review by year distribution

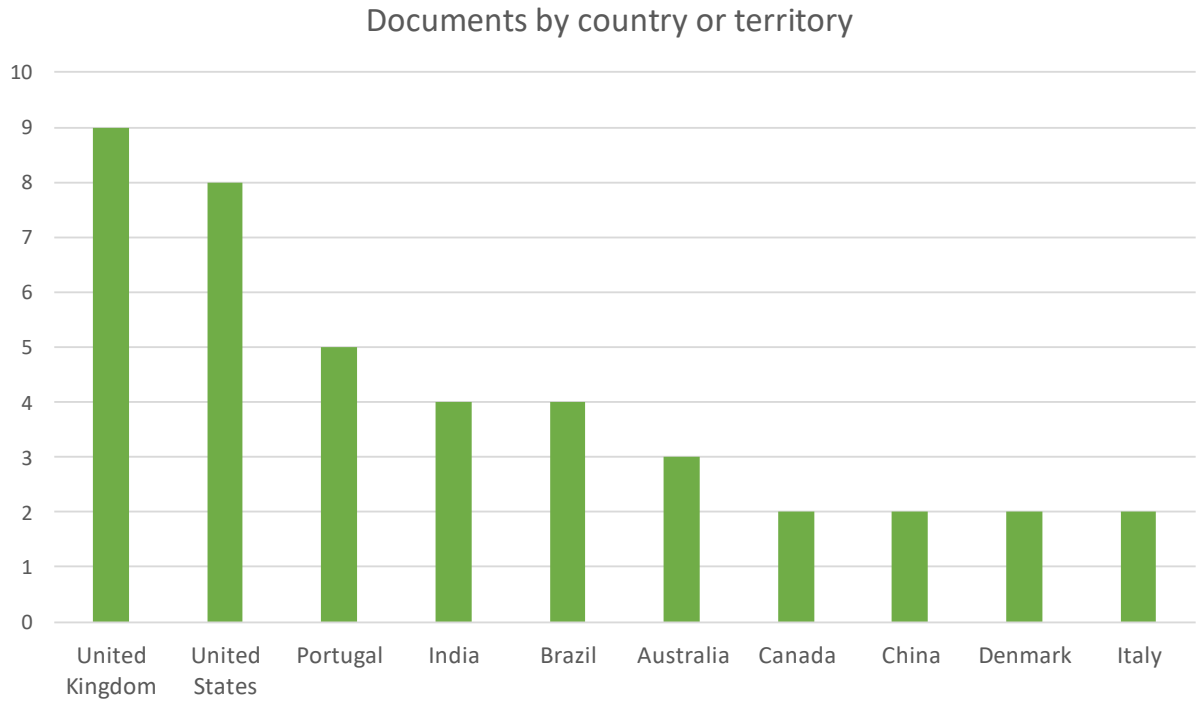

Figure 4. Publication of articles selected for the review by country/territory distribution

Area of application of the articles can be seen in Figure 5. 26% of the articles were theoretical approaches and 26% were based in the manufacturing industry. Additionally, 21% of the articles were conducted in the automotive industry and 18% used a multisectoral approach. The remaining papers were based on the service sector (3%), appliance sector (3%) or the foundry industry (3%).

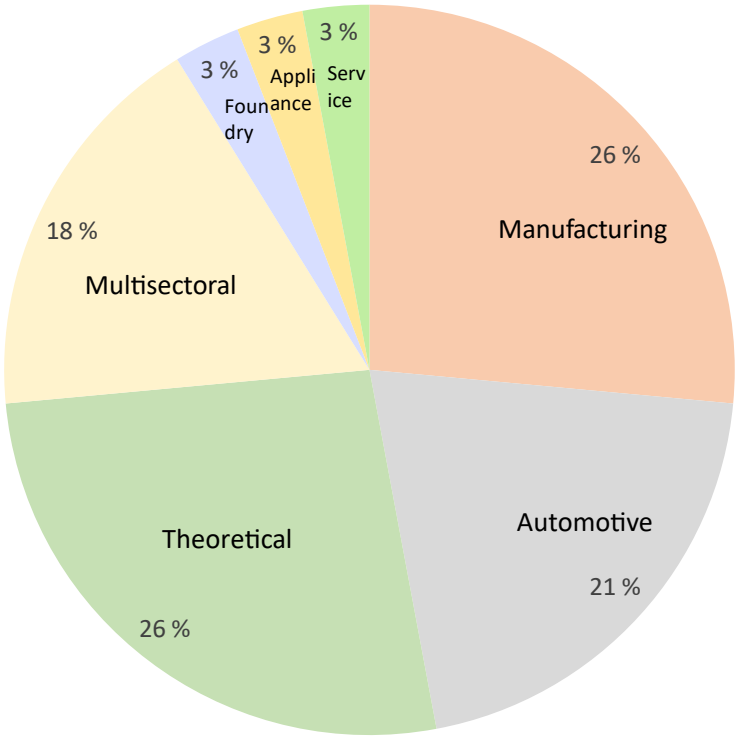

Figure 5. Distribution of papers by area of application

Several different research methods were also used in the selected 34 articles, presented in Figure 6. By distribution of research method, 34% were single or multiple case studies, 21% were literature reviews and 24% used surveys as a research method. The remaining papers were based on theoretical models (9%), interviews and surveys (6%), simulation models (3%) or used empirical analysis (3%).

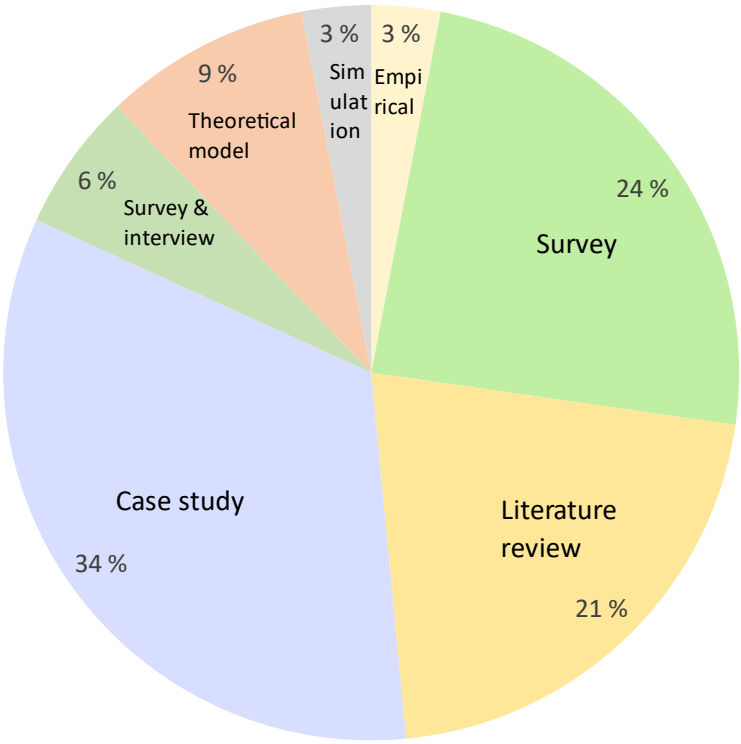

Figure 6. Distribution of papers by research method

In addition to these articles, a number of relevant papers were selected for sources used in the study due to frequent source citations, for example lean production pioneer Ohno's (1988) article, Womack & Jones' (1996) popular article on lean thinking, Florida's (1996) frequently cited and peer-reviewed empirical study on lean and green manufacturing, a case study published by Environmental Protection Agency (EPA 2013), Friedman's (2008) case study "*Leaning toward green: Green your supply chain with lean practices*" and Bergmiller &McCright's (2009a; 2009b) articles "*Parallel models for lean and green operations"* and *"Are lean and green programs synergistic*".

In order to ensure a sufficiently comprehensive background and appropriate definitions of the research topics, a number of additional sources were also used in the study on the basis of how relevant they were to the chosen scope of the topic and whether they supported the purpose of the thesis.

1.4. Structure of the study

This thesis consists of six main chapters, presented in Figure 7. The first chapter provides a brief introduction to the thesis topic and introduces the conceptual framework and key concepts of the study in order to give the reader a general idea of the main themes and concepts in the study. Additionally, the research method used in the study is explained.

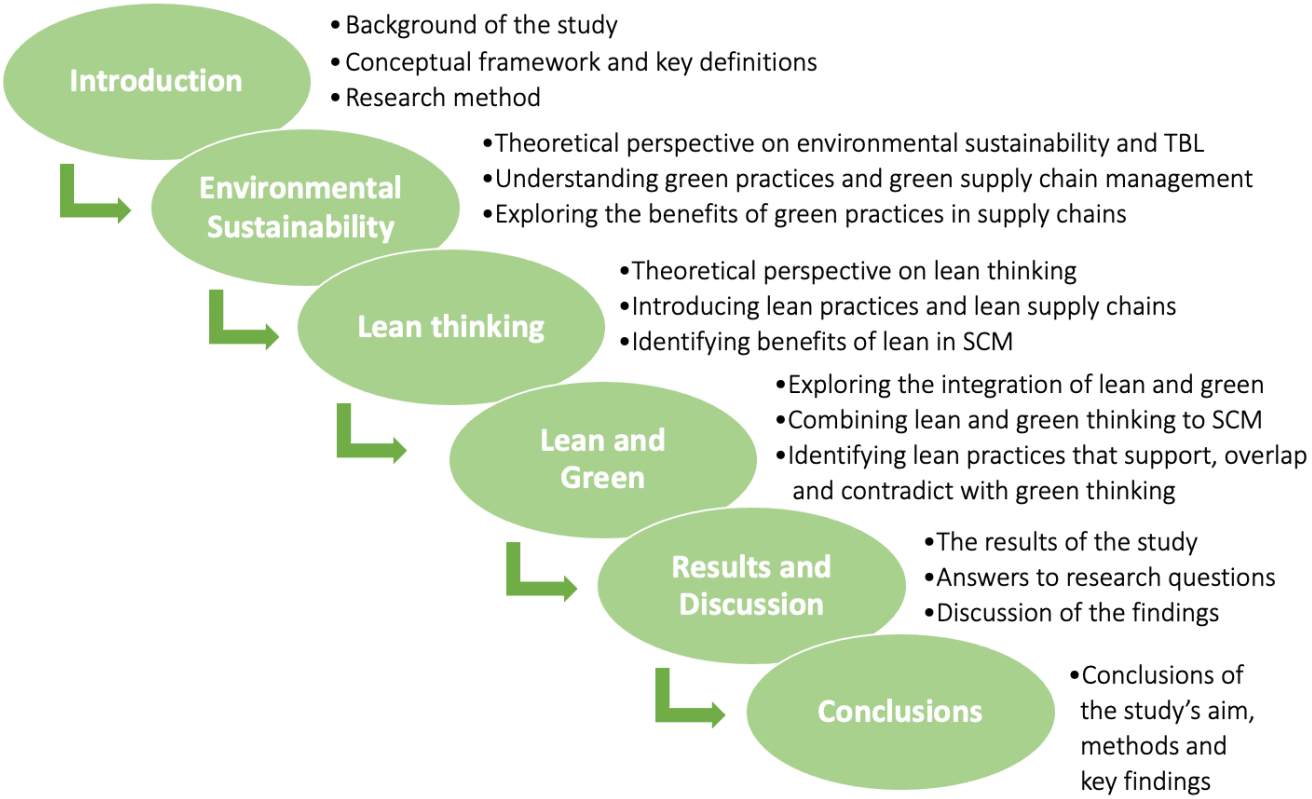

Figure 7. Structure of the study

The second and third main chapters focus on providing a comprehensive background and theoretical perspective of the study's main themes by exploring the main concepts in more detail. The second chapter briefly addresses the theme of sustainable development, first in general and then with focus on environmental sustainability and supply chains. The chapter presents various green practices that firms can use to improve the level of environmental protection of their operations and supply chains. In addition, the benefits of these practices are listed.

The third chapter focuses on lean thinking by first briefly introducing the background behind the philosophy and further defining the key principle and goal of lean, waste elimination, by also providing examples of waste in supply chain context. Finally, some key practices, tools, and methods are presented in more detail. In the fourth chapter, lean and green are linked together, and the benefits of the integration are explored. Further, the green benefits of specific lean practices and tools in addition to the combination of lean and green in supply chains are presented. Finally, the overlap between lean-green integration and also possible tradeoffs, differences and conflicts behind these two initiatives are addressed. The two final chapters are results and discussion and conclusions. As the aim of the study was to find out how lean and green practices can improve the green performance of suppliers, the results and the discussion chapter present the results of the study by answering the research questions. Additionally, possible limitations and generalizability of the presented results are discussed. The last chapter summarizes the purpose of the research and briefly reviews the main findings and results of the paper.

2. ENVIRONMENTAL SUSTAINABILITY

Earth has a limited amount of available environmental resources and capacity to support the growth of human population and needs. For the survival of our plant, the development and adaptation of new sustainable resource options and more sustainable and green business operations is becoming more and more important. (Karlsson 1999) At the same time, major phenomena such as the acceleration of globalization and industrialization challenge the progress of sustainable development. While environmental and social issues have become increasingly important concerns in our society, the trend towards sustainable development has continued to grow rapidly since the late 1980s (Fercoq et al. 2016). The popularity of the green paradigm rose more strongly in the 1990s as a philosophy aimed at improving negative environmental impacts of products and processes and the firm's green performance, while still achieving the firm's economic goals. (Garza-Reyes 2015) Dües et al. (2013) argue that the general industrial paradigm is gradually shifting towards environmentally friendly and sustainable businesses.

According to Wills (2009*), "it is a myth that being environmentally responsible is injurious to profitability"*. Since there has been recognized a link between environmentally conscious managing

practices and financial performance, (Klassen & McLaughlin 1996; Srivastava 2007; Azevedo et al. 2011; Green et al. 2012) increasing interest has been directed towards green initiatives (Rothenberg et al. 2001). Firms operating in the 21st century must survive under constantly changing and complex business environments (Mollenkopf et al. 2010). Competition between firms is constantly growing as new competitive factors emerge. In addition to traditional factors such as quality and price, environmentally friendly and socially responsible actions and practices are growing in popularity. As the awareness of environmental and responsibility issues grow rapidly, more and more people are recognizing these problems and want to support green thinking firms and choose environmentally friendly and clean products, that minimize pollution, hazardous materials and waste. (Wiese et al. 2015; Engin et al. 2019) Thus, in addition to wanting to have the right product at the right place, with correct cost and time, customers increasingly demand for greener products (Friedman 2008).

Due to the continuous and strong trend towards sustainability and responsibility in the business world, (Verrier et al. 2014) more and more firms are showing interest in green thinking (Caldera et al. 2017). Environmentally sustainable and responsible business practices have become an essential competitive factor in global markets (Wiese et al. 2015). In its essence, the main objective of green thinking is to help firms make more environmentally friendly decisions. Adopting a green strategy can have a significant positive influence on environmental sustainability by reducing harmful and hazardous waste and pollution (Zhu et al. 2010; Duarte & Cruz-Machado 2013; Al-Ghwayeen & Abdallah 2018). Green thinking can also have a strong positive impact on the firm's reputation (Wiese et al. 2015; Engin et al. 2019).

Today, greenness and sustainability are widely recognized phenomena and driving trends. They impact all levels of the society, change customer needs and create new laws and regulations. (Gordon 2001; Friedman 2008) There are many incentives to "go green". Environmentally conscious customers and stakeholders and government regulations are putting pressure on firms to incorporate environmental thinking into their business strategies (Mollenkopf et al. 2010). Increasingly, firms are also being held accountable for both their internal and suppliers' actions that can have an impact on the environment (Hartmann & Moeller 2014). For the wide majority of firms, sustainability is a highly relevant issue (Schneider & Wallenburg 2012) and more and more firms are recognizing the importance of sustainable supply chains and business processes (Ahi & Searcy 2013).

2.1 Sustainable Development and Triple bottom line (TBL)

There exists a number of definitions for sustainability or sustainable development, but a widely quoted definition is by the World Commission on Environment and Development in 1987: *"Development that meets the needs of the present without compromising the ability of future generations to meet their needs"*. Following this definition, attention towards sustainability in academic business literature has seen a steady growth (Rajeev et al. 2017). Norman & MacDonald (2004) discuss that when measuring the overall success or performance of the firm, in addition to measuring the traditional economic factors, the social and environmental performance of the firm must also be taken into account. Even though the early view of sustainability focused mainly on environmental performance, the social and economic aspects of sustainable development are increasingly taken into account when measuring the firm's sustainability (Ahi & Searcy 2013).

Elkington's (1997) widely used approach, commonly referred to as the "triple bottom line" or TBL framework considers sustainability to include three main dimensions. These three aspects are the financial, social and environmental performance. From a corporate point-of-view, sustainability can be defined as the correct combination of financial, environmental and social aspects. The three TBL elements integrate people, the planet and profit, also called 3Ps, into business strategy, culture and business operations, see Figure 8. The TBL framework was created to raise awareness and also measure the social and ecological performance in addition to financial performance. Accordingly, the TBL theory emphasizes that firms should take into consideration the environmental and social dimensions as much as the economic ones. (Gimenez et al. 2012) According to the framework, a fully sustainable organization aims to consider and improve all three triple bottom line elements simultaneously in its business activities (Fercoq et al. 2016).

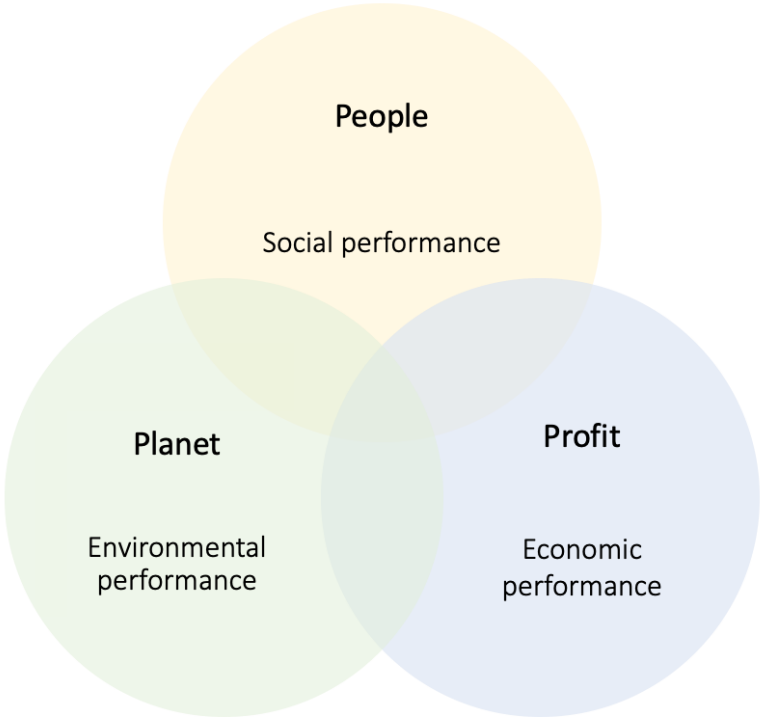

Figure 8. The TBL-framework (adapted from Elkington 1997)

According to Gimenez's et al. (2012) research, improving the firm's ecological performance benefits all three dimensions of the TBL. This effect can be explained by the fact that when environmental programs aim at efficiency and minimized resource utilization, it leads to a reduction in waste and lower costs, both of which improve the economic performance. Environmental programs include for example supplier development actions, designing more environmentally friendly products and taking into account the pollutions from transportation and production. These actions contribute to the social dimension of sustainability by improving the working conditions and quality of life in the surrounding areas due to lower pollution rates. Moreover, these can have a positive impact on the firm's social reputation. However, actions under the social and economic initiatives do not have as straightforward positive impacts on the other TBL dimensions.

There has also been criticism towards the TBL framework. Milne & Gray (2013) argue that is not possible to achieve equal balance between the three TBL elements, as they do not contribute to each other's performance evenly. Consequently, the TBL framework combines, balances or compromises between the three elements and does not provide a realistic and full picture of

sustainability. Sridhar & Jones (2013) also discuss issues of TBL. Firstly, according to them, the measurement of intangible assets of social and environmental performance can pose a number of issues. For example, it is difficult to define or quantify assets such as market reputation or customer loyalty. Furthermore, they may vary by industry. Another limitation of TBL is in the challenge of integration across the elements.

As interest towards environmental factors grows rapidly, in addition to financial data, firms are required to pay attention to their environmental performance (Sridhar & Jones 2013). If the firm does not take an initiative towards solutions and actions that support sustainability, they will soon start to feel pressure from stakeholders, customers and federal agencies to take actions towards sustainable development (Friedman 2008). In general, consideration of environmental impacts has widely been integrated as an essential part of ongoing business development activities towards better productivity, environmental performance and profit. (Florida 1996) Today, environmental sustainability can be considered an essential strategic business imperative and it needs to be integrated as part of firm's other goals and activities (Garza-Reyes 2015). From the TBL-framework, the main focus on this thesis is on the planet and the environmental performance aspect of sustainability.

2.2. Green Practices and Environmental Certifications

Environmental regulations and public pressure are driving firms towards more environmentally conscious and responsible business practices (Gordon 2001; Zhu et al. 2008; Green et al. 2012). The rising environmental consciousness from customers and depletion of resources has led legislators to move to tighter green regulations (Al-Ghwayeen & Abdallah 2018). Consequently, managers have increasingly implemented different green practices to their operations, including cleaner manufacturing processes and green certifications (Zhu et al. 2010). The objective of green practices is to improve the firm's environmental performance (Al-Ghwayeen & Abdallah 2018). More specifically, green practices aim to prevent and reduce the environmental impacts of production processes and enhance efficient natural resource utilization (Rothenberg et al. 2001).

Green thinking firms use a variety of processes, practices and tools that reduce usage of energy and materials with the goal of minimizing hazardous waste and pollution prevention (Inman & Green

2018). Hajmohammad et al. (2013) define environmental practices of firms as “the level of resources invested in activities and know-how development that leads to pollution reduction at the source”. Pollution levels have generally been used as a measure of green performance (King & Lenox 2001), as emissions and high energy consumption have a negative effect on the firm’s level of environmental performance (Thanki et al. 2016). Thus, the purpose of green practices is the reduction of hazardous materials, energy and pollution from production processes and products (Azevedo et al. 2011). In general, environmentally sustainable practices focus on pollution prevention and control practices (Rothenberg et al. 2001). The objective of the preventive practices is to proactively prevent the occurrence of environmentally harmful or damaging pollutions, whereas the control practices attempt to change the organization’s processes to limit the repercussions of environmental damage that has already occurred (Jakhar et al. 2018). Environmental practices can reduce both negative impacts on green performance and unnecessary use of scarce resources (Fliedner 2008) and aim to reduce waste and recycle materials through effective management tools such as the ISO 14001 certification (Hajmohammad et al. 2013).

Organizations can demonstrate their compliance with green and ethical values with green certificates. Different international certifications can be used for specific environmental issues. The ISO 14001 is an international environmental management certification (Azevedo at a. 2011). The publication of the ISO 14001 standard in 1996 can be seen as a major factor influencing organizations' views on business environmental impacts (Garza-Reyes 2015). Today, the ISO 14001 is a widely used standard that provides practical tools to manage and improve the green impacts of business operations for achieving the firm’s environmental goals and to comply with legal requirements (Duarte & Cruz-Machado 2013). Thanki et al. (2016) argue that the ISO 14001 is the most important green practice, and it has a significant role in improving the firm’s green performance. It improves customer satisfaction and has a great impact on reducing solid wastes and water consumption. Thus, managers should adopt it at an early stage. Environmental taxes also work as an incentive for many organizations in reducing their carbon footprint (Caldera et al. 2017). Another popular green standard is the global reporting initiative (GRI) model taking into account all three elements of sustainable development, which include the economic, social and ecological performance (Duarte & Cruz-Machado 2013).

Nowadays, "green" can be widely recognized as an important competitive factor (Martusa 2013). Environmentally sustainable and responsible business practices have become an essential competitive factor in global markets (Wiese et al. 2015). Moreover, due to increasing awareness and interest in environmental issues and protection, implementing ecological practices is becoming rather a necessity than a business decision (Al-Ghwayeen & Abdallah 2018). In order to gain competitive advantage and answer the concerns of both internal and external stakeholders, green management practices should be applied across the entire firm's business operations and along its supply chains (Azevedo at a. 2011; Foo et al. 2018). To successfully implement these practices and achieve the desired green benefits on the long run, efficient management of suppliers is essential.

2.3. Sustainable and Green Supply Chain Management

Supply chain management (SCM) manages the total flow of a distribution channel of information, goods and services (Cooper et al. 1997). Therefore, SCM covers all supply chain processes and activities involved in the products' journey all the way from raw materials to the final consumer. These activities include planning, integrating and controlling the supplier operations with the goal to create value and satisfy customer needs (Oliver & Webber 1982). SCM aims to create value for the entire supply chain, not only for the focal firm. As supply chain management can be considered a necessary function for the continuation and success of business, efficient and well-functioning SCM can offer significant competitive advantage for firms (Wiese et al. 2015). SCM mainly focuses on managing the suppliers and external resources. Therefore, it can have a strong influence on deciding the origin of raw materials and goods and the way they are delivered (Lintukangas et al. 2016). As a term, SCM was introduced in the early 1980s (Oliver & Webber 1982). During the past decades, attention towards sustainable and green supply chains has steadily grown (Fahimnia et al. 2015).

Firms have different motivations to move towards sustainable and green supply chains (Fortes 2009). Public environmental awareness and new regulations, such as restrictions on the use of environmentally harmful substances are growing demand for more sustainable and greener solutions (Al-Ghwayeen & Abdallah 2018). The changes have compelled managers to be more environmentally conscious and implement green thinking also beyond focal firm operations (Zhu et al. 2010). Because firms, suppliers and customers are connected to each other through different

flows of knowledge, goods and capital, the green performance of suppliers is important for focal firms (Seuring & Müller 2008). Consequently, the trends of environmental sustainability and business transparency are driving environmental improvements across supply chains. There is also increasing pressure from customers and other stakeholders to manage suppliers more efficiently and environmentally friendly (Fahimnia et al. 2015). With this, and recent environmental regulations, firms are required to extend the green initiatives also to their suppliers and customers (Green et al. 2012; Al-Ghwayeen & Abdallah 2018). Wiese et al. (2015) agree that consideration of the environmental aspect is important within supply chains. In addition to internal operations, firms should pay attention to external operations and partners across supply chains (Martínez-Jurado & Moyano-Fuentes 2014). A green supply chain extends the traditional supply chain by considering the environmental impact of all goods and processes in supply chain stages from raw materials to production, transportation, consumption and disposal (Wiese et al. 2015).

Schneider & Wallenburg (2012) argue that supply chain greenness and sustainability is key to the environmental sustainability of the entire firm. Therefore, in order to improve the firm's green performance, firms should focus more on the greenness of their suppliers (Hong, et al. 2018). Green et al. (2012) and Chin et al. (2015) agree that firms are increasingly pressured to integrate green thinking to their supply chain operations. Today's modern supply chains are more complex and dynamic while global competition poses new challenges (Hong et al. 2018). As the focal firm is responsible for its suppliers' environmental performance (Azevedo et al. 2011), managing the suppliers both environmentally friendly and efficiently is vital to an organization's success and greenness.

During the past decade, sustainable supply chain management (SSCM) has emerged as an important philosophy and research area (Rajeev et al. 2017). Ahi & Searcy (2013) have proposed a definition for SSCM as "The creation of coordinated supply chains through the voluntary integration of economic, environmental, and social considerations with key inter-organizational business systems designed to efficiently and effectively manage the material, information, and capital flows associated with the procurement, production, and distribution of products or services in order to meet stakeholder requirements and improve the profitability, competitiveness, and resilience of the organization over the short- and long-term". Thus, SSCM aims to enhance the overall sustainability of supply chains (Hong et al. 2018).

Wilding et al. (2012) argue that rather than treating sustainability individually as its own theory or business function, firms should integrate sustainability as part of their supply chain management. Sustainability and green issues should be given equal attention as economic performance, such as profits, costs and revenues. To improve their green image, firms are required to develop their supply chain practices towards better environmental sustainability (Hong et al. 2018). As firms have increasingly combined green thinking and SCM, it has led to the emergence of Green Supply Chain Management (GSCM) (Zhu et al. 2010). Whereas SSCM takes into consideration all three aspects of the sustainable development, including the social and economic aspects, GSCM focuses mainly on the environmental performance (Rajeev et al. 2017). Thus, SSCM refers to a much broader concept with a wider range of objectives than GSCM (Hong et al. 2018).

GSCM incorporates the environmental components to SCM to address the links between supply chain operations and green performance (Srivastava 2007). Srivastava (2007) has defined Green SCM as "integrating environmental thinking into SCM, including product design, material sourcing and selection, manufacturing processes, delivery of the final product to the consumers as well as end-of-life management of the product after its useful life". Thus, the aim of green supply chain management is to reduce all negative environmental impacts, pollution, waste and hazardous materials from all stages of supply chains. Environmental waste means the unnecessary use of resources or substances released into the air, water or land which may be detrimental to people, health or the environment (Vinodh et al. 2011). From an environmental point-of-view, a process-oriented approach should be applied to the assessment of emissions. This means that green thinking should focus on the entire supply chain, not just one separate department, such as transportation. (Simons & Mason 2003)

Green manufacturing favors energy-efficient, recyclable, easily disposable and less waste-generating solutions by supporting environmentally friendly and renewable production of goods. (Wiese et al. 2015) GSCM responds to changing customer requirements and government regulations (Green et al. 2012). Furthermore, it is an organizational management tool and philosophy, that allows the firm to achieve its business goals while also reducing environmental risks and impacts (Zhu et al. 2008). Green supply refers to environmentally conscious supply chains aiming to reduce environmental impacts with efficient SCM practices. The focus of GSCM is to improve the level of environmental performance of raw materials, products and by-products, as well as impact supplier

selection processes and supplier management. (Corbett & Klassen 2006) The ability of suppliers to offer green and sustainable products is becoming an increasingly important criterion for firms when selecting suppliers (Azevedo et al. 2011).

In order for the firm to successfully embrace green supply management, finding responsible and proactive suppliers that are able to provide green and sustainable supply solutions is important (Lintukangas et al. 2016). In sustainable supplier selection, in addition to other criteria such as quality and price, the environmental sustainability and responsibility of suppliers are taken into account (Jakhar et al. 2018). By adding the green component to SCM, the firm must take into account the impacts that suppliers and internal relationships across supply chains have on the environment. Efficient supplier audit programs can be used to select more environmentally friendly and quality suppliers. (Corbett & Klassen 2006) Suppliers' environmental audits, the ISO 14000 certification and green collaboration with suppliers are important in green purchasing. Additionally, the sustainability and greenness of second-tier suppliers should be taken into account. (Zhu & Sarkis 2007)

Simply, GSCM efficiently combines green thinking and SCM. Green distribution includes a number of different activities that take into account the environmental aspect, such as analyzing the environmental impacts of transportation and distribution. The main objective of green supply is to minimize the carbon footprint of distribution activities. (Wiese et al. 2015) Moreover, GSCM aims to minimize all hazardous chemicals, emissions and energy across supply chains (Chin et al. 2015). To achieve these goals, there can be recognized a number of different green supply practices, which are next introduced.

2.4. Green Supply Practices

Green supply practices seek to take environmental impacts into account at all stages of the supply chain, including product packaging and design, sourcing options and the use of raw materials. In addition, greener choices can be made at production processes and deciding on transportation and delivery options. It is also important to consider the product's final disposal or recycling options (Srivastava 2007). The main goal of implementing green practices is to achieve more efficient use of natural resources and to reduce processes, materials and activities that have negative impacts on

green performance (Pampanelli et al. 2014). Effective green supply practices can play a key role in mitigating negative environmental impacts (Foo et al. 2018) and also aim to find a successful win-win relationship between environmental and financial performance (Fortes 2009). Firms can incorporate green supply practices in their operations by implementing green procurement activities, developing eco-product designs and with other green initiatives, such as investment recovery (Green et al. 2012).

Foo et al. (2018) listed important green supply practices, including

- Internal environmental management
- Environmental collaboration with suppliers and customers
- Eco-design
- Investment recovery
- Supplier evaluation
- Supplier selection

Zhu et al. (2010) recognized similar important green practices, such as green design, investment recovery and eco-purchasing. Investment recovery refers to identifying and reusing, recycling, selling or other ways disposing excess end-of-life or unused assets, scrap, equipment, items, materials and inventories in order to recover and maximize their value (Zhu & Sarkis 2007; Foo et al. 2018). As a practical example, in Japan, Sony Corporation makes cement by recycling sludge (Foo et al. 2018). Cherrafi et al. (2018) also listed a number of important green practices that have significant contributions to greenness of suppliers, including eco-design, waste management programs, life cycle assessment and reverse logistics. Life cycle assessment (LCA) evaluates which functions, materials and processes cause the most environmental impacts during each stage of a product's life from raw materials to end of life (Pampanelli et al. 2014).

Wilding et al. (2012) discuss that commonly used green supplier policies focus on emissions from transportation. The main source of emissions from transport are caused by use of energy and fuel in vehicles. Especially with large volume freights, the ways goods are packaged can be a huge contributor to pollution. The design of packaging, the materials used and weight of goods are

important factors, that can increase environmental impacts. Therefore, more efficient and sustainable packaging options can provide significant green improvements. Environmentally friendly packaging is a green practice, that promotes the use of reusable, returnable and easily recyclable packing materials with the aim to reduce environmental impacts and waste and improve customer satisfaction and firm reputation (Carvalho et al. 2017).

According to Fortes (2009), five different components of green supply can be identified, including reverse logistics, eco-design, green operations, eco-manufacturing and waste management. Geng et al. (2017) also listed similar green supply practices, such as inter-organizational environmental management, eco-design, green supplier and customer collaboration and reverse logistics. Chin et al. (2015) discuss that effective green supply practices, which improve the firm's sustainable performance, include the production of greener products, green designs and environmental collaboration with suppliers. Environmentally conscious design or eco-design includes, for example, the use of environmentally friendly raw materials, developing products that minimize the use of materials and energy and the use of cleaner energy technologies to reduce waste. Thus, eco-design develops less energy consuming materials and goods by reusing, recycling and recovering materials, items and products (Zhu & Sarkis 2007).

The ISO 14001 environmental certification is also an effective and easy way to determine supplier sustainability (Zhu et al. 2010). Supporting this, Azevedo et al. (2011) identified three main green practices that can be considered essential in achieving a green supply chain. These practices include waste elimination, reverse logistics and the ISO 14001 certification. In reverse logistics, goods move in the opposite direction from the end user back to the producer, for example, when a customer returns a product. Thus, reverse logistics generally includes all activities related to the reuse of goods or retrieving goods back through the supply chain from their final destination with the aim of creating value (Wiese et al. 2015). Geng et al. (2017) states that reverse logistics uses three "*Re*" functions: *Recycling*, *Reusing*, and *Reducing* the use of raw materials at all stages of production.

Environmental collaboration with suppliers is a green practice, that includes mutual planning and sharing green knowhow with supply chain actors. It ensures the greenness of suppliers and helps firms to support their delivery partners' environmental performance. (Vachon & Klassen 2008) According to Geng et al. (2017), close firm-supplier collaboration is important for the effective

implementation and use of GSCM practices. Florida (1996) agrees, that in order to improve the firm's environmental sustainability, manufacturers ought to work together with their suppliers and customers. Green et al. (2012) support this by emphasizing collaborative work with suppliers as an important green initiative. In order to reduce environmental impacts, green collaboration requires the firm to invest resources to develop ways to capitalize value created by interacting with other actors in the supply chain. The aim is to improve the level of environmental performance in the supply chain by working closely together with suppliers (Foo et al. 2018).

With environmental collaboration, it is important that the suppliers are assured that it is also in their best interest to accept the environmental guidelines. Therefore, building a close relationship with suppliers is highly important in ensuring the environmental sustainability of goods and services (Simpson & Power 2005). Tebini et al. (2016) agree, that in order to create better value and improve the firm's environmental credibility, after developing environmental strategies, managers should prominently communicate these strategies to stakeholders. Both Hong's et al. (2018) and Florida's (1996) research also support the importance of communication and collaboration. In order to achieve the firm's green goals, it is vital that the goals and means are mutually understood and communicated with all partners in the supply chain. The practices and policies of sustainable management should also be clearly defined at a strategic level before implementation. Thus, cooperation with suppliers and mutual understanding of goals and practices are highly important in achieving sustainable supply chain management.

Firms should also collaborate with customers on green activities. Working closely with customers can help to develop greener products, packaging and production (Foo et al. 2018) and provide means to improve visibility and service level (Geng et al. 2017). Corbett & Klassen (2006) argue that high level environmental performance can be attributed to excellent management practices. Effective internal environmental management programs can be viewed as an important green practice (Chin et al. 2015). Moreover, high-quality management practices generally result with better green practices (Zhu et al. 2007).

2.5. Benefits of Green Supply Practices

By adopting green supply practices, firms can gain huge advantages over its competitors (Green et al. 2012). Effective environmental practices in supply chains can aid firms to both gain and maintain competitive advantage (Zhu et al. 2008). Al-Ghwayeen & Abdallah's (2018) study supports the fact that GSCM activities reduce negative environmental impacts of business processes and thus improve the environmental performance of the firm. Both Zhu's et al. (2010) and Hussain's et al. (2019) research showed similar results with also improvements in economic performance. According to Corbett & Klassen (2006), integrating environmental practices into supply chains can help organizations to identify previously unnoticed sources of wastes and remove unnecessary or unproductive processes. Simpson & Power (2005) also listed several benefits of implementing green thinking in supply chains, for instance a lower risk in the management and storage of hazardous materials, meeting the goals of social responsibility and environmental standards and improving reputation and innovation.

There has been recognized a connection between green practices and improvements in both environmental and economic performance of an organization (Zhu et al. 2010) and its supply chains (Hussain et al. 2019). According to Tebini et al. (2016) study, by improving the firm's environmental performance, significant short-term and long-term benefits can be recognized on firm performance. Azevedo et al. (2011) and Geng et al. (2017) support the positive connection between green practices and environmental, economic and operational performance. Geng et al. (2017) provide a systematic literature review based on empirical evidence studying the impacts of GSCM on firm performance. According to their research, implementing GSCM practices improves the firm's performance on all these three aspects including the environmental, financial and operational performance with the strongest impact on economic performance. Both Green et al. (2012) and King and Lenox (2002) also agree that green purchasing practices can provide benefits for economic performance. By adopting green practices, the firm can gain superior advantages over its competitors such as improved efficiency and quality, lower costs, reduced waste and higher customer satisfaction (Green et al. 2012).

Azevedo et al. (2011) agree that even though integrating green practices help firms to meet the legal standards and requirements, improving the firm's environmental performance can also

provide competitive advantage and better profitability. In addition to cost savings, GSCM practices can improve the firm's public image and reduce environmental liability (Zhu & Sarkis 2007; Chin et al. 2015). Supporting this, study by Foo et al. (2018) showed that many GSCM practices, including internal environmental management, investment recovery, eco-design and environmental collaboration, act as significant and positive predictors towards sustainable development. Geng et al. (2017) argue that internal green management practices can also have a significant positive impact on firm's financial performance and flexibility. Singh's et al. (2020) recent empirical study further supports the relationship between firm's GSCM practices and improved levels of both environmental sustainability and financial performance with additional competitive advantages. Identified green benefits were reductions in waste and pollutions with the inclusion of efficient waste management and recycling systems. Improved economic performance included better profitability, higher operational efficiency and improved final cost of the product. Additional identified competitive advantages include better quality, productivity, customer satisfaction and an enhanced firm image. Thus, implementing green practices can improve overall firm reputation.

Eco-design reduces the use of hazardous materials by increasing the amount of reusable and recyclable materials (Zhu & Sarkis 2007). Supporting this, Geng's et al. (2017) research found that environmental design can have a significant positive impact on the firm's level of environmentally sustainable performance by reducing life cycle environmental impacts as well as energy usage and improving waste management. Life cycle assessment can improve green performance by identifying the environmental impacts of materials, activities and production processes during a product's life cycle (Yang et al. 2011). Identifying these activities can help firms to focus their green improvement efforts more effectively (Pampanelli et al. 2014). According to Green's et al. (2012) study, as a green practice, investment recovery also has a positive impact on environmental performance but only an indirect influence on financial performance. However, Zhu and Sarkis's (2007) study did not find a significant relationship between investment recovery and environmental improvement.

Additionally, by implementing effective reverse logistics practices, the firm may improve the efficiency of their return policy and thus reduce transportation emissions. Geng's et al. (2017) study supports the fact that reverse logistics can reduce pollutions and increase both operational and economic performance through efficient recycling and reusing practices that reduce energy, raw material and water use. Supplier selection and environmental cooperation are also important green

supply practices. Selecting suppliers based on their green certifications, green performance, and other environmental criteria has a huge impact on a firm's overall environmental performance (Foo et al. 2018). Purchasing contracts can sometimes also include incentives that may work against the firm's green goals, for example including suppliers of hazardous materials or harmful chemicals that aim to sell with high volume, which should be kept in mind when selecting suppliers (Corbett & Klassen 2006).

Firms can demonstrate their commitment towards better environmental sustainability through environmental collaboration with suppliers. Close firm-supplier collaboration in green activities supports the firm's environmental goals and can help to achieve better performance and service level (Foo et al. 2018). In addition to enhancing the firm's green performance, benefits from environmental collaboration include improved flexibility and flow of deliveries, reduced waste and reduced environmental costs. Environmental collaboration with suppliers can also improve customer satisfaction and the workflow of business operations. (Azevedo et al. 2011) Further, working together with customers on environmental practices can provide firms insight into customers' green requirements to produce products that better meet customer demand (Geng et al. 2017). Green et al. (2012) study showed, that whereas collaboration with customers had a straightforward influence on environmental performance, it did not have a strong impact on financial performance. However, Zhu & Sarkis (2007) did not identify any important neither environmental nor economic impacts from customer collaboration, whereas Foo et al. (2018) surprisingly noticed a negative influence on sustainability from cooperating with customers.

Reduced emission levels can be associated with significant improvements in firm's economic performance (King & Lenox 2002). Accordingly, King and Lenox (2002) argue that investing in efficient waste prevention programs can be very profitable for firms. From a different point-of-view, Konar & Cohen's research (2001) found that poor environmental performance has a negative impact a firm's valuation of intangible assets and market valuation, as high pollution levels impair the firm's economic performance. Flammer (2013) agrees, that whereas environmentally friendly behavior leads to higher stock value, on the other hand, poor green performance can reduce stock prices. Tebini et al. (2016) also discuss the importance of firms not taking negative green actions, because, as their study shows, these actions can have a negative impact on both short-term and long-term financial performance. However, there can be recognized an asymmetric effect between economic

and environmental performance, which means that financial benefits gained from focusing on environmental strengths can be cancelled by environmental issues, if not considered first. Therefore, firms should first seek to reduce the environmentally harmful impacts before concentrating on the environmental strengths, as these negative impacts can increase costs.

Friedman (2008) argues that a well-functioning sustainability program should always start at the top management level in the firm. To succeed, it requires commitment from every level from top to bottom. Green et al. (2012) research also highlights the importance of implementing environmental sustainability as a strategic necessity, always starting with top-level managers incorporating green initiatives as part of the firm's mission. Furthermore, the green initiatives should be supported and part of supplier and customer activities. Martusa (2013) argues, that separating the environmental initiatives from day-to-day productions processes and business management can lead to poor optimization and unutilized opportunities in terms of continuous improvement towards sustainability and greenness.

Overall, huge advantages and improvements in operational, environmental and economic performance can be identified that can be linked to a variety of green supply practices. The main identified green supply practices and their benefits in literature are listed in Table 1.

Table 1. Green practices and related benefits listed in literature

Green practice	Benefits	Literature
Supplier selection	• Selecting suppliers based on various sustainability and green criteria improves environmental performance of the firm and supply chains	Corbett & Klassen (2006); Azevedo et al. (2011); Duarte & Cruz-Machado (2013); Chin et al. (2015); Foo et al. (2018); Inman and Green (2018); Jakhar et al. (2018); Dieste et al. (2019)
Environmental collaboration	• Working together with suppliers can improve waste management and environmental performance	Florida (1996); Zhu & Sarkis (2007); Vachon & Klassen (2008); Green et al. (2012); Dües et al. (2013); Chin et al. (2015); Geng et al. (2017); Foo et al. (2018); Hong et al. (2018)
Reverse logistics	• Improves return policy and reduces emissions from unnecessary transportation • Reduces pollutions and energy use by recycling and reusing parts and materials	Fortes (2009); Azevedo et al. (2011); Wiese et al. (2015); Geng et al. (2017); Cherrafi et al. (2018)
Investment recovery	• Maximizes value of unused or end-of life assets by recovering, reusing or selling them	Zhu & Sarkis (2007); Zhu et al. (2010); Green et al. (2012); Foo et al. (2018);
Eco-design	• Improves waste management and recycling • Reduces the use of hazardous materials by using more reusable and recyclable materials • Reduces energy consumption • Minimizes life-cycle environmental impacts	Srivastava (2007); Zhu & Sarkis (2007); Fortes (2009); Green et al. (2012); Dües et al. (2013); Chin et al. (2015); Geng et al. (2017); Foo et al. (2018); Cherrafi et al. (2018)
Life-cycle assessment	• Improves green performance by identifying the environmental impacts of products and production processes during their life cycle	Yang et al. (2011); Dües et al. (2013); Pampanelli et al. (2014); Caldera et al. (2017); Cherrafi et al. (2018)
Waste management and elimination	• Elimination of wastes can be associated with improved environmental sustainability • Developing waste management and recycling systems improves green performance	Srivastava (2007); Fortes (2009); Zhu et al. (2010); Azevedo et al. (2011); Hajmohammad et al. (2013) Dües et al. (2013); Cherrafi et al. (2018); Singh et al. (2020)
ISO 14001 certification	• An effective and easy way to determine supplier sustainability and greenness • Supports reduction of wastes and pollutions across supply chains • Huge improvements in green performance	Zhu & Sarkis (2007); Zhu et al. (2010); King & Lenox (2001); Azevedo et al. (2011); Green et al. (2012); Hajmohammad et al. (2013); Wiese et al. (2015); Thanki et al. (2016); Campos and Vazquez-Brust (2016); Carvalho et al. (2017)

Zhu et al. (2007) discuss that even though a number of green supply chain practices have a clear link to better environmental and economic performance outcomes, the strength of the connection may depend on how thoroughly and for how long the practices have been used. Mixed performance results of green practices can be explained by lack of experience or knowledge from managers or by implementing inefficient green initiatives. Therefore, it is important that the management chooses the correct and effective green supply chain practices for their firm and also implements them thoroughly. Furthermore, Angell (2001) argues that green practices are more successful if they

are implemented in response to widespread external pressure and not just as means of addressing internal organizational issues.

According to Florida (1996), close relationships and working together with suppliers can offer firms a great opportunity to gain mutually beneficial economic and environmental outcomes. Joint efforts between end-users and suppliers can create advanced practices, technologies and strategies aiming to prevent toxic pollutions, eliminate defects, reduce costs and enhance productivity levels. Integrated partnerships with suppliers are more likely to support greenness and improve the firm's level of environmental protection compared to more direct strategies designed specifically to reduce pollution. By working together with suppliers, the firm can strive to develop superior environmental solutions that minimize the negative environmental impacts of the entire supply chain (Vachon & Klassen 2008).

In conclusion, Simpson & Power (2005) argue that effectively managing and developing supplier relationships can work as a key factor and important way to influence the firm's environmentally sustainable performance. Environmentally sustainable supply chains can have an impact on both economic and environmental performance of the firm (Fahimnia et al. 2015). In addition to benefits on economic performance, actions towards improving environmental issues allows firms to comply with regulations and even avoid possible sanctions (Tebini et al. 2016). Srivastava (2007) also argues, that incorporating environmentally friendly practices into supply chain operations can enhance business performance, increase profitability and meet the required environmental regulations and standards.

Overall, a green supply chain has the potential to simultaneously improve the firm's green performance and provide competitive advantage by reducing waste and pollutions, increasing efficiency and quality. Thus, implementing green practices to supply chains with a successful and efficient green SCM strategy can provide environmental benefits without compromises in quality, performance, efficiency, costs, reliability or the efficient use of energy (Martusa 2013).

3. LEAN THINKING

Lean thinking, also known as lean production or simply “lean”, is a systematic philosophy of ongoing efforts and continuous improvements aimed at resource efficiency and waste elimination, encompassing the firm’s processes, strategy, human resources and work culture (Shah & Ward 2007; Jakhar et al. 2018). In its essence, lean thinking aims to make many small changes and actions in order to achieve big results (Friedman 2008). For the past four decades, lean thinking has been one of the most commonly implemented philosophies for business improvement (Sony 2019). According to Gordon (2001), implementing lean thinking is the most effective way to lead a production firm. Womack and Jones (1996) identify five key steps of lean thinking, illustrated in Figure 9.

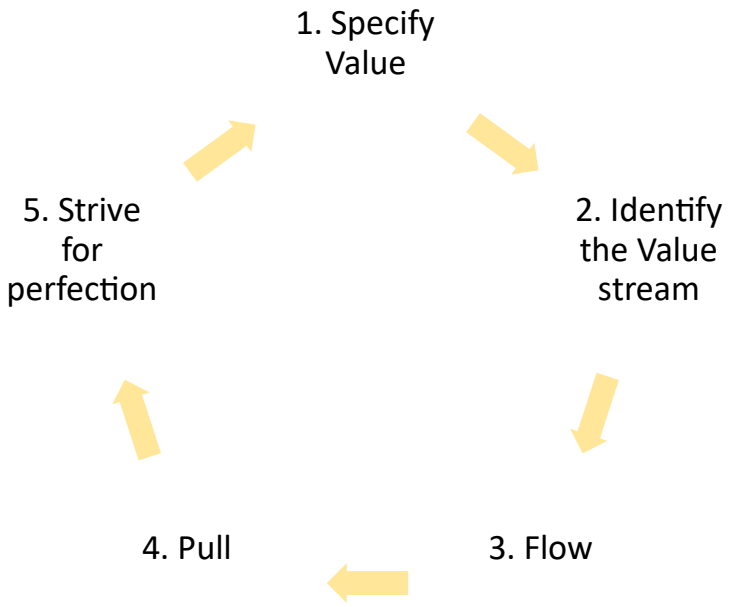

Figure 9. Five steps of Lean thinking (adapted from Womack & Jones 1996)

Lean thinking begins with specifying value and mapping the value stream. Value is determined from the end customer’s perspective. By mapping the product’s value stream, unnecessary steps can be identified and eliminated. The next steps are to create flow, establish pull and pursue perfection. With eliminating waste and creating a flow, goods can move fluently without interruption across the value stream and production processes can be optimized. The pull production responds to

customer demand accurately with “sell one, make one” principle. As lean strives for continuous improvement, the same process is repeated over and over again with the goal of achieving perfection with superior value and zero waste. (Womack and Jones 1996)

The core goal of lean thinking is to minimize waste and maximize value for customers by using less of everything (Shah & Ward 2007). This includes using as little as possible energy, equipment, time, space, materials and capital (Womack & Jones 1996). Essentially, therefore, lean strives to create superior quality and value for customers by minimizing waste, inventory and delivery times while increasing efficiency and productivity (Wahab et al. 2013). Lean aims for high operational performance and sustainability with improvements in the flow and speed of production processes. According to Womack & Jones (1996), lean thinking aims to provide better customer value by eliminating waste from all production stages. Lean’s key aim is to produce high quality goods with minimal costs and time by eliminating non-value-adding activities (Cherrafi et al. 2018) and to maximize stakeholder value in order to enhance all processes (Khodeir & Othman 2018). Overall, lean aims to create a well-organized and efficient system that utilizes the philosophy of continuous improvement to dispose of all wastes and to provide high value for customers (Simpson & Power 2005).

3.1. History of Lean

The history of lean originates from early automobile industries (Hobbs 2003, 14-17). A famous lean concept was created by Henry Ford. Ford made the assembling line of building cars more efficient by breaking down the production to 30 seconds tasks (Worley & Doolen 2006). The simplified assembly line production eliminated waste, but the manufactured cars had no variety (Hobbs 2003, 14-17). The lean concept was revisited and advanced in the mid 1950’s Japan, which is often credited as the true origin of lean management. The pioneers of the modern lean philosophy were two Japanese engineers; Toyota production system's creator Ohno and Shingo. Toyota’s Production System (TPS) concentrated on eliminating all unnecessary costs. The costs were eventually interpreted as waste and Toyota’s focus was to eliminate all varieties of waste. Additionally, Toyota build a lean production line for mixed products to improve performance and reduce inventory. (Krafcik 1988; Hobbs 2003, 14-17) Consequently, Toyota was able to produce a variety of

automobiles with a smaller inventory and lesser human effort, investments and a smaller number of defects.

The term "*Lean*" was first proposed in Krafcik's "*Sloan Management Review* (1988)" article describing the TPS. In the article, Krafick (1988) used the term *Lean* to describe the TPS system requiring much less resources in comparison to the typical productions systems. (Krafcik 1988*;* Samuel et al. 2015) After the introduction, the term was popularized by Womack, Jones & Roos (1990) in their best-selling management book "*The Machine that Changed the World*" and also featured in Womack and Jones's (1996) book "*Lean Thinking*". Despite the origins of lean, the philosophy can be adapted to a wide variety of small and big industries all around the world (Womack & Jones 1996). The term has developed over time and has diverse meanings to different people at different times. Even though lean was originally introduced as an alternative manufacturing system, it has evolved and broadened its activities and can nowadays be applied to various areas in organizations (Samuel et al. 2015). Therefore, there are many definitions for lean production varying from specific production processes to widespread and general applications (Worley & Doolen 2006). Womack et al. (1990) have simply defined lean production as a journey aiming to use less resources.

Because lean considers employee motivation and participation as essential factors of efficiency, lean firms focus resources on an effective workforce selection process and invest in employee training and development (Rothenberg et al. 2001). In lean, participation of each employee at every level of the organization is essential (Torielli et al. 2011). In order to achieve its goals, lean uses tools and techniques that aim for reductions in waste, energy, lead time, inventory levels, transportation and costs (Jasti et al. 2012).

3.2. Defining waste

Lean managements' most fundamental principal is to reduce various kinds of waste by eliminating all non-value-added activities (Shah & Ward 2007; Hajmohammad et al. 2013). According to Womack and Jones (1996), lean thinking should begin by differentiating muda from customer value. Muda is a Japanese term for waste. Waste includes all activity that is not necessary or does not add customer value (Worley & Doolen 2006).

Ohno (1988) categorized the seven deadly mudas or wastes. They include *overproduction, waiting, transportation, defects, overprocessing, unnecessary inventory* and *motion*. The seven mudas are described in Table 2 with examples of waste in contexts of manufacturing and supply chain operations.

Table 2. The Seven Deadly Wastes in manufacturing and SCM (adapted from Engin et al. 2019)

Muda	Definition in manufacturing context	Activity in the SCM context
Overproduction	Producing goods before they are required or demanded	Shipping a product or an item before it is required
Waiting	Goods are waiting to be processed or not moving	Waiting before loading or unloading cargo, waiting for vehicles or drivers
Transportation	Transporting goods between places	Transporting goods between places
Overprocessing	The use of overly complex equipment in situations where simple tools are sufficient	Use of half-loaded large trucks instead of smaller vehicles, empty cargo transports
Defects	Poor quality goods due to reprocessing or scrap impose huge costs on businesses	Improper communication with suppliers and customers leads to delivery of products to the wrong places and deterioration of goods
Unnecessary inventory	Keeping unnecessary extra stock	Keeping unnecessary extra stock
Unnecessary Motion	All movements related to ergonomics, bending, stretching, walking, lifting or rotating items	Re-packing or re-unpacking, re-delivering or re-picking, unoptimized delivery routes

Lean's main focus is on detecting and disposing of the seven deadly wastes while providing added value to the customer at all stages of the process (Fercoq et al. 2016; Caldera et al. 2017). Any other activity that is not absolutely necessary or does not add value to the product or service can be considered as waste. This means using a minimum amount of equipment, materials, parts, space and human capital. (Womach & Jones 1996; Ugarte et al. 2016) The value-creating factors and activities are easy to identify, but the non-value-adding activities and waste around them can be much more difficult to recognize. In general, it can be said that in a firm's factory, less than 5% of the activity generates added value, 35% are necessary but non-value adding activities, and up to 60% of activities do not produce any value (Ohno 1988; Alvim & Oliveira 2020). The key objective of eliminating waste is to achieve the best possible level of customer satisfaction (Womack & Jones

1996). Moreover, efficient and well-functioning waste management is essential, as poorly or incorrectly stored waste can cause a variety of health and safety problems and negatively affect a company's financial and environmental performance (Caldera et al. 2017).

3.3. Lean Practices & Tools

The lean philosophy is derived from practices and tools such as kaizen and JIT (Carvalho, Duarte & Machado 2011). According to Thanki et al. (2016), the three main practices and tools that enhance leanness and efficiency are TPM, kaizen and 5S. Additionally, SMED and VSM can be recognized as influential lean tools. With efficient lean practices, firms can benefit with improved quality, more efficient responsiveness to customer demand and lower costs (Ugarte et al. 2016). Some of lean's popular practices, tools and methods are next described.

Kaizen

According to Womack and Jones (1996) and Garza-Reyes et al. (2018), the key practice of lean thinking is kaizen. Kaizen refers to the principle of continuous improvement on all production processes. Kaizen is a process-oriented policy that focuses on gradual improvements (Womack & Jones 1996). As a term, kaizen is a Japanese word for small incremental changes, referring to gradual and ongoing improvement everywhere and a strive for perfection. Lean's aim is to achieve perfection by continuously improving everyone and everything in the organization. (Womack & Jones 1996; Garza-Reyes et al. 2018) Overall, kaizen is a policy of continuous improvement that concentrates on eliminating waste from all of the firm's operations and processes. Kaizen does not require expensive investments from the firm. It is people-based and continuous improvement strategy with the goal to make working methods simpler and to increase the flow of working processes (Soltero & Waldrip 2002). As kaizen is a people-based philosophy, it relies heavily on the engagement of people and depends on the ongoing efforts and commitment of everyone in the organization (Pampanelli et al. 2014).

Kaizen can be viewed as a building block of all lean methods, as it plays a key role in creating a lean culture of continuous improvement and waste disposal. Thus, kaizen is a not a single tool or method, but a holistic philosophy, that can be associated with tools such as JIT, VSM and 5S. Kaizen can also

be seen as a platform for maintaining lean operations, once they have been successfully implemented in the organization. (Garza-Reyes et al. 2018) Thus, kaizen acts as an implementation tool and unifying factor for lean's various tools and methods (Soltero & Waldrip 2002). In lean, the employees are responsible for identifying potential issues, and unlike in mass production, they are able to immediately detect problems and react to them accordingly. (Rothenberg 2001). With kaizen, all members of the firm work together to make significant improvements with only minimal capital investments (Soltero & Waldrip 2002).

5S and 7S

5S is an effective visual management system, that eliminates waste and optimizes productivity flow by using visual cues and by maintaining a well-organized working environment (EPA 2003; Sharma & Lata 2018). Thus, 5S supports lean's main goal of reducing waste by identifying which activities and processes can be considered as waste (Torielli et al. 2011). While kaizen ensures continuous improvement, 5S can contribute by improving performance and processes with low investment requirements (Thanki et al. 2016). Originally, 5S comes from the Japanese words *Seiri, Seiton, Seiso, Seiketso* and *Shitsuke.* Translated, the words refer to

- *Sort* – Organize the workplace by identifying and removing all unnecessary items
- *Straighten* – Arrange the needed items for fast and easy use
- *Shine* – Keep the work environment clean, clear and safe
- *Standardize* – Make following these steps consistent and routine
- *Sustain* – Commitment to these steps. Order is maintained with help of visual controls

(Vinodh et al. 2011; Sharma & Lata 2018)

In addition, *Safety* can be added as sixth "*S"* letter, then referred to as 6S. (Torielli et al. 2011; Chiarini 2014). The original 5S is still more widely used, although the popularity of the 6S is growing. Further, Vinodh et al. (2011) proposed a 7S model, which can be seen in Figure 10. By complying with these steps, they provide a method for organizing, cleaning, developing and maintaining a productive work environment and teach employees to reduce lead time, waste, unplanned downtime and inventory levels (EPA 2003).

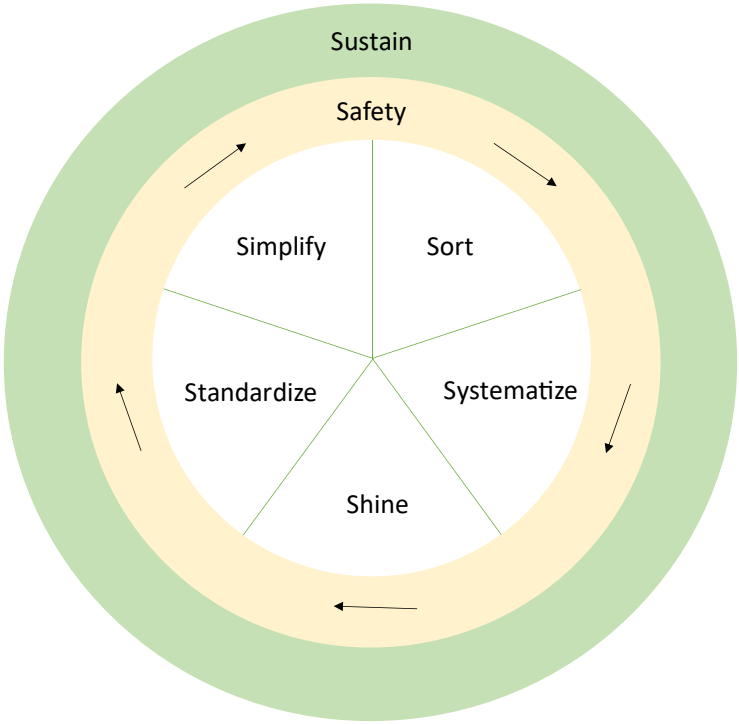

Figure 10. The 7S model (adapted from Vinodh et al. 2011)

As a system, 5S seeks to organize working environments more efficiently and identify leaks to reduce the use of chemicals and materials. Overall, 5S improves the flow of materials and products, working conditions, resource productivity, waste management and energy efficiency and reduces unnecessary time and space. (Caldera et al. 2017; Sharma & Lata 2018) Reduced waste and well-organized equipment, materials and tools can also make a positive contribution to green performance (Cherrafi et al. 2018). Furthermore, 5S provides a good basis for the effective deployment of other lean methods, such as TPM, cellular manufacturing and JIT (EPA 2003).

TPM

Total Productive Maintenance (TPM) is a management system, that consists of various tools and principles, which were originally invented in Japan (Ohno 1988). The key goal of TPM is to achieve a reliable manufacturing system by maximizing efficiency of equipment, improving quality of goods and increasing overall plant productivity. To maximize production equipment's overall efficiency, TPM strives to involve all levels of the organization and to include employees from all different departments in the process (EPA 2003). TPM is based on tools, such as SMED, a clean and safe

environment and 5S, as well as scheduled, quality and autonomous maintenance (Chiarini 2014). Autonomous maintenance is one of the key functions of TPM, which teaches employees to take care of their equipment and machines (EPA 2003).

Further practices that TPM focus on include preventative maintenance, equipment troubleshooting, corrective maintenance, maintenance prevention and breakdown maintenance. The purpose of these policies is to prevent equipment failures, eliminate potential equipment malfunctions and defective products, design and install equipment that requires little or no maintenance, and repair defective equipment fast after failures. (EPA 2003) As TPM was developed with the goal to reduce machine downtime by focusing on failures, general TPM activities include accurate maintenance of machines, including, for example, regular maintenance, inspections and cleaning of equipment and also replacing critical parts of the machines when necessary. TPM is managed at two levels; autonomous maintenance and an engineering level. At the basic level, general cleaning and basic maintenance of machines is performed. At the second level, fault frequency data is collected for developing and installing an effective preventive maintenance program. (Chiarini 2014) With proactive and preventative maintenance strategies, TPM aims to achieve zero equipment failures and minimize defective products. Through these functions, with more efficient use of production resources and plant capacity, TPM can significantly improve the overall effectiveness of equipment (EPA 2003; Thanki et al. 2016).

Cellular manufacturing

Cellular manufacturing groups machines, workplaces, and personnel dedicated to similar products together in one cell, compared to being located in different parts of the factory. In order to save space and time, the tools and machines are put in a specific U-shape close to each other. (Chiarini 2014; Cherrafi et al. 2018) With machines being are arranged in a strict U-shape, it enables single-piece flow and multi-machine operation (Womack & Jones 1996). This also automatically reduces both the time required to process the materials and the transport distances. (Chiarini 2014; Cherrafi et al. 2018).

Instead of processing several parts before sending them to the next process step, the goal of cellular production is to move products from the manufacturing process one part at a time and rate of

customer demand ("pull"). Cellular production reduces uncertain forecasting and associated unnecessary waste with increased flexibility and faster response time to different customer demands. Cell manufacturing is closely related to JIT production, as the layout of cell production typically serves as a prerequisite for JIT. JIT takes advantage of the layout with the goal of achieving significant reductions in inventory levels and work processes (EPA 2003).

JIT and "Pull" production

Just-In-Time (JIT) is a production system, which was developed in the mid 1950's for Toyota by Ohno. Ohno (1988) explained JIT as having the correct number of right parts at the right time. Thus, JIT produces only products that their customers demand in the correct quantity and time they request (Womack & Jones 1996). JIT philosophy's objective is to eliminate waste from the supply chain by delivering materials and producing goods just in the right time when needed and usually is small batches. The aim of the JIT is to reduce lead time and create a functioning flow between production processes by distributing production evenly. JIT also simplifies processes by eliminating excess inventory and reduce lot sizes. A number of firms that have implemented lean thinking also demand their suppliers to supply materials and goods according to JIT principles, for example, by informing suppliers when more of a particular component is needed, resulting in reduced inventory, packaging and overproduction. (EPA 2003)

As the goal of lean is to "get it right the first time" (Rothenberg 2001), JIT supports this by aiming to always have the correct number of right parts at the right time with low inventory levels. According to Ugarte et al. (2016), a JIT system refers to a synchronized flow of goods from supplier to buyer, where only the necessary number of materials and end products are pulled to where and when they are needed to meet consumer demand. Therefore, closely related to JIT, lean focuses on a "pull" production instead of "push". A pull production eliminates all sources of waste with controlling the flow and replacing only the lacking or consumed goods. Womack and Jones (1996) describe pull as "don't make anything until it is needed, then make it very quickly." Instead of forecasting market demand, lean focuses and responds in real time to customer orders. In comparison, a push method is based on demand forecasts, whereas a pull management is triggered by actual customer demand. To achieve this, lean shifts managers' focus from optimizing different technologies, activities and assets to optimize the flow of goods throughout the entire value stream. (Carvalho et al. 2017)

VSM & GVSM

A value stream includes all activities that participate in the production flow from raw materials to end user and from product design to launch (Rother & Shook 2003). Value stream mapping (VSM) is a visual method that aims to describe, identify, and measure waste caused by, for example, the inability, inefficiency, and unreliability of time, machinery, people, money, information, space, tools, and materials under manufacturing processes (Cherrafi et al. 2018). The VSM technique helps to understand the value flow of materials, goods and information by following the entire path from customer to supplier and visualizing the process. Drawing a map of the process flow visualizes the critical process steps where the value is added or not added, which can help improve the value and efficiency of the value stream. (Rother & Shook 2003) VSM is based on the assumption that examining the value stream over time reveals latent defects, errors, and quality problems, and identifying and developing these issues can result with improved supply chain performance with better cost-effectiveness and efficiency (Simons & Mason 2003).

VSM is an important lean tool in achieving sustainable and continuous improvement in lean supply chains. As a lean supply chain aims to identify and reduce all non-value-adding activities, the VSM identifies the difference between unnecessary wasteful activities and important value-adding activities. (Wee & Wu 2009) Thus, VSM can be used to efficiently illustrate the flow of materials and information through supply chains from supplier to customer. In addition to the material flows, a Green Value Stream Map (GVSM) extends the VSM tool to include also the flows of energy and wastes. GVSM can be used to monitor energy flows through systems to reduce unnecessary energy consumption (Torielli et al. 2011). GSVM is an effective way to improve green performance by identifying opportunities for improvement and allocating resources (Belhadi et al. 2018).

SMED

Single-Minute Exchange of Dies (SMED) is a lean method developed in Japan. The goal of SMED is to reduce setup times to a single digit or for less than 10 minutes. This can be achieved by converting internal functions, which are performed only when the machine is switched off, to external functions, which can be performed while the machine is still running. SMED enables the firm to efficiently and quickly transfer from one product to another in the production process. SMED is one

of the most popular lean tools designed to reduce waste. It was originally invented in to meet the requests for smaller batch sizes needed to achieve the required flexibility and satisfy changing customer demand. (Ulutas 2011; Chiarini 2014)

Since the aim of SMED is to organize and adjust machine replacement functions more efficiently, the tool helps firms to shorten installation times. SMED reduces significantly the time required for to complete a device replacement, as the aim is to reduce setup time to minutes. Shorter changeover times can allow better production flexibility and increased machine use with a larger product range and product replacements. It also allows better responsiveness to customer demand, as smaller batch sizes allow higher flexibility. (Ulutas 2011) As the use of SMED can save time at user and machine level, it can help to minimize storage, transport, movement and waiting during installation work (Leme et al. 2018). A practical example of the use of SMED is how Formula 1 pit stops are handled; to minimize time, everyone has their own specific work task and all the necessary equipment are already on display.

3.4. Lean Supply and benefits of Lean in SCM

Lean practices have huge potential to become a core competency not only for the firm but also for the entire supply chain (Jakhar et al. 2018). Firms have increasingly adopted lean practices across their supply chains with the aim to identify and reduce waste (Ugarte et al. 2016). Shah & Ward (2007) support the fact that lean thinking can be efficiently adapted into supply chain management. In addition to waste reduction, lean practices have been extended to SCM to improve quality, reduce costs and increase flexibility throughout supply chains (Inman and Green 2018). Reichhart & Holweg (2007) define a lean supply chain or lean distribution as “minimizing waste in the downstream supply chain, while making the right product available to the end customer at the right time and location”. Whereas traditional SCM tolerates inefficiencies and has high inventory levels, the application of lean thinking to supply chains seeks to maximize flow and eliminate all inefficiencies and waste. Lean thinking provides a way for firms to enhance their supply chain management with greater flexibility and simplicity by reducing reliance on demand forecasts. (Alvim & Oliveira 2020). A lean supply chain is capable of fast deliveries with minimum waste, high flexibility and quality and low inventory levels through the use of lean practices and tools (Al-Aomar & Weriakat 2012). Applying lean initiatives to supply chains optimizes all activities and functions

involved in the product's journey from sourcing raw materials to ordering, transportation and delivery to the end customer (Duarte & Machado 2017).

Shah & Ward (2007) listed characteristics of lean supply, including

- Supplier feedback
- JIT delivery
- Supplier development
- Customer and employee involvement
- Pull
- Continuous flow
- Total productive maintenance
- Set-up time reduction

The goal of lean SCM is to reduce waste and costs while increasing flexibility and quality across all supply chains. (Womack & Jones 1996; Martínez-Jurado & Moyano-Fuentes 2014). Corbett & Klassen (2006) also discuss that lean supply chain management eliminates all waste through supply chain operations with the goal of enhancing the level of customer service, improving quality and reducing costs. Thus, a lean supply chain can improve efficiency and provide competitive advantage for firms by eliminating non-value adding activities from supply chains and saving money from unnecessary investments. (Engin et al. 2019) As adapting lean to SCM aims to eliminate waste, enhance quality, flexibility and customer service and reduce costs throughout the supply chain (Cherrafi et al. 2018), practicing lean can offer great improvements in transport utilization and transportation cost reduction (Friedman 2008). Wu's (2013) research supports the fact that in long term, lean suppliers reduce logistic costs in comparison to non-supplier firms.

Lean practices involved in the adaptation process of lean thinking to supply chains include, for example, JIT, cellular manufacturing, TPM, VSM and 5S. Additionally, supplier evaluation and developing close and long-term supplier-customer relationships are important initiatives in lean supply. (Duarte & Machado 2017) In general, firms have implemented lean practices across supply chains with the aim to create and provide superior value for customers, eliminate waste, enhance

quality and lower costs (Womack & Jones, 1996; Sony 2019). Mollenkopf et al. (2010) found that lean supply chains require large amounts of information sharing, low transaction costs and rapid improvements with suppliers. Instead of seeking to improve individual actors of the supply chain, lean focuses on the firm's entire supply chain with a process-centered approach. Lean always strives for the best possible outcome, in which case partial or not-fully-optimized solutions are not a valid option (Simons & Mason 2003).

Lean logistics is generally based on a JIT delivery system, where the delivery batches are small with high shipment frequency often underloading delivery vehicles. In its essence, a JIT system delivers raw materials and finished goods at the exact time they are necessary. This can lead to poor and inefficient transport utilization. However, implementing lean techniques to supply chains can provide a number of benefits on the long run. With JIT delivery, lean suppliers require minimal inventory of finished products. Lean suppliers can improve on-time staging performance and reduce the expedited outbound shipments. In order to successfully implement and use a JIT system, it is important that the manufacturers are able to control the inbound transportations. (Wu 2013)

Alvim & Oliveira (2020) recognized five main features of lean logistics including (1) customer demand-orientation, (2) timely, accurate and quick, (3) cutting down costs ja increasing efficiency, (4) systematic integration and (5) informatization. In lean logistics, production is pulled by actual demand from customers, which also work as a starting point of value. Timely, accurate, and fast refer to the timely production of materials based on accurate data, warehousing, customer demand forecast, and delivery volume with a quick response to demand and cargo transfer rate. Lean supply also emphasizes the efficient allocation of resources by sharing benefits, information, and services. Informatization refers to modern logistics, where the rapid flow of electronic information can ensure fast and efficient deliveries.

Lean eliminates all types of waste throughout supply chains through proper management of supply, internal operations and demand (Inman and Green 2018). Lean aims for all production activities to work with maximum efficiency and reduced down time. Lower run times and improved cycle productions naturally lead to more efficient use of resources and reduction in costs. Lean processes help the extended supply chains to achieve the same level in customer demand and production capacity by efficient use of raw materials and energy and manufacturing line optimization. Lean also

supports supplier-retailer collaboration. (Friedman 2008) Hajmohammad et al. (2013) discuss that in order for the firm to reap the potential advantages of lean, the lean practices should be spread across the entire supply chain, from placing the order with suppliers, to distribution of goods and delivery to consumers. Close collaboration with key suppliers ensures that deliveries are on time (Friedman 2008). Thus, a key factor for achieving successful lean supply chains is open communication and developing and maintaining close relationships with suppliers (Simpson & Power 2005). Through close supplier relationships and collaboration, lean SCM can be associated with improved waste management practices and lower emissions (Caldera et al. 2017). Lean supply practices also reduce production cycles, time and costs (Friedman 2008). With the goal of increasing efficiency at lower costs and time, lean SCM considers it important that all partners involved participate in continuous improvement practices (Rothenberg et al. 2001). Supporting this, Simpson and Power (2005) also emphasize the importance of employee participation in lean thinking. Alvim & Oliveira (2020) argue that the main reason why firms have not implemented lean or have not successfully adopted lean in their supply chains is lack of sufficient knowledge of lean practices and concepts. However, the benefits of lean may motivate managers to consider expanding their business models to incorporate principles of lean.

Lean practices can make the distances between supply chain partners shorter. However, in present global marketplace, as global supply chains need to move large volumes of cargo over longer distances, this increases the consumption of fuel and emission levels thus having a negative impact on green performance. (Carvalho et al. 2017) Geographical concentration promotes supplier development close to the manufacturer. The practice supports production in small batches, which increases the frequency of deliveries and reduces the number of suppliers required. In addition to increasing trust across supply chains, it can improve volume and diversity of suppliers and reduce inventory levels and lead times (Azevedo et al. 2012; Carvalho et al. 2017). However, this practice can negatively affect the firm's financial performance, as in general, broader and global sourcing strategies offer lower costs and better quality due to more competition (Carvalho et al. 2017). Overall, lean supply practices can help to improve sustainability by cooperating with all stakeholders involved and taking into account environmental criteria in the selection of suppliers (Inman and Green 2018). Thus, Lean SCM can also be seen as a strategy to improve sustainable performance by preventing pollution and waste and reducing lead time (Martínez-Jurado & Moyano-Fuentes 2014; Huo et al. 2019).

4. LEAN AND GREEN

Lean thinking has been widely associated with environmental sustainability (Martínez-Jurado & Moyano-Fuentes 2014). According to Friedman (2008), *"when lean goes green, everybody wins".* Supporting this, there are studies that have studied the link between lean and green (e.g. Florida 1996; King & Lenox 2001; Rothenberg et al. 2001; Bergmiller & McCright 2009a; Franchetti et al. 2009; Mollenkopf et al. 2010; Carvalho et al. 2011 & 2017; Yang et al. 2011; Jabbour et al. 2013; Duarte & Cruz-Machado 2013 & 2017; Dües et al. 2013; Martínez-Jurado & Moyano-Fuentes 2014; Wiese et al. 2015; Fahimnia et al. 2015; Piercy & Rich 2015; Campos & Vazquez-Brust 2016; Caldera et al. 2017; Garza-Reyes et al. 2018; Belhadi et al. 2018; Zhan et al. 2018; Thanki & Thakkar 2018; Leme et al. 2018; Jakhar et al. 2018; Cherrafi et al. 2018; Inman and Green 2018; Dey et al. 2019; Dieste et al. 2019; Hussain et al. 2019; Singh et al. 2020). EPA (2003) acknowledged the synergy between lean and green in its report, highlighting lean's potential in improving environmental performance. According to Caldera et al. (2017), an integrated lean and green approach can offer a significant opportunity to improve firm performance and sustainability. Franchetti et al. (2009) discuss that lean practices can be used to support environmental thinking and a way to achieve the firm's green goals. Bergmiller & McCright (2009a) agree that there can be recognized similar motives behind the theoretical models of green and lean thinking. Carvalho's et al. (2011) study focused on firms operating with green and lean practices. According to their research, while green and lean practices have some different drivers and approaches, they can also work well together and even appear synergistic. This connection between lean and green is supported by e.g. Florida (1996), King & Lenox (2001), Yang et al. (2011), Piercy & Rich (2015), Campos & Vazquez-Brust (2016) and Carvalho et al. (2017).

More recently, Inman and Green (2018) studied the effects of lean and green SCM practices on firm's environmental and overall performance and found that lean practices can be positively associated with green SCM practices, while Zhan et al. (2018) identified a win-win relationship between green and lean practices. Among others, Garza-Reyes et al. (2018) and Hussain et al. (2019) also identified lean tools and practices that can contribute to environmental sustainability. Jakhar et al. (2018) found a significant connection between lean thinking and sustainable supplier selection, whereas Belhadi's et al. (2018) case study showed great benefits from lean practices on firm's green performance. Findings from Hussain's et al. (2019) research also showed that the

impacts of lean and green complement one another and can benefit both economic and green performance of supply chains. Supporting these, Dey (2019) also argues that lean has a positive impact on firm's environmental sustainability. Dieste et al. (2019) recently carried out a systematic literature review on the effects of lean on firm's green performance. According to their research, the vast majority of studies (83%) showed that lean has positive impacts on green performance, whereas 14% had mixed results with both positive and negative green impacts, and only 4% of studies argued that lean has negative impacts on firm's greenness.

Essentially, lean strives to create superior quality and value for customers by minimizing waste, inventory and delivery times while increasing efficiency and productivity (Wahab et al. 2013). Thus, Dües et al. (2013) argues, *"It is rather undeniable that the ultimate Lean will be Green".* As the goals of lean thinking can provide support for achieving the firm's green goals (Bergmiller & McCright 2009a; Dües et al. 2013), firms have implemented both green and lean thinking to achieve more efficient and environmentally sound operations (Zhan et al. 2018). Fliedner (2008) further discusses how lean thinking leads to green thinking. Practicing the main principles of lean imperceptibly can result with enhanced environmental performance as a byproduct. As lean production generally requires lower inventory levels, aims to eliminate waste and produce fewer defects, these principles result with lower energy consumption and reduced amount of hazardous and harmful waste. Furthermore, lean thinking improves the reliability in product quality with simple product designs increasing the lifespan of products. With additional support for green thinking, lean also focuses on low resource requirements, types of materials and different product parts making recycling easier.

Inspired by the five steps of lean thinking, Pampanelli et al. (2014) proposed an integrated Lean and Green five-step model designed to reduce waste, improve production flow and performance by using a kaizen approach. The model combines lean thinking and green thinking by introducing environmental concerns to the five basic principles of lean introduced by Womack & Jones (1996). The model is presented in Figure 11**.** The model emphasizes, that a lean environment serves as a good basis for implementing the Lean & Green model, thus supporting Dües's et al. (2013) and Garza-Reyes's et al. (2018) arguments that lean works as a catalyst towards better environmental sustainability and supports the implementation of different green practices.

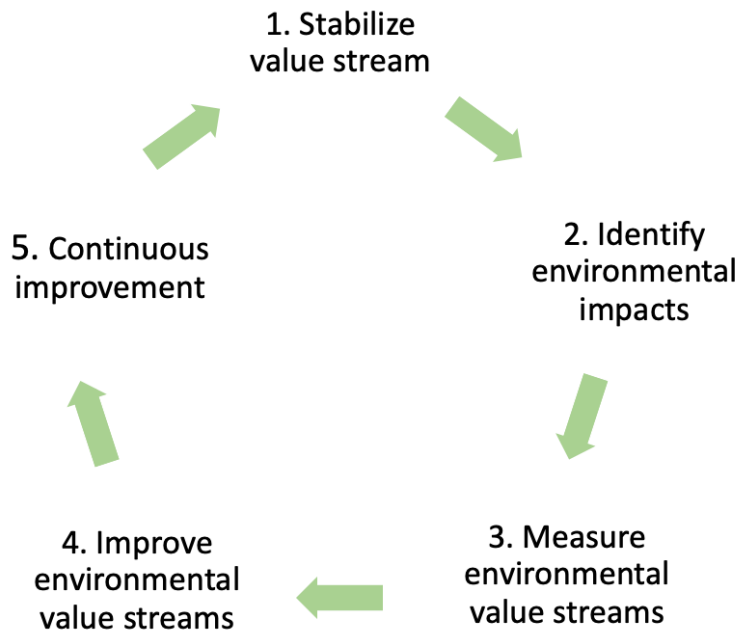

Figure 11. The Lean and Green Model (adapted from Pampanelli et al. 2014)

The first step is to recognize the need for improvement and identify a suitable operational cell that is generally resource-intensive and has a stable production flow. Next, the environmental impacts of cell inputs and outputs are identified. The third phase identifies and collects environmental data and maps the cell's current processes to measure the cell's environmental flows. Next, areas of waste elimination are identified, and key flows are prioritized by conducting kaizen workshops. Finally, the identified actions and communication are developed using the principle of continuous improvement. By implementing the presented model, both production and green advantages were identified. Optimizing the flows of material and energy consumption as well as waste generation can lead to improvements in the productivity of production process resources. Other identified benefits were reduction in costs, environmental impacts and environmental wastes. However, the model comes with advance requests and limitations. It is limited to the manufacturing cell level and requires, for example, human participation, stable processes, supportive managers and a sufficient number of implemented lean tools. As the model is initially implemented at cellular level, it could also be applied to plant-level production processes and even extended to the upstream and downstream supply chains. (Pampanelli et al. 2014)

In general, more and more firms are using various eco-efficiency indicators with a “doing more with less” principle (Leme et al. 2018). Considering this, Leme et al. (2018) proposed a theoretical Lean-Green model of eco-efficiency, consisting of three different phases, moving from lean to green and from there to eco-efficiency. The first step involves identifying and timing setup activities and waste based on the SMED tool. Next, the green phase calculates the carbon footprint of the devices used during the setup process from a life cycle perspective. The results of the model are then combined with various eco-efficiency measures and proposals for cleaner production can be made. According to Leme’s et al. (2018) case study, applying the Lean-Green model led to significant reductions in setup times as well as carbon footprint, among other green benefits.

Overall, most research on the integration of lean and green seem to agree on the mutual and reciprocal advantages of combining lean and green strategies (Fercoq et al. 2016) and on the fact that lean and green practices can benefit from each other (Wu et al. 2015). The goal of integrating lean and green practices is to increase resource efficiency and the use of recycled and reused materials, while minimizing lead times, inventory levels, energy consumption and all waste (Azevedo et al. 2012). In their well-cited study, King & Lenox (2001) explained the efficient integration of lean and green by proposing, that lean systems make it easier for firms to identify opportunities for sustainable development by spreading awareness with employees and increasing the flow of information. Supporting these, research conducted by EPA (2013) stated that overall, lean can provide a well-functioning and favorable environment to minimize waste and prevent pollutions, thus improving green performance. In general, both initiatives can also be applied to a variety of industries, both industrial and service (Duarte & Machado 2017).

However, there are also some mixed results on the impacts of lean on green performance (Dües et al. 2013; Huo et al. 2019). Next, the benefits of combining lean and green are described, followed by identifying overlapping lean-green practices, green benefits of specific lean practices and recognizing potential conflicts and tradeoffs between the two initiatives.

4.1. Combining Lean and Green and benefits of the Integration

To simultaneously improve the firm's operational and green performance, some organizations have explored the combination of lean and green. The lean-green integration can offer significant benefits to firms. By identifying and minimizing all unnecessary steps, processes, and resources that generate waste in day-to-day activities, the firm can achieve significant cost savings in firm operations and supply chains. Implementing both lean and green thinking to business operations and management strategy can also provide huge competitive advantages for the firm with both green and operational performance improvements. (Wiese et al. 2015; Inman & Green 2018; Engin et al. 2019) According to Torielli et al. (2011), by working together, green and lean have the potential to significantly improve the efficiency of the entire firm and its suppliers. Vinodh et al. (2011) also discuss that lean promotes significant environmental benefits and Duarte & Machado (2017) argue that mutually supportive lean and green practices can be identified. Supporting these, both Zhan et al. (2018) and Hussain et al. (2019) found a connection between the firm's environmental and economic performance and implementing both green and lean practices. Green can be considered a natural extension of lean, as a number of lean practices are green without a clear intention to be green (Dües et al. 2013).

Klassen & McLaughlin (1996) also recognized a causal link between green and lean by identifying a clear positive impact on market valuation from engaging in environmentally friendly and lean practices. Firms can gain significant competitive advantage with lean thinking by identifying and eliminating non-value-adding resources and processes from supply chains and production without compromising quality factors (Engin et al. 2019). According to study by Inman & Green (2018), although huge improvements in operational performance can be observed with lean practices alone, the overall impact of lean practices on green performance is small. However, by combining lean and green practices, significant improvements in green performance can be observed in addition to a higher level of operational performance. Khodeir & Othman (2018) also argue that lean practices have a clear role, either intentionally or unnoticed, in positively influencing environmental sustainability. Research by Bergmiller and McCright (2009b) provides support that the combination of lean and green can offer better results compared to firms that only implement lean practices and Dües et al. (2013) agree that successful integration of lean and green improves overall firm performance.

According to Campos & Vazquez-Brust (2016), waste reduction can be considered a key practice leading to the integration of lean and green. Thus, a clear synergy can be identified between lean and green thinking in terms of similar goals for eliminating waste and enhancing efficiency (Yang et al. 2011). Both initiatives also emphasize resource efficiency and the waste identification process (Bergmiller & McCright 2009b) and aim to extend product life and improve process efficiency to reduce waste (Dües et al. 2013). Jabbour's et al. (2013) study supports the "*lean is green*" statement by identifying a positive connection between lean and environmental management practices and research by Yang et al. (2011) found that knowledge and experience gained by practicing lean thinking can be positively associated and highly relevant for environmental thinking. Dües et al. (2013) described the synergy of lean and green with the equation "1 + 1 = 3", referring to the fact that the combination of the two practices leads to superior results than either initiative could achieve by itself. King & Lenox's (2001) research supports the argument that lean thinking can improve environmental performance. According to their study, practicing lean can support green thinking by lowering the marginal cost of reducing environmental pollutions. As lean production aims for efficiency, reduced inventory and waste elimination, it results with lower consumption of energy, materials and water. These actions also reduce pollution levels (King & Lenox 2001; Corbett & Klassen 2006).

According to Mollenkopf's et al. (2010) extensive literature review, the practices used by the lean and green strategies are interrelated and that practicing lean supports green thinking. Thus, lean firms can improve their environmental performance through efficient management practices including minimization of waste and reduction of material costs while enhancing production efficiency, quality and customer value. Further benefits of integrating lean and green practices are reduced lead time and costs, better process flow and better relationships with suppliers, customers and other stakeholders. Additionally, enhanced green performance, worker morale and commitment are recognized advantages. (Cherrafi et al. 2018) Miller's et al. (2010) study suggests that by practicing lean, the firm can avoid both overproduction and underproduction, which reduces unnecessary energy consumption. Piercy & Rich (2015) also identified many benefits of lean and green, including more efficient use of resources, better quality leading to fewer defects and better occupational safety through employee training and visual management. In addition, improving information sharing with suppliers and customers will lead to a reduction in unnecessary inventory as well as transport.

When a firm decides to implement lean thinking to its strategy, specific lean practices and tools are introduced that aim for the reduction of the seven mudas introduced by Ohno (Womack & Jones 1996). Linked with each of these seven deadly wastes, there can also be recognized clear environmental impacts, see Table 3. For example, excess inventory increases energy consumption (Franchetti et al. 2009), while both defects and overproduction increase consumption of raw materials. The cornerstone of lean thinking is to reduce these seven wastes, all of which have negative impacts on the environment. Therefore, the green performance of the firm will almost inevitably improve as these wastes are reduced (Azevedo et al. 2011; Yang et al. 2011; Campos & Vazquez-Brust 2016).

Table 3. Environmental impacts of the seven deadly mudas (adapted from EPA 2003)

Muda	Environmental impacts
Overproduction	• Raw materials and energy consumed in the manufacture of unnecessary products • Excess amount of defects • Unnecessary products may become obsolete and need to be disposed • Potential increases in substances and emissions • Safety concerns caused by hazardous substances
Waiting	• Possible contamination of materials or damage to components causes waste • Wasted energy from waiting and production downtime • Customers and operatives waiting with delayed deliveries and production • Delayed payments for suppliers • Production processes waiting for materials or parts to be delivered
Transportation	• Increased energy use and emissions from transport • More space and packaging required • Increased risk of harmful leaks or spillage with hazardous freight • Sending back unsold goods to the warehouse • Increased order times with distant suppliers
Overprocessing	• Unnecessary processing increases energy use, waste and emissions • More parts and materials consumed per unit • Potentially dangerous processing
Defects	• Wasted raw materials and energy from producing defects • Defective parts require recycling or disposal • Additional space for reprocessing and repair leads to increased energy use • Producing potentially dangerous products • Products not meeting customer demands • Products shipped to wrong locations
Unnecessary inventory	• Increased energy consumption for storage space • More packaging, materials and waste from work-in-process • Products can go out-of-date before selling or usage • The possibility of contamination of products before sale
Unnecessary Motion	• Workers searching for inconveniently located materials, tools and equipment • Unnecessary packaging, transportation and movement increases emissions, energy use and waste with additional investments • Insufficient stock supply

Additional identified benefits of lean and green include reductions in inventory, overcapacity, transportation and production times, in addition to improved integration of information sharing across supply chains (Cherrafi et al. 2018). Campos & Vazquez-Brust (2016) also identified benefits of the lean and green synergy, including less overproduction and lower number of defects, less improper handling and reductions in packaging waste, pollutions and harmful materials. A successful combination of lean and green can enable firms to reduce the risk of not complying with green regulations and to find out excellent ways to enhance both business and environmental performance (Vinodh et al. 2011). By concurrently adapting lean and green practices, firms can improve operational efficiency and achieve significant cost savings (Al-Aomar & Weriakat 2012; Miller et al. 2010). Khodeir & Othman (2018) and Huo et al. (2019) agree, that to achieve the best results and benefits, instead of separately implementing the practices, green and lean should be implemented in supply chains at the same time.

There are also several real-life business examples that show that lean thinking can support the firm in achieving its green goals (Martínez-Jurado & Moyano-Fuentes 2014). As a globally successful lean firm, Toyota has effectively combined green and lean thinking with its supply chain strategy. Toyota demonstrates its commitment and support to sustainable development and responsible business through certifications and by investing in and supporting environmental research (Mollenkopf et al. 2010). Moreover, WalMart, General Motors, Andersen Corporation and Intel are examples of firms that successfully practice green and lean thinking in their supply chain operations (Engin et al. 2019). The Boeing Co also noticed huge improvements in productivity as well as green performance from implementing lean practices (Franchetti et al. 2009). As a practical example, WalMart has successfully combined lean and green thinking by reducing the height and space of their store buildings, leading to lower energy consumption (Fliedner 2008).

Overall, lean and green can be seen as highly compatible initiatives (Piercy & Rich 2015). Lean thinking aims for efficient and sustainable production while showing benefits in both environmental and economical business aspects (Caldera et al. 2017). There can also be recognized a number of specific lean tools and practices, that can support the firm’s green goals and enhance the environmental performance of firms (Mollenkopf et al. 2010; Chiarini 2014; Garza-Reyes et al. 2018). These lean practices are next explored.

4.2. Lean tools & practices that have green benefits

Despite the fact that the original purpose of applying lean tools and techniques was to increase leanness, a number of these practices lead to waste reduction, indirectly leading to better green performance (Franchetti et al. 2009). Garza-Reyes et al. (2018) identified specific lean tools that contribute to environmental performance. According to their study, the most important lean methods were TPM, JIT and kaizen, that had a positive impact on green performance, from which TPM and JIT had the strongest effects. In general, the green benefits of these practices are mainly due to reduced inventory, overcapacity, transportation times, and production times (Cherrafi et al. 2018). Findings from Chiarini's (2014) and Hussain's et al. (2019) study support the fact that TPM has a positive impact on environmental performance while Thanki's et al. (2016) research recognized TPM as the most influential lean practice with improvements in quality and effectiveness and reduction in waste and costs. TPM can be used to reduce potential failures that occur on different machines and equipment. In addition, TPM can prevent the leakage of hazardous substances and reduce dust and smoke emissions. (Chiarini 2014)

With effective autonomous maintenance, TPM can promote earlier detection of possible issues or leaks, thus reducing unnecessary energy and water consumption (Belhadi et al. 2018). Thus, TPM can be associated with improving equipment reliability and durability while reducing potential spillage and poor conditions, resulting in less waste (Fliedner 2008). With TPM, by shutting down energy use in cells and in devices in general, the firm can also reduce non-value-adding standby energy use (Chiarini 2014; Garza-Reyes et al. 2018; Belhadi et al. 2018). In addition to lower energy consumption, TPM can significantly contribute to use of materials and reduce pollutions. TPM's positive influence on the use of materials can be explained by the fact that when the production equipment is better available and in excellent working conditions, they process materials more efficiently (Belhadi et al. 2018; Garza-Reyes et al. 2018). With reduced waste levels, TPM can provide efficient device management, which reduces unexpected failures and potential human errors, which in turn often lead to unnecessary loss in raw materials (Garza-Reyes et al. 2018). As TPM aims to extend the life of equipment, it reduces the need for replacement machinery and equipment and thus reduces the associated negative environmental impacts that can occur with repeated replacement activities. (Fliedner 2008)

JIT can reduce emissions with lower transportation times (Sarkis 2001). Further, Garza-Reyes et al. (2018) proposes that as JIT can improve quality with minimal inventory levels, it helps to detect possible issues or problems. Hereby, JIT reduces the number of required materials and other resources, such as electricity and fuel with smaller delivery patches. With reduced inventory levels, JIT can also help to reduce the amount of energy needed for storage. As JIT requires smaller delivery batches, the firm can use smaller vehicles, which require less fuel consumption, resulting with lower emissions (Cherrafi et al. 2018). With efficient waste elimination, the inventory levels are lower, resulting with lower storage and energy requirements, benefitting green performance. JIT has also been associated with improved resource utilization efficiency (Carvalho et al. 2017).

Kaizen ensures continuous improvement in performance, cost and quality with efficient waste and pollution elimination (Thanki et al. 2016; Caldera et al. 2017). Singh et al. (2020) also emphasizes that by focusing the kaizen efforts for efficient waste disposal, waste management and recycling operations, improved overall green performance, customer satisfaction, productivity and quality can be achieved. Thus, to achieve environmentally sustainable results, kaizen can be used as a basis for developing efficient pollution prevention and elimination programs. Implementing kaizen is not the sole responsibility of managers, but responsibility is shared with all employees in the organization. Kaizen's idea is to fully engage the intellectual capital of its employees in continuous improvement of the firm's operations. Therefore, high awareness and participation of everyone in the organization is essential in implementing the kaizen philosophy. (Soltero & Waldrip 2002) Furthermore, in order to successfully pursue kaizen, all employees in the organization should be educated and work together in line with the firm's vision (Singh et al. 2020). Kaizen helps to manage the firm's inventories, machines and other resources more efficiently, leading to less waste. Thus, kaizen can contribute to environmental performance by significantly reducing the amount of material waste and pollutions. (Soltero & Waldrip 2002; Khodeir & Othman 2018; Garza-Reyes et al. 2018; Singh et al. 2020). Hussain et al. (2019) also support kaizen's positive impact on the sustainability of supply chains.

With kaizen, gradual and small improvements will often lead to more sustainable results (Soltero & Waldrip 2002) Firms can significantly improve their green performance through kaizen and new innovative technological solutions. Green alternatives can also be made in choosing environmentally friendly materials and using renewable energy sources. Examples of technologies

and innovations that improve energy efficiency include the introduction and installation of energy-efficient machinery and equipment, improving lighting to increase the use of natural light, environmentally friendly building plans, zero-emission transportation and the use of renewable energy sources such as hydropower, wind power and solar energy. (Caldera et al. 2017). As another typical and successful lean tool, VSM can be useful for mapping all activities and processes included in the supply chain from raw materials to transportation to the end customer. After mapping this process, managers can identify the seven lean wastes along the journey (Wee & Wu 2009; Chiarini 2014). VSM can also be designed to detect various environmental impacts across the value stream (Chiarini 2014). By adding the sustainability aspect to the VSM tool, it aims to improve the green performance of supply chains to also identify environmental emissions as a source of waste across supply chains (Simons & Mason 2003).

Green VSM (GVSM) improves environmental performance by removing waste throughout supply chains, leading to better customer value and more efficient use of resources. GVSM can be used to recognize sources of green wastes, pollutions and energy and to identify unnecessary non-value-adding activities (Torielli et al. 2011; Belhadi et al. 2018). GVSM can also uncover sources of hidden wastes (Fliedner 2008). Overall, GVSM can help better control the firm's processes by taking into account both the current and future state of the firm as well as its resources, waste and activities (Duarte & Cruz-Machado 2013). By identifying unnecessary use of energy, materials and water, the consumption of these can be avoided and reduced resulting in better green performance (Belhadi et al. 2018). Additionally, with help of VSM, the firm does not necessarily have to look for new lean suppliers, but instead lean thinking can be adapted to existing suppliers, which means that green benefits can be more efficiently achieved (Fliedner 2008). VSM can also focus on transportation, with the aim of increasing efficiency and improving environmental performance of logistics, referred to as sustainable transportation value stream mapping (STVSM). By illustrating and mapping out the entire transportation process, the potential causes of waste, green issues, unnecessary travels and fuel consumptions and other inefficiencies can be visualized. After that, the firm can develop more efficient transportation processes or a strategy to improve efficiency and reduce green impacts and pollutions. (Garza-Reyes et al. 2016).

In cellular manufacturing, working locations and machines are placed very close to each other, which saves a lot of space and time, thus reducing handling time of materials and products. This

also allows unnecessary transport of materials at the factory to be significantly reduced, which greatly reduces the energy consumption of vehicles and improves green performance. (Chiarini 2014; Cherrafi et al. 2018) Fliedner (2008) discusses, that cellular manufacturing can be associated with green benefits such as reduced waste with better detection of defects, reduced energy and resources with improved changeover and smaller set-up times. Faster changeover allows for smaller batches and reduces waste and material losses (Piercy & Rich 2015). Belhadi's et al. (2018) research support that cellular manufacturing improves energy efficiency with reduced transport between places and lower need of space use. Geographical concentration with suppliers also has green advantages. As the practice reduces transport distances between actors in the supply chain, it reduces fuel consumption and, at the same time, environmentally harmful emissions. (Carvalho et al. 2017).

According to King and Lenox (2001), TPM's tool SMED adds cleaning thus removing undesired materials. By reducing set-up times, potentially, SMED could impact machine standby time and thus lower non-value adding energy use. The implementation of SMED has also been associated with significant productivity improvements, reduced cycle time and enhanced delivery performance. As SMED enables small batch size production, this results in lower inventory levels and higher productivity (Thanki et al. 2016) Belhadi et al. (2018) also identified similar benefits of SMED, such as reduced energy use from lower storage requirements and enhanced flow, improved productivity and reduced consumption of water and energy. According to Leme's et al. (2018) study, green benefits with the use of SMED include significant reductions in setup time and improvements in firm's carbon footprint, which measures the total greenhouse gas emissions caused by the firm. However, with reduced standby times, the production time of machines increases, thus the energy consumption of machines increases, which leads to a potential tradeoff situation between lean (SMED) and green (carbon footprint). On longer term, however, the overall green benefits of introducing SMED are reported to be somewhat greater compared to not using SMED. Chiarini's (2014) study also showed, that SMED had only a small influence on green performance. SMED can be integrated as part of TPM and kaizen to achieve better green benefits (Leme et al. 2018).

A number of lean practices aim to reduce inventory, such as JIT, SMED and kaizen. According to King & Lenox (2001), lean's pursuit for low inventory levels can improve the firm's environmental performance with reduced waste and emissions. Minimized inventory levels and improved quality

reduces material waste, which leads to a better level of environmental performance (Huo et al. 2019). Reducing inventory levels can also support green thinking by making it easier to identify defects and faults and thus avoiding extra consumption and waste (Rothenberg et al. 2001).

From an environmental point-of-view, Chiarini's (2014) study showed empirical evidence that after the implementation of 5S, the share of mixed waste was almost non-existent in all firms involved. Because the 5S improves the process of identifying and sorting various materials, debris, and waste, it reduces store space on production facilities and helps minimize mistakes made during waste collection. 5S can improve energy efficiency by considering which machines and equipment should be used in accordance with normal system processes (Torielli et al. 2011). With 5S, equipment, parts and materials are better organized and therefore easier to find, thus reducing the consumption of materials and harmful chemicals. Leaks can also be detected more quickly. (Fliedner 2008). According to Ohno (1988), 5S can reduce floor space in manufacturing operations, which can lower the need of energy consumption and even reduce the amount of land required. Additionally, keeping the floors and spaces tidy and clean make it easier to detect potential leaks and effectively reduce material loss. Duarte and Cruz-Machado (2013) agree that firms should adopt 5S to ensure a safer and better work environment.

According to Singh et al. (2020), through continuous improvements and efficient identification, management and elimination of wastes, lean can provide significant improvements for firms. Overall, a number of specific lean practices can be related to huge improvements in both green and operational performance. A summary of the above discussed main lean practices and tools with green benefits are presented in Table 4.

Table 4. Lean tools and practices and related benefits listed in literature

Lean practice	Benefits	Literature
Just-In-Time (JIT)	• Manage lead time and quality • Easier to detect issues with lower inventory • Reduces storage energy consumption • Smaller vehicles require less fuel • Lower transportation times reduce emissions • Better resource utilization, avoid overproduction	Sarkis (2001); Azevedo et al. (2012); Wu (2013) Hajmohammad et al. (2013); Dües et al. (2013); Campos & Vazquez-Brust 2016; Ugarte et al. (2016); Carvalho et al. (2017); Cherrafi et al. (2018); Garza-Reyes et al. (2018)
Kaizen	• Ensures and supports continuous improvement • Reduces costs and improves quality • Facilitates actions to reduce materials, waste and pollutions and water consumption • Reduces energy consumption • Minimal capital investments • Increases productivity • Improves overall performance and environmental sustainability	Rothenberg et al. (2001); Soltero & Waldrip (2002); Fliedner (2008); Vinodh et al. (2011); Pampanelli et al. (2014); Thanki et al. (2016); Garza-Reyes et al. (2016); Caldera et al. (2017); Garza-Reyes et al. (2018); Khodeir & Othman (2018); Hussain et al. (2019) Singh et al. (2020)
Value Stream Mapping (VSM) & Green VSM	• Identifies causes of wastes, green issues and unnecessary travels and fuel consumptions • Uncovers hidden non-value-adding activities • Reduces lead time • Improves efficiency and green performance • Reduces waste with less scrap & defects • Reduces energy consumption • Helps to take better control of firm processes	Simons & Mason (2003); Fliedner (2008); Torielli et al. (2011); Vinodh et al. (2011); Jasti et al. (2012); Dües et al. (2013); Duarte & Cruz-Machado (2013); Chiarini (2014); Campos & Vazquez-Brust (2016); Garza-Reyes et al. (2016; 2018); Thanki et al. (2016); Caldera et al. (2017); Belhadi et al. (2018)
Total Productive Maintenance (TPM)	• Improves energy efficiency, waste management and product quality • Reduces emissions and waste • Prevents leakage of process failures, that can cause scrap, leaks of hazardous substances • Reduces machine failures and equipment replacement frequency • Increases longevity of equipment with preventative maintenance	Fliedner (2008); Vinodh et al. (2011); Chiarini (2014); Piercy & Rich (2015); Thanki et al. (2016); Caldera et al. (2017); Garza-Reyes et al. (2018); Belhadi et al. (2018); Hussain et al. (2019)
5S	• Reduces floor space and required land space • Cleaner and safer working environment • Improves resource productivity & lead time • Improves waste management & reduces waste • Lowers energy and material consumption	Ohno (1988); Fliedner (2008); Torielli et al. (2011); Vinodh et al. (2011); Duarte and Cruz-Machado (2013); Chiarini (2014); (Piercy & Rich 2015); Thanki et al. (2016); Caldera et al. (2017); Belhadi et al. (2018)
Cellular manufacturing	• Saves space and time with lower inventory • Reduces uncertain forecasting and waste • Improves waste management and energy efficiency • Improves set-up and changeover times • Reduces energy, material and resource consumption • Improves defect detection • Reduces handling time of products and unnecessary transportation	Ohno (1988); EPA (2003); Fliedner (2008); Vinodh et al. (2011); Chiarini (2014); Caldera et al. (2017); Cherrafi et al. (2018); Belhadi et al. (2018)
Geographical concentration	• Reduces transportation distances & lead time • Lower fuel consumption and emissions • Reduces inventory levels and lead times • Increases trust across supply chains • Increases supply chain performance with volume and variety	Azevedo et al. (2012); Carvalho et al. (2017)
SMED	• Reduces set-up time and changeover time resulting in lower consumption of energy and resource use • Reduces batch sizes and overproduction • Promotes continuous flow and saves time • Reduces inventory, transport and movement • Improves delivery performance • Less machine downtime	Ulutas (2011); Chiarini (2014); Thanki et al. (2016); Leme et al. (2018); Belhadi et al. (2018); Garza-Reyes et al. (2018)

In summary, many lean practices effectively improve green performance, although some tools are more powerful than others. However, the aforementioned results and studies show clear evidence that lean and green practices can help reduce the environment impacts and improve green performance of the firm (Dües's et al. 2013; Fahimnia et al. 2015). In addition to firm operations, the green and lean practices can be expanded to also the firms' suppliers (Dey et al. 2019).

4.3. Lean and Green Supply Chains

While the global environmental situation has deteriorated significantly, attention towards lean and green supply chain management practices has grown. The increases in pollution, overflowing wastage as well as diminishing raw materials have led customers as well as firms to pay more interest to green values. The current global economy requires supply chains to be both lean and cost-effective while also while being environmentally sustainable. (Srivastava 2007; Al-Aomar & Weriakat 2012; Engin et al. 2019; Dey et al. 2019) In general, effective management of supply chains is essential for the firm's success (Sony 2019). Thus, while the trend of sustainability continues to grow, to meet the firm's financial and sustainability goals firms are expanding lean thinking practices to permeate through the whole supply chains (Friedman 2008). Lean firms are increasingly becoming aware of the importance of considering the environmental impacts of suppliers' actions (Simpson & Power 2005; Dey et al. 2019).

In the 21st century, huge trends of supply chain management have been implementing green and lean practices to supply chain processes (Mollenkopf et al. 2010; Dey et al. 2019). Among others, Inman & Green (2018) and Hussain et al. (2019) argue that a number of lean practices can be positively associated with greenness of supply chains. Firms have adopted green and lean to identify and eliminate non-value-added activities and manage supplier relationships more efficiently while also improving supply chain's environmental performance (Zhan et al. 2018). The process of achieving a green and lean supply chain can begin with initiatives such as VSM, 5S or kaizen (Duarte & Machado 2017). More and more firms are implementing lean principles to improve their sustainability and supply chain performance by reducing all non-value adding activities in the supply chains. Unnecessary waste can be found in different stages of supply chains, for example in waiting time, transport, stock, movement, excess processing and mistake detection. (Mollenkopf et al. 2010) Lean and green supply chains not only reduce waste, but also address the green demands of

stakeholders, customers and various agencies (Jasti et al. 2012). Inman & Green (2018) found that the combination of lean and green SCM practices can offer significant boosts in operational performance by reducing wastes and costs while improving the firm's financial sustainability and also in green performance by minimizing green wastes. Initially, the main goal of lean and green SCM is to improve supply chain efficiency through a variety of lean and green practices that cover both inbound and outbound logistics as well as reverse logistics (Engin et al. 2019).

Hajmohammad et al. (2013) argues that green practices, such as the ISO 14001 management system, pollution prevention programs and recycling can be positively associated with both lean and supply activities. As the ISO 14001 is used to evaluate and implement green practices, it supports reduction of waste and pollution across supply chains (Carvalho et al. 2017). Campos and Vazquez-Brust (2016) also support the adoption of the ISO 14001 certification for suppliers, because it can benefit both leanness and greenness of the firm. The ISO 14001 can also have an indirect impact on supply chain members towards greener practices (Azevedo et al. 2011).

An efficient and successfully integrated green and lean supply chain requires the adaptation of several initiatives to the organization's culture and practices. Important initiatives include strong participation, commitment and mutual trust between all involved parties, functional and safe workspaces, reduction of waste and continuous improvement and optimization of functions, resources and activities in the firm. (Dües et al. 2013; Duarte & Machado 2017) Overall, firms can gain double benefits with lean and green supply chains (Al-Aomar & Weriakat 2012). Duarte & Machado's (2017) case study of lean and green also supports that integrating both green and lean thinking to supply chains can provide benefits to firms by reaping the benefits of both initiatives. An integrated green and lean strategy increases profitability, reduces costs and improves sustainability throughout the entire supply chain (Wiese et al. 2015; Engin et al. 2019). Al-Aomar & Weriakat (2012) discuss that while some green practices may increase costs, lean can offset these costs by eliminating non-value-adding costs from supply chains. Reducing set-up times and waste elimination are also lean practices, that can have significant improvements on green performance of firms' supply chains. (Cherrafi et al. 2018).

Womach & Jones (1996) also support the fact that applying lean principles to supply chains enhances efficiency and reduces both costs and lead times. Finding an appropriate balance between

lean and green can guide the firm towards successful and sustainable supply chains. There are a number of examples of firms, that have shown great success in both economic and environmental performance by integrating both green thinking and lean practices in supply chains. For instance, a firm in the furniture industry shows a successfully balanced lean and green supply chain strategy by reusing recyclable raw materials, reducing pollutions with new technologies and eliminating unnecessary work to improve production efficiency (Mollenkopf et al. 2010). As another example, Hajmohammad et al. (2013) discuss how Walmart, a multinational retail corporation, uses a packaging scorecard to determine the packaging efficiency of their suppliers. As suppliers' packaging efficiency improves, the ecological footprint is reduced and green performance improved. The application of lean and green is not limited to a specific industry or firm sector, as lean-green initiatives can be applied to different industries and supply chains (Dües et al. 2013; Duarte & Machado 2017).

Simpson & Power (2005) also support the connection between lean and green by arguing that the leanness of the supplier firm has a positive impact on the firm's green practices. Mollenkopf et al. (2010) point out, that implementing green thinking to supply chains maximizes the firm's lean performance while Cherrafi's et al. (2018) research supports the positive influence of lean and green thinking on the environmental impacts of a firm's suppliers. Further, Hajmohammad et al. (2013) agree that implementing lean principles in supply chains results in improved environmental performance and Thanki & Thakkar (2018) argue that applying lean and green practices to supply chain management can provide significant benefits to firms, such as improvements in quality, performance, efficiency, deliveries, as well as reductions in costs, energy consumption, lead times and waste. Thus, the ultimate goal of lean and green SCM is to increase the efficiency of supply chains by eliminating non-value-adding activities with lean tools and at the same time improving the green performance of suppliers through various green practices (Al-Aomar & Weriakat 2012). According to Carvalho et al. (2011), the synergy of lean and green in SCM can provide several benefits to firms and supply chains, including lower inventory levels, improvements in transport and production times, and better information sharing between supply chain members.

Managing supplier relationships can work as a key factor and important way to influence the firm's environmentally sustainable performance (Simpson & Power 2005) and provide significant competitive and strategic advantages for organizations (Corbett & Klassen 2006). Lean and green

supply chain management can offer huge benefits from significant improvements in quality throughout supply chain functions to reduce risk and costs. (Engin et al. 2019). Applying green thinking to supply chains also involves challenges in situations where the green practices reduce suppliers' profits. For this reason, strong, close and well-functioning supplier relationships are essential to successfully implement lean and green practices (Torielli et al. 2011). According to Campos & Vazquez-Brust (2016), the suppliers and customers in the supply chains act as bridges and important communication channels between lean and green, so increasing the commitment of suppliers reinforces the lean-green synergy. By involving suppliers in the firm's ongoing improvement programs, it reduces material defects, which in turn reduces investments in recycling and waste management (Yang et al. 2011). Huo et al. (2019) argues, that involving customers in green processes and suppliers in lean processes can provide the best green performance with low costs. In lean supply, the suppliers must be able to produce and deliver the right number of materials, so it is essential that the firm has open communicates and information sharing with its suppliers (Huo et al. 2019). Simpson & Power (2005) also emphasize the importance of developing the customer-supplier relationships and sharing information between suppliers and customers in supply chains. According to Mollenkopf et al. (2010), cross-functional and inter-organizational involvement from stakeholders in both lean and green supply chain management is important. The overall influence of lean practices on green performance should be measured as a whole by taking into account all activities of the supply chain (Jakhar et al. 2018).

In general, the main focus of lean supply chains is to eliminate waste, whereas green supply chain strategies aim to reduce the negative environmental impacts of suppliers and firm activities. Reducing unnecessary non-value-adding activities from equipment, production time, space, inventories and labor across supply chains can provide firms great economic benefits and improvements in environmental performance. As lean supply requires seamless information sharing, fast and efficient supplier performance, and minimal transaction costs with reduced waste, these improvements in production can also provide a number of green benefits. Consequently, these types of successful lean supply arrangements can encourage firms to merge environmentally friendly and lean supply practices. (Mollenkopf et al. 2010) An integrated lean and green supply chain management strategy focuses on similar sustainability dimensions as the triple bottom line framework. Lean and green SCM promotes the firm's financial performance by aiming to improve productivity, taking into account the social dimension by supporting people-centered work and

considers the environmental perspective by eliminating unnecessary waste and minimizing the use of unnecessary resources. Thus, firms are more and more noticing the strong positive impacts of lean and green thinking on the firm's TBL (Engin et al. 2019).

As supply chains are increasingly becoming longer and more complex, practicing and sustaining lean thinking can become more difficult. (Mollenkopf et al. 2010) To succeed, the firm's integrated green and lean strategy must permeate all levels and departments of the firm, including all parties of the supply chain (Duarte & Cruz-Machado 2013). In addition, to ensure the effective implementation of green and lean, strong and committed leadership that moves from the top to down in the organization is essential (Zhan et al. 2018). Duarte & Machado (2017) and Singh et al. (2020) agree, that a supporting, involved and committed management is important in lean and green supply chains.

However, some barriers to the implementation of lean and green thinking in supply chains can also be identified (Mollenkopf et al. 2010). Lack of sufficient information and the ignorance of green initiatives is one of identified obstacles. Strictly lean firms do not strive for a better level of environmental performance and thus often do not take into account environmental impacts or risks. (Rothenberg et al. 2001) In addition, the general perception that green practices increase costs and require large investments and a lot of time contradicts with lean's drive for efficiency and low cost (Wills 2009*;* Huo et al. 2019). Tebini et al. (2016) examined the influence of environmental initiatives on the firm's economic performance. Their study suggests that investments in environmental performance increase costs in the short run and generate profits in the longer run. Therefore, the overall impacts of green practices on economic performance should be considered on a longer term.

Hartmann & Moeller (2014) discuss that customers traditionally view the focal firm as responsible for the entire supply chains' actions. Because unsustainable or environmentally harmful behavior of one supply chain actor may create a "chain liability effect", it is important for firms ensure that the green initiatives and sustainable behavior encompass all supply chain actors. In successfully implementing green and lean practices, the firm must change not only procedures and processes but also people's ways of thinking. It is therefore necessary to take into account the different ways of thinking and attitudes of people operating the green and lean systems. (Zhan et al. 2018) Alvim & Oliveira (2020) argue that in lean SCM, managers should take into account the product's entire

journey from the customer's order, to the order given to the raw material producer and onwards, including all actors involved in the manufacturing and delivering process of the product to the customer. By comparison, individual and separate optimization of each stage of the supply chain does not provide the desired results.

Overall, green and lean SCM practices can have significant contributions to sustainability of supply chains, with benefits such as reduced wastage and improved green image (Azevedo et al. 2012). As lean aims for continuous improvement, implementing lean practices can improve the performance of suppliers with improvements in delivered product and service quality. However, the environmental sustainability of lean supply chains does have some divergent results among researchers (Torielli et al. 2011). Lean's aim for reducing inventory can be positively associated with reductions in waste and emissions. However, it can also contribute negatively to supply and logistics related pollutions with increased transportation activities. Therefore, when implementing lean practices, managers should thoroughly consider the entire supply chain's performance as a whole and aim for reducing both costs and pollutions. (Jakhar et al. 2018). Essentially, lean aims to reduce costs and green aims to reduce pollutions by lowering the need of transportation and creating more responsive and shorter supply chains (Simons & Mason 2003; Venkat & Wakeland 2006). By combining lean and green thinking in supply chains, the supplier's operations expand to cover the journey from product design to end-of-life, and by introducing reverse logistics that manages processes from packaging to defect handling (Dües et al. 2013). Thus, a lean-green SCM strategy can offer a great opportunity to reduce the firm's carbon footprint while remaining highly competitive (Azevedo et al. 2012).

4.4. Overlap of Lean and Green

Both lean and green share the initial aim to "do more with less" (Womack & Jones 1996; Simons & Mason 2003). Hereby, lean can work as a complementary force for firms in achieving their green goals (Caldera et al. 2017). Lean and green strategies can be seen as compatible initiatives, as they share a number of similar goals, such as elimination of waste, efficient resource utilization and providing high value while minimizing costs. (Mollenkopf et al. 2010; Duarte & Cruz-Machado 2013) Additionally, a number of studies agree, that lean and green share similar goals for improvement and satisfying customer demands (Khodeir & Othman 2018). According to Piercy & Rich's (2015)

multi-year case study, lean and green have a mutual goal of continuous improvement that stems from a positive work environment. Dües et al. (2013) comment that a good and well-functioning lean environment also serves as a good stimulus and facilitator for green thinking implementation. In general, it has been recognized that lean thinking supports green practices, thus having a positive impact on the firm's environmental performance.

Bergmiller & McCright (2009a) recognized undeniable similarities between the theoretical models of lean and green and Inman & Green (2018) argue that firms that adopt lean practices are also likely to adopt green supply chain management practices. As capabilities gained through practicing lean can provide support for initiating green actions, Hajmohammad et al. (2013) discuss that lean promotes the adoption of environmental practices. Thus, lean can help firms to identify opportunities to improve sustainable performance by spreading awareness and information within the organization (King and Lenox 2001). Supporting this, Caldera et al. (2017) also propagates that green thinking can help with implementing lean thinking to the organization and Jakhar's et al. (2018) research proposed, that by applying lean practices, firms can gain sustainable advantages. Embracing both initiatives may have a win-win relationship in terms of environmental benefits and business performance (Zhan et al. 2018). While the main objective of lean thinking is to eliminate waste and provide superior value and quality for customers, green thinking aims to reduce unnecessary activities to preserve the environment for next generations (Bergmiller & McCright 2009a). Considering the fact that the goal of lean is to reduce all types of waste and environmentally sustainable practices are designed to eliminate environmental waste, Inman and Green (2018) argue that lean practices can provide support for successfully adapting green practices to the firm. Therefore, both lean and green thinking initially share similar motives to reduce waste and create value.

The key overlap between lean and green is their aim to eliminate waste (Al-Aomar & Weriakat 2012; Dües et al. 2013; Hajmohammad et al. 2013; Campos & Vazquez-Brust 2016). Dieste's et al. (2019) study also strongly supports the argument that both lean and green practices share the common focus on waste reduction. Lean and green have even been described as "parallel universes of waste reduction" by The United States Environmental Protection Agency (EPA 2003). As can be seen in Figure 12, among others, waste reduction is a mutual objective of both lean and green. Lean and

green thinking also share similar waste reduction targets, including storage, transportation, and the production of by-products or non-production (Dües et al. 2013).

Lean identifies and eliminates waste, or "muda" through continuous improvements across supply chains and business operations. Both lean and green thinking divide waste to seven different categories. Ohno (1988) divided lean's deadly waste to seven categories (*overproduction, waiting, transportation, defects, overprocessing, unnecessary inventory and* motion). (Engin et al. 2019) Inspired by the seven lean waste categories, Hines (2009) recognized green production wastes as excessive water usage, excessive power usage, excessive resource usage, pollution, rubbish, greenhouse effects and eutrophication. Additionally, "poor health and safety" can be added in some literature as an eight category (Verrier et al. 2014). Due to lean's key goal of becoming waste-free, it can be argued that lean inevitably leads to better green performance (Rothenberg et al. 2001; Hajmohammad et al. 2013).

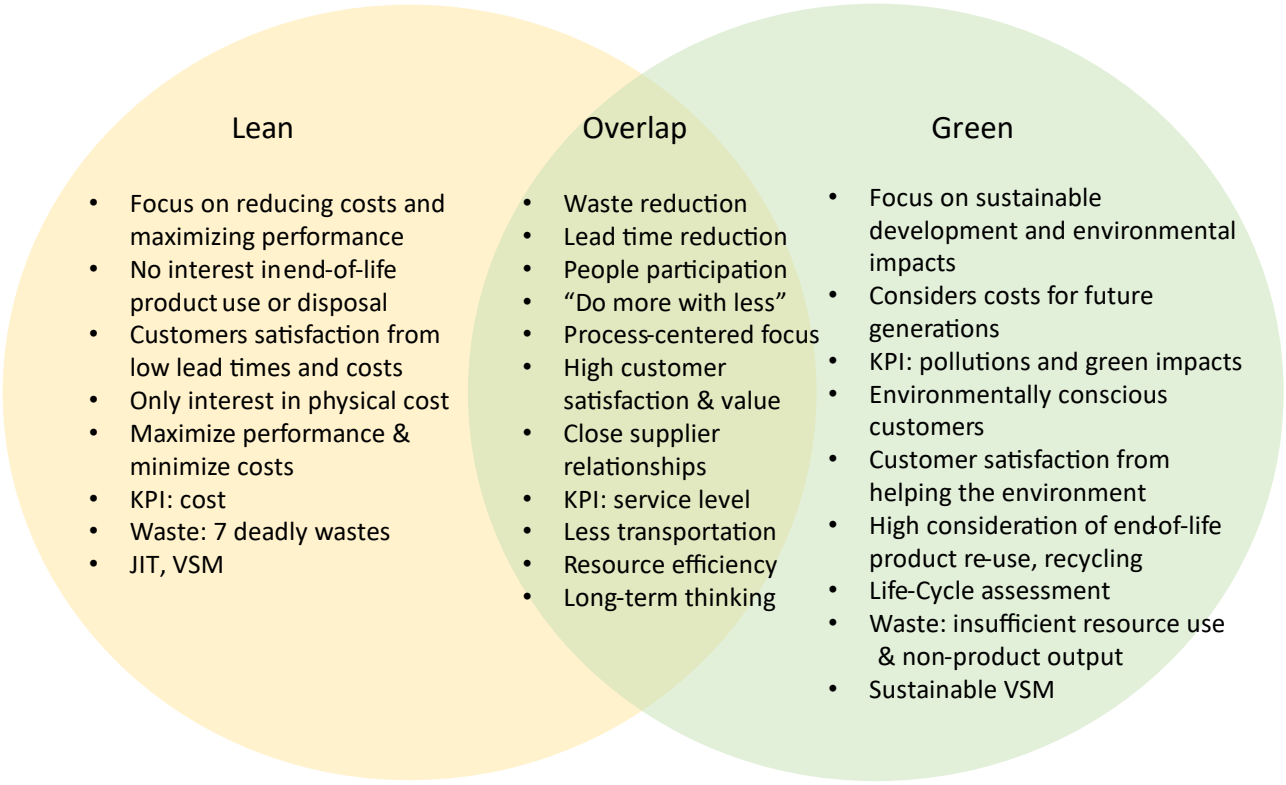

Figure 12. Overlapping attributes and goals of Lean and Green (adapted from Dües et al. 2013)

However, the initiatives view waste from slightly different perspectives. Green thinking views waste from environmentally sustainable perspective and aims to eliminate environmentally harmful and unnecessary waste and pollutions to prevent and reduce environmental impacts. On the other hand, lean aims to reduce non-value-adding resources and processes in order to provide superior value for customers. (King & Lenox 2001; Martínez-Jurado & Moyano-Fuentes 2014) However, Dües et al. (2013) argues that despite of slightly different waste disposal targets, the lean waste view can be extended to include green wastes and both initiatives can ultimately aim to reduce similar wastes. Consequently, the common goal of lean and green to eliminate waste and achieve efficiency will lead to lower emissions. (King & Lenox 2001; Martínez-Jurado & Moyano-Fuentes 2014) Piercy & Rich (2015) and Campos & Vazquez-Brust's (2016) also strongly support the fact that both lean and green practices share the objective for waste reduction. With less waste, lean benefits from better quality, productivity and reliability in addition to lower costs, whereas green benefits from reduced material and energy consumption and less pollutions (Piercy & Rich 2015).

In addition to wastage reduction, Khodeir & Othman (2018) identified other goals that lean and green share, including the effort to improve the quality of life of stakeholders and to enhance all business processes through monitoring and self-evaluating activities to continuously improve (Khodeir & Othman 2018). The pursuit for high quality can be identified as an overlapping practice between lean and green (Piercy & Rich 2015). Hajmohammad's et al. (2013) research supports the findings from Simpson & Power (2005) and Rothenberg et al. (2001). According to them, the skills and knowledge gained from the application of lean principles promote the adoption of green practices. Furthermore, lean practices can improve the effectiveness of green practices.

Both lean and green also aim to reduce the amount of required transportation, although with different end purposes. With less transportation, lean aims to save costs, while green aims to reduce emissions (Venkat & Wakeland 2006). In general, transport or movement is a commonly mentioned non-value-adding activity. Moving a product from one workstation to another does not add value to it, although it is to some extent necessary, for example to reduce the required skills of workers or to increase performance with the least possible work time due to workload sharing (Fliedner 2008). Shorter transport times lead to shorter supply chains, which in turn are able to react faster and better, thus reducing the need for transport in general, reducing pollutions and benefitting the environment (Dües et al. 2013). According to Venkat & Wakeland (2006), the mode of transport and

the frequency of transport throughout the supply chain have a major impact on emissions. Therefore, delivering large quantities at once and less frequently reduces has significant benefits to green performance of supply chains.

Dües et al. (2013) recognized further overlapping areas of green and lean including service level and supplier collaboration. Thus, another principle that a green-lean approach shares is high people participation in the implementation process by emphasizing the involvement of suppliers and customers (Rothenberg et al. 2001; Huo et al. 2019). For both lean and green practices, participation and strong involvement of all people in the organizations can be considered as an essential factor in the implementation process (Dües et al. 2013; Caldera et al. 2017; Duarte & Machado 2017; Belhadi et al. 2018). To successfully operate a green and lean organization, all workers should have clearly divided responsibilities. Martínez-Jurado & Moyano-Fuentes (2014) support this by identifying three main complementary factors with lean and green, including reduction of waste, a process-centered focus and high levels of involvement and participation from people. King & Lenox (2001) and Simons & Mason (2003) also recognized that both initiatives have a process-centered approach by focusing on the entire supply chain instead of separate actors.

High level of human involvement is a core principle in lean thinking (Womach & Jones 1996). In improving green performance, among others, Rothenberg et al. (2001), Simpson and Power (2005), Mollenkopf et al. (2010), Dües et al. (2013) and Huo et al. (2019) also emphasize the importance of employee participation at all levels of a lean and green organization. In support of this, Duarte and Cruz-Machado (2013) argue that a successful lean and green transformation requires managers to encourage people to be innovate and provide employees with appropriate training and flexible work opportunities. Involving all people in continuous improvements and in the process of identifying and eliminating lean and green wastes will support the transition towards a lean-green organization. Lean and green also share the philosophy of long-term thinking by viewing goals from a wider perspective (Dües et al. 2013; Duarte & Machado 2017).

Florida (1996) argues the environmental sustainability impacts of lean are due to close and long-term relationships, that initiate the implementation of green practices. Both Dües et al. (2013) and Campos & Vazquez-Brust (2016) support the argument, that collaboration with supply chain partners, and suppliers in particular, can be considered as a synergic lean and green practice.

Furthermore, developing trusting and long-term relationships with suppliers are essential factors for close collaboration and for achieving a successful synergy between lean and green (Campos & Vazquez-Brust 2016). Mutual understanding of environmental goals with suppliers can benefit all parties in supply chains. Cooperation with suppliers expands the environmental responsibility and reduces unnecessary freight transport, thus reducing emissions. Furthermore, a well-managed supply chain that meets the firm's green and financial requirements can usually offer better prices and better product liability. (Corbett & Klassen 2006) Simpson and Power (2005) argue that successful leanness depends on effective supply chain coordination, which is related to customer-supplier relationship management. More specifically, in order for the products, raw materials and other activities used in the production process to be environmentally friendly, green supply chain management requires close cooperation with all involved people. On the other hand, lean thinking requires similar collaboration with all actors involved in the supply chain to achieve continuous improvements (Campos & Vazquez-Brust 2016; Huo et al. 2019).

Bergmiller & McCright's (2009b) research concludes, that lean and green share similar structures and elements. Therefore, it is easier for firms that have applied lean practices to enhance their green performance compared to firms that have not implemented lean thinking. On the other hand, firms that have started by focusing on green practices such as waste identification and reduction tools to improve the environment, may again find it easier to apply lean practices and tools compared to firms that are not focused on green values. Consequently, it can be suggested that there is a synergistic and parallel relationship between lean and green. (Bergmiller & McCright 2009b) Both lean and green also emphasize energy efficiency and productivity while also aiming for minimization of waste and emissions (Inman and Green 2018). The basic objective of lean thinking is to strive for superior quality at all stages of production processes and to ensure that same mistakes are not repeated. Similarly, environmental management seeks to prevent environmental issues from occurring rather than focusing on resolving issues at the end of processes (King & Lenox 2001; Martínez-Jurado & Moyano-Fuentes 2014). Both initiatives also aim for lead time reduction aiming for shorter supply chains and reducing the need for transportation (Simons & Mason 2003; Dües et al. 2013). With a number of similar goals, lean and green can reduce costs by eliminating waste and improving sustainability, while supporting customer demand for manufacturing environmentally friendly products (Inman and Green 2018).

Together, lean and green practices can facilitate each other to work towards better sustainability, competitiveness and profitability (Wu et al. 2015). Lean and green share the same strive to reduce similar types of waste, such as stock levels, transportation and production of defects. In addition, both emphasize fast and reliable operations while maintaining a high service level and producing high quality and affordable products to customers. (Dües et al. 2013) However, despite the many overlapping goals and practices of lean and green, several scholars have identified certain tools and areas between the two initiatives, which may conflict with each other's goals and create potential tradeoffs situations. Next, these differences and conflicts are explored.

4.5. Conflicts, Differences and Tradeoffs between Lean and Green

While the combination of green and lean has shown to have a number of practices that support each other in improving the firm's sustainable performance, (Dües et al. 2013) they also have some conflicting and different practices (Rothenberg et al. 2001; Mollenkopf et al. 2010) and potential tradeoffs (Fahimnia et al. 2015). What lean considers as a resource, green can view as a limitation (Campos & Vasquez-Brust 2016). According to Carvalho's et al. (2017) research, all parties involved in the same supply chain cannot be completely lean or green. Therefore, in order to achieve the environmental and economic objectives of the supply chain, some tradeoffs may need to be made in the behavior of individual firms. As some lean principles include potentially conflicting objectives with green practices, practicing lean thinking alone may not enhance the firm's environmental performance (Yang et al. 2011).

Rothenberg et al. (2001) argues that there cannot be recognized a clear and simple win-win relationship with lean and green. While lean practices can support environmental practices and resource efficiency, some practices may conflict with green initiatives and do not address all green issues. There can be identified some compromises, that firms have to make with some lean principles in order to comply with green thinking and reduce pollutions. For example, according to Thanki et al. (2016), timely deliveries and high quality are important features of lean, while reducing emissions and energy consumption as well as other green impacts are essential for green. Angell (2001) discuss that green and quality management practices, such as lean, generally differ in their driving forces and motives. Green practices do not require formal strategic formulation process. In terms of external pressures, quality management practices primarily face customer-related

pressures, while environmental practices are more strongly driven by pressures from a variety of external sources.

The initiatives also differ from each other with their views on waste and goals of waste reduction (Dües et al. 2013; Duarte & Cruz-Machado 2013; Campos & Vazquez-Brust 2016). The goal of lean is to reduce all wastes across supply chains, whereas green concentrates on eliminating green wastes (Inman & Green 2018). Thus, Azevedo et al. (2012) argues, that one of the main differences between green and lean SCM is their goals of reducing environmental impacts (green) and eliminating wastes (lean). From an environmentally sustainable perspective, waste elimination is viewed from a long-term and broader perspective, concentrating on minimizing waste to improve the firm's green performance as a whole, not just as single process. Green initiatives seek to eliminate material wastes and harmful emissions that have a negative impact on the environment. In comparison, lean eliminates both tangible and intangible wastes with the goal of increasing efficiency, reducing costs and meeting customer requirements (Khodeir & Othman 2018).

Lean and green also view the environment from different perspectives. Lean views the environment as a resource and not a constraint (Dües et al. 2013). Whereas lean considers waste to be an activity that does not add value to the product, from green point-of-view, waste means unnecessary use of natural resources (Duarte & Cruz-Machado 2013). Waste reduction efforts for green emphasize actions such as redesign, recycling, disassembly and waste segregation and target environmental wastes due to inefficient use of resources or production of scrap (Dües et al. 2013; Campos & Vazquez-Brust 2016). On the other hand, lean views waste elimination and performance improvements more from the customer's point-of-view (Verrier et al. 2014) by aiming to minimize waste on all operational processes including overproduction, transportation, waiting, defects, production processes and excess inventory (Campos & Vazquez-Brust 2016). In conclusion, lean aims to reduce operational waste through non-value adding activities with the goal of improving efficiency and green aims to minimize environmental waste with the aim to prevent emissions and pollution (Thanki et al. 2016; Dieste et al. 2019).

Dües et al. (2013) recognized several additional differences between lean and green. In addition to viewing waste from different perspectives, the two practices have different key priorities and different KPIs (key performance indicators), a different management perspective for end-products

and different views on product design. Lean's KPI is cost, whereas green's KPI focuses on pollutions and green impacts. Furthermore, when compared to green thinking, which highly considers different re-use, recycling and disposal options in the end use of products, lean does not take into account the end-of-life use of products. Lean and green have also different customer targets; lean customers want lower costs and lower lead times, whereas green customers mainly demand for products with low environmental impacts, despite of higher costs. In product design, green aims for environmentally friendly solutions and lean aims for low costs and high efficiency. (Dües et al. 2013) A conflict between lean and green can also arise if costs increase from greener practices, leading to resistance from customers, because not everyone may want to pay more for environmentally friendly products (Campos & Vazquez-Brust 2016). Moreover, Huo et al. (2019) states that financial investments in green technology contradicts with lean's goal of minimizing all unnecessary costs.

In supply chains, both lean and green tend to have shorter lead times, but with different approaches. Lean shortens lead times until costs increase, whereas green reduces transport lead time as long as it does not increase emission levels (Dües et al. 2013). A difference and potential conflict between lean and green supplier selection process is that lean emphasizes more affordable and high-quality suppliers compared to green purchasing, which focuses on the environmental performance of suppliers (Carvalho et al. 2011; Dües et al. 2013). As more and more customers and regulations demand greener production, and at the same time firms want to remain cost-effective, firms can seek for compromises between green and lean to satisfy both firm goals and customer needs (Thanki et al. 2016). Thus, according to Duarte and Cruz-Machado (2013), firms should consider both lean and green criteria when selecting suppliers. Further, both Pampanelli et al. (2014) and Campos and Vazquez-Brust (2016) argue that lack of managerial support can create a potential barrier to lean and green synergies. Therefore, in the successful adoption of a lean and green thinking, it is important that the management team fully supports it.

According to Rothenberg's et al. (2001) study, a number of lean factories have compromised some lean principles, such as the JIT delivery system, to achieve environmental benefits and reduce pollution. The influence of JIT on environmental pollutions and on the green performance of the firm has some controversial results (Hajmohammad et al. 2013). Dieste's et al. (2019) study recognized JIT as the most conflicting lean practice in terms of its green impacts with low inventory, small batches and frequent transportation. Supporting this, among others, Venkat & Wakeland

(2006) and Al-Aomar & Weriakat (2012) argue that with a JIT delivery system, smaller batches increase packaging, handling and the frequency of transportation, which generate greater amounts of emissions. Additionally, long transport distances and a wide range of production lines can cause green conflicts with JIT logistics (Venkat & Wakeland 2006; Dieste et al. 2019). Dües et al. (2013) also support the fact that the replenishment frequency of materials and goods poses the main conflict between lean and green, while Cusumano (1994) agrees that JIT can increase environmental impacts by increasing the frequency of transportation and Rothenberg et al. (2001) support that the minimization of stock levels and batch sizes can increase the amount of generated waste and thus negatively impact the environment.

Ugarte's et al. (2016) study also found that JIT increases transport frequency and greenhouse gas emissions and Campos & Vazquez-Brust (2016) agree that having a JIT delivery system can cause conflicts between lean and green. Therefore, as JIT supports more strongly lean thinking than green, JIT can be viewed as a tradeoff practice between lean and green (Campos & Vazquez-Brust 2016). Even though larger batches would reduce emissions levels, it contradicts with the main JIT principle (Rothenberg et al. 2001). Chiarini (2014) and Carvalho et al. (2017) further agree that JIT can create conflicts between green and lean goals. While JIT reduces inventory levels, materials and products used in manufacturing, on the other hand, the frequent delivery of materials and small batches increase emissions, which impact negatively on the green performance of supply chains. Compared to lean's strict JIT delivery, a more flexible supply chain would better support green performance (Campos & Vazquez-Brust 2016).

There is some inconsistency in the empirical results on whether lean thinking improves green performance (Huo et al. 2019; Dieste et al. 2019). Whereas some lean practices seem to have positive green impacts with lower pollution and reduced energy consumption, others may increase environmental impacts. For example, the production of small batches requires replenishment and transportation more often, which raises emissions. On the other hand, low inventory levels and continuous quality improvement reduce waste and improve environmental performance. (Campos & Vazquez-Brust 2016; Huo et al. 2019) According to Dieste et al. (2019), air emissions are a main measurable difference between lean and green. As JIT has been associated with increased traffic and emissions, managers should pay attention to the efficient management of their activities when implementing JIT. Dües et al. (2013) suggest that the negative environmental impacts of JIT can be

mitigated by selecting suppliers from a specific geographic area or with sharing truckloads with small batch deliveries and supplying goods to multiple customers in the same area at the same time. Other potential ways to reduce JIT's negative green impact could be, for example, the use of reusable or environmentally friendly packaging or adjusting batch sizes to optimize deliveries (Mollenkopf et al. 2010). An additional potential conflicting lean practice is VSM, as it can work either as an incentive or disincentive for improving environmental performance. According to Campos & Vazquez-Brust (2016), if the firm already has an effective and successful VSM program, it can prevent firms from adopting green and sustainable VSM models. Additionally, as lean practices such as kaizen strive for superior quality, Rothenberg et al. (2001) argues that some production processes may require more water use and energy consumption to achieve great quality. Thus, the pursuit for high quality can potentially cause some tradeoffs between lean and green.

Fahimnia et al. (2015) studied tradeoffs between lean and green practices in supply chain management. According to their research, a flexible supply chain can provide superior green performance and efficiency compared to more centralized and strict lean supply chains. Campos & Vazquez-Brust's (2016) study supports the findings of Fahimnia's et al. (2015) study. If the firm follows lean practices too strictly and the lean philosophy guides the entire firm's strategy and vision, synergies between lean and green less likely to develop and tradeoffs between lean and green more likely emerge (Campos & Vazquez-Brust 2016). However, it is generally easier for firms that already practice lean thinking to start implementing green practices, while it may be more difficult for green firms to begin implementing lean practices (Piercy & Rich 2015).

Lean principles generally tend to shorten the distances between supply chain partners. Although the supply chain is concentrated on a specific geographical area, with global markets, raw materials can be delivered over long distances, thus increasing pollutions (Carvalho et al. 2017) Venkat & Wakeland (2006) also point out that all lean supply practices may not fully support green thinking. According to them, an important environmental factor is distance. Long and geographically wide supply chains may be lean, but not necessarily green because of the increase in emissions caused by increased transport. For example, if the lean supply chain is located in a small area, it will have a positive impact on green thinking due to low inventory levels and short transportation distances leading to lower emissions. As the distance grows, conflicts between lean and green thinking may increase and require changes in supply chains. Therefore, aiming to minimize pollution in supply

chains may require some tradeoffs between lean and green. Supply chain emissions can be reduced by choosing more efficient modes of transport, such as using full capacity modes of transport or sharing vehicles with other firms. However, in long-distance transport, this can increase transport complexity as well as make it more difficult to stay on schedule according to lean's JIT system. (Dües et al. 2013)

Huo's et al. (2019) study argues that lean practices can have a great impact on sustainability on the manufacturer-customer relation, whereas green practices influence sustainable performance more strongly on manufacturer-supplier interface. On the customer side, while lean practices can directly affect the performance of all three triple bottom elements, green processes only improved the environmental performance. On the other hand, on the supplier side, green processes were able to improve both the social and economic performance, while lean processes only influenced the economic performance.

A summary of the identified main potential tradeoffs, conflicts and differences between lean and green practices, tools and attributes in literature are presented in Table 5. These findings are important to keep in mind when considering implementing lean practices with the aim of improving green performance. Moreover, by acknowledging these potential differences and tradeoffs, firms can seek to develop measures to mitigate the identified negative impacts (Mollenkopf et al. 2010).

Table 5. Identified potential conflicts and differences between Lean and Green in literature

Practice/tool/ attribute	Tradeoff/Conflict/ Difference	Literature
JIT and small batch production	• JIT delivery requires less inventory, but transportation frequency can increase by delivering smaller batch sizes • High frequency of transportation increase emissions and pollutions from transport • With small batch sizes, packaging and handling materials increase, causing excess waste and pollution	Cusumano (1994); Venkat & Wakeland (2006); Mollenkopf et al. (2010); Al-Aomar & Weriakat (2012); Dües et al. (2013); Campos & Vazquez-Brust (2016); Ugarte et al. (2016); Carvalho et al. (2017); Huo et al. (2019); Dieste et al (2019)
Value Stream Mapping (VSM)	• A successful VSM program can work as a disincentive in adopting a green VSM model	Campos & Vazquez-Brust (2016)
Waste reduction	• Different end goals: lean eliminates waste to improve efficiency, green reduces waste to prevent emissions and pollutions • Different perspectives: lean eliminates waste from all processes and views waste as non-value-adding activity, green views waste as unnecessary use of natural resources • Lean eliminates the 7 deadly wastes,green eliminates environmental wastes with focus on green impacts	Corbett and Klassen (2006); Dües et al. (2013); Duarte & Cruz-Machado (2013); Campos & Vazquez-Brust (2016); Thanki et al (2016); Khodeir & Othman (2018); Dieste et al. (2019)
Investments and costs	• Green practices may require financial investments, whereas lean aims to reduce all unnecessary costs • Lean focuses on physical costs, green considers also the environmental costs for future generations • If green increases costs, some customers may resist and do not want to pay more for greener products • Producing high quality may increase consumption of energy	Rothenberg et al. (2001); Dües et al. (2013); Campos & Vazquez-Brust (2016); Huo et al. (2019)
Customer target	• Lean gains customer satisfaction from low prices and lead times, whereas green satisfies more environmentally conscious customers	Dües et al. (2013); Campos & Vazquez-Brust (2016); Thanki et al. (2016)
End-of-life product use	• Lean has no interest, green has high focus on end-of-life product disposal, re-use and recycling options	Dües et al. (2013); Campos & Vazquez-Brust (2016)
Product design	• Green: eco-friendly options and life-cycle analysis, lean aims for high efficiency and low cost	Srivastava (2007); Zhu et al. (2008) Fortes (2009); Carvalho et al. (2011) Dües et al. (2013)
Supplier selection	• Lean's focus is on high efficiency and low costs; green purchasing focuses on suppliers' environmental performance	Simpson & Power (2005); Carvalho et al. (2011)
KPI	• Lean: cost; Green: pollutions and green impacts	Dües et al. (2013)

Because of these potential conflicts and tradeoffs between some green goals and lean, by itself, lean may not improve environmental performance (Rothenberg et al. 2001). Therefore, simply implementing some lean practices or tools to the firm or supply chains does not always necessarily have a direct effect the firm's environmental performance (Hajmohammad et al. 2013).

5. RESULTS AND DISCUSSION

This study set out to find out how lean and green thinking can improve firms' green performance with focus on the environmental sustainability of supply chains. The aim was to identify lean and green practices that support the firm's environmental goals and provide green benefits to supply chain operations. Additionally, lean practices that may contradict or create potential tradeoffs with green performance were explored. The research questions of the thesis were addressed through a systematic literature review. In the following, the main findings of the review process are presented.

In general, the concept of integrating lean and green is still a relatively new area of research, but interest towards investigating this connection is increasingly popular in academic literature (Garza-Reyes 2015; Caldera et al. 2017). In the literature review, a positive connection between lean and green was found in a number of studies using different research methods, such as empirical analysis (Florida 1996; King & Lenox 2001), case studies (Azevedo et al. 2012; Chiarini 2014; Piercy & Rich 2015; Campos and Vazquez-Brust 2016; Duarte & Cruz Machado 2017; Belhadi et al. 2018), using surveys (Inman & Green 2018; Zhan et al. 2018; Cherrafi et al. 2018; Hussain et al. 2019; Huo et al. 2019), secondary data (Yang et al. 2011), literature review (Mollenkopf et al. 2010; Duarte and Cruz-Machado 2013; Dües et al. 2013; Martínez-Jurado and Moyano-Fuentes 2014; Caldera et al. 2017; Dieste et al. 2019) and conceptual and theoretical models (Simpson & Power 2005; Pampanelli et al. 2014). Additionally, some controversial findings and tradeoffs with the lean-green integration were identified with surveys (Rothenberg et al. 2001; Hajmohammad et al. 2013) and case studies (Fahimnia et al. 2015). Overall, there is a general consensus among the majority of researchers that lean can improve the green performance of firms. Lean firms tend to be more environmentally sustainable than non-lean firms (King & Lenox 2001). There are also examples of large successful corporations that have been able to practice lean thinking while protecting the environment with green thinking, including Toyota, Walmart, Intel and General Motors (Mollenkopf et al. 2010; Hajmohammad et al. 2013; Engin et al. 2019).

Lean and green can support each other in different ways. Whereas lean practices improve green performance by eliminating environmental wastes, green thinking can have a positive influence on achieving lean goals (Dües et al. 2013; Caldera et al. 2017). By supporting each other's goals of reducing unnecessary non-value-adding activities, lean and green can be seen as well-compatible

initiatives (Piercy & Rich 2015) with an undeniable and strong relationship (Duarte & Machado 2017). Several lean practices inherently support better environmental performance and achievement of green goals (Martínez-Jurado & Moyano-Fuentes 2014). Moreover, where lean practices can offer green benefits, vice versa, green thinking practices can improve and support lean practices (Mollenkopf et al. 2010). Lean aims to use fewer resources to achieve the same end result, which inherently supports better environmental sustainability (Simpson & Power 2005). Both lean and green share the long-term goal of "doing more with less", which means producing the same end result using fewer resources (Piercy & Rich 2015). Lower resource consumption reduces energy, material and water consumption and also waste and pollutions (King & Lenox 2001).

Lean's main objective of eliminating waste leads to improved environmental performance as a by-product. This in turn can lead to the development of innovative production methods and business strategies to further prevent and reduce pollution. (Florida 1996) Lean is constantly striving to improve quality, leading to reduced levels of scrap, defects and reprocessing, which again supports environmental performance (Simpson & Power 2005; Cherrafi et al. 2018). By practicing lean thinking and minimizing waste from supply chains and production, the firm can satisfy customer demands and have excellent firm reputation in addition to great economic and environmental business performance. (Gordon 2001; Simpson & Power 2005; Corbett & Klassen 2006; Dües et al. 2013; Jakhar et al. 2018; Thanki & Thakkar 2018; Huo et al. 2019) As lean practices can be associated with improved green performance, integrating the goals and practices of lean and green philosophies can provide superior advantages for firms (Dües et al. 2013; Pampanelli et al. 2014; Zhan et al. 2018). Lean supply chains have been linked to environmental benefits such as reduced waste, defects and scrap as well as lower consumption of energy (Fliedner 2008). Thus, Lean SCM can support green performance through continuous improvements, aiming to reduce lead time, pollution and all wastes (Huo et al. 2019). According to Mollenkopf's et al. (2010) study, incorporating green thinking into the firm's supply chain strategy can provide significant competitive advantage as well as an opportunity to maximize lean quality practices in today's increasingly complex and dynamic supply chains.

Among others, Azevedo's et al. (2012) research shows that adapting a green and lean SCM strategy can enhance the firm's sustainable performance and Caldera et al. (2017) argues that an integrated lean and green approach can offer a significant opportunity of improving the firm's overall

performance and environmental sustainability. A combined lean and green SCM strategy can provide improvements in both operational and green performance, including benefits such as reductions in waste, costs and risks and improvements in quality, delivery efficiency, transport lead times and communication between actors in the supply chain as well as better green image (Carvalho et al. 2011; Inman & Green 2018). Further, lean and green SCM aims to improve resource efficiency and waste management by increasing recycling and reusing materials with minimized storage, consumption of energy and all wastes (Azevedo et al. 2012). Overall, the combination of lean and green can offer better sustainable performance and high efficiency with low resource requirements (Piercy & Rich 2015).

There are also conflicting findings on the benefits of lean and green, such as following the lean principles too strictly (Fahimnia et al. 2015) or intense focus on lean's requirement for high quality (Rothenberg et al. 2001) do not necessarily improve green performance, and tradeoffs between lean and green may be formed. Potential conflicts or difficulties in the synergy of lean and green can also arise from increased costs from green practices, overly dominant lean strategy or unsupportive managers (Campos & Vazquez-Brust 2016; Huo et al. 2019). Furthermore, some lean practices, such as JIT, can increase pollutions (Dieste et al 2019) while the adoption of green technologies to make operations more environmentally friendly may require financial investments, which contradicts with lean's goal of reducing all costs (Mollenkopf et al. 2010; Huo et al. 2019). According to Rothenberg et al. (2001), a completely clear win-win relationship with the lean-green integration cannot be distinguished. Nevertheless, although lean may not be 100% synergistic with green, the implementation of lean thinking, and in particular certain lean practices, can be clearly linked to improved green performance (Dües et al. 2013). Table 6 summarizes the main identified lean and green attributes, practices that help supply chains achieve these goals and benefits that support green supply. Potentially conflicting goals and features between lean and green are also presented.

Table 6. Summary of Lean and Green attributes, practices, green benefits and conflicts

Lean and Green attribute	Tools/practices/ methods	Supporting Green Supply	Conflicts/differences between Green and Lean
Waste management and reduction	5S, TPM, kaizen, VSM & Green VSM, SMED, cellular manufacturing, life cycle assessment, Lean and green SCM, waste management, reverse logistics, eco-design, green collaboration, ISO 14001	• In supply chains, important sources of waste include e.g. transport, waiting time, storage movement and packaging • Efficient identification and elimination of all wastes reduces material and energy consumption and pollutions and improves quality and green performance throughout supply chains	• Lean's focus is the 7 deadly wastes; Green focuses on environmental wastes with emphasis on waste segregation, reusing, recycling • Lean aims to improve efficiency; Green aims to prevent pollution and other green impacts
Continuous improvement and long-term thinking	Kaizen, environmental collaboration with suppliers, LCA, VSM & Green VSM	• Kaizen events and combining kaizen with 14001 standard can improve green performance of suppliers • Identifying and eliminating green wastes across supply chains with LCA and VSM • "Doing more with less" by reducing wastes and improving resource efficiency as a long-term goals	• Lean and green may have some conflicting motives and aims, such as cost reduction (lean) and green technology (green)
Supplier selection and close supplier relationships	Green and Lean SCM, kaizen, sustainable supplier selection, ISO 14001, environmental collaboration	• Selecting suppliers that share the goals with the firm improves quality and reduces defects and green impacts • Developing long-term and close supplier relationships improve quality and green performance with better control of suppliers' actions • SCM and collaborating with suppliers improves waste management	• Lean emphasizes low cost and high quality in supplier selection, green purchasing focuses on minimal green impacts and better environmental sustainability of supply chains
Transportation	JIT, cellular manufacturing, eco-design, geographical concentration, SMED, sustainable supplier selection, sustainable transportation value stream mapping (STVSM), kaizen, reverse logistics	• Less transportation, use of smaller vehicles, mapping and planning delivery routes reduce emissions and packaging • Shorter transport times and distances reduce vehicle emissions • Green supplier selection • Use of eco-friendly packaging materials reduces green impacts and defects and can maintain product quality during transport	• Lean aims to save costs, green aims to reduce emissions • In JIT delivery, small batch sizes increase transport volumes, which contradicts with green by increasing pollution
Low Inventory	JIT, geographical, concentration with suppliers, SMED, 5S, cellular manufacturing	• Less storage space reduces energy consumption and transport emissions • More efficient use of resources • Easier detection of defects and other potential issues, which reduces waste • Requires less packaging and materials	• Lean minimizes inventory to reduce costs, green aims to reduce pollutions and energy • Low inventory can increase frequency of transportation and stock replenishments, increasing pollutions
Lead time reduction	VSM, kaizen, 5S, SMED, JIT, geographical concentration with suppliers	• Reduces unnecessary transportation, movement and time, less emissions • Improved service level and detection of issues & defects	• Green reduces transport lead times as long as it does not increase emissions, lean reduces until costs increase

The core principle of lean thinking to identify and eliminate the seven deadly wastes can be seen as a key practice supporting green performance. Based on the systematic literature review, waste reduction was frequently identified as the most significant overlapping attribute of lean and green. Lean's continuous efforts to eliminate all non-value-adding activities and increase resource efficiency will simultaneously benefit green performance by reducing green wastes and pollutions. On the other hand, green thinking also aims to reduce waste in order to prevent and eliminate green impacts and environmental emissions and pollutions. Therefore, the disposal of wastes can be considered an important goal for both lean and green. (Ohno 1988; King & Lenox 2001; Rothenberg et al. 2001; Dües et al. 2013; Hajmohammad et al. 2013; Martínez-Jurado & Moyano-Fuentes 2014; Campos & Vazquez-Brust 2016; Dieste et al. 2019)

The green performance of suppliers can be significantly improved by reducing wastes across supply chain operations (Cherrafi et al. 2018). Waste in supply chains can be detected, for example, from waiting times, transportation, inventory, unnecessary handling and detection of defects (Mollenkopf et al. 2010). All seven deadly wastes of lean can also be found at different stages of supply chain activities with different environmental impacts. For example, defects in supply chains can be deterioration of goods, lack of communication with suppliers, or delivery of products to the wrong location, while unnecessary movement can lead to unnecessary packaging or re-delivery of products. Moreover, in supply chains, transportation, unnecessary inventory and overprocessing are also important wastes that can cause large amounts of unnecessary emissions and pollutions and add energy consumption (Engin et al. 2019). Identifying and reducing wastes throughout supply chains improves the overall environmental sustainability of supply chains.

Specifically, there can be identified several different lean and green practices that help to reduce waste, such as kaizen, which is based on the philosophy of continuous improvement (Garza-Reyes et al. 2018) and 5S, which reduces waste by optimizing flow of production and maintaining a well-organized working environment (Torielli et al. 2011) and SMED, which aims to lower wastes through short changeover times, small batch sizes and increased flexibility (Leme et al. 2018). VSM and Green VSM can help to identify unnecessary activities and hidden lean and green wastes across supply chains (Torielli et al. 2011), whereas eco-design aims to design and produce products that cause less waste (Geng et al. 2017). However, there are also some differences and potential conflicts with the waste elimination goals and targets between lean and green. As lean's main goal is to

improve efficiency, green aims to prevent pollution and other green impacts (Thanki et al. 2016; Dieste et al. 2019). Additionally, lean views waste as an activity that does not add any value, green views waste as unnecessary use of natural resources (Duarte & Cruz-Machado 2013). Despite some different waste targets and perspectives, according to Dües et al. (2013), lean's view of waste can be extended to environmental waste, allowing both perspectives to benefit together by achieving their waste disposal targets.

Supplier selection and supplier relationship management are also key practices of lean and green, as both can be used to influence firms' green performance and to gain other significant competitive advantages. (Simpson & Power 2005; Corbett & Klassen 2006; Jakhar et al. 2018) Sustainable supplier selection is an important practice to improve environmental performance of supply chains (Jakhar et al. 2018). Considering suppliers' green performance and criteria when selecting suppliers can significantly improve environmental sustainability of lean suppliers (Inman and Green 2018). By reducing the number of risky or unsuitable suppliers and selecting suppliers with the same values and goals as the firm, product quality can be maximized, and defects and green impacts minimized (Franchetti et al. 2009). An effective way to ensure the environmental sustainability of suppliers is to include the ISO 14001 environmental standard in the supplier selection process (Azevedo et al. 2011; Carvalho et al. 2017). The ISO 14001 can provide advantages for both lean and green by improving service level and customer satisfaction and eliminating waste (Thanki et al. 2016; Campos & Vazquez-Brust 2016) while it also strongly encourages all members of the supply chain to adopt green practices (Azevedo et al. 2011).

Building and maintaining close relationships with suppliers plays an important role in the firm's environmental sustainability performance (Simpson & Power 2005). In order to achieve the best possible green performance with efficient waste management practices, firms should work closely with both their suppliers and customers (Dieste et al. 2019). Developing collaborative, trusting and long-term relationships with suppliers supports the synergy of lean and green by improving economic performance, delivery efficiency and waste elimination and reducing defects and emissions (Yang et al. 2011; Campos & Vazquez-Brust 2016; Caldera et al. 2017). Overall, integrating lean and green to SCM strategy can offer a number of benefits, including smaller inventories, better delivery and production performance and time, lower costs, better quality and more efficient communication with all members of the supply chain (Carvalho et al. 2011; Thanki & Thakkar 2018).

In supplier selection and supplier management, possible conflicting areas between lean and green can arise from having different goals for suppliers. While lean aims to achieve high quality and low-cost suppliers, green considers more the environmental performance of suppliers (Carvalho et al. 2011). However, sustainable suppliers and lean thinking have been found to have a positive relationship with some common goals, such as reducing waste and satisfying customer needs (Jakhar et al. 2018). Therefore, in order to meet customer demands for greener products while remaining efficient and profitable, the selection of suppliers should take into account the objectives of both lean and green (Thanki et al. 2016; Duarte & Cruz-Machado 2013). However, in order to improve the overall sustainability of the firm, it is important that the firm ensures the greenness of its own operations before evaluating and requiring suppliers to perform green (Mollenkopf et al. 2010).

Continuous improvement through kaizen can improve environmental sustainability of supply chains by reducing waste through better waste management and recycling systems and enhance the efficiency of resource use and energy consumption (Pampanelli et al. 2014; Caldera et al. 2017; Singh et al. 2020). Kaizen's pursuit for high level of people participation supports sustainable performance (Pampanelli et al. 2014). Moreover, by integrating kaizen with the ISO 14001 environmental standard, the firm can target its continuous improvement efforts toward more environmentally sustainable business practices (Caldera et al. 2017). Using a kaizen approach, Pampanelli's et al. (2014) Lean and Green model combines the goals of both initiatives with excellent productivity and customer service levels, meaning that customers get exactly what they want, when they want it, at the lowest possible cost and waste, while also taking into account green impacts and use of natural resources. Both lean and green aim for sustainable and long-lasting improvements by using various tools and methods, such as LCA, VSM and kaizen. VSM is a powerful mapping tool for continuous improvement and addressing long-term solutions, whereas LCA can provide green benefits on the long run by identifying the environmental impacts and risks of products and processes throughout their life cycle. By combining VSM with LCA, they can work together to identify potential green impacts throughout the product's life cycle from raw materials to end-of-life use (Caldera et al. 2017).

The designing phase is a crucial part of the product's life cycle, when considering environmental impacts (Geng et al. 2017). In product design, lean strives for maximum performance and low cost,

whereas green also takes into consideration the green impacts of the product from sourcing of raw materials to end-of-life. Environmental design and LCA are effective tools for assessing green risks and impacts. (Dües et al. 2013) Eco design can reduce life-cycle environmental impacts through efficient reuse, recycling and recovery methods (Zhu & Sarkis 2007). With LCA, green performance can be improved by designing and developing products that require less packaging material and storage space, cause less pollutions and scrap, do not require complex and lengthy manufacturing processes and require fewer specific materials or product parts to reduce deliveries. As these improvements reduce waste and improve efficiency, they also support lean thinking (Dües et al. 2013; Pampanelli et al. 2014).

Conflicts in transportation with lean and green supply chains can occur if supply chains are long and geographically wide, which increases traffic-based pollution (Venkat & Wakeland 2006). These green impacts can be mitigated, for example, by planning delivery routes with sustainable transport value stream mapping (STVSM) (Garza-Reyes et al. 2016), using more efficient or greener modes of transport, fully loading vehicles or sharing the delivery of products with other firms and minimizing transport distances (Dües et al. 2013).

The frequency of replenishment can be considered as one of the most significant attributes that can create a tradeoff situation between lean and green (Dües et al. 2013). Where Lean aims to increase, green tends to reduce replenishment density (Carvalho et al. 2011). Therefore, JIT delivery can be identified as a highly conflicting practice between lean and green (Ugarte et al. 2016; Dieste et al. 2019). With JIT, transportation frequency is increased due to smaller batch sizes, thus increasing pollutions (Chiarini 2014; Campos & Vazquez-Brust 2016). However, on the other hand, JIT can also improve quality and the use of resources, reduce inventory levels and require smaller vehicles and packaging materials in deliveries, reducing consumption of energy and pollutions (Carvalho et al. 2017; Garza-Reyes et al. 2018). Overall, however, as JIT is more supportive of lean goals, some green compromises may have to be made. Possible examples of mitigating JIT's negative impacts on green performance include using suppliers located in geographically close areas, designing supply routes to serve multiple customers on the same supply routes, using reusable packaging or optimizing batch sizes (Mollenkopf et al. 2010; Dües et al. 2013). Finding the right balance between suppliers' frequent replenishments and low inventory levels can benefit all parties (Huo et al. 2019).

Lean and green supply chains also overlap with objectives for short production and transport times and low stock levels (Carvalho et al. 2011; Dües et al. 2013). Lower inventory levels can be associated with green benefits such as more efficient use of resources and productivity, better waste management, lower energy consumption and lower amount of emission from transportation (Caldera et al. 2017). Lean strives to minimize inventories with the goals of reducing costs and wastes, improving quality, efficiency and productivity and freeing up resources and assets (Dües et al. 2013; Jakhar et al. 2018). However, low stock levels often increase the need for replenishments, which increases the volume of deliveries and transport emissions, creating a lean-green conflict (Huo et al. 2019). A variety of tools and practices are designed to reduce inventory, such as JIT and SMED where lower batch sizes and lead times result in less inventory (Thanki et al. 2016). Although reducing inventory can increase pollutions, efficient inventory management has also been associated with reduced environmental emissions (King & Lenox 2001). Because of the inconsistent inventory practices between lean and green, in inventory management, managers should assess the impacts throughout the supply chain and take into account both objectives to reduce costs and emissions when implementing lean practices (Huo et al. 2019). Both lean and green also share the aim for lower lead time with practices such as JIT, SMED, 5S and supplier concentration. However, lean aims for lower lead time until costs start to rise, while green's goal is to achieve shorter transport lead times until green impacts increase (Dües et al. 2013).

In general, in order to achieve the desired results in adapting lean and green practices to supply chains, it is important to take into account the objectives of both initiatives to minimize both costs and environmental impact (Ugarte et al. 2016). Participation of all people in the organization, including employees, managers and suppliers, is a common attribute of lean and green and an essential factor in the process of implementing the initiatives and achieving sustainable results (Rothenberg et al. 2001; Dües et al. 2013; Thanki et al. 2016; Belhadi et al. 2018). To maintain a successful and efficient lean-green organization and reap the benefits in the long run, managers should provide appropriate training and education opportunities for employees and encourage them to continually develop their knowledge and skills (Duarte and Cruz-Machado 2013; Singh et al. 2020). Managerial involvement and strong commitment are also crucial in lean and green supply chains (Duarte & Machado 2017; Singh et al. 2020), as lack of support from managers can work as an obstacle in achieving a successful lean and green synergy (Pampanelli et al. 2014; Campos & Vazquez-Brust 2016)

6. CONCLUSIONS

Climate change, resource shortages and loss of biodiversity are strongly impacting both our personal lives and business markets. Today, customers increasingly demand cleaner and greener products that minimize environmental impacts. Growing environmental concerns have forced firms to adopt green thinking into their supply chains and production processes. To meet the changing customer needs while improving the firm's greenness and profitability, firms are implementing new business strategies. Lean thinking is a widely used and influential customer-focused philosophy that aims to reduce waste, lead time and inventories and improve quality and efficiency. Recently, lean has been increasingly associated with green thinking, as a number of lean goals and practices have been found to improve green performance. The combination of lean and green thinking can offer huge benefits in terms of both green and operational performance.

The aim of this thesis was to explore the synergy of lean and green by identifying similar goals, overlapping attributes, as well as potential conflicts and differences between the two initiatives. The focus of the study was to find out how firms can improve the green performance of their supply chains by identifying green and lean practices and attributes that can affect the environmental sustainability of supply chains. The thesis used a systematic literature review as a research method including 34 articles on the topics of lean and green and supply chains.

Overall, most of the articles and studies suggested mainly positive outcomes from the lean-green integration and support the "lean is green" statement. Lean can act as a bridge towards better green performance. The majority of articles identified green benefits with certain lean practices, whereas a smaller part of literature showed mixed results or negative green impacts of lean. Therefore, the findings suggest that there can exist a mutually beneficial relationship between lean and green. The lean-green synergy can help firms achieve both their performance and environmental goals by using resources more efficiently and improving the prevention and disposal of waste and pollution. Further synergistic benefits of lean and green include lower lead times and inventory levels, reduced costs and improved process flow and quality.

Some potentially conflicting features can also be identified between the lean and green supply chain operations. These include, for example, JIT delivery, frequent inventory replenishments and small

batch deliveries, which increase pollutions or costly investments in green technology, leading to tradeoffs between the KPI's of green (pollution) and lean (cost). Green's goal is to prevent and reduce pollutions and lean aims for minimizing all costs. Lean and green also have different waste disposal targets and conflicting views on product design and end-of-life use. Despite some tradeoffs, there are more overlapping practices, such as their main goal of "doing more and more with less and less" through efficient waste disposal and resource use, short delivery times, close and collaborative supplier relationships, high customer service and long-term thinking.

Important attributes of successful lean and green supply chains include elimination of wastes, continuous improvement, optimization of activities, strong managerial engagement, safe working environments and close relationships between suppliers, employees and managers. A variety of specific lean and green practices that support the achievement of these attributes and goals can be identified, such a kaizen, TPM, 5S, SMED, green collaboration, life-cycle assessment, sustainable supplier selection and Green VSM. A lean and green SCM strategy can improve quality, delivery performance and efficiency, in addition to reduced risks, costs, wastes, lead time and lower inventory levels and energy consumption. Lean strives for complete change in the organization, including supply chain operations, managerial leadership and the day-to-day work of employees. Thus, in general, the successful adaptation of a lean and green thinking to supply chains requires changes throughout the organizational culture and vision. Moreover, when implementing lean and green practices to the firm, it is important that the lean-green strategy fits the firm's own needs and goals and that all members of the organization are strongly involved in the process.

In summarization, although lean and green differ in some objectives, attributes and priorities, they both share the fundamental aim to do more with less with the idea that efficient use of resources is the key to better performance and that non-value-adding activities should be reduced. Together, lean and green can provide a successful and sustainable business strategy to achieve the best possible financial, environmental and operational performance for firms and their supply chains. The combination of lean and green can provide huge benefits by reducing all wastes and minimizing green impacts while meeting customer demand for high-quality and environmentally sustainable products and enhancing the firm's green image.

Due to the limited time and scope of the thesis, only a limited number of articles were used in the literature review. The results of the study are based solely on previously published research, articles, and empirical findings. Because the case studies used in the review process were limited to a few specific industries, the results cannot be widely generalized to different industries. Therefore, some of the identified green benefits of lean thinking and of the green-lean combination may be case-specific and realized only in some industries, supply chains or firms. It is also worth noting that as the popularity of research on the topic of lean and green is increasingly growing and new studies and literature are constantly published, new information on the subject is constantly being added. This thesis was carried out using only currently available studies and articles.

The main contribution of this study was to add information to the existing literature on lean and green supply chains by providing a systematic review of studies on the topic. Although the results cannot be widely generalized to all firms due to limited time and sample size, the results can nevertheless provide some guidance for managers and future researchers on the topic. The study was also able to reveal some inconsistencies in the reviewed literature, leaving plenty of space and research topics for further research. Possible interesting future research topics could focus on the tradeoffs between lean and green and finding ways to confront the identified issues or study the impacts of the combination of lean and green when adopted more broadly to different supply chains, regions and industries.

REFERENCES

Ahi, P., & Searcy, C. (2013). A comparative literature analysis of definitions for green and sustainable supply chain management. *Journal of cleaner production*, *52*, 329-341.

Al-Ghwayeen, W. S., & Abdallah, A. B. (2018). Green supply chain management and export performance. *Journal of Manufacturing Technology Management*.

Al-Aomar, R., & Weriakat, D. (2012). A framework for a green and lean supply chain: A construction project application. In International Conference on Industrial Engineering and Operations Management Istanbul (pp. 289-299).

Alvim, S. L., & Oliveira, O. G. (2020). Lean Supply Chain Management: a lean approach applied to distribution–a literature review of the concepts, challenges and trends. *Journal of Lean Systems*, *5*(1), 85-103.

Angell, L. C. (2001). Comparing the environmental and quality initiatives of Baldrige award winners. Production and Operations Management, 10(3), 306-326.

Azevedo, S. G., Carvalho, H., & Machado, V. C. (2011). The influence of green practices on supply chain performance: A case study approach. *Transportation research part E: logistics and transportation review*, *47*(6), 850-871.

Azevedo, S. G., Carvalho, H., Duarte, S., & Cruz-Machado, V. (2012). Influence of green and lean upstream supply chain management practices on business sustainability. IEEE Transactions on Engineering Management, 59(4), 753-765.

Belhadi, A., Touriki, F. E., & El Fezazi, S. (2018). Benefits of adopting lean production on green performance of SMEs: a case study. Production Planning & Control, 29(11), 873-894.

Bergmiller, G. G., & McCright, P. R. (2009a). Parallel models for lean and green operations. In *Proceedings of the 2009 industrial engineering research conference* (Vol. 1, No. 1, pp. 22-26). University of South Florida and Zero Waste Operations Research and Consulting.

Bergmiller, G. G., & McCright, P. R. (2009b). Are lean and green programs synergistic. In *Proceedings of the 2009 Industrial Engineering Research Conference* (pp. 1155-1160).

Caldera, H. T. S., Desha, C., & Dawes, L. (2017). Exploring the role of lean thinking in sustainable business practice: A systematic literature review. *Journal of Cleaner Production*, *167*, 1546-1565.

Campos, L. M., & Vazquez-Brust, D. A. (2016). Lean and green synergies in supply chain management. *Supply Chain Management: An International Journal*.

Carvalho, H., Duarte, S., & Machado, V. C. (2011). Lean, agile, resilient and green: divergencies and synergies. *International Journal of Lean Six Sigma*.

Carvalho, H., Govindan, K., Azevedo, S. G., & Cruz-Machado, V. (2017). Modelling green and lean supply chains: An eco-efficiency perspective. *Resources, Conservation and Recycling*, *120*, 75-87.

Chiarini, A. (2014). Sustainable manufacturing-greening processes using specific Lean Production tools: an empirical observation from European motorcycle component manufacturers. *Journal of Cleaner Production*, *85*, 226-233.

Chin, T. A., Tat, H. H., Sulaiman, Z., & Muhamad Zainon, S. N. L. (2015). Green supply chain management practices and sustainability performance. *Advanced Science Letters*, *21*(5), 1359-1362.

Cooper, M. C., Lambert, D. M., & Pagh, J. D. (1997). Supply chain management: more than a new name for logistics. *The international journal of logistics management*, *8*(1), 1-14.

Corbett, C. J., & Klassen, R. D. (2006). Extending the horizons: environmental excellence as key to improving operations. *Manufacturing & Service Operations Management*, *8*(1), 5-22.

Denyer, D., & Tranfield, D. (2009). Producing a systematic review.

Dey, P. K., Malesios, C., De, D., Chowdhury, S., & Abdelaziz, F. B. (2019). Could lean practices and process innovation enhance supply chain sustainability of small and medium-sized enterprises?. Business Strategy and the Environment, 28(4), 582-598.

Dieste, M., Panizzolo, R., Garza-Reyes, J. A., & Anosike, A. (2019). The relationship between lean and environmental performance: Practices and measures. *Journal of Cleaner Production*, *224*, 120-131.

Duarte, S., & Cruz-Machado, V. (2013). Modelling lean and green: a review from business models. *International Journal of Lean Six Sigma*.

Duarte, S., & Machado, V. C. (2017). Green and lean implementation: an assessment in the automotive industry. International Journal of Lean Six Sigma.

Dües, C. M., Tan, K. H., & Lim, M. (2013). Green as the new Lean: how to use Lean practices as a catalyst to greening your supply chain. *Journal of cleaner production*, *40*, 93-100.

Elkington, J. (1997). Cannibals with forks. The triple bottom line of 21st century, 73.

Engin, B. E., Martens, M., & Paksoy, T. (2019). Lean and Green Supply Chain Management: A Comprehensive Review. In *Lean and Green Supply Chain Management* (pp. 1-38). Springer, Cham.

EPA (2003). Lean Manufacturing and the Environment, Office of Solid Waste and Emergency Response, United States Environmental Protection Agency, EPA100-R-03-005

Fahimnia, B., Sarkis, J., & Eshragh, A. (2015). A tradeoff model for green supply chain planning: A leanness-versus-greenness analysis. Omega, 54, 173-190.

Fercoq, A., Lamouri, S., & Carbone, V. (2016). Lean/Green integration focused on waste reduction techniques. *Journal of Cleaner production*, *137*, 567-578.

Fliedner, G. (2008). Sustainability: a new lean principle. In *Proceedings of the 39th annual meeting of the decision sciences institute, Baltimore, Maryland* (pp. 3321-3326).

Flammer, C. (2013). Corporate social responsibility and shareholder reaction: The environmental awareness of investors. *Academy of Management Journal*, *56*(3), 758-781.

Florida, R. (1996). Lean and green: the move to environmentally conscious manufacturing. *California management review*, *39*(1), 80-105.

Foo, P. Y., Lee, V. H., Tan, G. W. H., & Ooi, K. B. (2018). A gateway to realising sustainability performance via green supply chain management practices: A PLS–ANN approach. *Expert Systems with Applications*, *107*, 1-14.

Fortes, J. (2009). Green supply chain management: A literature. *Otago Management Graduate Review*, *7*(1), 51-62.

Franchetti, M., Bedal, K., Ulloa, J., & Grodek, S. (2009). Lean and green: industrial engineering methods are natural stepping stones to green engineering. *Industrial Engineer*, *41*(9), 24-30.

Friedman, P. (2008). Leaning toward green: Green your supply chain with lean practices. *Outsourced Logistics*, *1*, 16-17.

Garza-Reyes, J. A. (2015). Lean and green–a systematic review of the state of the art literature. *Journal of Cleaner Production*, *102*, 18-29.

Garza-Reyes, J. A., Villarreal, B., Kumar, V., & Molina Ruiz, P. (2016). Lean and green in the transport and logistics sector–a case study of simultaneous deployment. *Production Planning & Control*, *27*(15), 1221-1232.

Garza-Reyes, J. A., Kumar, V., Chaikittisilp, S., & Tan, K. H. (2018). The effect of lean methods and tools on the environmental performance of manufacturing organisations. International Journal of Production Economics, 200, 170-180.

Cherrafi, A., Garza-Reyes, J. A., Kumar, V., Mishra, N., Ghobadian, A., & Elfezazi, S. (2018). Lean, green practices and process innovation: A model for green supply chain performance. *International Journal of Production Economics*, *206*, 79-92.

Geng, R., Mansouri, S. A., & Aktas, E. (2017). The relationship between green supply chain management and performance: A meta-analysis of empirical evidences in Asian emerging economies. International Journal of Production Economics, 183, 245-258.

Gimenez, C., Sierra, V., & Rodon, J. (2012). Sustainable operations: Their impact on the triple bottom line. *International Journal of Production Economics*, *140*(1), 149-159.

Gordon, P. (2001). *Lean and green: profit for your workplace and the environment*. Berrett-Koehler Publishers.

Green, K. W., Zelbst, P. J., Meacham, J., & Bhadauria, V. S. (2012). Green supply chain management practices: impact on performance. *Supply Chain Management: An International Journal*.

Hajmohammad, S., Vachon, S., Klassen, R. D., & Gavronski, I. (2013). Reprint of Lean management and supply management: their role in green practices and performance. *Journal of Cleaner Production*, *56*, 86-93.

Hartmann, J., & Moeller, S. (2014). Chain liability in multitier supply chains? Responsibility attributions for unsustainable supplier behavior. *Journal of operations management*, *32*(5), 281-294.

Hines, P. (2009). Lean and Green, Source Magazine the Home of Lean Thinking.

Hobbs, D. P. (2003). Lean manufacturing implementation: a complete execution manual for any size manufacturer. J. Ross Publishing.

Hong, J., Zhang, Y., & Ding, M. (2018). Sustainable supply chain management practices, supply chain dynamic capabilities, and enterprise performance. *Journal of Cleaner Production*, *172*, 3508-3519.

Huo, B., Gu, M., & Wang, Z. (2019). Green or lean? A supply chain approach to sustainable performance. *Journal of Cleaner Production*, *216*, 152-166.

Inman, R. A., & Green, K. W. (2018). Lean and green combine to impact environmental and operational performance. *International Journal of Production Research*, *56*(14), 4802-4818.

Jabbour, C. J. C., de Sousa Jabbour, A. B. L., Govindan, K., Teixeira, A. A., & de Souza Freitas, W. R. (2013). Environmental management and operational performance in automotive companies in Brazil: the role of human resource management and lean manufacturing. *Journal of Cleaner Production*, *47*, 129-140.

Jakhar, S. K., Rathore, H., & Mangla, S. K. (2018). Is lean synergistic with sustainable supply chain? An empirical investigation from emerging economy. *Resources, Conservation and Recycling*, *139*, 262-269.

Jasti, N. V. K., Sharma, A., & Kodali, R. (2012). Lean to green supply chain management: a case study. *Journal of Environmental Research and Development*, *6*(3), 890-899.

Karlsson, S. (1999). Closing the Technospheric Flows of Toxic Metals: Modeling Lead Losses from a Lead-Acid Battery System for Sweden. *Journal of Industrial Ecology*, *3*(1), 23-40.

Khodeir, L. M., & Othman, R. (2018). Examining the interaction between lean and sustainability principles in the management process of AEC industry. *Ain Shams Engineering Journal*, *9*(4), 1627-1634.

King, A. A., & Lenox, M. J. (2001). Lean and green? An empirical examination of the relationship between lean production and environmental performance. *Production and operations management*, *10*(3), 244-256.

King, A., & Lenox, M. (2002). Exploring the locus of profitable pollution reduction. *Management Science*, *48*(2), 289-299.

Klassen, R. D., & McLaughlin, C. P. (1996). The impact of environmental management on firm performance. *Management science*, *42*(8), 1199-1214.

Konar, S., & Cohen, M. A. (2001). Does the market value environmental performance?. Review of economics and statistics, 83(2), 281-289.

Krafcik, J. F. (1988). Triumph of the lean production system. Sloan Management Review, 30(1), 41.

Lambert, D., Stock, J. R., & Ellram, L. M. (1998). *Fundamentals of logistics management*. McGraw-Hill/Irwin.

Leme, R. D., Nunes, A. O., & Silva, D. A. L. (2018). Creating value with less impact: Lean, green and eco-efficiency in a metalworking industry towards a cleaner production. *Journal of cleaner production*.

Lintukangas, K., Kähkönen, A. K., & Ritala, P. (2016). Supply risks as drivers of green supply management adoption. *Journal of Cleaner Production*, *112*, 1901-1909.

Lummus, R. R., & Vokurka, R. J. (1999). Defining supply chain management: a historical perspective and practical guidelines. *Industrial management & data systems*.

Manikas, A. S., & Kroes, J. R. (2018). The relationship between lean manufacturing, environmental damage, and firm performance. *Letters in Spatial and Resource Sciences*, *11*(2), 141-155.

Martínez-Jurado, P. J., & Moyano-Fuentes, J. (2014). Lean management, supply chain management and sustainability: a literature review. *Journal of Cleaner Production*, *85*, 134-150.

Martusa, R. (2013). Green supply chain management: strategy to gain competitive advantage. *Journal of Energy Technologies and Policy*, *3*(11), 334-341.

Milne, M. J., & Gray, R. (2013). W (h) ither ecology? The triple bottom line, the global reporting initiative, and corporate sustainability reporting. *Journal of business ethics*, *118*(1), 13-29.

Mollenkopf, D., Stolze, H., Tate, W. L., & Ueltschy, M. (2010). Green, lean, and global supply chains. *International Journal of Physical Distribution & Logistics Management*, *40*(1-2), 14-41.

Norman, W., & MacDonald, C. (2004). Getting to the bottom of" triple bottom line". *Business ethics quarterly*, 243-262.

Ohno, T. (1988). Toyota production system: Beyond large-scale production. London: CRC Press

Oliver, R. K., & Webber, M. D. (1982). Supply-chain management: logistics catches up with strategy. *Outlook*, *5*(1), 42-47.

Pampanelli, A. B., Found, P., & Bernardes, A. M. (2014). A Lean & Green Model for a production cell. *Journal of cleaner production*, *85*, 19-30.

Rajeev, A., Pati, R. K., Padhi, S. S., & Govindan, K. (2017). Evolution of sustainability in supply chain management: A literature review. *Journal of Cleaner Production*, *162*, 299-314.

Reichhart, A., & Holweg, M. (2007). Lean distribution: concepts, contributions, conflicts. *International journal of production research*, *45*(16), 3699-3722.

Piercy, N., & Rich, N. (2015). The relationship between lean operations and sustainable operations. International Journal of Operations & Production Management.

Rothenberg, S., Pil, F. K., & Maxwell, J. (2001). Lean, green, and the quest for superior environmental performance. *Production and operations management*, *10*(3), 228-243.

Rother, M., & Shook, J. (2003). *Learning to see: value stream mapping to add value and eliminate muda*. Lean Enterprise Institute.

Samuel, D., Found, P., & Williams, S. J. (2015). How did the publication of the book The Machine That Changed The World change management thinking? Exploring 25 years of lean literature. International Journal of Operations & Production Management, 35(10), 1386-1407.

Seuring, S., & Müller, M. (2008). From a literature review to a conceptual framework for sustainable supply chain management. Journal of cleaner production, 16(15), 1699-1710.

Soltero, C., & Waldrip, G. (2002). Using kaizen to reduce waste and prevent pollution. *Environmental Quality Management*, *11*(3), 23-23.

Schneider, L., & Wallenburg, C. M. (2012). Implementing sustainable sourcing—Does purchasing need to change?. Journal of Purchasing and Supply Management, 18(4), 243-257.

Shah, R., & Ward, P. T. (2007). Defining and developing measures of lean production. Journal of operations management, 25(4), 785-805.

Sharma, K. M., & Lata, S. (2018). Effectuation of lean tool “5S” on materials and workspace efficiency in a copper wire drawing micro-scale industry in India. Materials Today: Proceedings, 5(2), 4678-4683.

Simpson, D. F., & Power, D. J. (2005). Use the supply relationship to develop lean and green suppliers. *Supply chain management: An international Journal*.

Simons, D., & Mason, R. (2003). Lean and green:'doing more with less'. *International Commerce Review: ECR Journal*, *3*(1), 84.

Singh, J., Singh, H., & Kumar, A. (2020). Impact of lean practices on organizational sustainability through green supply chain management–an empirical investigation. *International Journal of Lean Six Sigma*.

Sridhar, K., & Jones, G. (2013). The three fundamental criticisms of the Triple Bottom Line approach: An empirical study to link sustainability reports in companies based in the Asia-Pacific region and TBL shortcomings. *Asian Journal of Business Ethics*, *2*(1), 91-111.
Srivastava, S. K. (2007). Green supply-chain management: a state-of-the-art literature review. *International journal of management reviews*, *9*(1), 53-80.

Sony, M. (2019). Lean Supply Chain Management and Sustainability: A Proposed Implementation Model. In Ethical and Sustainable Supply Chain Management in a Global Context (pp. 57-76). IGI Global.

Tebini, H., M'Zali, B., Lang, P., & Perez-Gladish, B. (2016). The economic impact of environmentally responsible practices. *Corporate Social Responsibility and Environmental Management*, *23*(5), 333-344.

Thanki, S., Govindan, K., & Thakkar, J. (2016). An investigation on lean-green implementation practices in Indian SMEs using analytical hierarchy process (AHP) approach. *Journal of Cleaner Production*, *135*, 284-298.

Thanki, S., & Thakkar, J. (2018). A quantitative framework for lean and green assessment of supply chain performance. *International Journal of Productivity and Performance Management*.

Tranfield, D., Denyer, D., & Smart, P. (2003). Towards a methodology for developing evidence-informed management knowledge by means of systematic review. *British journal of management*, *14*(3), 207-222.

Torielli, R. M., Abrahams, R. A., Smillie, R. W., & Voigt, R. C. (2011). Using lean methodologies for economically and environmentally sustainable foundries. China Foundry, 8(1), 74-88.

Ugarte, G. M., Golden, J. S., & Dooley, K. J. (2016). Lean versus green: The impact of lean logistics on greenhouse gas emissions in consumer goods supply chains. *Journal of Purchasing and Supply Management*, *22*(2), 98-109.

Ulutas, B. (2011). An application of SMED Methodology. *World academy of science, engineering and technology*, *79*, 101.

Vachon, S., & Klassen, R. D. (2008). Environmental management and manufacturing performance: The role of collaboration in the supply chain. *International journal of production economics*, *111*(2), 299-315.

Venkat, K., & Wakeland, W. (2006). Is lean necessarily green?. In *Proceedings of the 50th Annual Meeting of the ISSS-2006, Sonoma, CA, USA*.

Verrier, B., Rose, B., Caillaud, E., & Remita, H. (2014). Combining organizational performance with sustainable development issues: the Lean and Green project benchmarking repository. *Journal of Cleaner Production*, *85*, 83-93.

Vinodh, S., Arvind, K. R., & Somanaathan, M. (2011). Tools and techniques for enabling sustainability through lean initiatives. Clean Technologies and Environmental Policy, 13(3), 469-479.

Zhan, Y., Tan, K. H., Ji, G., Chung, L., & Chiu, A. S. (2018). Green and lean sustainable development path in China: Guanxi, practices and performance. *Resources, Conservation and Recycling*, *128*, 240-249.

Zhu, Q., & Sarkis, J. (2007). The moderating effects of institutional pressures on emergent green supply chain practices and performance. *International journal of production research*, *45*(18-19), 4333-4355.

Zhu, Q., Sarkis, J., & Lai, K. H. (2007). Initiatives and outcomes of green supply chain management implementation by Chinese manufacturers. *Journal of environmental management*, *85*(1), 179-189.

Zhu, Q., Sarkis, J., & Lai, K. H. (2008). Confirmation of a measurement model for green supply chain management practices implementation. *International journal of production economics*, *111*(2), 261-273.

Zhu, Q., Geng, Y., Fujita, T., & Hashimoto, S. (2010). Green supply chain management in leading manufacturers: Case studies in Japanese large companies. *Management Research Review*, *33*(4), 380-392.

Wahab, A. N. A., Mukhtar, M., & Sulaiman, R. (2013). A conceptual model of lean manufacturing dimensions. *Procedia Technology*, *11*, 1292-1298.

Wee, H. M., & Wu, S. (2009). Lean supply chain and its effect on product cost and quality: a case study on Ford Motor Company. *Supply Chain Management: An International Journal*.

Wiese, A., Luke, R., Heyns, G. J., & Pisa, N. M. (2015). The integration of lean, green and best practice business principles. *Journal of Transport and Supply Chain Management*, *9*(1), 1-10.

Wilding, R., Wagner, B., Abbasi, M., & Nilsson, F. (2012). Themes and challenges in making supply chains environmentally sustainable. *Supply Chain Management: An International Journal*.

Wills, B. (2009). The business case for environmental sustainability: Achieving rapid returns from the practical integration of lean & green, rev. *A02-09, HPS Inc., Paulsboro, NJ*.

Womack, J. P., Jones, D. T., & Roos, D. (1990). Machine that changed the world. Simon and Schuster.

Womack, J. P., & Jones, D. T. (1996). Lean thinking—banish waste and create wealth in your corporation. Journal of the Operational Research Society, 48(11), 1148-1148.

Worley, J. M., & Doolen, T. L. (2006). The role of communication and management support in a lean manufacturing implementation. Management Decision, 44(2), 228-245.

World Commission on Environment and Development. (1987). Brundtland, G. H., Khalid, M., Agnelli, S., Al-Athel, S., & Chidzero, B. J. N. Y. Our common future. Oxford: Oxford University Press.

Wu, Y. C. (2003). Lean manufacturing: a perspective of lean suppliers. *International Journal of Operations & Production Management*.

Wu, L., Subramanian, N., Abdulrahman, M. D., Liu, C., Lai, K. H., & Pawar, K. S. (2015). The impact of integrated practices of lean, green, and social management systems on firm sustainability performance—evidence from Chinese fashion auto-parts suppliers. *Sustainability*, *7*(4), 3838-3858.

Yang, M. G. M., Hong, P., & Modi, S. B. (2011). Impact of lean manufacturing and environmental management on business performance: An empirical study of manufacturing firms. *International Journal of Production Economics*, *129*(2), 251-261.

Appendix 1. List of articles selected for the literature review

Author(s)	Title	Study method	Area of application	Contributions
King and Lenox 2001	Lean and green? An empirical examination of the relationship between lean production and environmental performance	Empirical analysis	Multisectoral	Lean positively influences the adoption of green practices
Rothenberg et al. 2001	Lean, green, and the quest for superior environmental performance	Survey	Automotive	Identified some conflicts between lean and green, but also agreed that lean facilitates the adoption of environmental management practices
Simpson and Power 2005	Use the supply relationship to develop lean and green suppliers	Single or multiple case study	Automotive	Developing a theoretical model for the integration of lean, lean supply and green practices. Found a positive connection between lean and pollution prevention
Corbett and Klassen 2006	Extending the Horizons: Environmental Excellence as Key to Improving Operations	Literature review	Theoretical	Lean naturally improves environmental change
Mollenkopf et al. 2010	Green, lean, and global supply chains	Literature review	Theoretical	Literature review of drivers, barriers, synergies and conflicts between lean, green and global supply chains
Vinodh et al. 2011	Tools and techniques for enabling sustainability through lean initiatives	Theoretical model	Theoretical	Exploring the green impacts of lean initiatives and developing a method for the integration of lean and green initiatives, transition from 5S to 7S
Carvalho et al. 2011	Lean, agile, resilient and green: divergencies and synergies	Literature review	Theoretical	A comprehensive literature review on synergies and conflicts of lean and green
Torielli et al. 2011	Using lean methodologies for economically and environmentally sustainable foundries	Theoretical model	Foundry	Provides a broad perspective on combining lean practices with environmental sustainability
Azevedo et al. 2012	Influence of green and lean upstream supply chain management practices on business sustainability	Single or multiple case study	Automotive	Lean and green practices have positive impacts on environmental and economic performance
Dües et al. 2013	Green as the new lean: how to use lean practices as a catalyst to greening your supply chain	Literature review	Theoretical	Lean SCM acts as a catalyst that facilitates the implementation of Green SCM. Green practices also have a positive influence on existing lean practices.
Duarte and Cruz-Machado 2013	Modelling lean and green: a review from business models	Literature review	Theoretical	Proposed a lean-green transformation model and identified connection between lean and green at strategic, tactical and operational levels
Hajmohammad et al. 2013	Lean management and supply management their role in green practices	Survey	Manufacturing plants	The impact of lean on green performance is mainly mediated by environmental practices
Martínez-Jurado and Moyano-Fuentes 2014	Lean Management, Supply Chain Management and Sustainability: A Literature Review	Literature review	Theoretical	Lean is beneficial for adopting green practices and improving environmental performance
Pampanelli et al. 2014	A Lean & Green Model for a production cell	Single or multiple case study	Automotive	Proposed a new Green and Lean model with a kaizen approach to support sustainable production
Chiarini 2014	Sustainable manufacturing-greening processes using specific Lean production tools: an empirical observation from European motorcycle component manufacturers	Single or multiple case study	Automotive (motorcycle components manufacturers)	Identified the green impacts of implementing specific lean practices including 5S, VSM, cellular manufacturing, SMED and TPM
Fahimnia et al. 2015	A tradeoff model for green supply chain planning: A leanness-versus-greenness analysis	Single or multiple case study	Manufacturing	Presents a supply chain model to identify trade-offs between cost and greenness
Pierch and Rich 2015	The relationship between lean operations and sustainable operations	Single or multiple case study	Multisectoral	Lean and green are linked. Lean can provide various sustainability outcomes beyond environmental benefits, such as supply monitoring and transparency

Campos and Vazquez-Brust 2016	Lean and green synergies in supply chain management	Single or multiple case study	Appliance sector	The majority of the studied lean and green practices are synergic with both initaitives
Ugarte et al. 2016	Lean versus green: The impact of lean logistics on greenhouse gas emissions in consumer goods supply chains	Simulation model	Theoretical	JIT increases frequency of transport and greenhouse gases in supply chains
Thanki et al. 2016	An investigation on lean-green implementation practices in Indian SMEs using analytical hierarchy process (AHP) approach	Theoretical model	Theoretical	Lean and green both influence the overall performance of the firm. TPM, Kaizen and 5S are most important lean practices and ISO 14001 green practice
Carvalho et al. 2017	Modelling green and lean supply chains: An eco-efficiency perspective	Single or multiple case study	Automotive	All firms belonging to the same supply chain cannot be completely lean or green. Some compromises may be required to achieve green and financial goals
Duarte & Cruz Machado 2017	Green and lean implementation: an assessment in the automotive industry	Single or multiple case study	Automotive	Firms in the automotive industry have high levels of green–lean implementation with identified benefits from both initiatives
Caldera et al. 2017	Exploring the role of lean thinking in sustainable business practice: A systematic literature review	Literature review	Multisectoral	A review of implementing lean and green practices to achieve sustainable business practices
Jakhar et al. 2018	Is lean synergistic with sustainable supply chain? An empirical investigation from emerging economy	Survey	Manufacturing	Lean and sustainable supplier selection and sustainable production have a positive connection but inconsistent results in delivery & logistic service
Zhan et al. 2018	Green and lean sustainable development path in China: Guanxi, practices and performance	Survey	Processing and manufacturing	Recognized a win-win relationship between green and lean practices in firm's green and business performance
Garza-Reyes et al. 2018	The effect of lean methods and tools on the environmental performance of manufacturing organisations	Survey	Manufacturing	By Investigating the impact of lean practices on green performance identified that TPM and JIT had the strongest impact on environmental performance
Inman & Green 2018	Lean and green combine to impact environmental and operational performance	Survey	Manufacturing	Lean practices can be positively associated with both green and operational performance
Belhadi et al. 2018	Benefits of adopting lean production on green performance of SMEs: a case study	Single or multiple case study	Manufacturing	Benefits of various lean practices on green performance are recognized
Leme et al. 2018	Creating value with less impact: Lean, green and eco-efficiency in a metalworking industry towards a cleaner production	Single or multiple case study	Manufacturing	The use of lean's tool SMED reduces setup times and improves firm's eco-efficiency and carbon footprint
Cherrafi et al. 2018	Lean, green practices and process innovation: A model for green supply chain performance	Survey	Multisectoral	The study revealed a synergetic impact between process innovations, green and lean practices, which play an important role in GSC performance
Huo et al. 2019	Green or lean? A supply chain approach to sustainable performance	Survey and interview	Multisectoral	Lean improves social, green, and economic performance, while green improves only environmental performance
Hussain et al. 2019	Assessment of lean-green practices on the sustainable performance of hotel supply chains	Survey	Service sector (hotels)	Lean and green impacts complement each other. Optimal TBL performance can be achieved through the synergic implementation of lean and green
Dieste et al. 2019	The relationship between lean and environmental performance: Practices and measures	Literature review	Multisectoral	Lean supports green with the majority of lean practices benefitting green performance
Singh et al. 2020	Impact of lean practices on organizational sustainability through green supply chain management – an empirical investigation	Survey and interview	Multisectoral	Lean improves organizational performance by identifying and eliminating waste with continuous improvement