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A Review of the Connections Between Lean Mudas and Green Wastes

Yalın İsraflar ve Yeşil Atıklar Arasındaki Bağlantılara Yönelik Bir İnceleme

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ABSTRACT

In addition to the operational concerns of today's businesses, environmental and social goals have increased the interest in lean and green paradigms. This study focuses on waste (waste), a common focal point of lean and green; it aims to discover the connections between lean and green waste. The protocol adopted a flexible approach to including/excluding studies on lean waste and green waste that were of interest to different disciplines, and a semi-systematic literature review method was used. According to the findings, publications examining individual connections between lean and green waste types are limited and scattered. Lean waste types have direct/indirect connections with green wastes, especially energy-material consumption, emission release, and these connections have attracted attention in the literature. In fact, studies on wastes and their connections have evolved into studies on business performance in recent years. This study will provide insight to businesses for eliminating lean and green waste, which is essential for economic and environmental impacts. It is important for this study to contribute to the synergy that can be created by combining lean-green paradigms with a waste perspective in industrial and academic settings.

MAKALE BİLGİSİ

Makale Türü
Araştırma Makalesi

Anahtar Kelimeler
Yalın İsraf (Muda)
Yeşil Atık
Atıklar Arasındaki Bağlantı
Yarı-Sistematik Literatür İncelemesi

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ÖZ

Günümüz işletmelerinin operasyonel kaygılarının yanında çevresel, toplumsal hedefleri yalın ve yeşil paradigmalara olan ilgiliyi artırmıştır. Yalın ve yeşilin ortak odak noktası olan atıkları (israf) konu edinen bu çalışma, yalın israf ve yeşil atıklar arasındaki bağlantıları keşfetmeyi amaçlamaktadır. Farklı disiplinlerin kapsamındaki yalın israf ve yeşil atıklara ilişkin çalışmaların dahil edilmesi/dışlanması protokolünde esnek bir yaklaşım benimsenerek yarı sistematik literatür inceleme yönteminden faydalanılmıştır. Bulgulara göre yalın israf ve yeşil atık türleri arasındaki münferit bağlantıları inceleyen yayınlar oldukça kısıtlı ve dağınıktır. Yalın israf türlerinin özellikle enerji-malzeme tüketimi, emisyon salınımı gibi yeşil atıklarla doğrudan/dolaylı bağlantılara sahip olduğu, bu bağlantıların literatürde ilgi gördüğü söylenebilmektedir. Atıklar ve aralarındaki bağlantılara ilişkin çalışmaların son yıllarda işletme performansına yönelik çalışmalara evrildiği görülmektedir. Bu çalışma ekonomik ve çevresel etkileri açısından önem taşıyan yalın israf ve yeşil atıkların eşzamanlı ortadan kaldırılmasında işletmelere içgörü sağlayabilecektir. Sanayi ve akademik alanda yalın-yeşil paradigmaların atık yaklaşımında birleştirilmesiyle yaratılabilecek sinerjiye katkı sağlayabilmek bu çalışma için önem taşımaktadır.

1. Introduction

Today's intensely competitive environment challenges businesses to provide customized products and production environments sensitive to customer needs at affordable costs and puts pressure on them to manage the environmental and social impacts of the activities carried out responsibly. Therefore, in addition to known performance criteria, such as profitability, efficiency, quality, and flexibility, the necessity to comply with laws and regulations regarding environmental protection has also been used as an essential criterion in evaluating the performance of businesses in recent years. The increase in customer demand for environment-friendly products/services and the need to meet this demand with low-cost and efficient use of resources have also brought about

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the need to reorganize business processes and operations. Lean and green production, which serve these needs, have become two approaches adopted by companies, researched, and discussed in the academic field to improve operational and environmental efficiency while meeting customer demands.

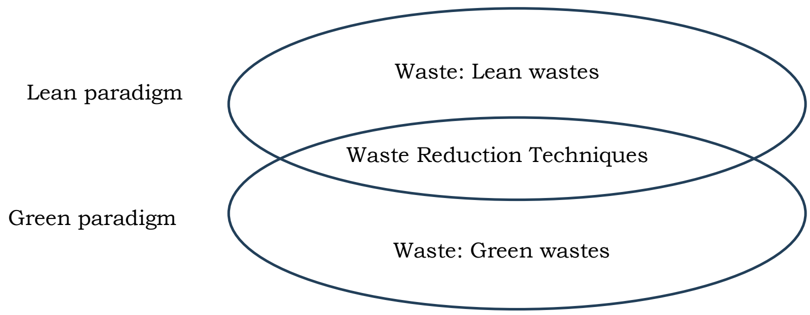
Lean manufacturing is a multidimensional management paradigm that systematically eliminates waste by developing faster, more reliable, and lower-cost operations that produce higher-quality products/services (Choudhary et al., 2019). This paradigm encompasses all processes from product design to product sales, emphasizing process improvement by eliminating any operations that do not provide value (Jasiulewicz-Kaczmarek, 2014). Lean manufacturing, which enables increased productivity and better use of production resources, has been comprehensively applied by different industries worldwide. It improves enterprise operational performance in various ways (Flynn et al., 1995). Operational performance is related to the ability of a production facility to produce products more efficiently and deliver them to customers smoothly (Inman and Green, 2018). Operational performance in enterprises measures key indicators, such as productivity, flexibility, delivery, quality, unit production cost, and waste reduction, as well as meeting customer expectations, maintaining the customer base, and reaching the targeted market share (Duah and Nadarajah, 2020).

However, the environmental concerns experienced worldwide in recent years, and the awareness in society on this issue, show that it is not enough to improve production resources and increase operational performance in businesses. Additionally, environmental performance should be improved by reducing the use of natural resources and the adverse effects of manufacturing operations on the environment (Farias et al., 2019; Garza-Reyes, 2015). Green production, which emerged with this requirement, is a modern industrial engineering method that minimizes waste and pollution, aims to reduce resource consumption and environmental impact, and ensures that businesses' economic and environmental performances are synchronized (Prasad et al., 2016). Green production, which transforms traditional production practices into environmentally friendly and energy-efficient processes and resource conservation practices to produce green products/services (Sumant and Negi, 2018), supports environmental responsibility through legislation and increases the environmental performance of businesses (Chen, 2014). Environmental performance is related to the ability of manufacturing facilities to reduce air emissions and liquid and solid waste, as well as the consumption of hazardous and toxic substances (Inman and Green, 2018).

Lean production increases operational performance, whereas green production increases environmental performance. These paradigms also support the crosswise performance dimensions of the business: lean practices facilitate environmental performance, and green practices facilitate operational performance (Farias et al., 2019). For example, green production can reduce production costs and improve production time by reducing material waste and energy consumption (Deif, 2011). It can also increase product quality (Hallam and Contreras, 2016a). However, on the other hand, within the framework of the green paradigm, it is stated that the target of reducing product delivery frequency to reduce carbon dioxide emissions can hurt operational performance (Carvalho et al., 2011). Similarly, although lean manufacturing helps adopt environmental management practices (Yang et al., 2011), thereby improving environmental performance (Hajmohammad et al., 2013; Jabbour et al., 2013), there is no consensus on this issue. Some lean practices may negatively impact the environment (Venkat and Wakeland, 2006; Rothenberg et al., 2001) and may not improve environmental performance in businesses either absolutely (Dües et al., 2013) or alone (Yang et al., 2011). Therefore, connections exist between lean and green production (Johansson and Sundin, 2014). Although lean and green production are approaches that go side by side and positively affect each other (Salvador et al., 2017), the relationship and interactions between these two paradigms in terms of behavior exhibit a complex structure (Hallam and Contreras, 2016a). According to Teixeira et al. (2021), current research on this subject is still the first step in revealing these interactions. Indeed, according to Sumant and Negi (2018), there is a need to unravel the nature of the relationship between green production and lean production because discovering the connection between them will enable the determination of the contributions or negativities of these two paradigms.

Lean and green manufacturing embrace the concepts of waste reduction, process orientation, and high degrees of interaction and engagement (Martínez-Jurado and Moyano-Fuentes, 2014). Although support for participation in human resource and process management approaches is required, the majority of the literature accepts that the waste reduction approach is the key area of these production paradigms (Fercoq et al., 2016; Sumant and Negi, 2017; Salvador et al., 2017) (Figure 1).

Figure 1: Lean and Green Paradigms from Waste Perspective



Reference: Fercoq et al., 2016:570; Dües et al. 2013:97.

Lean production focuses on waste to increase efficiency and reduce non-value-added activities, whereas green production targets waste to prevent pollution and emissions from an ecological perspective (Dieste et al., 2019). It is necessary and essential to keep in mind that the concept of waste, which is considered the focus of lean and green production paradigms (Johansson and Sundin 2014), is also a different perspective and fundamental contradictory area of these paradigms (Abualfaraa et al., 2020). However, the fact that both lean and green waste directly impact business performance, resource consumption, customer focus, cost, and ecology makes the concept of waste remarkable (Verrier et al., 2016). Moreover, according to the data by EUROSTAT (2024) published in 2024, the total waste production of economic activities and households in the EU is approximately 5 kg per person, reinforcing the importance of waste in the environment and society. Therefore, waste has created an agenda worldwide.

Lean and green approaches have a common goal of reducing waste (Sumant and Negi, 2017; Salvador et al., 2017). Therefore, both approaches converge on a strategic goal. However, the literature also indicates that waste is the area where these two approaches contradict (Abualfaraa et al., 2020). This contradiction is at the operational level because they aim to reduce different types of waste from operations/activities. For example, emission release, which is one of the most basic wastes of the green approach, is not directly included in the waste target of the lean approach (Bashkite et al., 2012); similarly, to increase product quality at low cost, the use of environmentally harmful substances may be in question in the lean approach (Rothenberg et al., 2001). This is precisely why the connections between different types of waste need to be explored. However, studies in the literature focus on the general relationships between lean and green waste rather than their individiul relationships (Hallam and Contreras, 2016b); the one-way effects of lean waste on a specific green waste such as emissions or energy (Balinski and Grantham, 2013; Golzarpoor and González, 2013) or the general environmental impacts of lean waste and lean practices (Moreire et al., 2010; Dieste 2019). While environmental issues are an essential agenda item worldwide, and while business activities directly affect environmental issues, the lack of sufficient and up-to-date studies on the connections between lean waste and green waste creates a paradox. Hallam and Contreras (2016a) explain this situation as the fact that lean and green connections have further complicated the already complex and variable production environments. However, it is a fact that much more discovery is needed regarding wastes and the connections between them to achieve both operational and environmental goals. Indeed, discovering the connections between the waste types defined and targeted by both approaches will be important in terms of measures and strategies to be taken both socially, environmentally and economically. This study fills the gap in the literature by making inferences in the context of detailed and individual relationships regarding which waste types are connected to which waste types within the scope of lean waste and green waste. The study also differs from many studies in the literature because it includes all waste types defined in both lean and green paradigms instead of considering a certain number of waste types. In addition, by acknowledging the fact that more studies are needed on the connections between lean and green (Teixeira et al., 2021; Sumant and Negi, 2018), it will contribute to the literature in terms of determining the direction in which today's developments in the relevant field are evolving.

The study continues with the importance of lean and green wastes and their effects on operational and environmental performance. The research questions determined within the scope of this study were investigated using the literature review method in the methodology section. The study ends with the results obtained and a discussion section.

2. Lean Waste (Muda)

The lean manufacturing paradigm, developed by Ohno in 1988 at Toyota Motor Corporation in Japan, aims to systematically eliminate waste by producing faster, more reliable, higher-quality products and services and, more importantly, developing low-cost operations (Choudhary et al., 2019). Bergmiller and McCright (2009) stated that the lean manufacturing system is a never-ending commitment to reducing waste using best practices; everything that does not directly contribute to creating value is waste. The Japanese equivalent is muda (Fercoq et al., 2016). The types of waste that cause time, resources, and space consumption are divided into seven classes: over-production, defects, inventory, over-processing, transportation, waiting, and movement (Çetindere Filiz et al., 2018; Sutrisno et al., 2018; Hallam and Contreras, 2016a; Nadeem et al., 2017; Choudhary et al., 2019). Considering that employees and human behavior have an essential share in the success of the lean production system in recent years, "unused talent" is regarded as the eighth waste (Verrier et al., 2016).

Table 1: Lean Wastes

Type of Lean Waste	Definition
Over-production	Producing more or early than what the customer has requested (unordered products).
Defects	Producing faulty goods is a situation that requires re-making and leads to costs such as labor and materials.
Inventory	Stocks of materials or completed goods that are awaiting processing, transportation, inspection, etc.
Over-processing	Any production-related work that is done in excess of what the customer requests.
Transportation	Repetitive handling of the same materials or final product and needless movements.
Waiting	People wait for information, others, resources, equipment to finish automatic cycles, etc., prolonging manufacturing or distribution cycles.
Motion	Movement of people or equipment that doesn't provide value can lower process productivity.
Lost people potential	Lost potential for improvement

Reference: Choudhary et al., 2019: 355; Waheed et al., 2024: 349; Verrier et al., 2016:8.

Lean waste increases a company's costs, reduces performance, and even causes a loss of motivation (Verrier et al., 2016). For example, "over-production" leads to longer process cycle times, higher costs, and longer lead times; "waiting" leads to increased cycle times and costs; "over-processing" leads to excessive transportation and poor communication; and "movement" leads to higher cycle times and costs (Awaritoma, 2010), negatively affecting the performance of the production process. Many studies have proven that reducing waste through lean production can significantly improve operational performance metrics, including cost, efficiency, and quality (Hallam and Contreras, 2016a; Choudhary et al., 2019). Rahman et al. (2010) stated that minimizing waste positively correlates with operational performance. In their study, Aljunaidi and Ankrah (2014) stated that lean practices reduce waste and improve operational performance indicators, such as quality and cost. Rahani and Al-Ashraf (2012) concluded that reducing waiting waste in the production process, and Suroso and Santosa (2024) concluded that reducing inventory waste is significantly related to operational performance.

Lean waste affects businesses' operational and environmental performance (Sutrisno et al., 2018). The inefficient use of business resources, keeping excess inventory, and encountering too many defects lead to low environmental performance (Hajmohammad et al., 2013; Dües et al., 2013). According to King and Lenox (2001), there is a positive correlation between reduced emission releases, waste output, and inventory levels. The Environmental Protection Agency [EPA] (2007) supports the fact that lowering lean waste provides environmental gains, which indicates that less over-processing and a more efficient transportation system reduce emission levels, and less inventory in the right-sized production unit also reduces material, land, and energy consumption (www.epa.gov). Contrary to studies proving that reducing lean waste improves the environmental performance of businesses, Rothenberg et al. (2001) stated that the inventory level of lean waste is not statistically related to the amount of emissions released.

However, Hajmohammad et al. (2013) stated that improving environmental performance is not due to decreased inventory; he skills and technical knowledge developed and applied in this process facilitate the adoption and implementation of environmental initiatives. Choudhary et al. (2019) emphasize that businesses use an integrated strategy based on lean and green synergies; finding the areas where lean and green waste intersect is one method of identifying this synergy.

3. Green Waste

The green approach seeks to lessen the harm that product and service production and usage do to the environment and living things (El Faydy and El Abbadi, 2020). It includes processes and practices that consume fewer energy and materials, reduce possibly harmful waste through reuse and recycling, and avoid pollution at the source (Inman and Green, 2018). Accordingly, green production focuses on integrating environmental improvements into industrial processes and products (El Faydy and El Abbadi, 2020).

The definition and purpose of green production include waste (Bergmiller and McCright, 2009). Green waste, also called environmental waste (EPA 2007, Hallam and Contreras 2016b, Hallam and Contreras, 2016a), is defined as the needless or excess use of resources and material released into the air, water, or soil that may endanger human health or the environment (EPA, 2007). Although the EPA (2007) lists green waste as energy, water, raw material, and material waste, pollution, and hazardous waste that happens when businesses use resources to provide products or services to their customers and/or when customers use and discard products, it emphasizes that it is not limited to these. Inspired by the lean approach and waste types, Hines (2009) grouped green waste into eight green mudas categories. Some of these include greenhouse gas emissions, eutrophication, excessive resource and water usage, excessive power use, pollution, waste, and poor health and safety. Choudhary et al. (2019) added transportation waste to these waste types and defined it as unnecessary material product or human transportation. The green waste types and their definitions are listed in Table 2.

Table 2: Green Wastes

Type of Green Waste	Definition
Energy	Overusing power from lights, motors, and electronics.
Emission	Overspending to produce and release pollutants on-site, then being hit with the penalties and charges that come with it.
Water	One example of overusing freshwater is using more water than necessary and then paying to have it removed and cleaned again.
Garbage	Purchasing something that will be discarded, such as something that has a detrimental effect on the environment, and then having to pay for disposal again.
Material	Creating items using pristine raw materials that would end up in the landfill or creating resource-expensive non-recyclable products with a limited life period.
Transportation	Unnecessary movement of people, products, and commodities.
Biodiversity	Either adversely affecting plants and animals directly or overusing resources more quickly than they can be replenished.

Reference: Choudhary et al., 2019: 355.

Green waste types are also used as direct criteria to evaluate the environmental performance of enterprises (EPA, 2007). The GRI guide, which provides a practical framework for sustainability reporting, known worldwide as the ISO 14001 standard, evaluates environmental performance using green waste indicators such as resources, energy, water consumption, waste amount, emission amount, and pollution (Istanbul Chamber of Industry, 2008; GRI, 2011). Verrier et al. (2016) stated that enterprises create environmental impacts from green waste. Therefore, it would not be wrong to say that green waste is both an environmental performance indicator and a tool for environmental performance because many studies have directly accepted green waste as an environmental performance indicator (Nadeem et al., 2017; Nishant et al., 2012; Inman and Green, 2018).

Like lean waste, green waste that does not create added value can directly affect production flow, time, quality, and cost, and can cause a decrease in the operational and financial performance of businesses (EPA 2007). Hallam and Contreras (2016a) stated that preventing pollution can reduce cycle times, efficiency, and costs by eliminating unnecessary steps in operations; improving process quality also increases product quality. Nishant et al. (2012) concluded that reducing emissions levels affects energy and material efficiency and cost reduction. However, Jabbour et al. (2013) stated in their research that reducing waste positively and weakly affects operational performance. There is a greater need for research on green waste and its effects on businesses to be successful in a competitive market where consumers' environmental awareness is increasing, on the one hand, and to reduce the environmental impact.

4. Research Design and Methodology

One of the main areas where lean and green paradigms, which have common waste reduction goals, contradict each other is the waste approach (Abualfaraa et al., 2020). Although they meet the denominator of waste reduction, the literature agrees that these paradigms target different waste types (Dües et al., 2013; Abualfaraa et al., 2020). Bashkite et al. (2012) stated that emission release, one of the most basic wastes of the green approach, is not directly included in the waste target of the lean approach. Similarly, Rothenberg et al. (2001) stated that using environmentally harmful substances may be in question in the lean approach to increase product quality at a low cost. In addition, the US EPA (2003:23) defines lean and green approaches as "parallel universes of waste reduction" despite sharing many waste reduction practices. Hallam and Contreras (2016a) argue that it is necessary to investigate the complex relationships between these approaches (Hallam and Contreras, 2016a; Johansson and Sundin, 2014). However, Teixeira et al. (2021) stated that current research is still the first step in revealing the interactions between lean and green paradigms. Similarly, Verrier et al. (2016) and Sumant and Negi (2018) also emphasized that more studies are needed. According to Bashkite et al. (2012), solutions to discover potential relationships between lean and green approaches are hidden in the contradictions between the approaches. Indeed, one of the main contradictory areas of these approaches is the waste approach (Dües et al. 2013), which constitutes the motivation of this study in terms of the relationships between waste. The starting point of this study was that providing insight into the connections between lean and green waste types could be vital for unraveling the relationships between lean and green approaches.

A limited number of studies have examined the general connection between lean and green waste. Hallam and Contreras (2016b) discovered a repulsive relationship between lean and green waste in their research based on a literature review; that is, environmental waste decreases directly or indirectly with a decrease in lean waste. They stated that no evidence exists for the opposite situation except for a theoretical assumption in the literature. Nadeem et al. (2017) concluded in their qualitative study of industrial enterprises in China and Hong Kong that lean and green waste are related. However, these studies have concentrated on the general connections between lean and green waste rather than the individual relationships between waste types. Indeed, the complex relationships between lean and green approaches (Hallam and Contreras, 2016a) are reflected in the connections between waste types, and providing a more precise look at the individual relationships rather than the general relationship between wastes is an essential step for business performance. In addition, Choudhary et al. (2019) emphasized that investigating the overlap between lean and green waste is necessary to achieve lean and green synergy. Therefore, this study sought to answer the following questions:

• What are the individual connections between the lean and green waste types?

• What are the research trends in recent years regarding the connections between waste types compared with past research?

4.1. Method

According to Snyder (2019), the production of interdisciplinary knowledge in business research continues to increase rapidly; however, it becomes more challenging to follow developments and evaluate evidence in a particular research area, and the importance of literature review as a research method also increases. A literature review offers a thorough overview of earlier research by methodically gathering and summarizing (more or less) earlier publications on a particular topic (Denney and Tewksbury, 2012). A systematic literature review, a scientific research method, is an open and repeatable method with strict requirements regarding the search strategy and selection of studies to be included in the review (Snyder, 2019). However, in literature studies based on topics that have been conceptualized differently and examined within the scope of various disciplines, Snyder (2019) recommends a semi-systematic review approach instead of a complete systematic review process, stating that it may be appropriate to examine theoretical approaches and identify knowledge gaps in the literature. The semi-systematic literature review methodology, which aims to provide a descriptive overview of the literature, adopts a more flexible approach to the inclusion/exclusion protocol of the studies to be reviewed (Zunder, 2021: 2).

The semi-systematic literature review approach is designed for topics conceptualized differently and studied by researchers from various disciplines (Wong et al., 2013). In addition to examining a topic in general terms, it usually aims to reveal how the selected topic has progressed or developed across research traditions (Polat, 2021). This approach provides an understanding of complex areas by identifying research traditions related to the topic during the review process and synthesizing them using meta-narratives. The semi-systematic literature review method, which generally adopts approaches in qualitative research, helps explore themes, theoretical perspectives, common problems within a particular research discipline or methodology, or identify components of a theoretical concept (Snyder, 2019). Stating that a semi-systematic literature review plays a vital role in highlighting the strengths and weaknesses of different research approaches, Buonincontri et al. (2021) listed the steps to be followed to ensure a rigorous and transparent process as follows:

• Define the topic area, determine the search terms, and the databases. Not all publications collected through this process are relevant to the subject of the review. Therefore, some publications are eliminated using inclusion and exclusion criteria.

• Conduct the review. Information on the publications selected using the inclusion/exclusion criteria is extracted. A search protocol is developed to ensure the reliability and transparency of the review process, and the relevant characteristics of the studies included in the review are specified (e.g., year of publication, authors, type and place of publication, context of publication, methodology, findings, etc.).

• Analyze the publications. The data extracted from the publications can be descriptive information, impacts, findings, or conceptualizations of a particular idea.

• Report: A report is prepared to synthesize the publications and indicate developments related to the subject of the review. The report provides information on the evolution of the research topic over time, main authors, methodologies adopted, etc.

This study adopted a literature review approach to critically analyze and synthesize the main ideas and findings regarding the individual connections between lean and green waste types and to follow the current trends and developments regarding waste. The waste approach is one of the topics examined within the scope of various perspectives and disciplines (Amasuomo and Baird, 2016:88). Taking into account Snyder's (2019) suggestion regarding such situations, this study chose a semi-systematic literature review approach to examine the connections between lean and green waste types.

Strategy and Scope of Search

This study used Web of Science (WOS) and Scopus databases, the most widely used databases in literature reviews, and have a significant scientific impact. These databases are characterized by the high quality of the documents they report (Pranckutė, 2021). Since this study is based on the types of waste defined by lean and green production, it used the expressions "green waste" and "lean waste" as keywords. Publications were searched in relevant databases (as of July 2024) using keywords without any period or field of study limitations. The search strings used for the databases are listed in Table 3.

Table 3: Databases and Search Strings

Database	Search within and Keywords
SCOPUS	TITLE-ABS-KEY ("lean waste*" OR "lean muda*") AND TITLE-ABS-KEY ("green waste*" OR "green muda*" OR "environmental waste*" OR "environmental muda*")
Web of Science (WOS)	All fields ("lean waste*" OR "lean muda*") AND All fields ("green waste*" OR "green muda*" OR "environmental waste*" OR "environmental muda*")

According to the searches made in the databases using keywords, the SCOPUS database listed eight publications, and the WOS database listed three. The publications obtained by the search in the SCOPUS database were broader in scope, including those in the WOS database (Table 4).

According to the search results, the databases listed four conference proceedings and three articles (Table 4). While Taubitz's (2011) publication was repeated, Vincent's (2009), Bergmiller's, and McCright's (2011) publications were not found. Although the Operational Excellence Conference and Expo (2009) publication was listed in the search results, there was no information about the author and publication name.

Table 4: Search Results in Databases

Author	Year	Source	Database	
			Scopus	WOS
Abreu, M.F., Alves, A.C., Moreira, F.	2024	Sustainability (Switzerland)	●	●
Bortolini, M., Calabrese, F., Galizia, F.G., Mora, C.	2022	Computers and Industrial Engineering	●	●
Choudhary, S., Nayak, R., Dora, M., Mishra, N., Ghadge, A.	2019	Production Planning and Control	●	●
Taubitz, M.	2011	SAE 2011 World Congress and Exhibition	●	
Taubitz, M.	2011	SAE Technical Papers	●	
Bergmiller, G.G., McCright, P.R.	2011	61st Annual IIE Conference and Expo Proceedings	● (not accessed)	
[No Author Found]	2009	Operational Excellence Conference and Expo 2009	● (not accessed)	
Vincent, C.	2009	Operational Excellence Conference and Expo 2009	● (not accessed)	

Note: ●; The publication is included in the relevant database.

Inclusion and Exclusion Criteria

In the study that aims to provide insight into the connection between waste types, excluding publications that do not establish any connection between lean and green waste will help eliminate confusion and provide more realistic results. This study considered two essential criteria when determining the publications to be included in the review:

• The publication should include at least one of "lean waste" and "green waste."

• The publication should mention individual relationships between lean and green waste types (at least one waste type defined in the literature and another waste type/types).

We reviewed the publications listed in the databases (Table 4) regarding purpose, scope, and inclusion-exclusion criteria. In their study investigating whether lean companies are more sustainable, Abreu et al. (2024) emphasized waste prevention perspectives and continuous efforts to identify and reduce all causes of lean waste. Although the study focused on lean and environmental waste, it did not examine the connection between lean and green waste. Similarly, Taubitz (2011) used the concepts of lean and environmental waste but offered ideas on adapting lean techniques to the office environment; he did not mention the connections between waste types. Therefore, we excluded these two publications from the scope of this review.

The number of publications we accessed through the databases was minimal, and we found that some did not serve the purpose of the review. In fact, Lecy and Beatty (2012) stated that keyword queries in databases can be deceptive when publications do not regularly utilize keywords and proposed a snowball sampling technique. Ames et al. (2019) noted that the purposive sampling method helped determine the publications to be included in the literature review to obtain a manageable amount of data. Indeed, Snyder (2019:337) states that a semi-systematic approach can combine different sampling methods (systematic or unsystematic) and analysis and evaluation (qualitative or quantitative).

In addition to the publications listed in the databases, this study used purposive sampling to access publications that touched on the connections between lean and green waste types and snowball sampling to access other publications through citations in the publications. The difficulty of this study is that it requires reading and examining every accessible publication in the research process, including publications within the scope of the study. Seventeen accessible publications met the specified conditions were included in this study (Table 5).

Table 5: Publications Included and Reviewed in The Study

Number of publication	Author	Data		Industry	Type of Research			Related waste		Performance		Type of Publication	Source
		Quantitative	Qualitative		Conceptual/ Literature Rev.	Research application	Case study	Lean	Green	Operational	Environmental		
1	King and Lenox (2001)	•		Manufacturing		•		inventory	emission		•	A	Production and Operations Management
2	Venkat and Wakeland (2006)	•		Manufacturing, Food			•	inventory, transportation	emission		•	CP	Proceedings of the Annual Meeting of the ISSS
3	EPA (2007)			Manufacturing	•			all wastes	all wastes	•	•	B/R	U.S. Environmental Pr otection Agency
4	Sawhney et al. (2007)		•	Metal cutting			•	inventory, over-production, defects, over-processing	emission, air pollution, energy, waste water, hazardous waste		•	A	Int. J. Enterprise Network Management,
5	Moreira et al. (2010)			Manufacturing	•			all wastes	emission, energy, material consumption		•	CP	Balanced Automation Systems for Future Manufacturing Networks
6	Bashkite and Karaulova (2012)			Manufacturing	•			all wastes	energy, toxic, solid waste, water, air pollution			CP/A	Annals of DAAAM/Proceedings of the International DAAAM Symposium
7	Balinski and Grantham (2013)	•		Automotive			•	inventory	emission			A	Engineering
8	Golzarpoor and González (2013)	•		Construction			•	transportation	emission, energy	•	•	CP	International Group for Lean Construction
9	Fercoq et al. (2016)	•		Manufacturing	•		•	all wastes	solid waste	•	•	A	Journal of Cleaner production
10	Folinas et al. (2014)	•	•	Food and farming			•	over-production, over-processing	emission		•	A	International Journal of Agricultural Resources, Governance and Ecology
11	Verrier et al. (2016)	•	•	Manufacturing	•	•	•	all wastes	emission, resource consumption, power usage, rubbish	•	•	A	Journal of Cleaner Production
12	Choudhary et al. (2019)	•		Manufacturing			•	inventory, transportation, defects, motion, waiting	emission	•	•	A	Production, planning & Control
13	Baysan et al. (2019)	•		Power distribution			•	all wastes	energy			A	Journal of Cleaner Production
14	Francis and Thomas (2020)		•	Construction	•			all wastes	air pollution, energy and raw material extraction, emission, material waste		•	A	Journal of Cleaner Production
15	Bortolini et al. (2022)	•		Construction		•		inventory	emission			A	Computers & Industrial Engineering
16	Waheed et al. (2024)			Construction	•			all wastes	material and resource consumption			A	HBRC Journal
17	Alazmi et al. (2024)			Construction	•			all wastes	energy, water, material, air and water pollution, hazardous, solid waste	•	•	CP	International Group for Lean Construction

Note: •, publication is covered by the option in the relevant column; A: Article; CP: Conference paper; B: Book, R: Report

4.2. Results

The publications we reached within the study's scope were from 2001 to 2024 (Table 5). The publications were conference papers and articles, 11 of which were articles, four conference proceedings, one book (report), and one book/report publication. Six publications, mainly in the manufacturing and construction sectors, were conceptual/literature reviews, seven were case studies, two were research applications, and two were conceptual/literature reviews/case-study research methods. Eight publications used quantitative data, two used qualitative data, and the others used quantitative and qualitative data. Five publications expressed the impact of waste type on operational and environmental performance, while six were interested in environmental performance. While the publications are included in sources related to engineering, manufacturing, environment, or the lean approach, it is noteworthy that two publications from the construction sector are included in the International Group for Lean Construction journal, and five publications are included in the Cleaner Production journal.

Results of the Scope and Conceptual Framework

Definitions and classifications of lean waste types have been established in the literature as over-production, over-processing, inventory, defects, transportation, motion, and waiting (Sutrisno et al., 2018; Hallam and Contreras, 2016a; Nadeem et al., 2017; Choudhary et al., 2019). Although in recent years, with the awareness of the importance of employees and human behavior, “unused talent” has been defined as the eighth waste (Verrier et al., 2016), no study has been found that addresses the environmental impact of this new lean waste type or its connection with green waste. Unlike lean waste, there is no consensus in the literature on the classification of green waste. The classification of these waste types, expressed as green waste (Bashkite et al., 2012; Verrier et al., 2016) or environmental waste (EPA, 2007; Alazmi et al., 2024), may differ among studies but is diversified based on the classification of the EPA (2007). The EPA (2007), a reference to many other studies, has collected green wastes in seven categories: energy, water consumption and raw material consumption, air emissions, wastewater, hazardous wastes, and solid wastes. Verrier et al. (2016) added a class of lost people potential, unlike other green waste classifications. The green waste classifications in the publications are listed in Table 6.

Table 6: Green Waste Classifications

Publication	Categories of green wastes
EPA (2007)	Energy, Water and Raw materials consumption, Air-emissions, Waste water, Hazardous and Solid wastes
Bashkite and Karaulova (2012)	Energy, Water, Air, Toxic and Hazardous waste, Solid waste
Verrier et al. (2016)	Excessive Resource and Power usage, Air emissions, Rubbish, Poor health and safety, lost people potential
Alazmi et al. (2024)	Excessive consumption (energy, water, material) Excessive emission (air pollution, water pollution, hazardous, solid waste)

Since green waste types are also environmental performance criteria of businesses (EPA, 2007), some studies have considered environmental performance indicators instead of green waste (Venkat and Wakeland, 2006; Sawhney et al., 2007; Folinas et al., 2014; Baysan et al., 2019). Considering the data obtained from the production sector, King and Lenox (2001) and Venkat and Wakeland (2006) evaluated the amount of emission release; Folinas et al. (2014) assessed the amount of emission release and energy consumption as environmental performance indicators. Another publication that considers the amount of energy consumption as environmental performance is Baysan et al. (2019), who examined an electrical component production facility.

Moreira et al. (2010) expanded the scope of the environmental performance indicator by adding the amount of material consumption. In their study on the metal-cutting process, Sawhney et al. (2007) included most of the green waste types in environmental performance, including air pollution, energy, wastewater, and hazardous waste.

The first detailed study examining the connection between wastes and based on the term of waste, rather than considering waste types as performance indicators, was conducted by the US EPA (2007). The EPA (2007) examined the environmental impacts caused by lean waste and stated that it could be considered environmental waste. This publication, which has a broad scope regarding lean and green waste, has been a reference for many studies in the literature. In their conceptual study, Bashkite and Karaulova (2012) created a contradiction matrix for all lean and green waste production processes. Verrier et al. (2016) contributed to the literature by investigating the synergies between all lean and green wastes. Their study used data from examinations, onsite observations, and industrial cases. Fercoq et al. (2016) evaluated the effect of reducing lean waste on solid waste performance using waste-reduction techniques. Balinski and Grantham (2013) presented a case study to quantify the relationships between wastes by calculating inventory waste in terms of carbon dioxide emissions. Similarly, Choudhary et al. (2019) considered the amount of emissions as a basis but expanded the scope of lean waste. Based on the idea that the process that produces lean waste in a packaging-production company also produces green waste, they calculated the carbon equivalent of other lean wastes, excluding over-production and over-processing, based on standard carbon conversion factors.

Publications in the construction sector have extensively examined the connection between lean and green waste. Golzarpoor and González (2013) limited the scope of lean waste to transportation in the relevant industry and the scope of green waste to energy consumption and emission amounts. Bortoloni et al. (2022) considered the inventory level (lean waste) and environmental emissions (green waste). Stating that establishing a relationship between environmental and lean waste in current construction application projects has not been successful, Alazmi et al. (2024) examined theories and practices concerning integrating production waste with current environmental waste concepts. They compiled the relationships between production and environmental waste in a matrix form. Waheed et al. (2024), who conducted a literature review on the combination of sustainability and lean approaches in reducing waste in the early design phase in the construction sector, examined lean waste and resource and material wastes, that is, the most critical green waste. Francis and Thomas (2020), in their literature on lean construction and sustainability, examined the direct and indirect relationships of different waste types with specific environmental parameters.

Results on the Connections Between Wastes

Although the literature accepts that lean and green approaches contradict each other from a waste perspective, the EPA (2007) concluded that lean waste co-occurs with environmental waste in companies in the United States and that environmental waste types are related to or embedded in lean waste types. Salvador et al. (2017) say this situation connects lean and green waste. Indeed, Abualfaraa et al. (2020) stated that lean activities without added value can be considered a waste of energy and natural resources. Thus, lean waste can be associated with green waste (Abualfaraa et al., 2020). For example, unnecessary movement of raw materials, semi-finished, and finished products is considered waste from both lean and green viewpoints regarding power consumption, gas emissions, and excessive resource use (Salvador et al., 2017). Therefore, the literature agrees that lean wastes are linked to green wastes owing to the environmental impact they produce and that there is a repulsive relationship between them (Balinski and Grantham, 2013). This indicates a positive correlation that green waste will also increase if lean waste increases. However, the studies in the literature on reducing lean and green waste types and their relationships are scattered and limited. It would not be wrong to say that the existing studies are based on the relationships in EPA's (2007) research. The results regarding the individual connections between lean and green waste types in publications are shown in Table 7 within the parameters of the investigation. We did not make any groupings in Table 7 to protect the green waste expression in the publications.

Accessible publications (Table 7) have drawn attention to the connections between all types of lean waste and various types of green waste. Publications have extensively examined the connections between lean waste types, particularly concerning energy consumption. Indeed, the definition of lean wastes in the literature as a waste of energy and natural resources (Abualfaraa et al., 2020) in publications in the relevant field (EPA, 2007; Moreira et al., 2010; Bashkite and Karaulova, 2012; Folinas et al., 2014; Baysan et al., 2019; Alazmi et al., 2024) encourages the examination of these connections.

Publications have also considered the links between emissions released from green waste and the lean waste types especially inventory and transportation (King and Lenox, 2001; Venkat and Wakeland, 2006; EPA, 2007; Sawhney et al., 2007; Golzarpoor and González, 2013; Balinski and Grantham, 2013; Verrier et al., 2016; Choudhary et al., 2019). These links are the direct relationship between inventory amount, transportation frequency, and emission release (King and Lenox, 2001; Venkat and Wakeland) and an indirect relationship in terms of increasing emission release and air pollution due to increasing transportation frequency with decreasing inventory amount (Sawhney et al., 2007). The amount of inventory is closely linked to energy consumption and material consumption, similar to over-production and over-processing waste (EPA, 2007; Moreira et al., 2010; Alazmi et al., 2024; Waheed et al., 2024).

According to the studies of Fercoq et al. (2016), Verrier et al. (2016), and Alazmi et al. (2024), every type of lean waste can also be defined as green waste. However, the literature has not examined the environmental effects of waiting and motion waste, which we call lean waste. Although not included in Table 7, Verrier et al. (2016) is the only publication that has considered poor health and safety and lost people potential as lean waste, stating that it could be linked to over-production, over-processing, transportation, and motion wastes.

Table 7: Connections Between Waste Types (Lean and Green) and Publication Number that Examining the Connections

Green Waste / Lean waste	Emission	Air pollution	Energy consumption	Excessive power usage	Excessive resource usage	Material consumption	Hazardous waste	Waste water	Solid waste /Rubbish
Over-production	(3) (10)	(6)	(3) (5) (10) (13) (14) (17)	(11)	(11) (16)	(3) (5) (14) (16) (17)	(17)	(17)	(17) (9)
Over-processing	(3) (10)	(5) (6)	(3) (4) (5) (10) (13) (14) (17)	(11)	(16)	(3) (5) (14) (16) (17)	(4) (17)	(17)	(9) (11) (17)
Inventory	(1) (2) (4) (7) (12) (15)		(3) (13)	(11) (17)	(16) (17)	(3) (5) (14) (16) (17)	(17)	(4) (17)	(9)
Waiting	(3)	(17)	(3) (5) (13) (17)						(9)
Transportation	(2) (3) (8) (11) (12)	(4) (14) (17)	(3) (5) (8) (13) (17)	(11)			(17)		(9)
Defects	(12)	(4) (5)	(3) (5) (13) (14) (17)	(11)	(11) (16)	(3) (14) (16) (17)	(4) (17)	(17)	(9) (17)
Motion	(3)	(14)	(3) (5) (6) (13) (17)					(17)	(9) (17)

5. Discussion

This study aimed to provide insight into individual connections between lean and green waste. Rather than covering all publications, this study used a semi-systematic literature review method to combine perspectives and inferences from different fields or research traditions and include publications in the review (Snyder, 2019). The study, which is limited to publications based on lean and green waste perspectives and addressing the connections between them, is essential in knowing the nature of the connections between waste types and in determining measures or strategies to reduce waste.

Garza-Reyes (2015) emphasizes that it is essential to determine lean and green waste in processes and analyze the causes and connections of these wastes for efficient and environmentally friendly production. However, according to the results of this study, the studies on the individual relationship dimension of lean and green waste types in the literature are scattered and limited. Waste management is a multidisciplinary subject covering different areas such as business, sustainability, and the environment (Tereshchenko et al., 2023). Although we kept the keywords within a general scope, especially for the systematic literature review method, we reached many publications that were not the subject of this study, and a limited number of related publications. This situation suggests that conceptual unity has not yet been fully achieved, especially in green production and green waste. Viles et al. (2022) express similar things for sustainable production associated with the green approach.

Publications on the connections between lean and green wastes are concentrated in the manufacturing and construction industries. According to the EUROSTAT EU (2022) waste production data, waste production from the construction industry ranks first in Europe; waste production from manufacturing ranks third. Therefore, examining the waste problem more intensively in the relevant sectors is natural and necessary. However, no research has been found in the service industry. Considering that the weight of the service industry has increased in the labor markets of industrialized countries in the last 10 years (Hsieh and Sossi-Hansber, 2023), the nature of the relationships between lean waste and green waste types in this industry may be a matter of curiosity. Comparing the connections between lean and green waste and the intensity of these connections in different industries (e.g., manufacturing and services) may be interesting for new studies.

The studies examining the connections between lean and green wastes mainly concern environmental performance. The literature defines environmental performance dimensions as the amount of emissions released and the energy consumption of green waste (Marrucci et al., 2024). Accepting green waste types as environmental performance indicators seems possible in this case. Bahedh and Al-Tamim (2024) also state that today's businesses see preventing the damage their waste causes to the environment as their commercial responsibility. This situation also explains the limited number of studies on the connections between lean and green waste and their lack of up-to-dateness. Because the term performance may evoke a more striking and strategic meaning than the term waste, this situation may make it more attractive for academics and industry to shift publications from a more specific dimension of waste to a strategic dimension of operational and environmental performance. However, Bota-Avram (2023) states that interest in sustainable business performance has increased significantly in recent years. This study's results also show that publications specifically addressing waste and the connections between them have evolved towards publications addressing business performance in recent years.

Notably, the studies examining the connections by considering all lean waste types and many green waste types (Francis and Thomas, 2020; Alazmi et al., 2024) are conceptual or literature studies. In this case, the individual connections of each waste type with all other waste types remain at a theoretical level. As suggested by Francis and Thomas (2020) for studies on the relationships between lean and environmental approaches, analyzing the data obtained by measurement with methods such as quantitative or simulation will provide more realistic inferences regarding the connections between wastes. Thus, legislators and business managers can make more rational decisions with more concrete data.

In terms of individual connections between lean and green waste, all lean waste types, especially their connections with energy consumption, have been studied in theory and practice. Relatively, all lean waste types, except inventory, are closely linked to energy consumption (green waste). Indeed, Baysan et al. (2019) and Salah and Mustafa (2021) stated that many lean wastes in production systems are closely linked to energy efficiency. Similarly, emission release has a strong connection, especially with inventory, transportation, and defects, and publications consider this (Choudhary et al., 2019; Bortoloni et al., 2022). Different fields of study have also accepted that inventory holding and transportation activities cause intense emission release (Assari et al., 2023). Publications consider emissions more than other types of green waste because emissions data are accepted as one of the most valid indicators for environmental assessment (Ritchie et al., 2023).

Unsurprisingly, material consumption in processes is linked to overproduction, overprocessing, inventory, and defects. This result is supported by Francis and Thomas (2020) and Waheed et al. (2024). Since these waste types cause reprocessing, spoilage, and unnecessary resource waste, they are directly linked to material consumption. No study has been found in the literature on the connection between motion and waiting from lean waste types and power, resource, and material consumption from green wastes. Therefore, whether there are direct and indirect connections between the relevant waste types can be investigated.

The literature accepts the direct positive effects of the lean approach on indispensable performance dimensions such as efficiency and cost (Duah and Nadarajah, 2020). However, there are no government-level sanctioning policies regarding lean practices. On the contrary, the green approach has a higher policy-level superiority over the lean approach, as it has become a part of government policies and regulations today (Francis and Thomas 2020). Considering that the lean and green approaches support each other and have a common goal, especially regarding waste (Abualfaraa et al., 2020), encouraging policies that support both approaches will ensure the satisfaction of different stakeholders. Therefore, integrating lean policies into the legal obligations regarding the green approach and green waste and implementing them in specific organizations can provide environmental and economic advantages.

This exploratory study provides up-to-date insight into the connections between lean and green wastes. It may contribute to unraveling the relationship between lean and green paradigms from a waste perspective. In addition, this study may provide insights into implementing waste reduction techniques adopted by lean and green paradigms by businesses separately, simultaneously, or sequentially. Exploring the connections between wastes may help practitioners identify which lean/green wastes to look for. According to Stanković et al. (2024), this makes integrating lean and green approaches in processes easier so that practitioners can synchronously improve operational and environmental performance.

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