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Lean, Green & Digital and the need for cross-functional collaboration – Requirements when heading from Industry 4.0 towards Industry 5.0

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1 Introduction

Supply chains are becoming significantly vulnerable. Furthermore, governmental regulations demand and the customers expect, that the products are made under best sustainable, ecological and social conditions. Competition is high, which leads to the challenge to create products fast, efficiently and under best ecological conditions. This all can be summarized as the high demand for *Lean, Green and Digital processes in value creation* that is discussed in this qualitative paper.

The purpose of this paper is to *qualitatively* explore how state-of-the-art management thinking in combination with digital solutions can help companies to be successful nowadays. It is expected, that cross-functional collaboration is essential to compete at these turbulent times. Efficiency and short response times to meet legal requirements as well as to create products under the paradigm of circular economy are key drivers for success. Additionally the technological and digital advancements need to be considered at the same time. Three fundamental aspects are not covered by Industry 4.0 so far, which are: i) the role of the human being during value creation, ii) SC resilience and iii) focus on sustainability. These elements are leading to the central theme of this paper and will be discussed in the following sections.

2 Methodology and research questions

The qualitative results of recently conducted empirical research (e. g. Surrow, 2021; Andrade, 2022; Stachowiak, 2022; Reif, 2021; Cheema 2022; Peimann, 2022; Papadomanolakis, 2023; Chia, 2023; Demir, 2023; Calderon, 2024) connected to relevant academic literature was incorporated for this paper.

The resulting *research questions* are:

1. ***How is Marketing connected to the principles of Lean, Green and Digital value adding processes?***
2. ***Why is cross-functional collaboration essential for the Lean transition from Industry 4.0 to Industry 5.0?***

The relevant qualitative results and empirical findings from the supervised theses are presented and combined with peer-reviewed literature, academic, fundamental sources (almost 100 sources). Additionally empirical research (50+ expert interviews conducted within supervised academic research, participant observation and the author's exchange with practitioners at management conferences) was used to explore both theory and practice and thus to obtain helpful insights as directly transferable results.

3 Answers to the research questions

This chapter presents the results of the research, which have been considered to find qualitative answers to the above presented two research questions.

3.1 How is Marketing connected to the principles of Lean, Green and Digital value adding processes?

Lean Thinking (Womack and Jones, 1996; 2007) is a Supply Chain and Operations Management (SCOM, Ivanov et al., 2021) philosophy connected to a variety of operational principles leading to competitive advantages, such as the reduction of costly non-value-added process steps, while at the same time improving quality, increasing customer focus and respecting people etc. (Ballé et al., 2017; Gaiardelli et al. 2019; Stevenson, 2018). "The term 'lean production' was first used by Krafcik in 1988 (Holweg, 2006, p.

15).” The origin for what we now call Lean methods were presented by Taiichi Ohno in the 1950’s in the Toyota Production System, centred around the principles of Just-in-Time (JIT) and automation with human touch, called “Jidoka” (Reke et al. 2022, Holweg, 2006).
Flawless supply chains (SCs) are the crucial enablers to meet the above mentioned marketing objectives, which means fulfilling customer demands in a profitable way (Kotler et al., 2015, p. 9). According to Marketing.ch[1], the principles of **Lean Marketing** are:

- **Customer centricity**: The customer is the focus. All marketing activities and decisions should aim to maximize customer value.
- **Continuous improvement**: Lean marketing emphasizes the need to constantly rethink and optimize processes.
- **Avoid Waste**: Any form of waste, be it in the form of time, resources or effort, should be avoided.
- **Efficient use of resources**: Resources should be used as efficiently as possible without compromising on quality.
- **Data-Driven Decisions**: Lean marketing relies on data and analytics to make informed decisions.

Dennis (2010, p. 143 – 145) identified some typical marketing wastes, which are poor processes, missing to capture customer needs (“capturing the sweet spot”) and misunderstanding what the customer considers as “value”. Ballé et al. (2017) formulated, that “the aim of Lean Strategy is to learn to solve the right problems and avoid wasteful solutions. We create flow (better quality, higher flexibility) in order to find our real problems; we then challenge ourselves to face them.” The five bullet points above summarize the adaptation of the classical Lean principles into the domains of Marketing. Thus, Lean and Marketing are very well mutually connected.

Efficiency in value creation for the customer

The classical Lean approach aims to identify all aspects of efficient value creation for the customer (Saetta and Calderelli, 2023), at the same time eliminating the 7+x types of waste, see Tsipoulanidis (2019): *1) over-production, 2) waiting, 3) transport, 4) over-processing, 5) inventories, 6) motion and movement, 7) Defects, plus “x”: not meeting customer needs, wasting talent & knowledge, water & energy, materials & resources… and thus increasing efficiency*. According to Modig and Ahlstrom (2012), Lean is an approach to manage “flow efficiency”, which means that it simultaneously incorporates the ideas of quality management and continuous improvement (Stevenson, 2018, p. 610).
Fiorello et al. (2020) consider Lean as a philosophy that strives to reduce any kind of waste in a process and making the time to customer shorter. Waste can be understood as anything, whether in a process to create a product or to provide services, that does not add value to the product or service. In essence, Lean techniques enable businesses to do more with less, which is nowadays strongly connected to sustainability (Tiwari and Tiwari, 2016). Examples are less resources, less time, less human and physical effort, less space, less transportation etc. with the target of fulfilling the customer’s exact needs (Kaban, 2023). Lean strategies help to continuously improve processes while in parallel enhancing quality and fostering a culture of practical problem solving with a focus on active employee participation (Keskin, et al. 2023), which highlights the culture of human-centricity – a key element of Industry 5.0 (which will be covered afterwards). Of course, all these principles are relevant to meet the objectives of Lean Marketing, too.
It has become evident for numerous businesses across different industries, that Lean practices rhave proven to be successful in value creation, improving efficiency, reducing costs and wasted efforts, while striving to achieve operational excellence (see Solaimani and Sedighi, 2019 or Kumar, 2023 with a focus on the construction industry). Ballé et al. (2017, p. 9) emphasized that “[Lean] Strategy … sets the direction for the firm: what distinctive value proposition to the customer will give us competitive advantage?” They further explained (p. 11) that Lean Strategy focuses on more value with less waste and suggest that this should be achieved by “small-step controlled changes by all teams: Kaizen with Plan-Do-Check-Act (PDCA).” Also, this is all relevant for efficient and customer-centric Marketing processes.

[1] https://marketing.ch/lexikon/lean-marketing/ (accessed 13.06.2024)

Lean practices applied

Various Lean practices are used in different industries, such as Just in Time (JIT), Kaizen, 5S, Six Sigma, Kanban, Poka Yoke, Value Stream Mapping (VSM) etc. (see Almeida et al., 2016; Bevillacqua et al., 2017). Just in Time JIT was explained by Lara et al. (2022) as a practice where only necessary products or materials, at the expected time, in the demanded quantities are assembled or delivered with the overall purpose to reducing the inventory levels to the minimum. This focus on lowest inventory levels is nowadays – at times of material shortages, strikes, pandemics, global crises etc. – intensively criticized. In order to mitigate SC disruptions, materials are buffered as a means of SCM Risk management, in other words it might be considered as a means of resilience to build up inventory.

Kaizen is - like many other Lean expressions - a Japanese word with two components, Kai (change) and Zen (for the better). Many other tools for efficient SCs were presented by Richards and Grinsted (2024). Kaizen has been used since the 1950's to refer to small, continuous improvement steps that are made in order to improve efficiency and productivity (Gasper and Mwenda, 2023). Also this is essential when the connection of Lean, Green and Digital is discussed. Kelechi (2023) states about continuous improvement, that this is focused to reduce operational cost, to increase productivity, to motivate (the empowered and involved) employees for innovation and practical problem solving and thus to enhance quality as well. Lara et al. (2022) presented a logical connection regarding the relevance, which Lean manufacturing has gained since many years with regards to the 7+x waste awareness, which is important to connect the Lean effects with sustainability. It shows, that a culture of Lean Thinking is closely related to the aspect of environmental sustainability (Kaban, 2023) and thus to the three fundamental factors which are commonly known as the *Triple Bottom Line: Economic, Social and Environmental Criteria*[2] (Lyskovskaya, et al., 2023).

In operations, sustainability covers the creation of products with sustainable value adding processes, highlighting the need for the simultaneous consideration of economic, social, and environmental implications while producing and delivering goods or services. Furthermore, saving all types of resources follows the reduction of waste. Hence, firms with a strong lean culture (Ditzer, 2023) tend to develop creative solutions to reduce their ecological influence (Kaban, 2023). A safe working environment is a core pillar of Lean as well as respect for people. The integration of lean and safety can help companies achieve a competitive edge that is critical while providing a safe workplace (Cudney and Murray, 2012).

Lean, Circular Economy and Green Strategies

Let us have a look at "Circular Economy". When a product is created, also the end of the product life has to be anticipated, how the product can be further used in the end. Often the *3Rs* (reduce, reuse, recycle) are mentioned. Weerakoon et al. (2023, p. 137) refer to the circular economy concept of the *10 Rs* (reduce, reuse, recycle, redesign, recover, rethink, refurbish, remanufacture, repurpose, and repair).

It is important for companies, to focus on their competitive advantages, but at the same time to consider all prerequisites towards value creation in a sustainable way. The objective has to be to identify and to avoid harmful effects on the environment. In parallel, companies need to ensure secure working conditions for their employees. In combination, they will be able to generate long-term ecologic, social and economic benefits (Utama and Abirfatin, 2023).

A company example is BMW. They have worked on initiatives to comply with the environmental criteria of sustainability, which is often referred to as "Green". BMW (2022) communicated, that their strategy is focused on Lean, Green and Digital[3]. Also capgemini stated, that Green, Lean and Digital is the new

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[2] In the Report from 1987, "Our Common Future" of the World Commission on Environment and Development, it is stated, that "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." www.un-documents.net/wced-ocf.htm.

[3] BMW iFACTORY. LEAN. GREEN. DIGITAL. - Der Masterplan für die Produktion der Zukunft.
29.04.2022 Pressrelease: Hochflexibel, effizient, nachhaltig und digital: Mit der BMW iFACTORY setzt die BMW Group neue Maßstäbe und definiert die Zukunft der Automobilproduktion für das Produktionsnetzwerk: „Neues Werk Debrecen wird erstes CO2-frei betriebenes Fahrzeugwerk."

mantra of the industries[4] and the T&O Group is annually identifying successful Lean and Green companies as part of their award (https://lean-and-green.de/). These are just very few examples.

Green strategies are implemented for example to decrease environmental pollution or to avoid the ecological impact, to improve proper resource usage or to highlight waste avoidance. This is to be in line with legal obligations or governmental regulations, but also for the creation of value and competitive advantage (Ye, et al. 2023; He, et al. 2023). Examples of implemented Green strategies in companies according to (Queiroz, et al., 2023; Kosasih et al., 2023) are: waste reduction, Life Cycle Assessment (LCA), 3Rs [or even 10Rs as presented earlier], CO_2 emission minimization, the implementation of Environmental Management Systems [5] (EMS, ISO 14001) or Design for Environment (DfE), to name just few (Boiral and Henri 2012; Hu, et al., 2023). "LCA" is described by Otero et al. (2023) as a suitable practice for the evaluation and calculation of the environmental impact and its sustainability throughout its life cycle and DfE as a process during the product development phase with the aim of eliminating or avoiding the use of environmentally problematic materials respectively to prepare for reuse or recycling. The ISO 14044:2006 (Environmental Management — Life Cycle Assessment — Requirements and Guidelines) serves as standardization model to evaluate environmental performance. "It can be used in any scope from the cradle of the product to its grave (Peiris et al., 2019, p. 84)".
Mosgaard and Kristensen (2023, p. 4) suggested a management *framework*, that focuses on three practices:

1. Cleaner production (in-house), with a technical and "do less harm" approach;
2. Product-orientation (SC), with a dominant perception on "doing good" to the environment and end-to-end lifecycle thinking and finally a
3. Sustainable development (network) perspective, with a "create a positive impact" mind.

In this sense, it is of highest relevance for Marketing, if products are engineered for a linear use [Linear Business Models: "make, take, consume, waste"] or under the philosophy of circular economy [further usage of the product or its materials in a specific sustainable way applying the 3R loops], see Lewandowski (2016) or Fischer et al. (2023, p. 130). Circular economy is relevant from an early product development stage because up to 80% of the climate footprint, possibly social impacts and the total cost of the product is determined already early in the design phase (Charter and Tischner, 2001, see preface). The principle of "Green IoT" (i. e. ecological IoT) is suggested by Fraga-Lamas et al. (2021) in connection to the transition to a smart circular economy.
Companies have now realized the importance of focusing on ecological customer requirements and the need to create environmentally friendly products. This is essential for Marketing – to create and to distribute the products that are requested by customers and markets. Green Manufacturing represents a suitable strategy (Thekkoote, 2022). Therefore, companies are willing to improve their processes, to identify environmental impacts and to invest in environmentally friendly technologies. In parallel, a negative impact on profitability must be kept to a minimum. A question, that has occurred during the author's exchange with practitioneers was: "What is the Cost for Green?". It shows, that there seems to be a challenge to find the right balance between cost reduction and satisfying customer requirements with high quality products, services and offerings, while at the same time reducing the harm to the environment and keeping profits high.
Alshammari (2023) and He et al. (2023) recognized that environmental sustainability and Green Manufacturing should be seen as an essential part of the corporate social responsibility culture. If this is not considered, it might negatively influence the company's brand reputation and competitiveness. That's why environmental sustainability is highly relevant for the company's products and they need to make their Green products more attractive to customers in order to improve their long-term financial performance (see also Fiorelleo et al., 2023).

[4] https://www.capgemini.com/de-de/insights/blog/green-lean-digital-das-neue-mantra-der-industrie/

[5] https://www.nqa.com/en-me/certification/standards/iso-14001/implementation;

https://www.iso.org/standard/60857.html

One could summarize, that an existing Lean Management Culture is a very good foundation for a greener and digitally supported ecosystem. In this context, Ye et al. (2023) described the focus should be placed on pollution control in combination with Lean strategies. Kosasih, et al. (2022) have elaborated how Lean and Green Strategies complement each other and how they are embedded in the concept of Lean and Green Supply Chain Management. They presented a *framework* of Lean and Green Practices pointing at important Lean tools and principles, such as 5S, Kaizen, Kanban, JIT, Pull Production, Total Quality Management (TQM), EMS, Life Cycle Analysis (LCA), ISO 14001 etc. for the implementation of Green strategies.
The synergies and trade-offs while combining Lean and Green strategies over several departments were mentioned by Queiroz et al. (2023). According to them, the most relevant principles are 7S, Lean and Green Supply Chain (LGSC), Lean Green Six Sigma, Total Quality Environmental and Green Material Requirements Planning.
In essence, companies that focused on Lean principles since long time seem to be naturally prequalified to go "Green" due to their continuous waste reduction efforts, that are already implemented.

Sustainability Performance
Hebaz et al. (2022) evaluated, how Lean and Green techniques work for sustainability performance. It has been revealed, that for example an Environmental Management Systems (EMS), continuous waste reduction and intensive cooperation with suppliers are important criteria to gain competitive and ecological advantages. They stated: "Lean and Green practices improve environmental performance in the first level. This is in line with several empirical studies suggesting that despite the fact that Lean and Green paradigms may differ in their drivers, tools, and techniques, they can be synergistic through their common aims to reduce waste and to use resources efficiently, thus contributing in enhancing environmental performance." Ait Hammou et al. (2022, p. 6) stated in their conclusion, that "based on the frequency of citation, «geographic concentration from suppliers» is the most identified Lean practice in previous research and «Environmental Management System (EMS) mandatory for suppliers» has been found as the most important green practice", but also «Cooperation with suppliers» was mentioned, too.

The measurement of SC performance has gained importance in leading companies in order to focus on Lean Supply Chain Management (LSCM) to assess the reduction or elimination of the Lean wastes along the SC. Green Supply Chain Management (GSCM) emerged more recently and the focus is on reducing environmental risks and impacts while increasing ecological efficiency at the same time (Kosasih et al. 2022; Min and Zhou, 2002). This combination is assumed to be an inspiration for companies how to assess the performance under consideration of Lean and Green Supply Chain Management. Thus, Hossain et al. (2023) took a holistic approach of the supply chain to incorporate Lean and Green principles, demonstrating the interdependencies between operational success and environmental sustainability, denominating it as "Green Lean Supply Chain Management".

Letchumanan et al. (2021; 2022) studied the connection of Lean, Green and Sustainability and this was also evaluated by Elemure et al. (2023). Salah et al. (2022) described that companies can achieve a competitive advantage and at the same time reducing negative social and environmental consequences as a result of the implementation of Lean and Green principles. To substantiate that qualitatively, they presented a framework with Lean and Green activities and categorized them by the impact the have from an Economic, Social and Environmental perspective.
This framework is shown (in a simplified way!) in the following illustration:

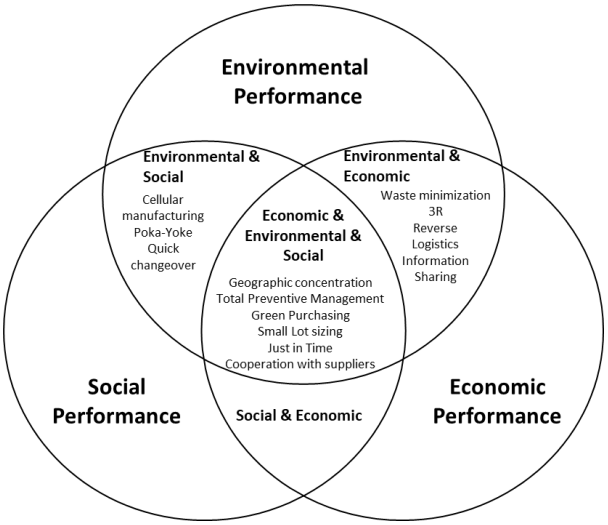

Figure 1: *Conceptual framework of Lean and Green practices and their impact on sustainable performance by Salah et al. (2022, p. 9 – full framework), here simplified by Calderon (2024, p. 20)*

Pathmalatha (2020) pointed out, that Lean thinking can influence or support Green practices, which will be leading to a positive sustainable performance and important Lean and Green characteristics as success factors have been identified by Khan et al. (2020), e.g. the mind-set and attitude within the firm, leadership and management support and employee involvement. *It is important to highlight, that a Lean and Green mind-set needs to exist in the company cross-functionally – not only in few departments, such as production.*

It is obvious, that the scholars see the mutual complementation between Lean and Green (Garza-Reyes, 2015; Gholami et al., 2020) initiatives and their potential to enhance each another. Keil et al. (2023) focused on "sustainability from the top" and highlighted, that their research results "stress the importance of leaders with an environmental focus as role models who can drive the transformation toward effective sustainability management in companies". Elemure et al. (2023) elaborated on the relevant barriers while implementing Lean and Green techniques. Avoiding the barriers are thus relevant factors for the implementation of Lean and Green successfully (Calderon, 2024, p. 21):

Lean Barriers	• Lack of expertise and technical training • Poor commitment from top managers • Low technical capabilities • Lack of continuous improvement culture • Complex processes involving supply chain • Requires financial capital and time
Green Barriers	• Lack of environmental awareness or knowledge • Resistance to change • Low information on product design and innovation • Low information on legal or regulatory requirements • Insufficient training on sustainable process • High costs on recovery and recycling
Success Factors for Lean Green Manufacturing	• Clear Strategy • Management commitment and strong Leadership • Employee involvement • Organizational culture • Skill acquisition for employees • Health and Safety Priority • Supply Chain Risk Management • Technological Advancements

Table 1: *Barriers and Success factors for Lean Green Manufacturing*

Source: Created by Calderon (2024), based on Elemure et al. (2023), adjusted by author (2024)

The table above also shows, that cross-functional collaboration is a key element for success (this is valid with or without digital technology) when striving for steady sustainability improvements.

The question is, how companies can measure their Lean and Green maturity systematically. A framework for the systematic implementation of Green, Lean and sustainability is SMEs was developed by Siegel et al. (2022), which strives to achieve long-term improvements of environmental, social, and economic processes and performance. Ciliberto et al. (2021) created an all embracing review and presented a *framework* of how Industry 4.0 (see section 3.2), Lean Manufacturing and Circular Economy can be jointly tackled.

Identified Limitations

Abualfara, et al. (2020) highlighted, that although Lean production practices can fulfil the customer's Green expectations, the relationship between Green practices and economic performance still needs to be further evaluated, also Hebaz et al. (2022) suggest further research on that, e.g. in the automotive industry. Thus, scholars recommend a further investigation on the expected influence in the different aspects of environmental, economic, and social criteria (Abualfara, et al. 2022). What is the cost to become Green?

3.2 Why is cross-functional collaboration essential for the transition from Industry 4.0 to Industry 5.0?

In the sections above, the connection between Lean and Green has been discussed from a literature point of view. One could already summarize the following: A Lean based culture is a very good foundation for the implementation of Green strategies, respectively it is a good starting point (author's discussion with experts, 2024). Now, it will be discussed, why Lean is also essential and the first step before going into digitalization, in other words how to manage the transition from Industry 4.0 to Industry 5.0.

What is Industry 4.0 and 5.0?

Industry 4.0, the fourth industrial revolution, has a huge impact on the global competition and regarding the way companies operate across a wide range of industries. Industry 4.0 is representing key technologies to mitigate today's manufacturing challenges, such as increasingly shorter product life cycle or increasingly complex manufacturing processes (Schuh et al. 2017). One of the biggest features of Industry 4.0 is the use of technology to connect devices. This facilitates the sharing and analysis of data in real time, it helps to improve value adding processes and improves quality. It also reduced cost[6] significantly, as Nahavandi (2019, p. 3) pointed out. The vision of Industry 4.0 also includes real-time improvement as well as self-organized value adding networks that enable cost and resource efficient production processes (Kagermann et al. 2013).

Industry 4.0 was very much focused on Cyber Physical systems (CPS) and the Internet of Things (IoT) (Jeschke et al., 2017; Zhang et al., 2021; Oks et al., 2022), i. e. to use technologies for efficient or leaner processes in operations and supply chain management (Dalmarco et al., 2018). The truth is also, that many companies did not even reach the maturity level of Industry 4.0 (Sony and Naik, 2019; Bakhtari et al., 2020), thus Industry 5.0 is still in the phase of development, respectively in the process of being implemented in companies or supply chains (Frederico, 2021). The concept of Industry 5.0 has been developed by the European Commission based on the already known technologies from Industry 4.0. But in addition to that, the three key elements of *human-centricity, resilience and sustainability* (Breque et al. 2021) have been added. Breque et al. (2021, p. 6) stated: *"Industry 5.0 complements the existing Industry 4.0 paradigm by highlighting research and innovation as drivers for a transition to a sustainable, human-centric and resilient European industry. It moves focus from shareholder to stakeholder value, with benefits for all concerned. Industry 5.0 attempts to capture the value of new technologies, providing prosperity beyond jobs and growth, while respecting planetary boundaries, and placing the wellbeing of the industry worker at the centre of the production process*."

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6 "The new concepts introduced by Industry 4.0 include CPS, IoT, the smart factory, big data, cloud storage, and cybersecurity. When it comes to efficiency and costs, Industry 4.0 has decreased: Production costs by 10–30%; Logistic costs by 10–30%; Quality management costs by 10–20%."

Furthermore, Carayannis et al. (2021, p. 594) added to that *"Industry 5.0, which can be considered the answer to the question of a renewed human centric industrial architype, starting from the (cultural, managerial, organizational, philosophical, and structural) restructure of an industry's production processes. The importance of this new perspective originates by the fact that Industry 4.0 is just at the early stage of development and that its main achievements can be expected not earlier than 2020–2025."*
In other words, it has been criticized, that the Industry 4.0 implementations are or were to a very high degree strongly connected to the pure implementation of digital technology and, thus lacking a focus on the human, environment and economic stability side (Breque et al. 2021, p. 5), which will be covered under the Industry 5.0 paradigm. It is clear, that Industry 4.0 as well as it enhancement – Industry 5.0 – are technologies to produce goods and services efficiently under usage of digital technology.

Lean, Green, Digital and Industry 5.0
One could state in a very simplified way, that once a company has been implementing Industry 4.0 technology and is adding sustainability, resilience and human-centricity, it will be heading towards Industry 5.0.
The following illustration exemplifies the how Lean, Green, Digital (and also Legal) are mutually connected. Lean is the foundation for the digital transformation due to the fact, that processes need to be analysed, non-value adding steps eliminated (VSA) and then appropriate digital solutions can be implemented, where reasonable. Also, Lean is the prerequisite for the implementation of Green initiatives as discussed throughout this paper.

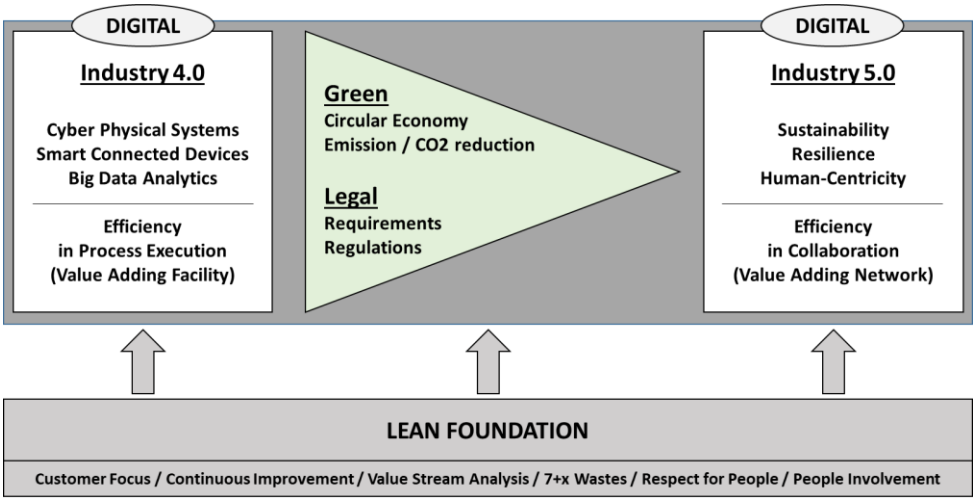

Figure 2: *The mutual connections between Lean, Green and Digital*
Source: Author's research, 2024

As the figure above shows, for the transition towards Industry 5.0, all elements in the illustration are necessary: Lean Management (Liker and Trachilis, 2014; Ballé et al. 2017) respectively a Lean Culture foundation (Mann, 2010; Cagnetti et al., 2021; Sonmez and Adiguzel, 2022), Industry 4.0 technology, Green supply chain and operations strategies (Ciliberto, 2021) as well as Legal compliance (e.g. European Green Deal). Additionally, the success factors elaborated by Calderon (2024, see table 1) are essential as well as the findings of Banholzer (2022).

As stated in the beginning of this paper, Lean is besides its origin in Operations, also highly relevant for the Marketing function. Nevertheless, that's not all. Already in 2010, Dennis pointed out that Lean Thinking needs to be applied outside the factory to transform the entire organization. Westerman et al. (2014) already emphasized, that strong cross-functional collaboration is needed in order to avoid, that digitial initiatives are conducted in silos ("Fashionistas"). A strong balance between the functions providing strategy and leadership as well as the functions dealing with digital solutions and the core business are all necessary, in order to become a "Digital Master".

This paper has shown, that companies need to specify cross-functional collaboration areas prior to the digital transformation project. Some examples of functions that need to jointly work in terms of cross-functional collaboration are shown in the following table (list is not complete, it serves as concept):

Cross Functional Collaboration	**Examples of Key Areas**
Product Development	Customized Product, considering DfE and Circular Economy
Marketing	Strong Customer Focus, Customer Journey & Experience, Customer Centric Products and Services
Operations	Efficient Production
Supply Chain Management & Sourcing	Transparent Supply Chain Legal Compliance with regards to the *Act* on Corporate *Due Diligence* Obligations in *Supply Chains*
Strategy and Leadership	Clear Digital Vision and strong Leadership
Legal / Compliance	Instruction regarding Legal requirements, auditing of compliance and ethics
Human Resources	Global HSE compliance, development of staff (e.g. programming, BDA, AI)
Digital / IT	Implementation of digital solutions to facilitate I4.0 / I 5.0

Table 2: *Inspirational List for Cross-Functional Collaboration and examples of Lean, Green, Digital (and Legal) Key Areas*
Source: Author's research, 2024

The table above serves just as an inspiration for the intertwined collaboration across business functions and most probably also across enterprises. This will be further researched by the author.

What are examples of digital Lean and Green use cases ?
Let's take the example of human-centricity. With this, the human being can better utilize their strategic and sensitive capacity instead of conducting error-prone, repetitive tasks that might be leading to fatigue. An example is RPA, Robotic Process Automation, that can be used successfully in highly repetitive procurement or other administrative tasks (Knotte et al., 2017; Das, 2019). Employees can e.g. focus on strategic tasks.
Also, a better collaboration between the human being and technology will take place. This would be the usage of cobots or also Augmented Reality AR to generate competitive advantage (Porter and Heppelmann, 2017). With this, the processes can be executed more efficiently, learning curves can be reduced and the workplace will become safer. Remote maintenance (maintenance 5.0) will also lead to shorter response times, less idle times of machine equipment and if experts do not need to travel, there is also a positive impact due to avoided CO_2 emissions. The usage of AI can help workers to better diagnose errors or to assist during visual inspections with the purpose to increase quality. AR can also be used to train new staff on the new job, it can be used for the design of products or workplaces and to show these designs to the customers or workers. This all will lead to higher customer satisfaction and will avoid the wrong products or facilities will be created.

It is very interesting, that all such technologies are also used for higher quality and shorter times in the domain of medical purposes as the exchange of the author with medical scientists has revealed. This is another example of cross-functional collaboration, where medical doctors, mechanical engineers, material scientists and data analysts are working together to use digital twins, big data diagnostics (Sharma et al., 2022) , 3D printing, robotics, augmented reality or virtual reality to better prepare for surgery or to create perfectly customized body replacement parts (Ostas et al., 2022). One could consider hospitals and surgery theatres as manufacturing facilities, in which human beings are cured under usage of highest technology.
Other examples can be found in areas with a lack of workers (heavy construction work, e.g. grape or asparagus harvesting…) where robots take over operational activities. Also dangerous tasks (military mine cleaning, bomb defusal, assessment of contaminated buildings, nuclear power plants etc.) can be done by robots, where the specialist works remotely and safely. Supply Chain Risks can be better predicted by the usage of Artificial Intelligence (AI) and counter actions can be defined early in advance (e.g. prewave.ai).

This was just a very short overview on potential use cases, but overall, one can state, that Lean, Green and Digital will in conjunction have a significant positive impact on the achievement of sustainability goals.

The exact quantification is still to be done. The following table shows a summary on the mutual connection and complementation of Lean, Green and Digital (the following table sets a special focus on the objectives of Marketing) and it highlights why cross-functional collaboration is essential.

Qualitative Potentials from Marketing Perspective	**Lean** → ***avoidance of the unnecessary 7+x wastes***	**Digital** ***Supporting Information and Operations Technology***	**Green** ***Resulting into Sustainability, Environment and Ethics***
	Motion and Movement		
High (due to cost avoidance and green reputation)	**Inventory**		Less warehouse cost, less material, less energy, less transports
High (due to avoidance of non-satisfied customers)	**Not Meeting Customer Requirements**	Digital postponement strategy	Less not-needed products.
High (due to cost avoidance and green reputation)	**Transportation**	**AI based transportation routing optimization**	Less CO_2 emissions
	Waiting	SC transparency, risk monitoring, network optimization	
High (due avoidance of not needed products, avoidance of stock-outs)	**Over-Production** (Capacity Utilization)	**AI demand forecasting**, Point-of-Sale Data analytics, trend identification	Less material, less energy, less transports
	Over-Processing		
High (due to impact on company reputation, brand image)	**Defects**		Less material, less energy, less transports, less returns
	Skills / Talent / Knowledge		

Table 3: *Lean, Green and Digital and their Potentials from a Lean Marketing Perspective*
Source: Author's research, 2024

The table above shows, that digital solutions such as AI will be used for higher precision in demand forecasting. From a Marketing perspective, stock-outs of the demanded products will be avoided, and over-production of products that no one wants, will also be reduced. Hence, higher customer satisfaction will be the result as well as the avoidance of the cost for the creation of the not needed raw materials, avoidance of not required transport, no production of not-needed products, no storage or distribution (ecological success).

4 Conclusion

This section finally concludes this qualitative paper titled ***Lean, Green & Digital and the need for cross-functional collaboration - Requirements when heading from Industry 4.0 towards Industry 5.0*** with the two research questions from page 1 and it shows in which sections the answers can be found.

Research Questions	**Findings / Results**
1. How is Marketing connected to the principles of Lean, Green and Digital value adding processes?	• Marketing is a key enabler, it will benefit from Lean principles and Marketing needs to be actively involved and it benefits from the focus on Lean, Green and Digital. • Marketing is a key player in terms of cross-functional collaboration. • For details, see Table 2 and 3
2. Why is cross-functional collaboration essential for the Lean transition from Industry 4.0 to Industry 5.0?	• Without cross-functional collaboration, the challenges ahead stated in the paper cannot be mastered. • It is a mandatory requirement. • Industry 5.0 by itself is demanding a broader scope covering human-centricity, resilience and sustainability. • Lean Thinking is the foundation for the achievement of the Green and Digital objectives. • For details, see Figure 2

Table 4: *Research Questions and Findings / Results*
Source: Author's research, 2024

Overall, a Lean Culture is needed as a strong base to ban the 7+x Lean wastes and to establish the thinking to avoid unnecessary activities, Then processes can be streamlined (VSA) to make them ready for digital solutions. Lean also serves as a solid foundation to continuously identify areas for improvement that will have a positive ecological impact. Conducting further qualitative research and providing quantitative evidence on the economic, ecological and social benefits are relevant areas for future research.

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