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LEAN AND AGILE: A COMPARISON BETWEEN TWO THEORIES

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Abstract

Lean and agile are both theories that firms can utilize for a variety of purposes. The purpose of this study is to compare the two on a general level and draw clear conclusions on when the two can be applied and what determines which approach should be used. The research questions are: "Are lean and agile equally applicable in various situations?", "Is there a specific factor that determines which approach is better suited for the a certain situation?" and "Can both approaches be used simultaneously?".

The paper first describes both approaches and their applications, comparing lean and agile in a variety of contexts. Finally, a systematic literature review is carried out and conclusions are made based on the review. The goal of the literature review is to determine what conditions lean and agile are each suited for and if both approaches can be utilized simultaneously.

The systematic literature review confirms that lean is more suited for stable conditions, whereas agile is recommended when the demand is unstable and markets are more volatile. Moreover, newer literature suggests that both approaches can be utilized simultaneously, even though some past literature has suggested that the two theories are competing paradigms.

Keywords

Lean, Agile, Leagile, SCM, Manufacturing

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INTRODUCTION

1.1 Background

Lean and agile are both philosophies and tools used for leadership and management. Both can be described as methodologies that seek to increase overall effectiveness and create value for the customer. (Hines et al. 2004, Conforto et al. 2016). Lean has its roots in Toyota's car manufacturing facilities, whereas agile emerged originally within software development industry (Hines et al. 2004, Corrêa et al. 2016). Both have gained increasing popularity within the last decades, evolving over time and becoming more universally applicable (Joosten et al. 2009). Both are applied to some degree for the same purposes, and there are uses for both lean and agile in manufacturing (Soltan & Mostafa 2015), supply chain management (Martin 2000) and as general operational philosophies for the organisation.

1.2 Goal of the research

Since lean and agile can be applied for the same purposes, the goal is to find out if there are clear cases where one is more applicable than the other. This particular topic was chosen because there is a research gap in clear comparisons of agile and lean on a general level. My study is a quantitative synthesis on existing literature that describes both lean and agile in-depth and compares their applications. The literature consists solely of academic journals from a variety of databases, with the exception of agile manifesto from it's original website. The focus of this study is to find out which factors to take into account when choosing between lean and agile and to present how they are used differently in a variety of contexts such as manufacturing and supply chain management.

Both theories have undergone massive change since their inception (Fadaki et al. 2019) and my goal is to find accurate, up-to-date information on how the two can be utilized today. Some of the most commonly quoted literature is 30 years old (such as Womack et al. 1990) which is why I seek to determine if this information is still valid in current practices.

Finding out how lean and agile can be utilized on a general level can give decision-makers a clear idea if these tools fit their purposes. The aim is to reduce confusion and offer a clear idea on how the two approaches are currently being used. Moreover, this study seeks to make a clarification and distinction on the two theories and their differences and applications, so the study can also assist managers in getting a clearer view on lean and agile in general.

1.3 Research gap

Currently, there is a gap in research in the sense that few studies compare lean and agile extensively and on a general level. Instead, both approaches are typically mentioned in a very specific context while providing a narrow explanation on the differences between the two. My goal is to bring these bits of information together to paint a cohesive, clear image on how to decide which approach should be used and if the two can be used at the same time.

The review also seeks to combine information from the last 30 years to determine the current situation and reduce confusion. Another goal of the review is to verify if there is any contradicting evidence or new information relating to the propositions that lean is suited for stable conditions and agile for volatile markets. Similarly, I seek to find out if there are any special circumstances where the general principles for both practices should be applied differently.

1.4 Research questions

Since previous research has mostly been concerned with lean and agile in very specific situations or cases, my research seeks to draw a conclusive synthesis based on past literature. The goal of this study is to find out the difference between lean and agile on a general level by answering the following questions:

-Are lean and agile equally applicable in various situations?

-Is there a specific factor that determines which approach is better suited for the a certain situation?

-Can both approaches be used simultaneously?

1.5 Research methods and structure of the study

The study begins with the introduction of lean and agile. Both approaches are first described in detail in their own chapters and then compared together in chapter 4. The use of lean and agile is discussed in a variety of contexts, such as supply chain management, manufacturing, software development and healthcare.

The research method is a quantitative literature analysis through a systematic literature review. The review and the results are presented in chapter 5, after which the findings are discussed in chapter 6. The goal for the literature review is to draw a synthesis based on past studies and then present conclusions and practical implications based on these past studies.

1.6 TERMINOLOGY

LEAN

5S = A lean principle that translates to sort, set in order, shine, standardize and sustain

GEMBA = a philosophy according to which managers should get out of offices and spend time on the plant floor to be in touch with manufacturing

HEIJUNKA = production scheduling where smaller batches are manufactured

JIDOKA = partial automation of the manufacturing process to reduce costs

JUST IN TIME (JIT) = pull system, reducing unnecessary inventory by meeting customer demands with precision

KAIZEN = continuous improvement, a strategy that includes all employees working together to achieving improvements regularly

KANBAN = pull system, automatic replenishment using signal cards

MUDA = waste, meaning unnecessary use of effort or time: anything that doesn’t add value to the customer

SMED = single-minute exchange of die, reducing the time it takes to do setups and repairs, converting setup into external so it can be performed while machine is kept running, making internal setups that can’t be converted to external more simple, standardization to work instructions to make setup simpler

SMART goals = specific, measurable, attainable, relevant, time-specific

TERMINOLOGY

AGILE

BACKLOG = list that includes anything that is needed to achieve a specific outcome

EPIC = large user story which describes what the project should ultimately do for the customer, broken down into smaller goals that take the team toward the final goal

ITERATION = incremental improvements to bring the project closer towards its end goal

KANBAN = signaling card used to communicate what work needs to be done, what is in progress and what has been done

KANBAN BOARD = a visual aid to display kanbans

LEAD TIME = time between customer's order and delivery.

MINIMUM VIABLE PRODUCT (MVP) = product that is not yet fully developed but is in a state that the customer can use it, iterations are then made based on feedback

SCRUM = daily meetings to reflect on progress towards goals

SPRINT = project is divided into sprints which typically last 1-4 weeks, after each sprint iterations are made to the product to get closer to what the customer actually wants

The main principle of lean is to reduce “waste” or “muda” from operations and create more value for the customer (Womack et al. 1990) (Caldera et al. 2017). There is heavy emphasis for standardization when it’s applicable to improve effectiveness (Joosten et al. 2009). Conditions are usually assumed to be relatively stable when using lean, so that predictions can be made and demand met with precision (Agarwal et al. 2006).

According to Hines et al. (2004), the practice was originally developed by Toyota within the Japanese car manufacturing industry and became more widely known for the rest of the world in 1990s with the book “Machine that changed the world” by Womack et al. (1990). Hines et al. also state that lean later developed into a more universally applicable tool, but it is still widely used with manufacturing and shop-floor productions where it originated from.

Cabral et al. (2012) write that lean has various definitions but all have the same basic principles, which are to minimize costs and eliminate any possible waste from the process.

1.7 Lean principles

Hines et al. (2004) write that value is created simultaneously as internal waste is eliminated since this reduces the overall costs, thereby improving the overall value proposition to the customer. When non-value adding parts are removed, the process improves and more value can be provided for the customer (Caldera et al. 2017).

Goldsby et al. (2006) describe the seven wastes or “muda” as they were originally defined by Taiichi Ohno, the creator of lean principles: excess inventory, product defects, overproduction, unnecessarily transporting goods, unnecessary processes, people moving around unnecessarily and employees

waiting around instead of working. Identifying and eliminating the waste is stated to be one condition to establishing a smooth flow of operations (Hines et al. 2004). Womack and Jones (1997) also add an eighth waste: products and services that fail to meet the customer's needs.

According to Hines et al. (2004), value should be derived from what the customer wants and not simply be defined as reduction of waste from a production perspective. Ultimately, the customer decides what constitutes as waste, so even if a process appears to be costly or wasteful from a production perspective it could still provide value for the customer. Value can also be increased through additional features or services that the customer sees as valuable. The authors list shorter delivery cycles and smaller delivery batches as examples that the customer could want and write that such value-providing features could add customer value even without increasing costs for the producer.

Joosten et al. (2009) write that lean emphasizes standardization to improve processes and to reduce both inventory and the time it takes for customers to receive the service or product. Another major principle is to improve the process incrementally one improvement at a time while aiming for perfection in the end (Womack et al. 1990).

According to Hines et al. (2004), lean exists on two separate levels: operational and strategic. They recommend lean thinking is applied to the strategic value chain dimension, whereas lean production can be utilized to improve shop-floor tools similarly how it was originally used by Toyota. According to the authors, lean also exists as a customer-centered strategic thinking that should be applied throughout the organization, where the value is always derived from what the customer considers to be desirable. Joosten et al. (2009) write that lean should be applied throughout the organization instead of applying it to a single process in order to create more value.

In their book “Machine that changed the world” (1990), Womack et al. describe five core principles of lean. The first one is **defining what brings value to the customer** and providing the customers something that they actually want, Understanding the customer and their needs is the key to bringing them a product that matches their values.

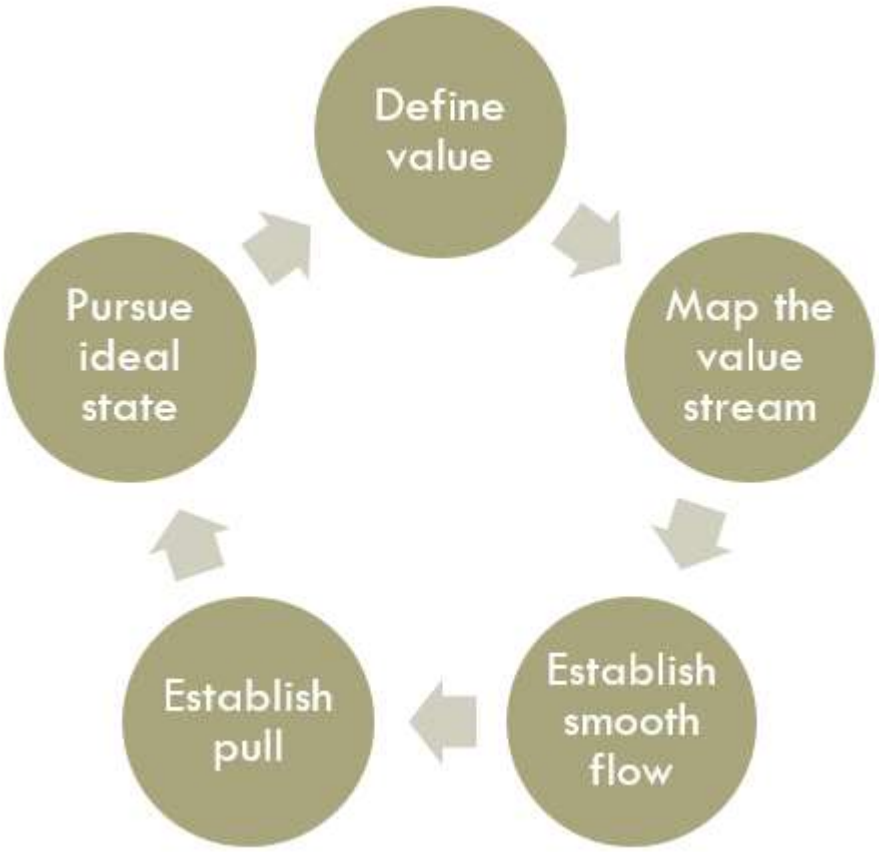
The second principle is **identifying and mapping the value stream**, which is defined as the collective of activities that create the results and value for the customer. This principle also includes the elimination of waste (muda), which means anything that doesn’t add value to the customer. There are two kinds of waste identified: the non-value adding but necessary and non-value adding but non-necessary. Anything non-necessary can be eliminated, thus improving the value chain and performance.

The third principle emphasizes **creating a smooth flow of operations that runs without interruptions**, while the remaining steps are implemented. This translates to making sure that the processes can be kept running and any breaks from production are avoided while improvements are made. Some listed examples of ensuring that value-adding activities keep running include leveling out the workload among different units, establishing cross-functional units within the firm and training multi-skilled employees that are capable of performing a variety of tasks instead of only operating one type of machinery.

The fourth principle promotes **creating a pull-based system that limits unnecessary inventory**, which is seen as waste, and reduces the amount of unfinished work-in-progress (WIP) items. The customer signals the need and the upstream then fulfills it. Pull-based system that originates from customer needs is said to allow for Just-in-time delivery (JITd) where products are delivered as they are needed without keeping unnecessary inventory. The authors state that following and mapping the value stream is key in achieving a working pull-based system.

The fifth principle is to **pursue perfection** and an ideal state of performance. Improvements are implemented continuously and an organisational culture is

emphasized where lean as an ideology is adapted throughout the organisation and everyone participates in reducing waste while adding value and does their part to incrementally introduce ideas on how performance can be improved. Womack and Jones (1997) write that perfection should be pursued incrementally, improving the process continuously to meet new needs and make it better.



Picture 1: The five principles of Lean as defined by Womack et al. (1990)

Lean also embodies various practices that are oftentime utilized. One key term is kaizen, which translates to continuous improvement (Womack & Jones, 1997). Processes are revised constantly to pursue perfection, instead of improving them once and expecting that it will be perfect forever. From a shop-

floor perspective, Womack and Jones describe creating cells for production, where the machinery is arranged in a U-shaped sequence, which is said to allow for a product to flow better. The queue time is measured, which is the time a piece has to wait before getting to the next step. These kinds of bottlenecks are solved to create a better workflow.

Excess inventory is seen as a “waste” that can be eliminated to optimize performance, so pull-oriented production is utilized (Hines et al. 2004). Just-in-time (JIT) systems are also often applied to reach this goal. With JIT-systems, the product is made and delivered with precision, according to customer needs (Womack & Jones, 1997). Womack and Jones also state that in order for JIT-system to work correctly, the firm needs to establish a smooth flow, a pull system signaling customer needs and standardize their work activities, so that time cycles are specified and each work activity is described with precision.

1.8 The history and origins of lean

Lean has its roots in Japanese car manufacturing industry. The development of these practices that would later become lean began at Toyota Corporation in 1950s to improve shop-floor performance and to make the plant run more efficiently. Lean developed gradually in-house at Toyota under the leadership of Taiichi Ohno, first beginning with car engine manufacturing, later moving to vehicle assembly in 1960s and eventually reaching the wider supply chain in 1970s. The intense domestic competition and scarcity of resources were the initial spark to develop lean practices (Hines et al. 2004).

Lean first spread to other Japanese car manufacturers before making its way to other countries, where it was utilized in similar production settings. The ideology later developed into a more generally applicable management tool to improve both operational and sociotechnical aspects in various situations. Overall, lean developed from a single-purpose tool to a more generally

applicable ideology that could be used in a variety of manufacturing and even on service sectors (Joosten et al. 2009).

The terms lean manufacturing and lean production were first introduced in the book “Machine that changed the world” by Womack et al. (1990). The authors described lean principles, how it could be applied in every industry globally and how it would change the world. In this book, lean is described to be capable of combining craft and mass production to produce higher quality items at a more effective rate. This is written to be achieved by employing teams of multiskilled employees on all levels of the organization and use automated, flexible machinery to produce high quantities of products. At the time, this book played a key role in furthering the advancement of lean movement and making the ideology known for Western manufacturers (Caldera et al. 2017).

1.8.1 Four historical stages of lean thinking

Hines et al. (2004) describe four stages that lean thinking has gone through and how it has evolved over time. This description outlines well how lean has changed over the years and how it has become more universally applicable. The first stage lasted from 1960s to 1990s and was heavily focused on improving shop-floor performance. Within the shop-floor level, cells and assembly lines were the main focus and tools such as cellular manufacturing, kanban, the 5S and SMED (single minute exchange of dies) were developed and applied. During this stage, lean thinking was mostly applied to running assembly lines and optimizing the machinery to run more effectively, the goals and focus being overall reduced costs and Just-in-Time techniques (JIT) to reduce inventory. The scope was very limited and the operations mostly took place within relatively stable, predictable business environments. During this time period, lean was developed by Toyota and then used by other car manufacturers to improve their own performance.

The second stage took place from 1990 to 1995 and was focused on total quality management (TQM). In this stage, using lean was still mainly limited to the manufacturing area but was also used for materials management. The main goals in addition to TQM were reducing costs, training personnel and re-engineering the processes. Lean was still mostly used within car industry for vehicle and component assembly. However, the authors state that in this stage lean was already gaining popularity and lean as a term was often used to describe the company's culture and core values, even if the tools were only applied to a lesser extent.

The third stage focused on value streams and lasted roughly from 1995 to 2000. Firms were beginning to adapt lean into a more wide variety of practices, but the scope was still mainly limited to manufacturing in general. Ideas such as lean organisation and collaboration within the supply chain were being promoted. The authors state that one problem was that manufacturers were still trying to apply the same principles that Toyota initially used to other situations where these same principles couldn't necessarily be directly applied. It was recognized that individual value streams or supply chains should be mapped out to find ways to improve them, but firms were still caught up on old patterns and looking to Toyota for "one best way" to do things. Quality, cost and delivery were the main focus for improvements and deriving value to the customer; however, the authors state that attributes such as image, brand, environmental concerns and producing goods locally were something that many companies overlooked. Since these factors might bring value to the customer, which is a core concept of lean, these factors would be important to take into account. Overall, the identified third stage of lean still had a narrow focus and was caught up on copying what Toyota had been doing in the past, attempting to apply these same principles to other industries.

The authors describe the fourth stage of lean as focusing on capability on a system level. The focus was on customer-based value, cost reduction, new product development and integrating lean into supply chain and other processes where it hadn't previously been applied. Adapters were beginning to take more case-relevant matters into account, such as company size, their

respective industrial sector and technology used. In this stage, the authors state that a range of tools from diverse management environments were utilized together, combining six sigma, earlier lean manufacturing, agile manufacturing, revenue management, theory of constraints and system dynamics. The ideology could be employed bottom-up throughout the organization, communicating the core lean processes to every person from all levels of the organisation. Each proposed change is viewed as a hypothesis that is tested and the organisation is constantly learning to improve its performance.

1.9 Lean and its applications

Lean is still widely used in manufacturing and seems to be quite common in this context (Shah and Ward 2003). In the recent decades lean has become more popular in other fields too (Hines et al. 2004). The following describes lean in some of the different contexts it is currently being used.

1.9.1 Supply chain management

Lean approach has been utilized in supply chain management to optimize the whole supply chain. Lean supply chain is focused on reducing waste, simplifying the process and removing activities that don't add value (Afonso & Cabrita 2015). From this description we can see that the principles are the same as with lean management in general, but they are utilized in a different context.

Managing a supply chain is different than using lean approach within the organization, since supply chain consists of multiple entities within the chain. According to Afonso and Cabrita (2015), a well defined lean system for supply chain management makes it easier to perceive areas that can be improved and thus higher level of performance and optimization can be achieved.

1.9.2 Healthcare

Radnor et al. (2012) write that lean principles have been embraced by the healthcare industry. They state that within healthcare, the removed waste includes things such as reduced waiting times, better service for patients. They write that lean was first implemented in the UK healthcare in 2001.

Lean has been used for healthcare purposes to reduce costs, standardize practices and overall improve the efficiency of healthcare. Mazzocato et al. (2010) write that in order for lean to be successfully applied for healthcare, there needs to be dedication to long-term continual improvement. Radnor et al. (2012) also share a similar suggestion. Mazzocato et al. (2010) also state that there should be focus on working across functional divides and creation of value for patients.

Womack and Jones (1997) also proposed the use of lean for healthcare. They write that patient time and comfort could be regarded as the key performance indicators and that patients could “flow” accordingly to lean principles.

1.9.3 Manufacturing

As stated earlier, lean originated within the Japanese car manufacturing industry (Womack et al. 1990) and it is still being applied with manufacturing in general. Shah and Ward (2003) state that plants that don't implement lean practices into their production are likely to put plants into a competitive disadvantage compared to their competitors that use lean. They list examples of lean practices that are implemented, such as JIT-system, continuous flow production, optimizing maintenance for machines and cross-functional work forces.

Wee and Wu (2009) suggest that when implementing lean in production, changes shouldn't be made too frequently since this will disturb improvements because of the lack of stable data.

The term "lean and green" refers to using lean principles to promote green values such as environmental sustainability by utilizing lean thinking to reduce waste, make more effective use of materials and overall reduce costs (Caldera et al. 2017). Wastefulness in itself is not environmentally sustainable, so lean could have some implications for eco-friendliness.

1.9.4 Software development

Nord et al. (2012) write that lean is utilized into software development in order to improve value flow towards the end user by eliminating waste. Poppendieck & Poppendieck (2003) also discuss eliminating waste and the general application of lean principles into software development. They also state that successful application of lean thinking requires the company culture and habits to change.

Ebert et al. (2012) write that one reason for interest in implementing lean into software industries is to reduce costs. They suggest lean as a complementary practice with agile, but state that lean principles are not always introduced properly into software development which can lead to frustration.

2.4 Criticism

One major criticism of lean thinking is that despite the many succesful applications for lean, it can fail to integrate the human aspect (Hines et al. 2004). In the past, lean has also been critized to be narrowly applicable and best suited for high-volume manufacturing environments such as the shop-floors it originated from (Hines et al. 2004)

Hines et al. (2004) write that when utilizing lean, human dimensions such as motivation, respect and empowerement should be taken into account as well. The authors say that the people play a key part in implementing lean successfully in the long-term, and therefore care should be taken to focus on these aspects. Another common criticism is that lean is best applicable to environments where conditions are stable, and that it has limited ability to adapt to variability (Hines et al. 2004).

Wee and Wu (2009) write that applying lean ideologies to the whole supply chain has its challenges since the system is quite complicated, which makes it difficult to make improvements to it. According to Wee and Wu, a lot of changing measurable indexes create a bullwhip effect, indicating possible fluctuation within the supply chain. They propose value stream mapping to identify various opportunities for implementing lean methodologies.

Hines et al (2004) state that lean has faced criticism in the past for the right reasons, but also add that critics often neglect the fact that lean as an idelogy is continuously developing and changing. They add that many critics even today are still focused on what lean was originally when it was introduced, not what it has become today. The ideology is still the same at it's core and it seeks to achieve the same goals, but the tools used today are very different than what they were 29 years ago when lean was first introduced as a term by Womack et al. (1990).

Martin (2000) defines agile as a set of tools that aims to increase the maneuverability and flexibility of the organization to respond to unexpected changes and changing conditions. Martin also suggests that agile organizations are able to manouver in changing conditions with ease and overall respond with flexibility, as opposed to being rigid and stuck to old patterns.

In general, agile project management is defined as an approach that aims to make project management more simple and flexible, increase the effectiveness in terms of time, cost and quality, bring more value to the customer and increase innovation within the firm (Conforto et al. 2016). Cabral et al. (2012) write that agility implies responding quickly to changes with demand and being overall flexible.

1.10 Basics of agile

Augustine et al. (2005) describe six practices for managing agile development projects: first one is **organic teams** with 7-9 members, the second is called **guiding vision**, which states that the team leader should give members initiatives and then let them fulfill the goals on their own, the third is **keeping the rules simple** to allow team members to exercise their own creativity and autonomy in achieving set goals, the fourth is **open access to information** and making sure the information flows between teams, the fifth **is light touch management style**, which translates to eliminating unnecessary micromanagement and control over the team and the sixth is **adaptive leadership**, where the project's internal forces are understood and changes to original plans can be made to better adapt for new conditions.

Corrêa (2001) suggests that rather than reviewing a process just once and then being happy with the result, firms should expect that more changes are constantly coming and therefore suggests applying an agile manufacturing strategy. He further goes on to suggest that firms should plan their processes to flexible so that they can be easily revised in the future to meet the changed conditions.

Corrêa also suggests that firms should seek to have control over unplanned changes and uncertainty by forecasting future conditions, better coordination and integration between units and relevant corporate entities, focusing cells to perform a narrow task that can then be altered in the future with a central control system that manages these specialized cells, outsourcing parts of production where change is constant and business partner is better adapted to surviving these changes, replacing unreliable suppliers, equipment or workers with reliable ones and increase the level of standardization to reduce the variety of parts and complexity. He also recommends flexibility to prepare for unexpected changes regarding product qualities, the mix of products, production volume, delivery times and the production system itself.

Cooper (2008) suggests that agile methods could help firms cope with the change and dynamics of certain industries or projects. Cooper also discusses boosting innovation with stage-gate models, where the innovation process is divided into a series of stages, each stage being closer to a finished product. Boehm and Turner (2003) also discuss innovation in their book, saying that organization embracing agile practices could boost their innovative capacities.

1.11 History of agile

Agile has its roots in software development, where the ideology has gradually emerged. In recent decades it has also started to make its way into other industries, such as general project management, agile supply chain and agile manufacturing. Conforto et al. (2016) write that agile project management (APM) has been widely used for software development, where it is still being applied.

A big point in the development of agile was the Agile Manifesto that was made in 2001. 17 individuals who had worked with and had lead software companies in the past came together and created the manifesto. They listed 12 principles of agile as seen in picture below (Beck et al. 2001). The manifesto can be seen referenced in multiple sources, such as Boehm and Turner (2004), Medinilla (2012) and Lee and Xia (2010). Medinilla (2013) says that the manifesto played a big part in the development of agile practices.

Picture 2: 12 principles, adapted from the agile manifesto

Agile alliance is self-described as a “nonprofit member organization dedicated to promoting the concepts of Agile Software Development as outlined in the Agile Manifesto” with over 60 000 members worldwide. The website has many of the terms explained and the principles from the website can be seen in the picture above.

1.12 Applications for agile

After emerging from the field of software development, the ideology has gained increasing popularity among general project management as well as some other industries (Corrêa 2001). The following describes agile in these industries and different contexts.

1.12.1 Software development

In software development, agile in itself is often used as an umbrella term that covers several methodologies, such as extreme programming (XP), SCRUM and Crystal (Augustine et al. 2016) (Poppendieck & Poppendieck 2003). A common feature for all tools that fit the agile ideology is that product development is divided into shorter periods called **sprints**, which typically last for one to four weeks. During each **sprint**, the product is tested by the customer and then changes are made to match customer needs better. These repeated changes towards the final product are called iterations.

Reaching set goals is measured on a **scrum** board, which is a visual aid to measure progress. Scrum master is someone who is dedicated to leading the meetings during each period and coordinates the process during the sprint they are in charge of. Augustine et al. (2005) state that the agile manager holds a key position in making the methodologies work, and is responsible for dividing the teams and assigning clear responsibilities and roles for team members.

Typically a scrum team is formed and this team meets for 15 minutes daily to discuss what has been achieved since the last meeting and how the goals are being met. Augustine et al. (2005) suggest that teams shouldn’t be dictated too strictly, and that team members should have the choice of switching teams if wanted, which allows for dynamic team composition and helps to adapt to changing conditions.

Conforto et al. (2016) state that using these shorter development cycles helps meet changing requirements and manage customer needs. Throughout the project life cycle, agile project management promotes change and continuous adaptation to better fit the purpose. Xia and Lee (2010) state that since business environments are changing at an unprecedented rate, agility with software development can assist in responding to customer needs.

Boehm and Turner (2003) write that agile methods can make the process lighter for software development and give customer involvement in the process and shorter cycle times as examples of agile practices. Ebert et al. (2012) write that most companies who have utilized agile did it to increase effectiveness. Agility is stated to have increased iterative and user-centric development, but they write that agile practices can often be too focused on short-term matters.

1.12.2 Manufacturing

Corrêa (2001) writes that agile manufacturing strategies could be the solution for environments that are constantly changing. According to Corrêa, proactive strategies, as opposed to reactive, are not only a key to competitive advantage in turbulent markets but a requirement for survival. He states that due to rapidly changing government policies, development of new communications technologies and e-commerce taking over the traditional ways of doing business among other things, firms have a harder time doing long-term predictions than they did in the past. Augustine et al. (2005) have similar suggestion, stating that traditional systems focusing on linear development are not fast enough to match changing environments. Elmosehy (2013) also describes agile manufacturing as being capable to respond to continuous and unpredictable changes in market demand.

Yusuf and Adeleye (2002) found in their research concerning various UK firms that agile manufacturing gives the firm an advantage over using lean. Agile was found to increase the firm's performance and said to give them a wider range of capabilities than lean did. They present agile as an continuation to lean, extending the focus beyond efficiency of firm's inner processes and into the supply chain as a whole. They also state that the traditional lean way of operating is in danger and agile might replace it in the future.

It should be stated however that Yusuf and Adeleye's study is almost 20 years old. Both practices are constantly evolving, as stated by Fadaki et al. (2019).

1.12.3 Supply chain management

Mostafa and Soltan (2015) write that agile organizations utilize something known as virtual corporation, which means collaboration between supply chain partners. This is said to allow the organization to use profitable opportunities better. Elmosehy (2013) also discusses the virtual enterprise, in which the organizations that form the value chain pursue cooperation to the point they could operate as a single entity. Resources and skills are shared and coordinated for faster and more cost-effective manufacturing and delivery, with emphasis on tailoring the product to customer requirements.

1.13 Criticism

Ebert et al. (2012) write that agile practices can be too focused on short-term matters, finding later that the overall life-cycle cost has been impacted in a negative way.

Mandal and Pal (2015) write that the main reason behind criticising agile has been the fact that it challenges traditional software engineering theories and practices. Cohen et al. (2004) also write that agile can be seen as a “step backwards from traditional engineering practices”. Cohn (2009) writes that rigid corporate culture can be a challenge for successfully implementing agile.

COMPARING LEAN AND AGILE

In this chapter, I will first compare lean and agile in general based on the existing literature and then compare their applications within different industries and internal sectors of the firm.

1.14 Lean and agile in general

Hines et al. (2004) write that agile is more oriented towards facing uncertain conditions and allows more room for unpredictability, whereas lean tends to promote planning ahead and keeping a smooth workflow. Lean also emphasizes reducing inventories, whereas this is not seen as a key factor with agile.

Martin (2000) also states that lean approach is best when demand is predictable, volumes are high and there isn't much requirement for variety, the same conditions in which Toyota originally developed lean thinking. Martin suggests that agility is better in conditions where the environment is less predictable but volumes are low, and that lean is better suited when environment is stable and predictable and volumes are higher. He also states that when demand for product variability is higher, agile methods suit the needs better, lean on the other hand is more compatible for environments where demand for variability is lower.

1.15 Lean and agile in supply chain management

Agarwal et al. (2006) write that flexibility is a requirement in supply chain management to counter uncertainty. Agile supply chain is presented to be better suited for turbulent environments where conditions are changing and to be able to respond quicker to changes in demand. Martin (2000) also suggests that the key to surviving in volatile markets is an agile supply chain that is quick to react to unexpected changes. Lean supply chain on the other hand is presented to be better suited when conditions are stable, demand is predictable and variety is low (Agarwal et al. 2006).

Martin (2000) writes that agile supply chain management is market sensitive. He states that instead of making forecasts based on past demand and building inventory based on past figures, agile supply chain should be demand-driven and take current customer requirements into account. Martin also writes that in addition to the physical supply chain, there should be a virtual supply chain of information between the network of corporate entities that work together. He states that this flow of information is a key to perceive and act upon real demand instead of making speculations.

Martin (2000) recommends process integration to share information better. Process integration is stated to be general collaboration between firms, mutual product development and shared systems. He also states that collaboration and networking between firms within the same supply chain gives a competitive advantage, and that firms in today’s markets can’t compete as stand-alone entities.

Martin (2000) writes there is also a possibility of a hybrid strategy, separately using both lean and agile. He suggests that firms that have a diverse porfolio of products and operate on different markets, could utilize agile for supply chains for products that operate in turbulent environments and use lean for cases where the conditions are more stable. He states that it is also possible that these firms use agile part of the time and switch to lean when it is appropriate.

He lists the fashion firm Zara as an example of a firm that uses an agile supply chain that still has many lean charecteristics. He writes that all operations that benefit from being done on a large scale are done in-house, while the rest of the manufacturing is done by specialized sub-contractors that exclusively work for the parent company of Zara, Inditex SA. He states that this effective use of both lean and agile has enabled Zara to develop one of the most effective fast-responding systems in fashion industry.

Martin and Towill (2001) write that there exists a possibility to use lean and agile simultaneously, especially when the range of products can be separated into categories based on volume or variability, or when a de-coupling point can be identified. Mason-Jones et al. (2000) concluded that lean, agile and leagile paradigms allows for the firm to match the supply chain with the marketplace.

1.15.1 Leagile

Goldsby et al. (2006) write that while lean and agile are sometimes wieved as opposites, they could be utilized together as leagile. For one strategy utilizing both lean and agile in supply chain management simultaneously, Martin (2000) and Martin & Towill (2001) describe a customer order de-coupling point, from which the firm can respond to customer demand with accuracy. This type of combination of lean and agile is referred to as leagile (Agarwal et al. 2006). Martin proposes that goods are kept in their generic or raw form before this point and then refined according to the customer demand. Olhager (2010) also recommends product customization after the de-coupling point, before which the goods are kept in their generic form.

Before the de-coupling point, lean strategies are utilized and the supply chain is operated based on forecasts and speculation rather than the actual demand. After the de-coupling point, operations are driven by demand and customer orders and the focus is more on agile (Martin 2000).

Agarwal et al. (2006) also write that a supply chain combining lean and agile as leagile lets the upstream part of the chain become more cost-effective with lean, while the downstream part can provide better service with agile.

Martin & Towill (2001) write that before the decoupling point the firm can utilize lean strategies to manage their supply chain. An appropriate amount of raw materials are procured and refined to a state from which they can then be customized according to customer needs. After the decoupling point, an agile strategy is utilized to quickly respond to a variety of orders. Martin (2000) writes that identifying the de-coupling point is important, since it dictates how far the product should be refined before specific customer order is received. According to Agarwal et al. (2006), the need to use lean or agility depends on the overall supply chain strategy and on where the de-coupling point is positioned.

Martin (2000) also describes another de-coupling point: first one for materials, the second for information. He states that the material de-coupling point, where strategic inventory is held in its unrefined state, should lie as close downstream in the supply chain and physically as close to the final market as possible. The second de-coupling point for information should be located as far upstream as possible, close to the end-user. The information de-coupling point refers to attaining the specifics for the product that will then be customized.

Picture 3: Hybrid supply chain strategy proposed by Martin (2000) and Martin & Towill (2001)

1.16 Lean and agile in manufacturing

In the context of manufacturing, Shah and Ward (2003) state that large plants are more likely to have the capability and resources to more effectively apply lean practices than smaller plants. Their study found that plant size is a major factor for implementing lean, regardless of the respective industry. Al-Tahat & Bataineh (2012) state that lean production and agile manufacturing should be viewed as complementary practices to each other, as opposed to being each others alternatives. They also state that lean tends to focus more on operations and technical side of things, whereas agile is more concerned for the people and enterprise matters.

Mostafa and Soltan (2015) state that traditionally manufacturing has been based on economics of scale, which has lead to lot of unnecessary waste and rigid processes. This has changed with the introduction of methodologies such as agile and lean. Mostafa and Soltan also write that lean manufacturing is used when resources are limited and the firm responds to competitive pressure, whereas agile is the response to the complexity of an environment that is constantly changing.

Hallgren (2009) writes that lean and agile manufacturing are driven by different factors. He finds that lean manufacturing is more popular when management is focused on reducing costs, wheras agile manufacturing is found to be negatively associated with this cost-based strategy. He also concludes that agile manufacturing is more driven by flexibility regarding the mix of products than lean manufacturing is.

Martin (2000) writes that agility and leanness shouldn’t be confused with each other, also stating that many firms that have adapted lean manufacturing are anything but agile with their supply chain. He says that even though many car manufacturers are cabable of utilizing lean and making the product in record time, they might have problems moving the product which ends up sitting in the warehouse, and eventually takes a long time to be delivered to the customer. However, this statement is countered by many authors who write that one of the main principles of lean is to reduce unnecessary inventory and avoid producing goods until the customer signals the need (Joosten et al. 2009) (Hines et al. 2004). Martins statement would implicate however that some firms might be cabable of utilizing lean in parts of their operations but not as an organizational philosophy that covers all operations, as it is defined by Hines et al. (2004).

Hines et al. (2004) write that initial adapters among the western manufacturers were excited to start applying lean ideology, being inspired by the perceived superior performance achieved by other lean producers and the better performance achieved when compared to traditional mass production systems. The structural parts and the practice in itself were more easily applied

but new adapters often found it hard to fully introduce the organizational culture and lean mindset. This theory could explain Martin's (2000) findings, since his paper was written in 2000 when lean was still developing and many firms were only beginning to adapt the practices, mainly for manufacturing purposes. Joosten et al. (2009) also write that application of lean is sometimes met with resistance, since the approach seeks to challenge existing hierarchies to optimize the process

1.17 Lean and agile in software development

Ebert et al. (2012) write that one reason for interest in implementing lean into software industries is to reduce costs. They write that agile is often utilized on working with short-term goals in software context.

Wang et al. (2012) write that there's a difference between utilizing lean and agile in software development. Agile processes are defined as processes within the organizational context, whereas lean is described as having the potential to encompass the entire organization with the goal of optimizing activities whenever applicable. The agile practices are said to be more tactical in nature and can be rejected by existing organizational forces.

Wang et al. also write that lean is a more recent arrival into the field of software development and isn't always properly understood in that context. Some firms are said to mistakenly use the terms lean and agile interchangeably. They conducted a study with 28 organizations to determine how lean is being applied and found that there are multitude of ways in which these firms can use lean in software development.

1.18 Lean and agile in healthcare

Waring & Bishop (2010) conducted a study on how lean was implemented in one UK hospital department to redesign services. Their findings suggest that the managers have a big role in ensuring that the ideology is accepted and effectively implemented but that the ideology has potential for healthcare process reformation. The authors suggest that the main idea behind lean, which is identifying and eliminating waste, is applicable to healthcare. They also state reconfiguring established boundaries can create a better flow of work. Challenging existing roles can be problematic, as Joosten et al. (2009) state that lean is sometimes met with resistance since the ideology seeks to challenge existing hierarchies.

Waring and Bishop's study concluded that implementing lean into healthcare might not always necessarily be as successful as it could be, since there are existing roles, hierarchies and social actors that ultimately determine how well these practices and theory can translate into reality.

Patri and Suresh (2017) discuss in their paper what could enable agile methods to be utilized in healthcare. They found that agile practices could help healthcare organizations in addressing unexpected medical demands, such as medical emergencies, and better provide customized services. They identified friendliness toward employees and a non-authoritative culture as factors that could enable agile practices to be utilized. Flexibility among the workforce and taking employee suggestions into account are also presented as factors that enable agile practices.

With lean, the studies concluded that the reason it was failed to implement on the long-term was because the human factors were failed to take into account (Waring & Bishop (2010) (Radnor et al. 2012). In Patri and Suresh's study (2017), similar factors were found to have an effect on how well agile practices could be utilized into healthcare. It could be concluded that on a highly social setting and service-based environment, the "human factor" becomes more

important than with something like supply chain management, both for lean and agile.

Radnor et al. (2012) also studied lean in UK healthcare. They concluded that while many improvements on the short term were made in terms of increased efficiency, these changes failed to stay in the long-term. They also write that while lean as a process was effectively implemented, there was a failure to apply lean thinking on a general level and principles such as “kaizen” or continuous improvement were not often recognized by the people who were utilizing these practices in their work.

Tolf (2017) compares lean, agile and leagile in her doctoral theses by conducting case studies with two Swedish hospitals. Her findings indicated that both lean and agile could be utilized together effectively. She presents that lean could be used to effectively manage resources, while agile would be applied to respond to external conditions such as market positioning and market orientation.

Aronsson et al. (2011) also studied lean and agile in the context of swedish health care supply chain management. They concluded that supply chain management as an ideology could be applied into healthcare practices. They also proposed a hybrid approach combining both lean and agile, to ensure flexibility and quick response.

In healthcare, lean and agile both seem to have similar enabling factors. From the two studies of Waring & Bishop (2010) and Patri and Suresh (2017), we can see that both lean and agile benefit from non-authoritative workplace culture and a readiness to challenge the existing roles and hierarchies. A rigid hierarchy could therefore be an obstacle for utilizing lean or agile in healthcare.

1.19 Lean and agile summarized

To summarize past literature used within the theoretical framework, lean and agile have many differences. The main difference in focus are the markets: lean is more geared toward a stable environment, whereas agile is used when demand is uncertain. In past studies, lean was often mentioned together with reducing waste from the process, whereas agile was associated with reacting to changing conditions and benefitting from them. Since lean emphasizes a standardization for both the process and the product, the product mix is usually recommended to be kept low. Conversely, agile emphasizes a tactic of mass customization which allows for a larger product mix. There was also a difference concerning production volume withing past literature: lean was associated with high production volumes whereas agile was mentioned with lower volumes. Both theories also received some amount of criticism: lean for being too rigid and unsuited for volatile conditions, agile for being too focused on short-term goals.

	Lean	Agile
Focus	Reducing waste	Reacting to change
Ideal for	Stable markets	Volatile markets
Product variability	Minimal	Large
Emphasis	Standardization	Mass customization
Inventory levels	Minimal	Unspecified
Production volume	High	Low
Criticism	Not suited for unstable markets	Too focused on short term matters

Table 1: Differences between lean and agile

1.20 Methodology

When constructing the theoretical framework, I didn't come across any studies that would've compared lean and agile extensively together. Rather, many studies mentioned in passing that lean is often used when conditions are more stable and agile is recommended when the conditions are more unpredictable. In some studies these bits of information were mentioned together but oftentimes the study would only mention lean or agile.

The original research question was whether or not lean and agile were equally applicable in various situations and based on the studies I've read so far, I present the propositions that lean is more suited for stable environments and agile is recommended when conditions are less stable.

I also present the proposition that lean and agile are not mutually exclusive paradigms and can be effectively used together. Articles concerning supply chain management often mentioned the two being used together, combined as leagile.

Proposition 1: Lean is more suited for stable markets than agile

Proposition 2: Agile is better suited for volatile markets than lean

Proposition 3: Agile and lean are not mutually exclusive paradigms and can be utilized together

Attempting to search articles dedicated solely to whether or not agile and lean are suitable for certain conditions didn't yeald very good results. The search words "agile volatile" and "lean stable" didn't provide results that actually focused on suitable conditions for lean or agile.

To find the relevant articles for my study, I chose the keywords "lean AND agile" to find studies that would discuss lean and agile together. When constructing the theoretical framework, it was these types of articles that mentioned the recommended conditions for lean and agile respectively. Trying to search articles that only mention lean or agile would give too many results, and even though these articles might explain both approaches in more detail, it is more effective to search for articles that would discuss lean and agile together and compare their applications.

I chose to search for the related articles from three different databases: Ebscohost Business source Ultimate, Elsevier and Proquest. Searching with the key terms lean and agile, using the Boolean connector AND to make sure both methodologies would be discussed, I found a total of 31936 results from Proquest, 2741 results from Elsevier and 497 results from Ebscohost. The search was conducted during November of 2020.

The next step was to limit the results. Since Elsevier and Proquest had such a large number of articles, I decided to limit the results only to articles that would have lean and agile on the abstract instead of the terms being anywhere in the text. Including lean and agile anywhere in the text could include results that only briefly mention either of the two terms. Since I was looking for articles that would compare the applicability of lean and agile on a general level, these articles would not be included in the study.

After choosing only the articles that had lean and agile in the abstract, Elsevier results dropped from 2741 to 111, while Proquest results dropped from 31936 to 957. Next, I only included the ones that had full text available. This limited the number of results from Elsevier to 107 and from Proquest to 790.

The next step was to choose articles based on titles. Articles were excluded based on several factors:

Some articles described lean and agile in the context of unrelated phenomena such as organizational learning or sustainability. Based on previously read articles, these studies would very likely not discuss or extensively compare either approach, so these studies were excluded. Other articles had their sole focus on a very specific part of either lean or agile such as just-in-time delivery, which meant that the likelyhood of both approaches being compared or discussed in relation to one another was relatively small.

Certain articles did not qualify the criteria of a scientific study and were therefore excluded. The language was also an important factor, and only English written articles were chosen. Most articles were in English and within the search results, the total number of articles written in other languages was less than 30.

It should be noted that Proquest had the largest amount of results that were not scientific studies in proportion to the total amount of search results found, only 195 of the 790 results with full text were scientific studies. The results from Elsevier were almost exclusively scientific studies, while Ebscohost had mostly scientific studies with some periodicals and others mixed in.

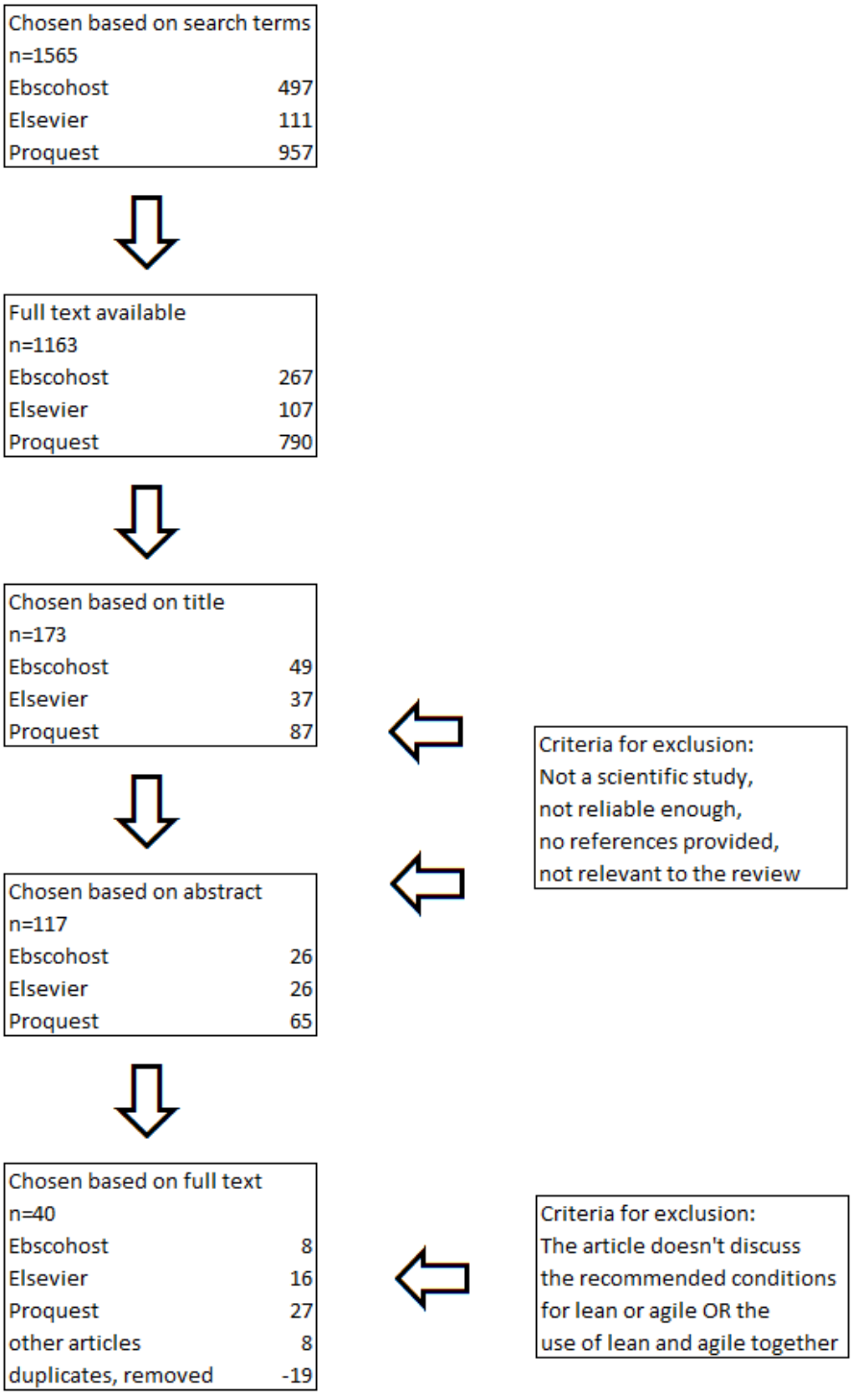
Academic journals that seemed to discuss lean and agile together or the applicability of either lean or agile in certain conditions were chosen based on the title. Also, if the article discussed the concept of leagility it was a clear indicator that both theories would be discussed. A total of 173 articles were chosen based on their title.

After choosing the articles based on their titles, I moved on to read the abstract. Similar criteria were applied during this phase, as the abstract gave more idea on what the study would focus on. Some articles seemed promising based on the title but after reading the abstract it became apparent that these studies would not be relevant to this literature review and more articles were excluded. A total of 117 were chosen for the next phase based on the abstract.

The last phase was to read all the studies to see which ones would discuss relevant themes to this review. A total of 40 articles were assessed as relevant to this study, either suggesting certain conditions and suitability to lean or agile, or discussing the use of both approaches together. 8 of these articles had been found earlier when I was building the theoretical framework and 32 came from the three databases. A total of 19 duplicates were found and excluded, 16 from Proquest and 3 from Ebscohost.

Database	Key terms	Parameters	Results	Chosen
Ebscohost	lean AND agile	boolean phrase, anywhere in text	497	8
Elsevier	lean AND agile	boolean phrase, anywhere in abstract	111	16
Proquest	lean AND agile	boolean phrase, anywhere in abstract	957	27

Table 2: Database search, keywords and results



Picture 4: The phases for the literature review

An interesting point is that most articles that were relevant to the study were either supply chain or manufacturing related articles. Some articles related to the medical industry and programming were also in the search results, but oftentimes these articles didn't provide anything in relation to the propositions of this review. Therefore, the review took a coincidental focus to manufacturing and supply chain related articles. The databases themselves could have also had a part in this result, as articles related to medical field at least have their own specific databases.

1.21 Validating the propositions

The following articles discussed the recommended conditions for lean and agile and their use together. In this section, each proposition is discussed separately and relevant literature findings presented.

Proposition 1: Lean is more suitable for stable, predictable environments

Matawale et al. (2016) write that lean manufacturing is typically adopted when demand is stable. Iqbal et al. (2020) also make a statement that lean manufacturing can be practiced more effectively when the conditions within the market are stable.

Hallgren and Olhager (2009) state that in order for lean principles to be applied for manufacturing purposes, the environment must be stable. They continue that a level schedule requires the manufacturing process to be protected from volatility, variation and uncertainty. The stable conditions provide the conditions for high-capacity utilization and production, which makes the lower manufacturing costs possible.

Lotfi and Saghiri (2018) write that lean is positively associated with flexibility, which would implicate that it is not solely suited for highly predictable and stable environments. However, their also study didn't contradict the statement that lean is suited for stable environments. Wan and Chen (2005) write that lean principles may not be sufficient in changing markets and that they are more suited for extremely stable markets.

Greene et al. (2008) state that utilizing lean is based on the conditions being stable, which directly contradicts agile principles, where opportunities are exploited in a volatile environment.

Qamar and Hall (2018) write that lean approach is better suited for predictable markets. Mason-Jones et al. (2000) describe lean supply chain as also being suited for situations where the marketplace demand is predictable. Shahin et al. (2016) write that lean supply chain is not always very flexible, which would also implicate that it is not best suited for volatile environments.

Sukwadi et al. (2013) write that lean supply chain might not be able to meet customer needs rapidly. They also write that lean works best in conditions where the demand is stable and predictable.

Carvalho et al. (2011) write that a lean supply chain might lack the responsiveness to fluctuating customer demands and that lean is considered to perform better when there is high production volume, low variety in the product mix and the demand is highly predictable with certainty in the supply. They add that lean supply chain may lack the responsiveness to customer demands and that the smooth production and kanban system aren't compatible with high levels of variability.

Goldsby et al. (2006) found in their research that lean supply chain can improve customer service performance in terms of reduced lead time, as long as demand is predictable with high accuracy. Their findings suggest that lean is best suited for stable conditions and not for uncertain, volatile markets.

Bezuidenhout (2016) writes that even though a lean supply chain is geared towards a consistent flow of products, the lack of inventory and spare capacity also means that any unexpected event is harder to deal with. This indicates that lean supply chain is not ideal for a market with fluctuating demand.

In the review paper by Trang (2016) it is suggested that lean planning is more suitable than agile when there is low demand uncertainty and the conditions are stable. Huang et al (2002) write that the major drawbacks of lean supply chain are its difficulty in responding to changing market needs and dealing with mass customization.

Stavrulaki et al. (2010) recommend agile supply chain when production volume is low and there is a high uncertainty concerning the products.

Mason-Jones et al. (2000) suggest that lean be used in marketplaces where the demand is predictable and thereby allows for a lean supply chain to be utilized. Their case study included a firm that manufactured complex mechanical systems and exported them to various countries. The case study concluded that the firm managed to reduce cumulative delays in processing and manufacturing from 23 weeks to just 2 weeks by utlizing lean practices and also improved their delivery times to the customer. Manufacturing in itself also became more efficient with the applied methods.

Christopher (2000) writes that lean is best suited for predictable environments and also recommends it for high production volume environments. Hines et al (2004) write that it is challenging to utilize lean in an unstable environment, further suggesting it is better suited for stable markets.

Findings

The results suggest that lean is indeed more suited for predictable, stable conditions than volatile and unpredictable markets. However, lean was less often talked in the context of turbulent/stable markets than agile was. Instead, lean was more often discussed in the context of cost-efficiency and elimination of waste. The proposition was not contradicted by any scientific study and none of the articles suggested that lean is not best suited for stable conditions, but based on the articles in this literature review it seems that market stability is not as strongly associated with lean as market volatibility is with agile.

Proposition 2: Agile is better suited for more unpredictable and volatile environments

Shahin et al. (2016) describe agility as a means to respond quickly to changes in business environment and the ability to meet the rapidly changing requirements of customers.

Hallgren and Olhager (2009) write that agile manufacturing is more strongly associated with product mix flexibility than lean manufacturing. The authors describe describe agile manufacturing system as being capable of operating in an environment of continually and unpredictably changing opportunities. They also write that agile is used to seek profitable opportunities in a volatile market. Agile is said to be the prequisite to responding effectively to changing customer needs is the ability to handle variety and introducing new products fast.Interestingly, according to Hallgren and Olhager, agile does not have a positive impact on cost performance while lean does.

Iqbal et al. (2020) state that agile manufacturing includes the ability to change operating state in response to changing conditions. They also state that agile manufacturing is more appropriate than lean in a volatile market environment, and that these market conditions can be exploited through the responsiveness and flexibility that comes along with agile approach.

Matawale et al (2016) describe agile manufacturing as a tool to thrive in the face of continuous change and withstand the turbulent conditions within the marketplace. They also write that agile manufacturing differentiated from lean manufacturing as a response to being more flexible and meeting customer expectations better.

Sahin (2000) presents agile manufacturing as an approach that optimizes customer relations and enables the firm to respond to any unplanned changes in a volatile environment. Through mass-customization, the firm is written to

achieve flexibility to these changes and making the firm capable of offering highquality, high variety and low cost for their products. Sahin also concludes that lean and agile are suitable for different business environments.

Wan and Chen (2005) write that agile manufacturing is geared towards unexpected situations and that the goal is to gain benefits from the markets before the competitors have a chance to react. Agility is said to be better suited for volatile environments than lean.

Corrêa (2001) mentions that agile is suited for environments that are constantly changing, discussing its use in manufacturing context. Cooper (2008) suggests that agile methods could help firms cope with the change and dynamics of certain industries or projects.

Christopher (2000) suggests agile for environments where conditions are uncertain, predictability is low and demand is volatile. Agile is also suggested to be suited for volatile environments in a software development context (Xia and Lee 2010) (Conforto et al. 2016)

The volume and variability of the product have also been stated to affect the decision between lean and agile, lean being recommended when variability in demand is low and volume is high, while agile being the more favored option when standardization isn't possible and conditions are expected to be more volatile (Christopher 2000) (Martin & Towill 2001).

Mason-Jones et al (2000) write that marketplace demands are typically highly volatile for agility, and that the agile supply chain must use this to their strategic advantage. They suggest using agile supply chain for highly volatile markets and products that have high demand uncertainty and short life cycles. Martin and Towill (2000) also write that agile supply chain means the ability to cope with volatile market demand. They also suggest that agile forecasting should rely on sharing information on current market demand and receiving from as close to the marketplace as possible, while lean forecasting is described as algorithmic.

Bezuidenhout (2016) writes that agile principles are used to respond to fluctuating demands, ensure a premium quality and associated with products that have short lifespans. He also adds that agile supply chain's goal is to meet customer demands with flexibility and to ensure a premium quality in both product and service. However, this can contradict cost-effectiveness, indicating that the choice to use agile supply chain is very product or market specific.

Madhani (2017) writes that agile principles are applied to a supply chain when demand is fluctuating and products have short lifespans. Agile supply chain strategy is also said to be a response to market volatility. Díaz and Tachizawa (2015) identified agility as a key factor to responding to sudden disasters. According to them, materials as well as information about the disaster need to flow rapidly to get the aid to where it's needed.

Sukwadi et al. (2013) support the notion that in an environment where the demand is volatile and there is high variety for customer demand, agile supply chain is the preferred choice over lean. The focus of agility is defined as the capability to respond rapidly to any possible changes in terms of variety or volume. They also add that agile approach is best suited for conditions where products have short life cycles, there is small volumes and higher margins for profit, competition is based upon product specification and the demand is unpredictable.

Huang et al (2002) write that the agile supply chain was developed as a means to respond to rapidly changing and continually fragmenting markets. The focus is on responding to unpredictable changes in the market and taking advantage of them.

Tarafdar and Qrunfleh (2017) define supply chain agility as the capability to adjust tactics and operations in a quick manner to adapt to sudden changes in production volume and sense and react to changes within the market. The authors identified information sharing between suppliers and partners as a key enabler of agility and determined that agile strategy can boost supply chain

performance if the firm has the information system capabilities to execute agile practices.

McMaster et al. (2020) write that agile supply chain management is based on giving the firm flexibility to respond and change supply chain entities to fit the new situation better. They write that firms within the fashion industry switched from a lean model into a more agile supply chain during the 2020 economic lockdown as a response to turbulent conditions.

Kovács (2017) mentions in his article that agile supply chains have to be flexible for the purpose of responding to changes in customer demands or market conditions, supporting the notion that agile strategy is suited for a volatile environment. He also adds that the strategy is typically applied when the products are innovative or new or they have a short product life cycle.

Carvalho et al (2011) write that with volatile supply chains and unpredictable customer requirements, a higher level of agility is recommended. The focus of agile supply chain is the ability to respond rapidly to any market changes and to comprehend these markets better. The agile supply chain is said to be an integration of business partners that enables rapid response to changing and continually fragmenting markets. Key enablers for this practice include relationship configuration, visibility of information throughout the chain and event-based and event-driven management.

Bruce et al. (2004) write that the agile supply chain is market sensitive, defined by the ability to respond quickly to any changes. Stavrulaki et al. (2010) suggest that lean supply chain should be used when there is high production volume and low uncertainty within product demand.

Qamar and Hall (2018) mention agility to being flexible and fast to respond to sudden changes within the market environment. They also write that agile approach is best suited for environments where the supply chain is turbulent.

Fadaki et al. (2019) also support the idea of agile supply chain being the preferred choice in volatile environments. They write that when companies utilize both lean and agile in their supply chain, more attention is paid to the agile side of supply chain when the business environment becomes more turbulent.

McMaster et al. (2020) write that agile supply chain management is based on giving the firm flexibility to respond and change supply chain entities to fit the new situation better. They write that firms within the fashion industry switched from a lean model into a more agile supply chain during the 2020 economic lockdown as a response to turbulent conditions.

Trang (2016) suggests utilizing agile planning and control when the firm needs capacity flexibility and the uncertainty for demand is high. Trang lists fashion industry as an example of an industry where the use of agile is appropriate.

Findings

The past studies included in this literature review heavily suggest that agile is the preferred choice over lean when market conditions are turbulent and customer demand is unpredictable. Some studies even suggest that agile approach can be used to achieve an advantage over competitors by exploiting the volatility of the market (Iqbal et al. 2020, Mason-Jones et al. 2000).

Agile approach was also commonly associated with product mix flexibility (Hallgren and Olhager 2009), meeting customer expectations better through a more customized product (Bezuidenhout 2016, Matawale et al. 2016) and short product lifecycles (Bezuidenhout 2016, Madhani 2017).

All of the research papers included in this thesis recommend using agile for environments where the conditions are unstable and unpredictable, while none that were included in this study made the claim that agile wouldn’t be suited for this type of environment.

Proposition 3: Lean and agile can be utilized together

Rashad and Nedelko (2020) present lean and agile as practices that have somewhat opposite goals, lean being used to achieve cost-effectiveness while agile practices used to achieve speed and flexibility in the supply chain. However, the authors state that when used together as leagile, both these goals can be pursued.

Iqbal et al. (2020) write that although lean manufacturing and agile manufacturing are said to support a different organizational strategy and known as competing paradigms, the are in fact complementary capabilities within the context of manufacturing.

Greene et al. (2008) state that under certain conditions, lean and agile manufacturing could complement each other well. They also write that many manufacturers have different definitions on what lean and agile actually constitute, and whether or not both can be used depends on the manufacturers own definition.

Ghobakhloo and Azar (2018) found in their questionnaire based survey of Iranian car part manufacturers that lean and agile manufacturing can exist together as a single system, while improving the firm's performance. They also write that lean manufacturing is a prequisite to agile manufacturing, indicating further connection between the two. The authors see lean and agile manufacturing as strategies that contribute to different parts of business performance, using both together could allow the firm to pursue both product mix flexibility and a cost-leadership strategy.

Shahin et al. (2016) write that lean and agile can support each other as a leagile supply chain. By using both approaches at the same time, the authors state that the advantages of both strategies can be achieved simultaneously. Waste can be reduced and resources utilized effectively (the lean part) while simultaneously meeting the rapidly changing requirements of the customer (agile). Shahin et al write that a common theme discussed in utilizing a leagile strategy is the correct determination of the decoupling point. However, whether or not leagile strategy is successful depends on the correct utilization of the decoupling point where the two strategies are separated.

Matawale et al. (2016) also recommend a leagile supply chain for similar reasons. The supply chain is described as utilizing a different paradigm depending on which side of the decoupling point is discussed, with lean being used where demand is stable and agile utilized where demand is volatile. The decoupling point is further described as the point in which forecasts and demands meet. Stavrulaki et al. (2010) suggest that when production volume and demand uncertainty are on a medium level, lean and agile should be used together as leagile supply chain. The supply chain is said to use a combination of efficient and flexible processes.

Goldsby et al. (2006) found in their study that lean and agile can be effectively utilized together as leagile supply chain, supporting previous studies. Their leagile strategy suggests that the product is assembled to base units positioned close to the end markets and assembled then according to customer requirements. The leagile approach was not found to be always the most cost-effective strategy, however leagile might be useful for specific scenarios.

Qi et al. (2009) found in their study that firms adopting lean, agile or a combination of both in their supply chain tend to perform better than firms that don't use either approach. The study was based on analyzing data of Chinese manufacturing firms. Firms using traditional supply chain strategies were found to perform significantly worse than their lean or agile utilizing counterparts.

Qi et al. also found that lean supply chain was better at improving costs than agile. They also found that agile didn't provide a better customer service. Their findings concluded that within the context of Chinese manufacturing firms, a lean supply chain or a combination of lean and agile tended to perform best. Traditional western agile model was found to not be a fully viable choice in the Chinese market.

Wan and Chen (2005) suggest emphasizing lean and agile for different scenarios, for example by utilizing agile tactics when entering a new market and using lean when conditions are established and stable. They state that in order to achieve a proper balance between the two approaches, a proper measurement system needs to be developed to measure and evaluate the performance of leanness and agility.

A case study by Mason-Jones et al. (2000) found that utilizing leagile supply chain allowed for specific products to be pulled by the current demand. They also write that the lean part of the supply chain allowed for delivering new technology faster, which prevented costly obsolence with old parts that were no longer in demand by the end user.

Naylor et al (1999) recommend using agile and lean together for supply chain management as leagile. Several other studies also suggested the use of leagile with a determined de-coupling point (Martin 2000) (Martin & Towill 2001) (Agarwal et al. 2006) (Olhager 2010).

Madhani (2017) suggests three possible strategies to utilize agile and lean together. Firstly, the pareto curve approach suggests that 20% of products that create 80% of firm's revenue are fast moving products that can be produced using lean, since their demand is assumed predictable and stable. Agile supply chain is identified as a possible choice for the remaining slow-moving products with a more uncertain demand.

The second approach is using the decoupling point, assembling products to base units using lean and then customizing them to order rapidly using agile. The third approach assumes a base demand and a surge demand. The base demand is dealt with using lean strategies while agile is used for any unexpected surges in customer demand.

Díaz and Tachizawa (2015) write that in the context of supply chain management in disaster response, agile and lean are both utilized. Agile is emphasized in the beginning when the aid is required urgently, whereas lean comes into use during the long-term recovery phase when conditions are more stable.

Fadaki et al. (2019) write that lean and agile are often utilized together in the context of supply chain management, adjusting the levels of agility or leanness to achieve cost minimization or customer response as needed. Leanness and agility are seen as complementary practices, however they also state that increasing agility may lead to the decreased leanness of the supply chain. Their study combined leanness and agility to a single scale, through which a firm's strategy could be assessed. They concluded that firms typically employ a balanced combination of lean and agile as leagile to suit their needs, rather than using a purely lean or agile approach.

Bezuidenhout (2016) also shares a similar idea, writing that leanness and agility are negatively correlated. However, he also states however that the approaches are not opposed to one another, and instead are very commonly used together as leagile in modern day supply chains.

Fadaki et al. (2019) also write that there is evidence that a purely lean or agile supply chain simply doesn't work in today's turbulent business environment, and that according to past studies, agile and lean have been found to complement each other in the context of supply chain management. Kovács (2017) supports using lean and agile together as leagile for innovative, custom designed and unique products.

According to Fadaki et al, cost leaders will usually have a predominantly lean supply chain strategy. However, when the market becomes more turbulent, the focus is shifted more into utilizing agile within the supply chain. According to Bezuidenhout (2016), both lean and agile principles are fundamentally linked to the supply chain's capability to properly react with fluctuations in product flow within various points of the supply chain, suggesting that both lean and agile can be useful in dealing with market turbulence.

Trang (2016) writes that the ideal supply chain should contain three qualitites: lean or agile, adaptability and alignment. Adaptability is defined as the ability to restructure the supply chain to conform to long-term changes in the markets. Alignment refers to aligning the benefits of all partners within the supply network. Trang does not discuss the combination of leagile or the decoupling point in his work, rather, lean and agile are seen as alternatives to each other. However, Trang's review also does not explicitly say that lean and agile were mutually exclusive practices.

Towill (2005) suggests using leagile supply chain with a decoupling point to deal with surges of unexpected demand. Towill discusses the bullwhip effect, which implies that the surges in demand are amplified the further upstream and further away from the customer an entity is located within the supply chain. Towill writes that the bullwhip induced risk reduces when a decoupling point separating lean and agile practices is placed at an appropriately close location to the marketplace and end customer. Seamless supply chain vision, information transparency among the entities within the supply chain and establishing a smooth material flow are also seen as reducers of the bullwhip effect.

In his case study, Mistry (2005) focused on an electronics manufacturing firm that had first employed lean practices to reduce waste and later started to use agile in the supply chain for more flexibility and responsiveness. The firm employed a combination of agile and lean utilizing the decoupling point,

moving from a "build to stock" into an "assemble to order" model. Mistry found that the case firm benefitted greatly in terms of savings, first from the use of only lean model and later from the combination of both.

Using the leagile model, the case firm was able to reduce unnecessary stock in finished goods and eliminate the need to do physical inventory on weekends. The firm also required less use of floor space when machines were assembled to order, reducing the costs of floor space requirements. The firm also made cost savings from lowered labor costs and was found to have an increased responsiveness to customer demands after moving the decoupling point closer to the customer order from their previous model.

A case study by Bruce et al. (2004) describes firms within the fashion industry, a market that according to them is charecterized by volatility, short product cycles and high variety in the product mix. Combined with the small profit margins, holding excess stock is not typically a viable option. Their case study identified four different categories within the fashion industry, each using and combining lean and agile to a different degree. Essentially, the more generalized the product, the more lean emphasized the supply chain becomes. Conversely, the more product customization is involved, the more agile the supply chain becomes overall. The study suggests using lean and agile together, with a more lean emphasized approach on certain cases and a heavier emphasis on agile on others. What really defines the need to use either approach according to Bruce et al is the product and the market itself.

Camargo et al. (2020) also studied the fashion industry in the context of supply chain management, with an emphasis on fast and ultra-fast supply chains specifically. They suggest that firms use a combination of lean and agile to achieve on-demand production, shorter lead times and the avoidance of excess inventory. They differentiate purely agile and lean supply chains by the fact that agile supply chains are more likely based on first hand information received through contacts in the market, whereas lean is more based on forecasts and economics of scale.

The study by Sukwadi et al. (2013) found that agile works better than lean for small and medium enterprises in the context of supply chain management of Indonesian garment industry. They found that leanness in that particular context did not improve supply chain performance, while agile did. Hallgren and Olhager (2009) state that agile manufacturing is negatively associated with a cost-leadership strategy, while having a stronger relationship with volume and product mix than lean. Lean is found to have a strong impact on costs.

Stavrulaki et al. (2010) have a similar theory, suggesting that lean is more emphasized when products are built to stock with little customization involved, and agile is more emphasized when there is more product customization involved. In their article, Stavrulaki et al. write that agile is most heavily emphasized when the product is designed to order. The types of supply chains that fall in the middle use lean and agile in a more balanced way. These supply chains are described as either make to order or assemble to order. Lean is first used before the decoupling point when product components are made, after which agile approach is emphasized when the components are assembled according to the customer's order.

Qamar and Hall (2018) found in their study that contrary to traditional thinking, lean firms were not more likely to be at the lower end of the decoupling point and were actually at the top, closer to the end customer. For the agile firms it was also the same, contrary to the traditional models suggesting agile firms being at the top of the supply chain or close to the end customer, their study found agile firms to be actually on the opposite side of the supply chain. Their findings suggest that firms operating within a complex supply chain are likely to use lean model when operating downstream and agile model when operating upstream.

Qamar and Hall propose that their lean agile automotive supply chain (LAASC) model is applicable if the product is complex and requires thousands of components, but not necessarily applicable if the product is of a more simple variety.

Ahmed and Rashdi (2020) discuss the differences of utilizing lean and agile supply chain strategies in terms of company resilience. Resilience is defined as the ability to bounce back after a risk event to an acceptable level and overall minimizing the damage caused by a specific risk event. Their study found that the more agile the organization, the more resilient it becomes. Leanness was found to not support organizational resilience, however they state that a lean strategy can be useful in reducing costs. To execute supply chain agility effectively, they suggest that market comprehension and knowledge must be on a high enough level. Ahmed and Rashdi's study did not discuss using lean and agile together, but the perspective brings another consideration into the differences between lean and agile approach.

Naim and Gosling (2011) state that even though the concept of leagility has faced criticism in the past, the criticism is “limited and contradictory”.

Findings

None of the studies included in this review suggested that leagile isn’t a valid form of supply chain management, although choosing between lean, agile and leagile would seem to depend a lot on the context. Past studies suggest that lean and agile can indeed be used simultaneously and are not competing paradigms.

Proposition	YES	NO
Lean is suitable for stable environment	19	0
Agile is suitable for volatile environment	34	0
Lean and agile can be utilized effectively together	29	0

Table 3: Summary of the results

FINDINGS AND DISCUSSION

At first glance, agile and lean seem like similar ideologies. Both approaches are very customer oriented and value is derived from what the customer wants: with lean, everything that doesn't add value to the customer is considered a waste and thus removed (Womack et al. 1990). With agile, the goal is to provide customer with a product that suits their needs (Conforto et al. 2016).

The original research questions sought to answer whether or not lean and agile were equally applicable in various situations, if they could be used together and if there was some specific detail that would determine which one to choose.

Whereas lean is mostly concerned with reducing waste and improving the processes (Goldsby et al. 2006), agile's main goal is to quickly respond to unexpected changes within the environment (Martin 2000). It is also often mentioned that on a general level lean is slower to respond to changes, while change is expected with agile and it is even seen as something that can give competitive advantage (Martin 2000).

When looking at the applications for lean and agile, this responsiveness to changing conditions and demand came up many times. Regardless whether or not the methodologies are being applied for manufacturing, supply chain management or healthcare, the same principle seems to come forward in multiple studies: lean is recommended when conditions are stable and demand is more predictable, whereas agile is suggested for when the conditions and demand are harder to predict. This reoccurring suggestion lead to the propositions that lean is more suited for stable markets than agile and agile is better suited for volatile markets than lean. The third proposition was that agile and lean are not mutually exclusive paradigms and can be utilized together.

With the literature review, all three propositions were confirmed with no opposing evidence found. It was universally suggested that lean is more suited for the stable conditions than agile, and that agile was the preferred choice for volatile conditions. Both approaches being used together was an especially common theme within supply chain management, where the two approaches could be utilized together as leagile supply chain.

On a general level, choosing between lean and agile seems to depend on several factors. While lean is more suited for stable conditions, it is also utilized more efficiently when less customization of the product is involved and the product mix is relatively small. A major focus of lean is still cost efficiency, which hasn't changed when compared to past literature. What has changed however is the context in which lean can be utilized, becoming more widely applicable from just the manufacturing process where it was originally developed.

Agile on the other hand is more suited for volatile conditions where the planning cycles need to be kept short and accurate forecasts are more difficult to make. Agile strategy allows the firm to engage in a mass customization strategy rather than putting out standardized products. Interstingly, it was often pointed out by past studies that agile is emphasized within the fashion industry, either together with lean as leagile or by itself. Fashion industry was mentioned as a volatile market, so this choice makes sense.

1.21.1 Managerial implications

According to a past studies, lean and agile were seen as alternatives to one another. However, this literature review fully supports the notion that both approaches can be used together. Individuals operating on older models and still using the original theories should consider both approaches, not as alternatives but mutually supportive and complementary practices.

Tailoring a strategy with the two approaches seems to depend on several factors, including but not limited to: market volatility, product mix, product lifetime and product customization. Careful consideration should be used when choosing the leanness and agility for a specific purpose. However, as stated by Fadaki et al. (2019), a purely lean or agile supply chain will likely not work in today's changing markets.

At least in the context of supply chain management, I suggest increasing both lean and agile capabilities and focusing on agileness when markets seem more volatile and emphasizing lean when markets become more predictable and accurate forecasts can be made. When introducing a new product to the market, several authors also suggested using an agile strategy first before switching over to lean when conditions have stabilized.

It is important for managers and decision-makers to understand what lean and agile are exactly and what they entail before they start implementing the two in their practices. Since both approaches are suitable for different environments, using the wrong tool in a specific context could lead to bad results. Also, past studies concluded that a rigid corporate hierarcies and authoritative culture can prevent lean and agile from being utilized properly (Joosten et al. 2009, Patri & Suresh 2017, Waring & Bishop 2010).

1.21.2 Limitations

Some of the source material is written over 20 years ago, which can become a problem since agile and lean as ideologies are both developing constantly. However, the core principles still remain the same (Hines et al. 2004). Many of the older sources are also more cited in past studies, which is typically associated with them being more viable sources, such as Martin (2000) with over 2000 citations. It should also be noted that no major contradictions were found between older and newer studies, with the exception that lean and agile

were originally seen as opposing paradigms while the newer literature recommends using both together.

A larger database of past studies would be required to create a more accurate theory on when lean and agile are applicable. The scope was also somewhat limited, with the main focus being the preferred market conditions for either approach and using both theories simultaneously. In order to fully determine when lean or agile should be used, more variables could be concerned. A study concerning more factors, such as product mix, production volume and firm size could bring more information to the differences between the two approaches. Also, different industry sectors or target countries could have differences in how these strategies could be applied. For example, several studies detailed the practices within fashion industry but these principles might not fully apply for something like startups or software development.

I would also propose interviews with firms that are currently practicing lean or agile to find out more on how they are practiced today. After reading the studies for this literature review, I can conclude that both approaches have undergone a significant change in the last decades, both in the ways they are practiced and how universally applicable they have become.

The study also omitted various alternative forms of lean and agile, such as Six Sigma that could provide viable alternatives for lean or agile. These newer variations should be studied to determine if they are more applicable in certain situations.

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