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# Rethinking the Applicability of Lean Philosophy

## A Conceptual and Empirical Analysis

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<b>Julkaisun nimike</b> Lean-valmistuksen soveltuvuuden arviointi – käsitteellinen ja empiirinen analyysi		
<b>Tiivistelmä</b> Tämä väitöskirja tarkastelee Lean-valmistusfilosofian sovellutusalueita. Työn pääfokus on pienet ja keskisuuret yritykset, joiden valmistuksessa on tyypillisestä matalat tuotantovolyymit ja korkea tuotevariaatioiden lukumäärä sekä tuotannon volyymin nosto (ramp-up). Tyypillisesti Lean-valmistusfilosofiaan liittyy ympäristökestävyyden huomiointi. Työssä käsitellään sekä valmistuksen että johtamisen näkökulmia.  Työn tutkimusmenetelminä käytetään kvalitatiivista ja kvantitatiivista tapaus-tutkimusmenetelmää, johon on liitetty käsiteanalyysiä. Kvalitatiivinen aineisto on kerätty neljästä pienestä ja keskisuuresta valmistavasta yrityksestä.  Tutkimus osoittaa, että Lean-filosofialla on yhä potentiaalia myös suurten yritysten ulkopuolella. Käyttöönotto tosin edellyttää tiettyjä toimenpiteitä PK-ympäristössä. Leanperiaatteiden käyttöönoton pitäisi liittyä yrityksen strategia- ja ympäristöjohtamiseen.  Työn kontribuutio on PK-yritysten lean johtamisen käyttöönotossa ja työssä esitetään avainkohtia kuten käytännöt, prosessit ja suorituskykykriteerit.  Tapausutkimuksen rajoitteena on yleistettävyyden puute. Työn tuloksia pitäisi validoida tekemällä lisätutkimuksia samoissa olosuhteissa. Näyttö kehittyvissä talouksissa olisi arvokasta. Käsitteellisen empiirisen todennuksen olisi myös hyvä tutkimuskohde tämän perusteella. Leanin käyttöönotto riippuu aina organisaatorakenteista.		
<b>Asiasanat</b> Lean-filosofia, pienet ja keskisuuret yritykset, lean strategia, valmistuksen ramp-up, toimitusketju, ympäristön kestävä kehitys		



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<b>Abstract</b> <p>This dissertation aims at exploring certain areas operations to which lean philosophy can be applied. The main focus is on small and medium enterprises (SMEs), manufacturing operations that are characterized by low volumes and high variability, production ramp-up, as well as the connection between lean implementation and environmental sustainability. Both manufacturing and managerial aspects are addressed.</p> <p>The dissertation mainly employs qualitative and quantitative case study as research methodology which is further enriched with conceptual approach. Mainly qualitative data, with additional quantitative evidence, was collected in four small and medium-sized manufacturing companies.</p> <p>The research shows that lean philosophy still maintains its potential for being applied beyond large-scale production. However, certain issues need to be addressed before any implementation process commences. The study shows that the specifics of SMEs call for a different approach than large companies. Moreover, the implementation of lean should be addressed from the perspective of company's strategy, and environmental sustainability.</p> <p>The study provides an original contribution that is realized through proposing a revised perspective on lean implementation in SMEs, which takes into account aspects such as key practices, processes, and performance criteria.</p> <p>As a limitation, a similar research could be conducted in several organizations in order to validate the presented results. The evidence from developing economies would be of value. In the case of conceptual research, empirical validation would be recommended. Moreover, generation might be challenging, as the implementation of lean is always affected by specifics of an organization.</p>		
<b>Keywords</b> Lean philosophy, small and medium enterprises, lean strategy, manufacturing ramp-up, supply chain, environmental sustainability		



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*Anna Rymaszewska*

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## Abbreviations

APQC	American Productivity and Quality Center
ATO	Assembly to Order
BPC	Business Process Change
BPM	Business Process Management
BPR	Business Process Reengineering
BTO	Built to Order
B2B	Business to Business
CRS	Corporate Social Responsibility
ETO	Engineered to Order
GVS	Green Value Stream
HRM	Human Resource Management
JIT	Just in Time
LM	Lean Manufacturing/Management
LSCM	Lean Supply Chain Management
MIT	Massachusetts Institute of Technology
MTS	Make to Stock
PCF	Process Classification Framework
QRM	Quick Response Manufacturing
R&D	Research and Development
SMEs	Small and Medium Enterprises
SMED	Single Minute Exchange of Die
TNGA	Toyota New Global Architecture
TPM	Total Productive Maintenance
TPS	Toyota Production System
TQM	Total Quality Management
VSM	Value Stream Mapping
WCM	World Class Manufacturing
XPS	Company- Specific Production System

## Articles

This dissertation is based on six appended articles that are:

[1] Rymaszewska, A. (2013). The challenges of lean manufacturing in SMEs. *Benchmarking: An International Journal*, 21(6), 987-1002.<sup>1</sup>

[2] Rymaszewska, A. (2013). When a set of tools is not enough- lean placed strategically. *International Journal of Industrial Engineering and Management*, 4(4), 215-220.<sup>2</sup>

An earlier version of this paper has been presented at LeanTech 2012, 1<sup>st</sup> International Conference on Lean Technologies, Novi Sad, Serbia.

[3] Rymaszewska, A. (2016). Lean implementation and a process approach. Forthcoming in *Benchmarking: An International Journal*, 24(5).<sup>3</sup>

[4] Rymaszewska, A. (2014). Towards a lean production ramp-up. Proceedings of the 21<sup>st</sup> International Annual EurOMA Conference , Palermo, Italy.

[5] Christensen, I. and Rymaszewska, A. (2016). Lean application to manufacturing ramp-up: a conceptual approach. *The Quality Management Journal*, 23(1), 45-54.<sup>4</sup>

[6] Rymaszewska, A. (2016). Development perspectives on improved environmental performance through lean philosophy. Forthcoming in *International Journal of Sustainable Economy*, 8(3), 208-223.<sup>5</sup>

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# 1 INTRODUCTION

## 1.1 A brief primer on lean

According to Womack et al., (1990) Japan has established itself as a birthplace of lean production due to the certain limitations of mass production which was, at that time (the 1950s), rapidly gaining momentum in North America. Due to the fact that not all products can be produced in a standardized form and in high volume, nor is management of such system feasible. Henry Ford had a vision of mass producing everything while drastically reducing production costs and making the masses rich (p. 39). However, he had no idea regarding how to organize such global undertaking. Japan initially tried to adopt mass production only to conclude that it will not work, given the country specifics such as much smaller domestic market with a strong demand for a variety of cars both small and big, plain and luxurious; native Japanese workforce displaying strong bargaining power, no financial resources for purchasing the latest Western production technology; and motor-vehicle producers from abroad reluctant for establishing their operations in Japan (Sugimori et al., 1997). Toyota company was a brave pioneer to start a production model that would defy the deficiencies in the logic of mass production as well as fulfill the needs of Japanese customers.

According to Womack et al., (1990) during the initial stages of perfecting the art of changing car dies frequently and quickly in Toyota, it was discovered that it actually costs less per part to produce small batches of stamping than enormous lots (p.40) This discovery was a breakthrough in the development of lean as it determined the shift towards ensuring quality thanks to the radical elimination of unnecessary inventories and early detection of mistakes. Simultaneously, the importance of workers anticipating and detecting potential problems has significantly increased (Womack et al., 1990).

The development of lean has been moving away from sole focus on manufacturing towards other areas of application. Hines et al., (2004) refer to the important process of the gradually shifting focus from thinking that lean equals shop floor, towards linking lean with the principles identification of customer value, value stream management, developing production flow, as well as using pull mechanisms to support that flow. The final stage is pursuing perfection through waste reduction. Hines et al., (2004) summarize this development as a path from focusing on quality and gradually extending this

focus towards quality cost and delivery, and then towards customer value and value stream management.

Once the concept of lean has rooted itself in manufacturing processes the example of Toyota's advancements did not become obsolete. Toyota Production System (TPS) (Liker, 1994) which assumes a comprehensive diffusion of lean principles within an organization served as a basis for the development of a company-specific production systems- XPS which is based on a success of Toyota, and the assumption that the best practices should be adopted to company's unique characteristics and environment (Netland, 2013). Furthermore, Toyota has also diffused their successful initiatives into the process of the new product development which is based upon integrating subsystems (people, process, tools and technology), identification of value, enabling value stream, creating pull and flow, striving for perfection, as well as cross-functional integration (Morgan and Liker, 2006).

Another important step in the development of lean thinking is its application to the process of launching new enterprises. According to Blank (2013) lean approach favors experimentation and iterative design rather than following of rigid steps. The author refers in particular to the fallacy of business plan, which rarely work confronted with reality, as well as the disadvantages of investing heavily into building and launching a product without getting a substantial input from the potential customers.

Moreover, researchers' attention has been evolving towards treating lean application in SMEs as a discipline of its own, building upon the necessity to acknowledge that the economic development is not solely determined by large companies especially today where focus on scale is not so important. In digital economy which is marked by its instability and turbulences, the unexpected is becoming an integral part of the new reality, and existing in order to exploit the benefits of being big no longer holds true (Hagel et al., 2009).

The concept of lean seen whether as a management philosophy or a set of manufacturing improvements has been developing over the years with the publication of *The Machine that Changed the World* and *The Toyota Way* marking the start of its rapidly growing popularity worldwide.

## 1.2 Lean research up to date

Lean has been traditionally promoted as a concept of "doing more with less" which is realized by systematic identification of non-value adding activities, also

described as waste. Lean thinking assumes that a road towards waste-free (therefore “lean”) operations is practically never ending, and that explains why the role of continuous improvement is so important.

The research into the concept of lean has been developing over the years, spanning over a variety of applications both in manufacturing and services, public and private organizations, those generating profits as well as non-profit organization. Such a wide evidence of applicability supports the claim that lean is a universal approach that can be applied to operations regardless of the specifics of their nature.

The research development of the concept of lean has been evolving through different stages starting with the focus on large, automotive companies, which operations were considered without the broader context of supply chains, through gradually expanding the scope of the research to e.g. services and office operations, as well as considering operations in a broader context of supply chains and networks.

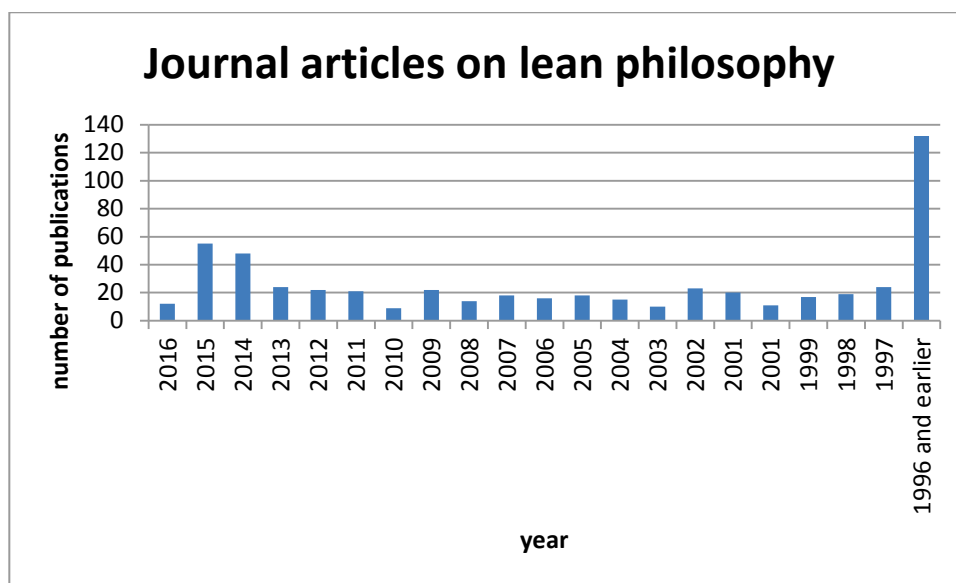
When analyzing the number of publications in the field of lean manufacturing and philosophy, it can be concluded that this particular field of research is developing dynamically. Lean approach to either manufacturing or management emerged as a strong opposition to the western approach to manufacturing which assumed production of low-variability and high volumes. Lean approach emerged as a spectacular success of Toyota that managed to build its power on the seemingly adverse conditions such as lack of raw materials, no inflow of cheap labor, and customers’ drive towards higher variability (Sugimori et al., 1977). When promotion of the concept started, many automotive companies embarked on a journey towards lean.

Frequently, the emergence of a new concept and immediate interest it awakes suspicions whether it might possibly be classified as a management fad. Usually short-lived yet, big enough to capture the attention of both researchers and business practitioners. Miller and Hartwick (2002) outline certain characteristics of management fads such as simplicity, prescriptiveness, being falsely encouraging, easy to copy without any adjustments, suiting all types of business environments, in tune with current challenges, and legitimated by the “gurus”.

However, over the years of the development of scientific publications in the field, the concept of lean has established itself as a solid approach to manufacturing and management. Even though its certain characteristics are described as fundamental and universal (Womack and Jones, 2010), the universality of lean approach has also been questioned (Cooney, 2002). Nevertheless, the growth

trend in the number of publications in the field of lean proves that lean is indeed an approach to both management and manufacturing that can not only withstand the challenges of the modern economy but also provide solutions.

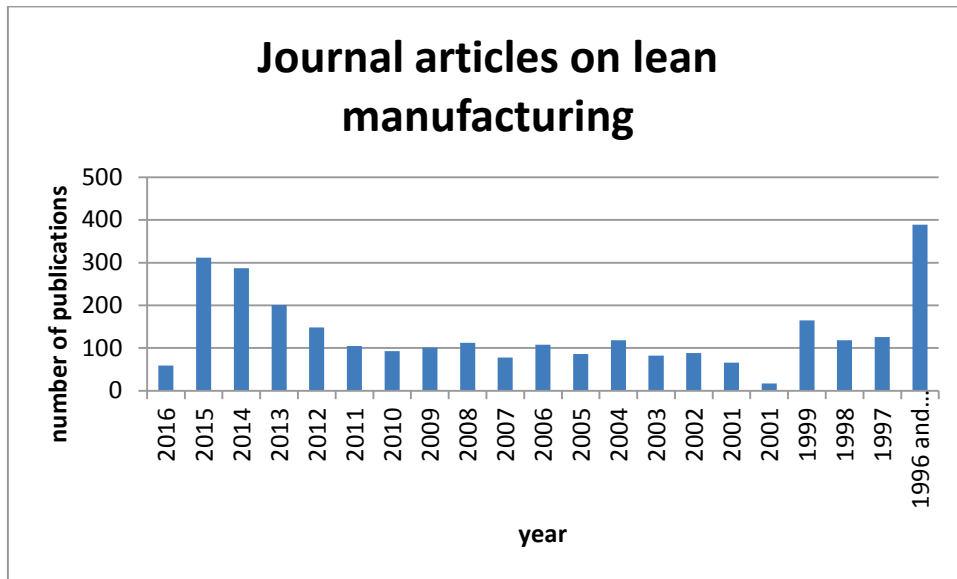
Figure 1 presents an overview of the number of articles that address the subject of lean philosophy in the period from the year 1996 (and earlier) till the year 2016 (February). The data was retrieved from the Science Direct database, using phrase “lean philosophy” as a search keyword. From the year 2011 the number of peer-reviewed journal articles has been increasing which shows that the topic is continually attracting researchers’ attention.



**Figure 1.** Peer-reviewed articles in the field of lean philosophy

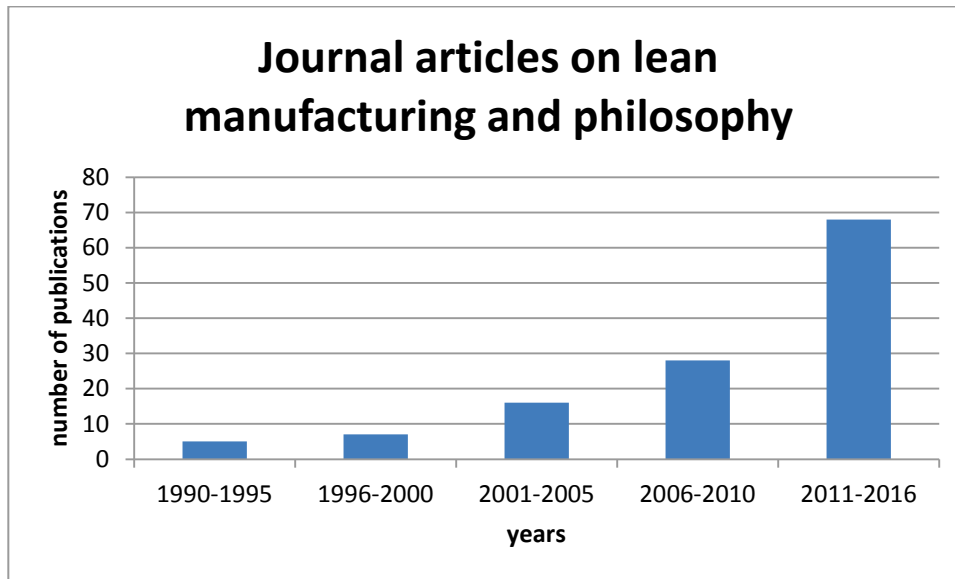
Figure 2 presents a similar overview of peer-reviewed journal articles that address the subject of “lean manufacturing” in the period from year 1996 (and earlier) till the year 2016 (February). The data was retrieved from the Science Direct database, using phrase “lean manufacturing” as a search keyword. The subject of lean manufacturing has also been on the rise since the year 2011.





**Figure 2.** Peer-reviewed articles in the field of lean manufacturing

The similar search of peer-reviewed articles performed within the Ebsco Host Business Source, where the number peer-reviewed journal articles were traced between the years 1990 and 2016 (February). Figure 3 presents an overview of the development where the steady increase in the number of publications can be noticed. This can be justified by the increasing trend in exploring the applicability of lean in other areas than manufacturing. This proves that even though the discussion on lean has been ongoing during the last 50 years, the subject itself has not become outdated. The new frontiers of lean are being discovered, and this study is also an attempt to contribute to the recent knowledge advancements in the field.



**Figure 3.** Peer-reviewed articles in the field of lean manufacturing and philosophy

The systematic literature search done with the key phrases “lean manufacturing” and “lean philosophy” resulted in data regarding the number of publications per year. The extended analysis involving an increased number of publication database, was performed in order to identify the main research domains. Based on the analysis of publication databases such as Emerald Journals, Academic Search Elite (EBSCO), Business Source Premier (EBSCO), and Sage Journals Online it can generally be stated that lean has been discussed in a variety of different contexts and the identified focal research areas (in the field of lean application). Those domains within which lean application has been discussed most frequently are presented in table 1:

**Table 1.** Main research domains identified

Research domain	References
Health care (and a broader context of lean in public sector)	Kim et al. (2011), Poksinska (2010), Radnor (2011), Kollberg et al.,(2006), de Souza and Pidd (2011), Mazzocato et al. (2010)
Construction (that industry has developed a distinctive approach tailored to its specifics)	Koskela (1997), Jørgensen and Emmitt (2008), Salemn et al.,(2006)
Small and medium enterprises (SMEs as an important contributor to economic development)	Anand and Kodali (2008), Achanga et al. (2006), Second (2010), Panizzolo et al., (2012), Zhou (2012)
Environmental sustainability (as a natural consequence of development that cannot be based on exploitation of the natural environment)	Florida (1996), Rothenberg et al., (2001), Larson and Greenwood (2004), Herrmann et al., (2008), Vinodh et al., (2011)
Services (due to the fact that economy is not based solely on production; lean is particularly applied to retail banking, hospital and airlines where time savings and zero-defects policy is of essence)	Liker and Morgan (2006), Bicheno (2008), Radnor and Osborne (2013),Piercy and Rich (2009), Bowen and Youngdahl (1998),
Supply chains (based on the fact that organizations are connected and interdependent)	Lamming (1996), Bruce et al. (2004), McCullen and Towill (2001), Goldsby et al., (2006)

The challenges of the economy have been changing during the years and different subjects have been drawing the attention of both scholars and business practitioners. The development of lean has started in times significantly different than we are faced with today. Customers are no longer satisfied with “one size fits all” solutions and while mass production is gradually losing its momentum, customization is on the rise. Nevertheless, variety of choices offered to customers should also be kept within reasonable frames as offering too many might prove to be counterproductive (Holweg and Pil, 2005). Growing complexity of operations expressed in terms of fluctuating and unpredictable demand levels, combined with pressure for shortening lead times while delivering the agreed levels of quality, pushes companies to explore various development paths and techniques that would aid their manufacturing processes (Mason-Jones et al., 2000).

This poses an additional challenge on the concept of lean, especially in terms of ensuring that it withstands the overall drive towards flexibility and resilience of operations. Holweg (2007) quotes an instance of lean concept being labelled as “fragile”, while Poppendieck (2002) claims that the alleged fragility of lean is in fact untrue, since being lean assumes inventory reductions which ultimately lead to the necessity to face the problems and gradual eradication thereof. Chowdary and George (2011) claim that the application of lean manufacturing that is aimed

at eliminating waste and streamlining processes, might ultimately lead organizations to flexibility in improving processes towards business excellence. The robustness of lean can also be approached from the perspective of how its implementation is being perceived. Lean can namely be defined and realized in terms of both manufacturing tools, and operations strategy that reaches far beyond production processes.

Globalization of operation has advanced even more rapidly with the development of the Internet which, in turn, led to a situation where companies are no longer competing locally. Globalization poses both challenges and opportunities on companies, and the implementation of lean philosophy will also be affected by the changes in business environments. Globalization also implies more opportunities in terms of building partnerships within supply chains and networks. Furthermore, forming and managing supply chains and networks has become significantly facilitated with the help of the internet platforms. Such a profound change also affects how the implementation of lean is realized.

The rapid industrial development is also affecting the natural environment and concerns of sustainability based upon the three pillars: environmental, social, and economic (Hansmann et al., 2012) need to be taken into consideration. The research into combining environmental concerns and is growing in popularity while being initially mentioned in the 90's. The growing concern about environmental performance is connected to tracking the complete product lifecycle (Alting and Jørgensen, 1993; Kloepffer, 1993; Finkbeiner et al., 2010), and this also provides an opportunity for rethinking lean operations in terms of ensuring their sustainability and possibly redefining the notion of waste.

In summary, the scientific research in the field of lean has been developing gradually towards widened area of applicability with manufacturing as a starting point. The state-of-the art of the scientific development in lean suggests that there still are certain deficiencies, and this dissertation is aimed at addressing them.

The need for additional research into lean can also be justified from the perspective of criticism that has been directed towards the concept. Lamming (1996) claims that lean systems lack flexibility while not allowing for experimenting and "taking time to think". Smart et al. (2003) and Lawson (2001) argue that lean removes resources that might be necessary while dealing with contextual uncertainty and non-routine behaviors such as unexpected changes to customer requirements. This claim is supported by Panizollo (1998) who states that the fragility of lean is caused by considerable reduction of resources, that lean production implies. The research presented in this dissertation is to provide

a revised view on the applicability of lean while acknowledging and addressing certain weaknesses of the concept.

The purpose of this dissertation is to describe, understand, and explore the possibilities for the extended application of lean in the contexts that have yet not been extensively addressed in the literature. The central phenomenon which is lean manufacturing is studied from different perspectives such as:

- its applicability in small and medium enterprises (SMEs)
- its connections to company's strategy
- its interfaces with environmental sustainability
- its applicability in less-predictable environments

The dissertation also needs to be put within certain frames and therefore, it is limited to the areas focused on manufacturing processes. The selection of the case companies needs to be also explained in terms of their specifics which also puts certain restrictions on the scope of the study. The studied companies are involved in designing of their own products which implies a considerable effort in engineering and prototyping. Only one case company actually manufactures according to a design provided by customers. Nevertheless, as products are often manufactured just once or in small batches production of test items or zero series is also required. This affects the production ramp-up.

Moreover, issues such as lean implementation in services and public sector are beyond the scope of the study.

The dissertation is composed of peer-reviewed journal publications and conference papers. Each of the aforementioned purposes addresses one of the above mentioned purposes.

## 2 RESEARCH PROBLEMS, OBJECTIVES AND QUESTIONS

Based on the literature review and challenges to lean implementation identified in manufacturing companies, initial research problems were outlined. The research problems were then transformed into more precise research objectives, and that was achieved by more focused literature review, with the actual focus on the gaps that could be addressed. In order to be able to direct the research towards the achievable objectives, the actual research questions were stated for each publication.

Creswell (2009: 98) defines research problems as “*The problem or issue that leads to the need for a study. It can originate from many potential sources*”. The formulation of the research problems outlined in this chapter was driven mainly by deficiencies in past literature as well as the empirical evidence of organizations struggling with the process of implementing lean. The research problems were outlined on the basis of the aforementioned, and since the dissertation is ultimately aimed at rethinking the applicability of lean as well as expanding the scope of thereof, in the context of the current challenges of the economy, the following research problems were outlined for further consideration:

*Research problem 1- Prevailing focus on large, automotive industries*

*Research objective 1- Examining the opportunities for applying lean in SMEs*

Research into the concept of lean is largely focused on large, automotive companies, which could potentially curb its universality (Cooney, 2002; White et al., 2009, Zhou, 2012). The universality of lean cannot be really supported without expanding the scope of applicability. Therefore, the first objective of this dissertation is to investigate the application of lean in small and medium enterprises towards assessing the possible changes that are required while implementing lean in the aforementioned environment. The empirical evidence for the study was obtained from manufacturing companies that, based on their number of employees and turnover, are classified as SMEs. This context is particularly important since SMEs are often referred to as a backbone of the European economy, providing employment and growth opportunities. In the years 2004 and 2006 SMEs were the main drivers of economic growth (Eurostat, 2016). In the year 2008 the vast majority (99,8 per cent) of enterprises active within the EU-27's non-financial business economy were SMEs which accounted for 66,7 per cent of jobs and 58,6 per cent of value added (Eurostat, 2011).

Furthermore, the presented considerations on a conceptual level, apply to both SMEs and large organizations.

*Research problem 2- Lean seen as a set of tools rather than as a part of organization's strategy*

*Research objective 2- Expanding the scope of lean applicability, moving beyond shop-floor towards treating lean as a part of company's strategy*

The focus on the tools and techniques is unarguably needed however, the research presented in this dissertation aims at expanding and exploring the applicability of lean. The main argument is that the development of a truly lean enterprise can be achieved through systematic and gradual expansion of the scope of its applicability (Melton, 2005; Bhasin and Burcher, 2006; Jones et al., 1999). Otherwise, an organization can hardly claim themselves lean. Companies need strategies not only to drive their overall development in the long-term. However, in order to be truly successful, the approach should be twofold-exploiting the present and exploring the future. O'Reilly and Tushman (2004) describe companies who are able to achieve and maintain that difficult balance as ambidextrous.

*Research problem 3- Lean is applied to predictable, low variability, high volume environments*

*Research objective 3- Expanding the scope of lean applicability beyond predictable, low-variability, high-volume production*

The concept of lean has been presented as rather inflexible and fragile and therefore best applicable to low-variability and high volume manufacturing environment. As such conditions are challenged in the context of globalization, necessity to quickly react to fluctuating demand levels and varying customer requirements (Lin and Hui, 1997; Slomp et al., 2009; Tatham and Worrell, 2010) is important. Therefore, the research presented in this dissertation proposes an exploration of the concept of lean in the context of unpredictable manufacturing conditions which are best represented in the ramp-up stage defined as transition between new product development process and volume production. One of the most important challenges of lean is its ability to understand customer value and ultimately, deliver it. Customers are rarely satisfied with "one fits all" solutions and therefore, mass production is no longer enough. Neither shop-floor based lean improvements solving the challenge of determining and delivering value to customer. Therefore, focus needs to be adjusted to the realms of modern, global economy.

*Research problem 4- Lean and its connection to sustainability of operations*

*Research objective 4- Exploring the applicability of lean in the context of organizations' environmental sustainability*

The definition of waste in the context of lean thinking does not encompass its environmental aspect and the research presented in this dissertation postulates rethinking the concept of lean in that particular perspective. The importance of environmentally sustainable operations is evident and there are numerous regulations that apply. Nevertheless, how organizations achieve the environmental sustainability still remains a challenge. Value and non-value adding activities are therefore explored in the context organizations' environmental perspective. The concept of sustainability is addressed from the environmental perspective, and the need for such research was indicated by for instance King and Lenox (2001), Dües et al., 2013, and Yang et al. (2011).

Table 2 presents the overview of the research objectives, outlined on the basis of the research problems, as well as corresponding research questions addressed by peer reviewed journal articles and conference proceedings. The presented research objectives serve as a basis for formulating research questions which are then supplemented with applicable research approaches.



**Table 2.** Research objectives, questions, approaches – an overview

RESEARCH OBJECTIVE	RESEARCH QUESTION(S)	RESEARCH APPROACH	ADDRESSED BY
1. Examining the opportunities for applying lean in SMEs	1. What are the common challenges awaiting SMEs in the process of lean manufacturing adoption?	Qualitative, empirical	P1
1. Expanding the scope of lean applicability, moving beyond shop-floor towards treating lean as a part of company's strategy	1. What are the potential pitfalls of an approach to implementation of lean that assumes lean as a "manufacturing toolbox"? 2. Which factors might hinder the implementation of lean? 3. How can a new perspective, that implies perceiving lean through the lens of business process, facilitate the implementation of	Qualitative, empirical	P2 and P3
2. Expanding the scope of lean applicability beyond predictable, low-variability, high-volume production	1. How can lean implementation facilitate production ramp-up? 2. How to include the application of lean, which is traditionally associated with stable, low variability, and high-volume production, to the process of ramping-up production?	1. Quantitative, empirical 2. Qualitative, conceptual	P4 and P5
3. Exploring the applicability of lean in the context of organizations' environmental sustainability	1. What are the possibilities for developing the current state of the lean research into improved applicability and sustainability regarding challenges of the future? 2. How universal and applicable is lean in the light of changing economic landscape.	Qualitative, conceptual and empirical	P6

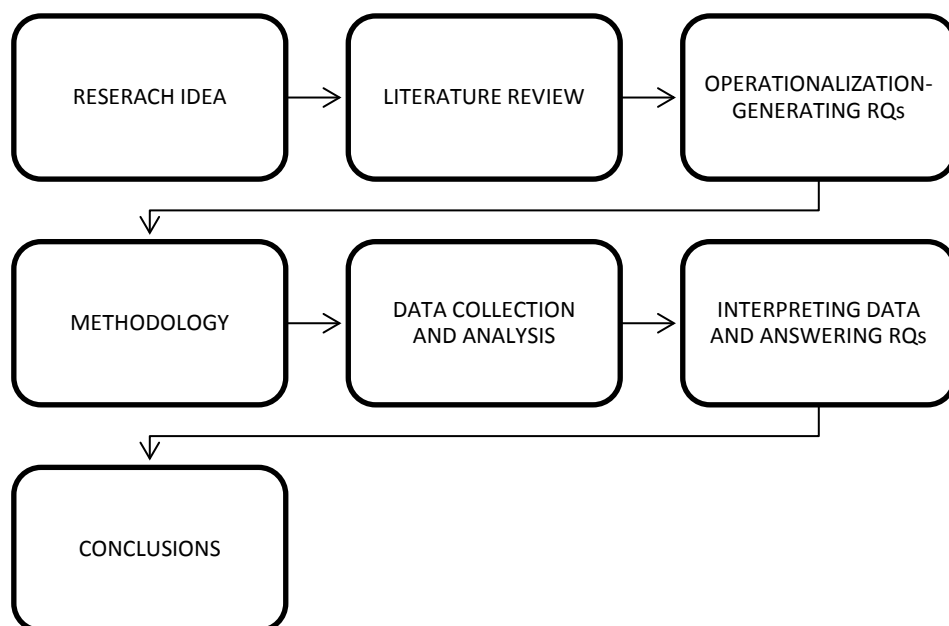
Table 3 presents the publication details, including publication outlets and timeline.

**Table 3.** Publication details

<b>PAPER NUMBER</b>	<b>PAPER TITLE</b>	<b>PUBLICATION DETAILS</b>
P 1	"The challenges of lean manufacturing implementation in SMEs"	Benchmarking: An International Journal, Vol. 21, Iss 6, 2014, pp. 987-1002.
P 2	"When a set of tools is not enough-lean placed strategically"	International Journal of Industrial Engineering and Management, Vol. 4, No.4, 2013, pp.215-220.
P 3	"Lean implementation and a process approach- an exploratory study"	Accepted for publication in Benchmarking: An International Journal.
P 4	"Towards a lean production ramp-up"	Proceedings of the 21st International Annual EurOMA Conference. Palermo, Italy 20-25 June 2014
P 5	"Lean application to manufacturing ramp-up: a conceptual approach"	The Quality Management Journal, Vol 23, Iss 1, 2016, pp. 45-54
P 6	"Development perspectives on improved environmental performance through lean"	Accepted for publication in International Journal of Sustainable Economy

### 3 RESEARCH DESIGN

The process of forming the final shape of the dissertation followed the common stages of research design. The proposed research design opens with a broader research problem, it is then narrowed down with the focus on operationalization, observation, and data analysis that ultimately leads to conclusions and possibilities for generalization that refers back to research questions. Figure 4 presents overview of the research design.



**Figure 4.** Research design in general

Since the dissertation is composed of peer-reviewed journal articles and conference proceeding, the operationalization part requires further explanation. Operationalization means forming research question that could be answered by further research. Each component of the dissertation is an independent research of its own however, the planning process for each publication was guided by the ultimate goal of achieving the purpose statement while simultaneously contributing to the state-of-the art of the literature and proposing managerial implications. Figure 4 can be interpreted as a roadmap towards achieving the purpose of the dissertation.

### 3.1 Research approaches, methodologies and methods

In general, the research methodology implemented in this research operates on the premises of the grounded theory. The strength of the grounded theory, to the great extent, comes from being rooted in empirical evidence (Glaser, 1992).

The foundations of the grounded theory stem from challenging certain assumptions, such as the strict division into theory and research, viewing quantitative methods as more “rigorous” than qualitative, separating the processes of data collection and analysis, as well as assuming that qualitative research could not generate theory (Glaser and Strauss, 1967).

The research presented in this dissertation is based on the following principles of grounded theory as outlined by Glaser (1992):

- Data collection and analysis phases occurring simultaneously
- Analytics are developed from the data not from the hypotheses
- Middle-range theories are constructed in order to explain behavior and processes
- Taking analytic notes
- Making comparisons within data sets as well as within concepts

Simmons (2010) outlines the steps of the grounded theory which are followed in the research presented in this dissertation:

- Preparations (outlining general research topic, rather than predetermined research problem)
- Data collection (most frequently realized through in-depth interviews; theoretical sampling comprises of an initial analysis which aims at determining the next steps in the data collection process)
- Constant comparative analysis (relating data to ideas and ideas to other ideas)
- Memos writing (aimed at capturing ideas already during data collection process while gradually integrating relevant literature)
- Sorting and theoretical outline (sorting concepts into emerging theories and writing the final version of the research)

Primary qualitative research which is exploratory in its nature (Creswell, 2009) is the basis for methodology, additionally supplemented with quantitative data collection and analysis. Morse (1991) quotes the following characteristics of a qualitative research problem:

- “Immaturity” of the concept due to a lack of theory and previous research
- A possibility that the available theory might not be accurate, inappropriate, incorrect, or biased
- Existing need to explore and describe the phenomena and to develop theory
- The nature of the phenomenon may not be suited to quantitative measures

The reasoning proposed by Morse (1991) justifies the selection of qualitative approach as prevailing. Even though the concept of lean can hardly be described as “immature”, the current state of research into lean still fails to present a sound connection to theory (Williams et al., 1992; Lewis, 2000).

Grounding lean within certain theories is challenging due to the plethora of various approaches to lean which implies a variety of definitions. Lean can be seen as both manufacturing improvement techniques and overall philosophy that can even guide the formulation of company’s strategy. In order to be able to place the concept of lean within the frames of a certain theory, an understanding regarding needs to be reached. Also in this case, the qualitative approach seems to be the best suited.

The nature of the stated research questions also guides the selection of the research methods and since “how” and “why” questions require exploration rather than quantification, the qualitative approach prevails.

Qualitative approach can be defined as based on either the constructivist worldview and observation behavior or participatory worldview with a narrative design and open-ended interviewing. In the first case researchers usually seek to establish the meaning of a studied phenomenon and one of the key elements of collecting data is the observation of participants’ behavior. In the participatory study individuals are addressed (Creswell, 2009).

Creswell (2012) quotes the following characteristics of qualitative research which also serve as a justification of the approach applied in this dissertation as well as provides some insight into how the research was conducted:

- Data collection tend to occur in the field
- Qualitative researchers collect data themselves, a protocol-instrument for collecting data might be used
- Multiple sources of data
- Inductive data analysis- building patterns, categories, and themes from bottom-up, data is organized into increasingly more abstract units of information
- Participants' meanings- the researcher's focus is on learning the meaning that the participants have about the studied problem
- Emergent design- the initial plan for research cannot always be follow accurately
- Theoretical lens- using lens to view a study
- Interpretive- qualitative research as a form of interpretive inquiry where researchers make interpretations of what they see, hear, and understand; multiple views of a problem can emerge
- Holistic account- qualitative researchers try to develop a complex picture of the studied phenomena

The research approach implemented in this dissertation is mainly qualitative, and such approach stems from the purpose statement, outlined research problems and objectives. Since the dissertation presented in the form of a collection of publications, the research methodology and methods will differ between publications as they need to be matched to the research objectives and questions. Nevertheless, two main traits can be outlined, and table 4 presents a general overview the implemented research types, methodologies, and methods.

**Table 4.** A general overview of the implemented research types, methodologies, and methods

RESEARCH TYPE AND METHODOLOGY	RESEARCH METHODS	DATA COLLECTION TYPE
Qualitative and quantitative, empirical	Case study	Interviews, observations, documents, reports
Qualitative, conceptual	Literature review (supplemented with conceptual framework)	Analysis of literature

This dissertation relies upon the two main ways of realizing the qualitative study-empirical and conceptual. While empirical research relies on gathering and using empirical evidence thus gaining knowledge by the means of direct and indirect observation as well as experience, conceptual research is more focused on gaining a better understanding of a given concept. Conceptual analysis yields better results when combined with other method and this is the reason for including those two facets of qualitative research.

Empirical research is realized through case studies while conceptual is focused on literature review as well as generation of conceptual framework which could then be used in the further exploration of a given concept.

Research methods can be described as viable ways of conducting qualitative studies. Case studies, and literature review are the two main methods implemented in this dissertation. Stake (1995) defines case study in terms of a strategy of inquiry in which the depths of a studied phenomenon are explored.

According to Creswell (2009) literature review serves as a mean for providing a theoretical background as well as justification for further research. Another important aim of literature review is to outline those areas of knowledge where certain deficiencies can be observed. Contribution is made by directing research efforts towards those areas, and that is also the aim of this dissertation.

### 3.2 Case study

Case study can be realized in qualitative or quantitative form. According to Baxter and Jack (2008) case study is a useful tool when studying complex phenomena within their contexts. Yin (2003) suggests that a case study design is particularly applicable in the following instances:

- The focus of the study is on “how” and “why” questions
- The behavior of those involved in the study cannot be manipulated

- The focus is on studying the contextual conditions
- Boundaries between phenomenon and context are not clear

The qualitative case study (single, multiple, comparable case) is utilized in Papers 1, 2, and 4. The above mentioned factors serve as a justification of the selected method.

### 3.3 Conceptual research

Meredith (1993) proposes that conceptual research serves as an important input to theory building and development. Conceptual models that are often a product of conceptual research are defined as integrating a number of different works on the same topic, summarizing the common elements as well as contrasting the different approaches and viewpoints on a given subject.

The conceptual research and drafting conceptual methods is realized in Papers 3, 5 and 6.

### 3.4 Research methodology explained publication wise

The general overview of the research is further supplemented with a more detailed description of the research design applied in each publication, answering the question of how arriving to conclusions was executed?

#### *Paper 1- "The challenges of lean manufacturing implementation in SMEs"*

The research questions were drawn upon the literature review and qualitative data collection through semi-structured interviews in two manufacturing firms. Results were discussed in the context of literature. Conclusions and managerial implications were provided.

The chosen methodology- qualitative single case study allowed for the exploration of the topic in more depth. Moreover, there is a considerable amount of publications that study barriers to lean implementation while gathering quantitative data or surveying literature. Therefore, a different approach was proposed.

The companies chosen for the study have certain experience with lean implementation, are of medium size, and operate in two different industries- boating and furniture. The specifics of product offered are different however,



both case companies operate in rather low-complexity and labor intensive environments.

*Paper 2- “When a set of tools is not enough- lean placed strategically”*

Research problem was preliminary identified and followed by literature review that served that besides of drafting the sufficient theoretical background for the problem, and facilitated the process of crafting the questions for semi-structured interview. Paper 2 is a single-case study in a medium-sized manufacturing company. Conclusions and managerial implications are provided.

The chosen methodology- qualitative single case study was chosen in order to provide the best possible insight into the studied phenomena of company’s strategic development which would be more difficult to capture otherwise.

The choice of a case company can be justified by the need to address the implementation of lean in the context of more complex products and therefore, more complex operations. The focus on SMEs has been maintained since the studied company is of a medium size.

*Paper 3- “Lean implementation and a process approach- an exploratory study”*

The research problem outlined in Paper 2 is examined in more detail. Focused literature review is followed by the qualitative study of two medium-sized manufacturing companies and a comparative analysis thereof is provided. Both case companies offer complex products that require considerable engineering effort and are frequently made or even engineered to order.

Conclusions and managerial implications are drawn upon the review of literature and studied cases.

The comparative approach was chosen to show the benefits of an approach that assumes treating lean as a part of strategy and contrast them with the pitfalls of an approach that assumes neither particular planning for lean implementation nor treating the implementation of company’s strategy. Qualitative data collection chosen for this study can be justified with the goal of providing exploring the case of strategic importance of lean in more detail with comparing and contrasting different approaches in two manufacturing companies. The nature of the stated research questions called for an approach that would allow for exploration of the specifics of lean implementations as well as opinions of professionals responsible thereof. An approach that would assume collection and analysis of quantitative data would not provide enough insight to the studied phenomena.

*Paper 4- "Towards a lean production ramp-up"*

Research problem was identified and suitable theoretical evidence was provided. Paper 4 is a quantitative single case study of the longitudinal data on manufacturing ramp-up process in a medium sized manufacturing company. Quantitative approach was selected in order to provide a background to the studied problem which is then explored in more detail using conceptual and qualitative approach. The chosen approach that assumes collection and analysis of quantitative data on manufacturing ramp-up which provides a particularly important insight into the possible time savings that could be achieved with the help of lean techniques. The nature of the research problem and question calls for the selection of quantitative data collection and analysis.

*Paper 5- "Lean application to manufacturing ramp-up: a conceptual approach"*

The research problem is addressed on the theoretical and conceptual level. Focused literature review is performed and based on the deficiencies discovered while researching into the subject of applying lean to fuzzy manufacturing environments, and manufacturing ramp-up in particular. Conceptual framework is presented as a proposal for combining two areas of knowledge that has not been extensively researched before. Furthermore, the proposed framework is supplemented with suggestions for managers with the special attention on quality management and assurance.

The chosen research methodology and approach can be justified by relatively sparse evidence of the studied phenomena being researched on a conceptual level. Furthermore, the publication is an attempt to contribute to the theoretical developments in the field.

*Paper 6- "Development perspectives on improved environmental performance through lean"*

The research problem is also addressed on a conceptual level. Extensive literature review is performed in order to determine state-of-the art, discover those areas where additional research should be performed, as well as to outline the areas of convergence between the concepts discussed. Based on the literature review, a conceptual framework for combining lean and environmental sustainability, as well as future research directions is proposed.

In case of Paper 4 and 5 the choice of an approach can be justified by relatively sparse evidence of the studied phenomena being researched on a conceptual level. Furthermore, the need to strengthen the theoretical and conceptual

contribution of the dissertation was an important factor that guided the selection of the methodology and approach. The process of revising the applicability of lean requires not only empirical evidence but also a strong theoretical foundations and proposals for further development thereof.

## 4 LITERATURE REVIEW

The development of the research in the field of lean manufacturing and philosophy suggests that lean as both a manufacturing and management concept has been developing to meet the challenges of rapidly changing economy. This chapter addresses the challenges and inefficiencies of the state-of-the-art research into lean in a manufacturing context, details the research questions and how they were approached.

In the specific context of SMEs, the evidence of literature shows that even though the implementation of lean has been addressed in a variety of contexts, the evidence from large companies is still prevailing. This could be partially explained by the variety of external and internal barriers. The barriers to lean implementation vary, and Bakås et al. (2011) outline lack of familiarity with the concept, assuming that lean will not work in an organization, employees' resistance to change, insufficient resources (human and capital), and implementation process not adjusted to company's specific needs, as the most prominent.

Essentially, lean thinking has been developing in various directions and areas of application as the economic condition and challenges change. It is important to acknowledge that lean philosophy, which is usually contributed to Toyota, has transformed to cover a variety of applications that reflect the challenges of rapidly changing economic landscape. According to Bhamu and Sangwan (2014) the notion of lean manufacturing can be described from the perspective of philosophy (guiding perspectives and goals) as well as management practices. The research presented in this dissertation combines the prevailing focus on manufacturing processes, with the significant attention given to management processes to reflect the changing nature of the concept of lean to the best possible extent.

Moreover, it is important to highlight that lean philosophy can be implemented throughout the organizational life-cycle as well as product life-cycle, and its applicability reaches far beyond high-volume and low-variety which is often associated with automotive industry. Example instances of the recent developments in the applicability of lean comprise of acquisition logistics within the US department of defense, as well as the Toyota's revised approach to developing multiple models simultaneously. Toyota New Global Architecture (TNGA) is characterized by simultaneous development of multiple models in order to increase the number of common parts used across models, as well as to

giving chief engineers more control power over the design review process while eliminating the intermediate levels in decision making (Toyota Global, 2013).

There is a vast amount of literature in the field of both lean manufacturing and management applied to different industries. In order to provide a theoretical background for the research presented in this dissertation, the literature review chapter is focused on those areas of knowledge which were determined as crucial to the realization of the purpose of the dissertation. Furthermore, the discussed areas of knowledge are the ones to which this dissertation aims to contribute.

The literature review chapter presents an analysis of the selected main topics in the field of lean. Due to the nature of the dissertation which is composed of independent publications, each addressing the specific theoretical development, this focused literature review chapter is aimed at providing an overview of the bigger areas of knowledge which are the building blocks of this dissertation. Furthermore, this chapter is focused on the identification of the main findings as well as deficiencies in the following areas which were drawn directly from the aforementioned research challenges, problems and operationalized objectives:

- Lean and its application in SMEs
- Lean implementation as a part of company's strategy
- Lean and its applicability in less-predictable environments
- Lean and its convergences with environmental sustainability

#### 4.1 Lean and its application within SMEs

The success of the lean approach can be attributed to the spectacular transformation of Toyota and the gradual diffusion of the idea within the large automotive companies. Nevertheless, as the importance of SMEs to global economy is rather indisputable, the issue of replicating the lean applicability has been identified as one of the crucial topics on the lean's research agenda (Shah and Ward, 2006) which is clearly understandable as, compared to large organizations, SMEs might be more constrained in terms of resources but also more flexible in terms of reacting to changes. The implementation of lean has been studied from the perspective of success factors (Kumar and Anthony, 2008; Chin and Rafuse, 1993; Achanga et al., 2006; Timans et al., 2012) as well as from the perspective of barriers to successful implementation (Jadhav et al., 2014). The common consensus is that the application of lean can be successfully

implemented, providing an organization is capable of addressing certain focus areas and adjusting the implementation plan accordingly. Based on a comprehensive literature review, Hu et al. (2015) conclude that there is a need for researching into lean in the context different from tools aimed at improving the shop-floor. The authors address the need for research into lean applied to organizational strategy and philosophy. Furthermore, Hu et al. (2015) signal the need for further research that spans beyond the boundaries of single organization, in other words, the consideration of a broader context of supply chains and networks. The authors recommend exploring the differences between large and small and medium organizations, and how this affects the implementation of lean, in more detail.

#### 4.1.1 Lean and organizational life-cycle

Different stages of organizational development also need to be acknowledged when discussing lean implementation as organizations learn and evolve. As part of this dissertation is dedicated to comparing SMEs with large organizations, and the possible consequences of blindly copying the solutions that have proved to be of benefit in large and mature organizations (Toyota), it is important to acknowledge the life-cycle theory of organizations. While large companies are usually in the mature stages of life-cycle, SMEs are classified somewhere in the early stage of organizational development thus, potentially encountering different challenges.

Tam and Gray (2016) state that organizational life-cycle theory is constructed on a concept borrowed from biology that assumes moving and evolving through the very initial stages until the eventual decay. Companies transitioning from stage to stage experience different problems, structural configurations as well as different management priorities.

Smeds (1994) highlights that the automotive industry has reached its maturity before lean improvements have been successfully introduced by Toyota, which enabled the post-maturity developments within the automotive industry through the superior way of combining cost-efficiency, quality, flexibility, and time. Smeds (1994) also claims that a lean enterprise can be defined through lean principles applied to all business processes within an organization and therefore, an enterprise-wide strategy of evolution towards lean enterprise is required. However, the strategy might be challenging to develop as individual traits of organizations need to be taken into consideration. Smeds (1994) proposes that organizational learning is addressed while implementing lean.

Tam and Gray (2016) relate organizational life-cycle to organizational learning, and their focus is on SMEs. The authors conclude that different levels of learning (individual, group, organizational, and inter organizational) will dominate during the consecutive stages of organizational life-cycle (inception, high growth, maturity).

The context of organizational life-cycle as well as organizational learning sheds a new light on drawing the distinctions between the characteristics of SMEs and large organizations. Moreover, it provides additional justification for one of the major arguments in this thesis namely, that the solutions that have proven to work for large organizations might not be feasible for SMEs.

## 4.2 Lean implementation as a part of company's strategy

Literature quotes several examples of lean strategy (Shah and Ward, 2003; Anvari et al., 2010; Wu and Wee, 2009) nevertheless, a significant number of publications postulates a systematic approach to the implementation of lean, that assumes e.g. step-by-step problem solving, rather than treating implementation of lean as a part of company's strategy thus, missing the organizational context (Shah and Ward, 2003; Karim and Arif-Uz-Zaman, 2013). While crafting and executing lean strategy is inarguably an extremely important success factor however, lean strategy can also be approached from the perspective of the implementation of lean being an important element of planning organization's development in a long term supported by a consistent vision (Sim and Rodgers, 2008). Therefore, the undertaken lean improvements will not be limited to manufacturing operations.

Bhasin (2012) outlines factors such as sustainability, culture, need to treat lean as profitable commercial initiative, lean change strategy and lean philosophy, as the facilitators of the authentic lean adoption, which means adopting the "full Lean ideology" (p.452).

Bhasin and Burcher (2006) propose treating lean as philosophy which can be described in terms of two types of requirements to be implemented by organizations- technical (such as continuous improvement, kanban system, process mapping, value stream mapping, and identification of waste), as well as cultural (such as employee empowerment, nurturing learning environment, and promoting leadership). The authors justify the concept of lean philosophy by stating that lean needs to be viewed as a journey not a tactic or a process. Essentially, a journey that never ends since lean should become a part of doing

business. Furthermore, Bhasin and Burcher (2006) claim that lean needs to be seen as a mind-set that “governs how one looks at the business or processes” (p.64).

Porter (2002) states that it is important to acknowledge and understand that operational effectiveness is not treated as equal. The author states that the pressure for shortening lead times and increasing efficiency has led many companies to confuse operational effectiveness with strategy however, both these elements are necessary to superior performance. Porter (2002) also emphasizes that the competition based solely on operational effectiveness is ultimately destructive to all competitors, since what happens is that organizations often fall into a trap of imitating their practices. What really needs to be taken into consideration is that “a company can outdo its rivals only if it can establish a difference that it can preserve” (Porter, 2002: 11). Therefore, competitive strategy is about being able to deliberately choose a different set of activities to deliver a unique mix of value, and the strategic positions can be based on customers’ needs, customers’ accessibility, or a variety of a company’s products or services (Porter, 1996).

Ovans (2015) summarizes Porter’s considerations on strategy by stating that competitive strategy is essentially about either doing what everyone else is doing, while spending less money on doing it, or doing something that no one else can do.

Lewis (2000) investigates how lean production can be translated into a sustainable competitive advantage. The author states that lean, and especially its core principles, can actually serve as a basis for building organizations’ competitive advantage. Lewis (2000) proposes defining competitive advantage in terms of an organization being a best player in its market, or being able to differentiate its offering. In the light of the findings proposed by Porter (1996, 2002), Lewis (2000), and Ovans (2015) it can be stated that lean can be utilized in building company’s competitive advantage and therefore, this dissertation postulates rethinking implementation of lean from the perspective of reaping the long-term benefits of lean that span beyond shop-floor improvements in a short term. Lean should be explored from the perspective of its utilization for building organization’s competitive advantage.

#### 4.2.1 The Process Classification Framework approach

The aforementioned context of organization’s strategy can be further supplemented with the Process Classification Framework (PCF) developed by the



American Productivity & Quality Center (APQC). The framework proposes the division of processes into two categories: operating as well as management and support processes. According to APQC (2016), the following processes are classified as operating:

- Understanding markets and customers
- Developing vision and strategy
- Designing products and services
- Marketing and selling
- Producing and delivering (for both manufacturing and service organizations)
- Invoicing and customer service

The processes classified as management and support, are the following:

- Developing and managing human resources
- Managing information
- Managing financial and physical resources
- Executing environmental management program
- Managing external relationships
- Managing improvement and change

The PCF is a comprehensive overview of the processes in organizations, and the evidence from literature proves that each of the aforementioned processes has been researched in the context of implementation of lean. This supports the claim of the universal applicability of lean.

### **4.3 Lean and its applicability in less predictable environments**

Lean manufacturing has been widely studied especially in the context of the World Class Manufacturing (WCM) with the manufacturing operations being described on a rather generic level without any specific references to company

type, size or nature of its business (Muda and Hendry, 2002). Challenges of the globalized economy are constantly questioning and reshaping the business environments. This is also described in terms of “turbulent” times, or high vulnerability environments, where predictable and stable demand levels are impossible to achieve. In the context of lean implementation, the applicability of lean needs to be explored from the perspective of the aforementioned condition, to safeguard the validity of lean in changing and uncertain economy.

Another challenge of lean manufacturing implementation is that it is largely based on the evidence of automotive industry where production can be described in terms of low variety, high-volume production where demand levels are easier to predict and in consequence the allegedly fragile and inflexible (Andersson et al., 2006) state of lean is not that easy to be faltered. Stevenson et al. (2005) emphasize that due to the increasing demand for customized products, many organizations have chosen to operate based on a make-to-order (MTO) basis which allows for production a high variety of products in small quantities (Slomp et al., 2009).

According to Slomp et al. (2009) the empirical evidence on lean implementation is still prevailing in the field of repetitive make-to-stock (MTS) production and this might be attributed to the widespread of Toyota Production System (TPS) which might be described as rather repetitive in its nature. Therefore, research into lean has been gradually developing exploring the applicability of lean in less predictable environments where variety is often high and volumes low (Slomp et al., 2009; Muda and Hendry, 2002; Jina et al., 2007; James-Moore and Gibbons, 1997; Qudrat-Ullah et al., 2012). Nevertheless, the challenge of rethinking lean in the context of changed business environments still remains valid.

Therefore, this dissertation provides an insight to a relatively sparsely researched topic of applying lean philosophy as well as lean improvements applied to manufacturing ramp-up which can be defined for instance in terms of a phase in the life cycle of a new product. It starts with the commercial production of a new product and ends when the production reaches maturity, and is characterized by time and cost pressures, as well as by uncertainty and complexity (Surbier et al., 2014).

In this dissertation a slightly more narrowed definition of production ramp-up is proposed and utilized, as an attempt to get to the core of the research problem which is combining the two seemingly dissimilar concepts.

#### 4.4 Lean and environmental sustainability

Rethinking and expanding the applicability of lean in the context of challenges of modern, global economy calls for addressing the aspect of environmental sustainability and the challenge of greening of the operations aimed at reducing pollution and waste. What is surprising, from the very beginning, the widespread of lean has somehow not addressed waste elimination from the environmental perspective. One of the first attempts to converge sustainable operations (“green”) with lean date back to the year 1996 (Florida, 1996), to be subsequently abandoned and readdressed in the first decade of the 21st century. Nevertheless, with scarce natural resources, rapidly degrading natural environment, and increasing pressure for sustainability of operations, lean manufacturing also needs to refocus on waste defined not only in terms of what is not adding value (i.e. is not a source of profit, a customer is not willing to pay for), but also in terms of reducing the negative influence upon the environment.

Literature quotes both empirical and theoretical evidence of combining lean and green operations both in the narrower- individual organizations (King and Lenox, 2010; Rothenberg et al., 2001) and broader (supply chains and networks) (Mollenkopf et al., 2010; Kainuma and Tawara, 2006; Dües et al., 2013) context. Nevertheless, the existing evidence is rather modest as compared to those publications that do not address the environmental aspect. Therefore, the aim of this dissertation is also to direct the attention to the aforementioned research challenge, as well as to systematize the existing knowledge with the help of building a conceptual framework and proposing future research directions towards increased exploration of lean implementation for more environmentally sustainable operations.

#### 4.5 Lean and related concepts

The concept of lean can be defined both in broad context of an overall management philosophy and narrower, as manufacturing improvement tools (Bhamu and Sangwan, 2014). Modig and Ålstrom (2012) call for the necessity of revising the existing plethora of definitions towards more understandable and unified “lean suit” that organizations should be aiming at developing.

This subchapter provides a brief overview of the concepts that are related to lean, which means that they may have either the same goal, or even aim at compromising any deficiencies that the concept of lean may have.

#### 4.5.1 Quick response manufacturing (QRM) and agile manufacturing

In generic terms, quick response is a manufacturing strategy of shortening lead-times in all phases of manufacturing and office operations. Competitive advantage is therefore built upon bringing product to market faster than competitors. Lean and six-sigma are the foundations of QRM. Most prominent empirical evidence of QRM can be found within textile industry where seasons change rapidly, and demand is shaped by trends (Britwistle et al., 2003; Forza and Vinelli, 1997).

Agile manufacturing is sometimes defined as the next logical step after lean manufacturing. The concept of agile manufacturing started evolving about the year 1991 when it became noticeable that organizations were no longer able to adapt to rapidly changing conditions. Agile company can be defined in terms of its ability to embrace change and to adapt rapidly and easily. Therefore, agility means the ability to reconfigure operations, processes and business relationships while simultaneously thriving on continuous change (Hormozi, 2001).

Agile manufacturing is generally aimed at building competitive advantage based on reacting quickly to change, especially to change in customer requirements. In other words, agile manufacturing as operating philosophy was a response to the reality of modern marketplaces where customer is the king, appreciates fast reaction more than anything else, as well as the possibility to choose from alternatives and change mind (Gunasekaran, 1999).

Sharifi and Zang (2001) claim that agility is not only required, but also inevitable for survival in increasingly changing business environments. The authors state that implementing manufacturing agility might be achieved by strategically utilizing manufacturing best practices and tools. As there is no universal roadmap for success, Sharifi and Zang (2001) state that since different organizations will undergo different set of changes which calls for implementation of different sets of practices.

Lean and agility are also being researched as one package- leagility (Hallgren and Olhager, 2009; van Hoek, 2000; Krishnamurthy and Yauch, 2007), especially in the supply chain context (Mason-Jones et al., 2000; Childerhouse and Towill, 2000).

#### 4.5.2 Total Quality Management (TQM)

TQM is often being discussed together with lean, and has been defined in terms of corporate culture focused on increasing customer satisfaction through

continuous improvement in which all are employees committed (Kristensen et al., 1998). TQM is also defined in terms of practices, tools, and training methods for managing companies aimed at achieving the aforementioned goal (Shiba et al., 1993). Hellsten and Klefsjö (2000) define TQM as a management system that is evolving continuously.

Lean and TQM have the same roots in the quality movement that originates in Japan however the two concepts have been developing differently. The main differences between lean and TQM are in their desired outcomes- lean aimed at reducing lead while TQM being more focused on customers. Lean and TQM can also be separated based on their primary effects which, in case of TQM are centered around increasing customer satisfaction, while lean is aimed at reducing lead time which ultimately translates into reduced inventory, increased productivity and customer satisfaction (Andersson et al., 2006).

#### 4.5.3 Cultural influences on lean implementation

The research into lean has also been developing in the field of analyzing cultural influences upon its implementation. Cultural influences are generally defined and researched in terms of organizational and national cultures. The successful implementation requires certain changes in organizational culture that ultimately leads to the creation of the lean culture, which is characterized by an important role of leaders who gradually introduce employee empowerment. Hines et al. (2004) highlight that the concept of lean has been criticized for its lack of human integration, and it might be one of the reasons why the concept of a lean culture started emerging gradually.

Angelis et al. (2011) claim that the creation of lean culture can be significantly facilitated by committed workforce while Jørgensen et al., (2007) state that creating a learning organization is crucial to creating a lean culture, which the authors define in terms of operating upon the principle of continuous improvement, with HRM functions aligned with lean objectives that support development in the long term.

On the other side, lean implementation is researched from the perspective of how the existing organizational culture can influence the implementation of lean, either positively or negatively, (Bhasin, 2013; Pakdil and Leonard, 2015). The authors seek to determine which elements of organizational culture are especially important from the perspective of implementing lean, based on the assumption that such awareness can help managers in achieving a successful implementation of lean.

Certain traits of national culture can also have an impact upon the success of lean implementation. Hofstede's et al., (1991) most prominent cultural dimensions assume division of national cultures into individualistic and collectivistic. Individualism is expressed in terms of preference of rather loosely-knit social framework in which individuals care for themselves and immediate family members. Collectivism stays in opposition to individualism and assumes that individuals are always seen as members of a certain bigger group within which they are looked after in exchange for unquestioned loyalty. Japan, the birthplace of Toyota and lean is classified by Hofstede et al., (1991) as displaying a number of collectivistic traits such as putting group harmony above individual opinions, as well as people having a strong sense of shame for losing face. Weingarten et al. (2015) look into the influence of collectivism upon implementation of lean, as well whether the potential inefficiencies of individualistic cultures can be compensated for on the level of organizational culture. In a similar vein, Wong (2007) addresses the influence of national culture on lean implementation and compares evidence from Taiwan with Japan. Cagliano et al., (2011) provide a wider perspective on influence of national culture upon the adoption of new forms of work organization and suggest that it is possible to explain the different patterns in the practices when taking company's size and cultural variables into account.

The brief analysis of lean, related concepts and areas of application allow for building a deeper understanding of why lean, seen as either approach to manufacturing or management philosophy, has far reaching consequences. Since the potential of improving operations is considerable, research performed in the field might contribute to the generation of knowledge in terms of both theory and practice.

## 5 SUMMARY OF PUBLICATIONS AND RESEARCH IMPLICATIONS

The dissertation is composed of independent publications that all contribute to answering the research questions outlined earlier. The development of the research work and the sequence of publications were directed by the dissertation's purpose which implies the gradual unfolding of certain areas of lean application. The concept of lean perceived both in terms of its aim to improve manufacturing and management processes. If this concept is to develop and remain valid, it needs to be tested in changing business environments, and this holds true for both its theoretical foundations and empirical evidence. The research presented in this dissertation is focused on revising the areas of the applicability of lean with the goal of exploring the areas both relatively sparsely researched and important from the empirical viewpoint. By addressing certain literature deficiencies as well as by confronting critique on lean, a refreshed approach to the understanding and implementation of lean is proposed.

Table 5 summarizes the publications and how they contribute to the realization of the thesis purpose. Focus is on addressing the research questions as well as the briefly explaining the outcome of the research towards answering those questions.

**Table 5.** Summary of research questions and realization thereof

PAPER NUMBER	RESEARCH QUESTION(S)	REALIZATION (ANSWER)
P 1	What are the common challenges awaiting SMEs in the process of lean manufacturing adoption?	The established barriers to implementation of lean should be revised so that they are also valid for SMEs. Organizations should plan the process of implementing lean regarding the limitations that stem from their size. Special attention should be put on the preparatory stages of the process.
P 2	What are the potential pitfalls of an approach to implementation of lean that assumes lean as a "manufacturing toolbox"?	Lean implementation should be well planned in long-term and as a part of company's strategy, rather than seen as a set of ad hoc shop-floor improvements.
P 3	How can lean implementation facilitate production ramp-up?	Implementation of lean can facilitate the effectiveness of production ramp-up by shortening the time needed for fixing (temporary) and closing (permanently) faults occurring during the production ramp-up phase.

P 4	<p>Which factors might hinder the implementation of lean? How can a new perspective, that implies perceiving lean through the lens of business process, facilitate the implementation of lean?</p>	<p>Implementation of lean can be facilitated by considering it from a business process management and change. Lean should be perceived in connection to company's strategy or development in a long term.</p>
P 5	<p>How to include the application of lean, which is traditionally associated with stable, low variability, and high-volume production, to the process of ramping-up production?</p>	<p>Application of lean ideas to manufacturing ramp-up since it offers extending the scope of lean and addresses the important opportunity to improve the manufacturing ramp-up process, especially in terms of quality and time. Time factor discussed in the context of being a determinant of a successful manufacturing ramp-up, as well as the aim of lean philosophy. Companies who fail to integrate lean with their process and quality improvement initiatives are unlikely to achieve the breakthrough results they desire.</p>
P 6	<p>What are the possibilities for developing the current state of the lean research into improved applicability and sustainability regarding challenges of the future? How universal and applicable is lean in the light of changing economic landscape.</p>	<p>Further research into the following aspects is proposed:</p> <ul style="list-style-type: none"> <li>- Empirical research targeted at examining the connections between essential concepts examined in the paper</li> <li>- Examining the connection between performance measured not only in well-established terms of environmental impact and greening of operations</li> <li>- Focus on value creation in supply chain context regarding delivering value to end customer as well as attributing value to organizations within supply chains</li> <li>- Further research into the issues of responsibility and transparency as those are the crucial aspects of both lean and supply chain operations</li> <li>- Broadening the scope of sustainability and further research into its economic and social aspects as well as looking into establishing lean change that lasts</li> </ul>



Table 6 presents a summary of publications and how they contribute to the dissertation's purpose. As answering the research questions does not always directly explain the actual contribution, additional explanation was provided.

**Table 6.** Publications and their contributions to the realization of the thesis purpose

TITLE	CONTRIBUTION TO THESIS PURPOSE
"The challenges of lean implementation in SMEs"	By examining the lean implementation in the context of SMEs, the potential applicability and validity of the concept is gradually extended. Lean as an approach to manufacturing and management is explored in the context of SMEs based on the research need identified on the basis of literature review.
"When a set of tools is not enough- lean placed strategically"	Based on an argument that the successful implementation of lean requires changes that span beyond shop-floor improvements, a strategic approach to lean is proposed, that is defined not only as having a strategy for implementation of lean but also treating the whole implementation process as an important element of organization's development strategy.
"Towards lean production ramp-up"	Qualitative evidence on manufacturing ramp-up is gathered and analyzed in order to examine whether lean can facilitate the ramp-up phase. In this particular context, time needed for closing and fixing problems is studied. The research introduces the topic of the applicability of lean in less predictable environments which is then complimented by further theoretical considerations.
"Lean implementation and a process approach-an exploratory study"	The above mentioned argument is researched in more depth by adding the context of business process change and managing thereof. The research is empirical in its nature and two contradictory approaches to lean implementation are presented and contrasted. Lean implementation is approached from a narrower perspective of business process and change thereof.
"Lean application to manufacturing ramp-up: a conceptual approach"	By exploring the applicability of the concept of lean in the context of fuzzy and difficult to predict environments, the conceptual conclusions are drawn, and managerial implications proposed.
"Development perspectives on improved environmental performance through lean philosophy"	By systematizing the current state of literature in the field of lean, environmentally sustainable operations, and supply chains operations, areas of convergence are outlined in order to discover how lean can be applied to achieve greening of operations. Considerations are presented on a conceptual level.

## 6 CONCLUSIONS, LIMITATIONS AND FURTHER RESEARCH

The research presented in this dissertation serves the ultimate purpose of exploring the implementation of lean in those areas which are particularly important in the context of modern global economy and competitive marketplaces. The study is focused on the four main areas such as lean implementation in SMEs, its connections to strategy, lean application to fuzzy environments such as manufacturing ramp-up, and lean's connection to environmental sustainability (greening of the operations). The research is based on the state-of-the-art literature in lean and seeks to contribute to both theoretical developments in the field and managerial implications. The research problems and objectives are drawn from the discovered deficiencies in the literature as well as empirical observations of real-life challenges to lean implementation that organizations might encounter. The research was conducted using mainly qualitative approach with additional quantitative evidence. The study is aimed at providing both empirical and conceptual evidence as an attempt of providing theoretical and empirical (managerial) contribution. Analysis of literature was mainly aimed at systematizing the existing knowledge, finding possible gaps and the areas where additional research is needed, as well as outlining the future research directions. The empirical research was focused on providing evidence of how lean is being implemented in manufacturing companies and how this real-life application reflect the theory.

The implementation of lean is generally recommended under a circumstance that it is well adjusted to the specifics of an organization.

Even though the research presented in this paper addresses a wide range of processes in manufacturing companies, the question regarding which process should be chosen to initiate the transition into lean remains unanswered. This is based on an assumption that each organization should base the implementation of lean upon the thorough understanding of the concept as well as the ability to identify the areas where the non-value adding activities prevail. By doing so, organizations will be able to decide whether to adopt a sequential approach, or to involve all processes. Similar logic applies to the proposed approach to processes through the Process Classification Framework (PCF). The studied organizations focused their processes of lean implementation on manufacturing, which is the core of their operation. The research presented in this dissertation sets to explore the possibilities extending the implementation towards other processes beyond manufacturing, and towards building a lean enterprise.

Furthermore, the context of large organizations implementing lean such as Toyota is introduced in order to acknowledge the roots of the concept, as well as to highlight that the development and the diffusion of the concept started in large organizations. Comparing characteristics of large and small and medium organizations, and discussing them in the context of the application of lean, allows for building an improving understanding regarding how organizations might adjust the implementation process towards taking into account both the benefits and challenges of being small or medium-sized. Copying the path of lean giants such as Toyota is unlike to work and therefore, organizations are encouraged to tailor the process of implementing lean, and the presented findings might help them to do so.

This study supports this claim while seeking for more general recommendations. Firstly, the specifics of SMEs are discussed, particularly in the context of how they can either serve as a barrier to lean improvements or facilitator thereof. Secondly, lean implementation is addressed from the perspective of companies' strategy. By contrasting different approaches, the importance of positioning lean as a part of strategy is emphasized. Then, focus is shifted to the challenge of applying lean beyond relatively predictable environments, with stable demand levels. Namely, lean application to manufacturing ramp-up is explored on a conceptual level, supplemented with managerial implications drawn from theoretical and conceptual considerations. Finally, the implementation of lean is explored from the perspective of the challenges of environmentally sustainable operations. The supply chain context is also introduced in order to provide a more actual view of business operations where organizations are connected rather than operating in separation from one another.

The results of publications show that the implementation of lean provides a feasible path to improvement and development for SMEs regardless of their specifics. Even though each instance of lean implementation needs to be tailored to the specifics of company, certain general recommendations can still be drawn. The research presented in this dissertation also addresses the challenges that the concept of lean and its applicability needs to withstand in the context of the modern, globalized and networked economy.

The dissertation's findings have both theoretical and practical implications. Theoretical contributions are achieved by careful examination of the current state of the research, not only in the field of lean, but also in those areas where lean ideas are applied. By exploring the current state of literature, and systematizing the recent development, the deficiencies were identified and, by planning research in those fields, contributions were achieved.

One relevant theoretical contribution that this study proposes is that the application of lean ideas to management is a potentially promising approach since it offers extending the scope of lean and addresses the important opportunity to improve the manufacturing process, especially in terms of quality and time.

It has been concluded that lean implementation evolves towards other dimensions and the development should start with lean and then towards green operations. Furthermore, value creation within networks and delivery to final customer are the concepts that should guide the further development of lean. The challenge of value creation lays at the core of lean and it simultaneously becomes a task for the entire supply chain. The creation of value should be perceived from the perspective of the revised approach to value that aims to redefine the notion of waste so that it encompasses factors that affect not only productivity but also environment.

SMEs, due to their size which often implies limited resources, should carefully address lean implementation challenges, preferably before implementation projects commence. The main focus should be on adopting a long-term orientation, which often implies sacrificing short-term goals for the sake of those planned in a long-term. Companies should also strive towards the creation of a learning organization where continuous improvement is in every employee's best interest. This cannot be achieved without employee empowerment which is realized by training towards a multi-skilled workforce, and encouraging people to find solutions on their own.

The proposed managerial implications comprise of addressing lean from a strategic viewpoint that assumes that lean improvements need to be embedded in company's strategic development plan. Top management's reluctance towards lean can be surmounted by the introduction of consistent key performance indicators which would facilitate decision making processes, as well as allow companies to determine whether the development is heading in the right direction. Moreover, implementation of lean should be preceded by spreading the awareness and understanding to that the foundations for employee empowerment are laid from the very beginning.

Furthermore, lean implementation was examined from the perspective of a process approach that is expected to help companies in reaching an alignment between understanding lean, its connection to company's strategy or development in a long-term. Empirical evidence gathered during the research process confirmed that such structured approach yields better results in advancing lean implementation than the lack thereof.

In the context of less predictable environments the potential for applying lean to manufacturing ramp-up was also examined. The time factor has been discussed in the context of being a determinant of a successful manufacturing ramp-up, as well as the aim of lean philosophy to achieve the same or better results in less time. The quantitative study of time required for fixing and closing problems arising during the manufacturing phase, as well as the analysis of most frequent faults showed that lean implementation has a potential of decreasing the time required for solving problems, as well as eradicating the common faults. In the case of the studied company which greatly depends on suppliers, it became clear that lean improvements should be gradually diffused throughout the entire supply chain.

While the contributions of this study are mainly on theoretical and conceptual levels, certain managerial implications, especially for quality managers, were also outlined. As lean applications are focused on efficiency and aim at offering products and services at the lowest cost and as fast as possible. Managers could utilize this information to develop targeted interventions to improve ramp-up process.

As lean implementation requires the actual effort both at the shop floor level and strategy levels, the research presented in this dissertation is firmly placed in the empirical research performed in SMEs being in various stages of lean implementation with mixed levels of “success”. Based on the empirical evidence gathered as well as on the theoretical considerations, recommendations are made on both practical and conceptual levels. In the context of the barriers to lean implementation identified both in the earlier literature and the research presented in this dissertation, SMEs adopting lean are offered with a set of important guidelines to help them navigate through the intricacies of the process, as well as to avoid being unable to reap the benefits of continuous improvement. The results of the research presented in this dissertation can help companies overcome the barriers to implementation in the following ways:

- Based on the analysis of organization’s own characteristics and comparing them with the characteristics of lean giant (Toyota), organizations are able to benchmark their own characteristics against the evidence of successful implementation towards building a tailored strategy to match the particular characteristics and needs.
- Developing an implementation plan on a company’s strategy increasing the chances for sustaining it in a long-term rather than abandoning once first challenges or successes arise.

- Addressing the more challenging and less predictable operations such as manufacturing ramp-up, with the aim of achieving efficiency without compromising the quality of offered products.
- Expanding the scope of lean improvements towards operations that are environmentally sustainable while simultaneously redefining the notion of waste.

The practical implications combined with them being firmly planted with theory provide an important insight into lean for managers, but also add value to the research into lean that needs to withstand the challenges of turbulent economy. As the philosophy of lean has its roots in low-variability, high-volume production, and has been propagated based on the success of automotive companies, this dissertation is dedicated to providing a revised outlook on lean's applicability in totally different setting which better reflect the reality of today's economy.

Table 7 provides a summary of the most important contributions of the dissertation.

The basis for comparison is drawn upon Toyota's example of successful implementation of lean. The proposed research contributions for SMEs reflect the inherent differences between SMEs and large organizations. Nevertheless, it might be noticed that since the core principles of lean suggest the applicability of the concept regardless of company's size and profile, there are also similarities that can be drawn between the Toyota Way and the discussed SMEs. For instance, in case of key lean techniques and practices there is no significant discrepancy between large organizations and SMEs. The identified challenges and research contributions drawn upon them can be expressed in terms of which processes to involve in lean implementation, how to approach the implementation strategically, and ultimately, what other factors should be included, taking into consideration the influence of company's size.

Even though forming a lean organization which operates on a principle of improved utilization of the existing resources, which seems to be a feasible option for small and medium enterprises that often do not have enough resources at their disposal, there is not enough evidence in the literature proving that it is a natural, frequently and deliberately chosen development path. SMEs implementing lean often encounter barriers that require deeper understanding and analysis to be surmounted

**Table 7.** Research contributions summarized

Characteristics	Toyota Production System	SMEs' production/operation
Principle	Toyota Way	Lean implementation adjusted to the characteristics, specifications and needs of SMEs (XPS)
Type for application	Manufacturing (assembly line) Management (Toyota Production System)	Manufacturing and Management (lean as a part of company's strategy; strategy for implementing lean)
Key techniques/practices	7-waste (muda), poka-yoke, just in time, kaizen, kanban, Continuous improvement, supplier involvement (developing suppliers, core suppliers located in close proximity), lean leadership	Long-term orientation (also implying sacrificing short-term goals) Waste elimination (might require redefining value adding and non-value adding activities) Organizational learning (learning will be different depending on the stage of organizational life-cycle, lean implementation should be adjusted accordingly) Employee empowerment (based on simplification and standardization of procedures where possible, training of multi-skilled workers) Reduction of lead-time, scrap, and rework
Stakeholders	Employees, suppliers and customers	Employees, suppliers, and customer (possibly other groups that might be affected by organization's environmental performance)
Processes	All process from customer-to-customer (design-to-use)	Manufacturing and management processes (based on Process Classification Framework)
Success factors and Performance criteria	Time, efficiency (focus on resource consumption, yield, machine downtime, etc.) and quality (focus on defects, rework, return, etc.)	Environmental performance Alignment between organization's long-term strategy and the implementation of lean Environmental performance (waste seen also from the perspective on its impact on the environment) Efficiency of manufacturing ramp-up (measured in terms of time-to-market, time-time-to-volume, and time-to-payback) Incorporating leadership, customer focus, process capability, and process management, integration of lean thinking within company's quality improvement capabilities

## 6.1 Limitations of the research

Certain limitations of the research presented in this dissertation need to be acknowledged. The identified deficiencies comprise of the following:

- Prevalence of the qualitative evidence and the challenge of generalization

Despite it being a deliberate choice, best suited to the research objectives, an increased amount of quantitative evidence would provide a valuable contribution. Qualitative data on lead times, number of faulty items, non-conformities occurring would provide an interesting insight into the effectiveness and efficiency of lean initiatives in manufacturing companies.

Prevalence of the qualitative evidence and relatively small amount of cases poses a challenge to generalization. According to Tsang (2014) there are two types of generalization to be addressed, theoretical and empirical, with empirical generalization best achieved with statistical data. The empirical generalization is addressed by seeking for common patterns among diverse cases and therefore, the sampling technique is crucial. The case companies were selected carefully so that any unusual traits were avoided. As a result, the studied organizations are either or small or medium size, offering industrial and consumer products that vary in complexity but not representing any unusual characteristics that would clearly set them apart from one another. Furthermore, an attempt towards achieving theoretical generalization is based upon trying to develop explanations of the relationships between variables observed in the studies, as it is suggested by Tsang (2014). Nevertheless, in order to achieve better opportunities for generalization as well as to improve the external validity of the research, more case companies should be taken into consideration both in terms of longitudinal and cross-sectional research.

- Limited number of manufacturing companies

Due to that it is challenging to generalize. Furthermore, evidence from the developing companies would serve as an important contribution to providing a “bigger picture”. The research would benefit in particular from additional data gathered in companies producing complex products on a basis of making or engineering to order. Additionally, evidence from supply networks could be added.

- The proposed conceptual frameworks might require additional empirical testing



In order to confirm the practical applicability of the proposed theoretical frameworks in the context of manufacturing operations, additional empirical research would be of use.

## 6.2 Future outlook

The research presented in this dissertation adopts a forward-looking stance that is aimed at exploring those areas of lean application where development potential can be observed. The research adopts different perspectives of lean and therefore, aims at showing a broadened spectrum of the applicability of the concept.

Further development of the research into lean would need to be focused on exploring lean implementation in the context of building competitive advantage or crafting unique business models based on lean enterprises. Even though the exact definitions and practical realizations of a lean enterprise will differ between companies, the research results and recommendations might serve as a basis for forming lean strategies. Furthermore, the applicability of lean should be explored in connection with the technological development and the rapid development of connected devices operating under the framework of the Internet of Things. Enterprises being able to stay at the forefront of innovative solutions should be able to reap the benefits of technology while maintaining their constant readiness to change or even transform. With the rapid development of technologies and analytical tools, the areas of combining lean and with the advancements of the Internet of Things where performance of devices can be monitored in real time. With the help of the new analytical tools, the new ways of determining what value really mean to customers. In other words, tools for eliminating waste and delivering customer value are changing while offering brand new ways of improving operations.

However, future of lean should not be solely attributed to technological advancements and constantly finding ways to eliminate waste in order to drive down manufacturing costs. The implementation of lean should continue to be firmly planted within the humane side of operations and therefore, the implementation of lean focused on an ultimate goal of decreasing the number of employees should be avoided and exchanged for an attitude that assumes freeing the human capital from performing activities that do not add value, and engaging them in more creative and value adding tasks.

Furthermore, as countries differ in the level of their economic development and since this dissertation provides evidence from Finnish companies, the further research should be focused on the developing economies. An approach that looks

into the future by embracing the rapid technological development should therefore be complimented with “the other side of the coin” which addresses lean improvements in economies where development is still in its early phases.

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# The challenges of lean manufacturing implementation in SMEs

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## Abstract

**Purpose** – The purpose of this paper is to identify the lean manufacturing implementation challenges in small and medium enterprises (SMEs). The study is based on experiences of the Finnish furniture and boating sectors. The paper outlines the overall characteristics of the studied organizations and contrasts them with one of the most famous example of lean implementation – the Toyota Company. By comparing the different manufacturing environments as well as organizational characteristics, the potential challenges of lean adoption are outlined.

**Design/methodology/approach** – The findings presented in this paper were achieved through the case study method. The research utilizes the deductive approach.

**Findings** – The results present an assessment of the companies' current situations. The results uncover their readiness for lean implementation and identify the challenges that might hinder lean implementation. Early identification of weaknesses will make companies more aware of their own capabilities. Moreover, it has potential for making them better prepared for lean implementation and more consistent in their process.

**Practical implications** – The importance of addressing certain aspect of lean implementation in the specific context of SMEs characteristics might contribute to the successful implementation of lean.

**Originality/value** – The author presents an original look at supporting companies in the process of adopting lean manufacturing.

**Keywords** Manufacturing strategy, SME, Small-to-medium-sized enterprises, Lean production, Lean implementation, Lean process

**Paper type** Research paper

## 1. Introduction

The initial stimulus for undertaking this study of lean manufacturing implementation in small and medium enterprises (SMEs) was dictated by the author's experience gathered during project work, and by a personal interest in development opportunities for SMEs. Such organizations frequently face the challenge of insufficient knowledge about production methods, adherence to methods that have been in use for years – especially in the case of family owned companies where the owner holds all the managerial responsibilities. The fairly modest existing research into SMEs implementing lean, as highlighted by Zhou (2012), further supports the need for the research presented in this paper.

Moreover, the literature on lean focusses on large companies representing the automotive industry in particular. For example, authors such as Dombrowski *et al.* (2010) highlight the successful adoption of lean among large organizations. Nevertheless, SMEs can also benefit from a conversion to lean, providing the process is adjusted accordingly. The authors emphasize the ability of lean to address the challenges that companies, regardless of their size, face. Lean as an approach to manufacturing has won many proponents over the years, and the vast literature on its application within both manufacturing and services serves as strong proof of its universality.



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However, there exists strong empirical research undermining the universality of lean principles. Many reservations have been outlined especially in the case of lean implementation in SMEs. According to Peter and Lanza (2011), SMEs are likely to encounter serious difficulties while attempting to copy the lean system invented and developed by Toyota. The authors emphasize the fact that lean should be tailored to the specific needs of small and medium organizations. In particular, the need for adapting lean to small series production, where lean processes are required to be flexible, is signaled. This paper claims that the adoption of lean in SMEs should always be adjusted to the characteristics of such organizations. This claim is further supported by Cooney (2002) who emphasizes the importance of general business conditions, the nature of buyer-supplier relations, as well as the structure of social and political institutions. The author also highlights the importance of business cycles that affect organizations' operations. Since the aforementioned factors affect the way companies operate, it is assumed that the claimed universality of lean does not need to hold true at all times.

The aim of this paper is to determine the main challenges regarding lean implementation in SMEs. The challenges are addressed through the creation of a simple conceptual framework. The framework is explained in more detail in Section 6. The common characteristics of SMEs are taken as starting point and then contrasted with the most important benchmark for the study – Toyota Company and its very own Toyota Production System (TPS). At first glance the selection of Toyota as a unit for comparison might seem awkward since the characteristics of an automotive giant and SMEs differ considerably. However, by emphasizing the sharp contrast between Toyota and the studied companies, the focal areas of lean implementation were outlined. The paper addresses those issues that have potentially the greatest influence upon lean implementation in its initial phase in particular. By contrasting the outlined common characteristics of SMEs with the realm of lean “genius”-Toyota, the research gap in lean implementation in SMEs as well as its challenges are outlined. The paper addresses the key elements of lean manufacturing and its broader apprehension – lean philosophy. Based on the aforementioned considerations, the following research question was posed:

*RQ1.* What are the common challenges awaiting SMEs in the process of lean manufacturing adoption?

The paper adopts a research framework aimed at providing a thorough understanding of lean thinking in the specific context of SMEs. The motivation for the research presented in this paper is the observed challenges in transferring the practices leading to a successful lean implementation. The popularization of lean stems from the fact of its universality. Nevertheless, the claim of universality should not be assumed without additional consideration. Moreover, the paper is aimed at addressing the research gap identified by Karlsson and Åhlström (1997). The authors claim that research that is too heavily focussed on large manufacturing companies might hinder the development of a widely applicable theory. According to Bhasin (2011) the existing literature on lean is still too strongly biased toward financial benefits as well as lacking a holistic approach to the subject. Therefore, this paper aims to shed light on the somewhat under-researched field of small and medium manufacturing firms while addressing lean from a wider perspective that reaches beyond the shop floor.

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The paper is structured as follows: the literature section that provides a complex and concise overview of the lean manufacturing. This section is followed by the case study description, analysis and presentation of the results. The paper closes with conclusions and managerial implications section.

## 2. Literature review

The concept of lean in its origins refers to companies' overall management philosophy and strategy in a long-term perspective (Liker, 1994). Nevertheless, the idea of lean can be summarized in a simple and short definition – “doing more with less.” Even though the definition is an obvious oversimplification, it conveys the crucial aim of the overall idea of lean – more effective utilization of available resources. The main goal of lean manufacturing is to enable organizations to provide their customers with the product or service they need exactly when they need it. Simultaneously, any potential sources of waste are identified and eliminated in order to achieve and maintain high quality and low manufacturing costs (Shah and Ward, 2003). Nevertheless, the concept of lean goes beyond the application of certain tools that are believed to make companies successful. Scientific literature provides evidence of various factors that might hinder the successful implementation of lean. Bhasin (2012) provides an overview over the barriers to lean both in small and medium, and large companies. Hancock and Zayko (1998) also refer to the problems that manufacturing companies are likely to encounter while adopting lean. Abernathy *et al.* (2000), claim that the success of Japanese automotive companies such as Toyota can be attributed to their persistence in “painstaking strategic management of people, materials and equipment.” This statement is also affirmed by Liker (2004). The author claims that perseverance, planning for the long term as well as the willingness to sacrifice short-term benefits in the name of more important merits planned in a long term.

Dombrowski *et al.* (2010) claim that the idea of lean encompasses various fields of activities such as:

- visual management;
- workplace organization;
- 5 s and process standardization;
- continuous improvement;
- total quality management (TQM) and total productive maintenance (TPM);
- just-in-time (JIT); and
- production leveling (*heijunka*).

The broad spectrum of lean areas served as a motivation to divide the literature according to the two main streams of research identified. The first part presents a holistic view of lean which assumes that it is a coherent concept that goes beyond seeing lean as a set of tools but rather as a process of company's turnaround that occurs at all levels. Another stream of research opposes the claim regarding the universality of lean and proposes that lean should rather be seen as an addition to whatever manufacturing methods companies are utilizing.

### 2.1 *The holistic view of lean*

The holistic view of lean addresses the lean application in the context of the whole value stream as well as claims that the lean tools should be implemented “somewhat



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simultaneously” (Bhasin and Burcher, 2006). The authors also state that the crucial element in understanding lean as philosophy is a journey rather than a final state that an organization aims to achieve. This goes in line with the philosophy of constant improvement (kaizen). Kaizen is a Japanese philosophy that promotes small improvements made as a result of continuing effort (Wittenberg, 1994). The author also claims that standardization is the key success factor in implementing kaizen. Improvement attributed to kaizen is achieved by setting higher standards and ensuring that management is able to execute them. Long-term improvement is therefore achieved by having people working toward higher standards.

Long-term orientation and seeing lean as a management system is also strongly promoted by Liker (1994). After the years of studying the TPS the author provides a complete picture of lean seen not only as a production system but also as a complete management system firmly based upon investing in people and developing a learning organization that treats lean as a journey toward becoming better and better. Since lean thinking has its roots in Toyota, the company is seen as an excellent benchmark for organizations that wish to step on the path toward lean. This paper also strongly focusses on lean philosophy as initiated and cultivated in Toyota. Liker (1994) focusses more on presenting lean as philosophy rather than a set of manufacturing tools. In such understanding lean emerges as a complete philosophy that requires deep understanding and a change in organizational mindset before the actual implementation of lean tools can take place.

### *2.2 Dubious universality of lean*

During the course of scientific research the critical approach toward lean has also emerged. Cusumano (1994) is one of the first researchers to refer to the limitations of lean. The author emphasizes that the pursuit of constant improvement and elimination of waste have led Japan to a state of gridlock where factories demand JIT deliveries, there is not enough suitable workforce and managers have trouble financing new investments. The author states that many Japanese companies will at some point need to convert to being more profit-oriented in a short term. In other words, Cusumano (1994) undermines the positive effects of long-term orientation.

Cooney (2002) argue that lean is not as universal concept as its propagators would like to see it. The author claims that there are several factors that companies are unable to control and those mainly external factors might in many cases seriously hinder the implementation of lean. According to Cooney (2002) the influence of external factor is especially critical in the case of JIT implementation. The author emphasizes that to achieve JIT flow the production needs to be leveled throughout the whole supplier chain. The achieving of the smooth flow throughout the whole value chain is strongly dependent upon the structure of an industry and the specifics of markets. Moreover, according to Cooney (2002) factors such as business conditions, industry structures as well as the influence of political and social institutions cannot be omitted when analyzing the implementation of lean. In fact, no business is an island of its own. Cooney (2002) claims that the implementation of lean manufacturing is just one of many development options, that a company is capable of implementing. Such reasoning is also supported by Lewis (2002) who states that each company will have its unique lean production development trajectory. Moreover, the implementation of lean manufacturing does not have to be an “all or nothing” option. Companies might choose to turn lean into a part of their competitive advantage. The author’s reasoning refers to the resource-based theory which states which puts

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unique internal resources in the center of attention since they create effective barriers to imitation. According to Lewis (2002) the success of lean production in providing sustainable competitive advantage is dependent upon external context of the firm. This refers to factors such as type of market, dominant technology in the sector and the structure of the supply chain. The author does not totally dismiss the idea of universal applicability of lean but suggests that companies should carefully examine their resources as well as the influence of external factors. The identification of competitive advantage factors will help companies decide about the form in which lean implementation can occur. The author strongly contradicts the generic approach to lean implementation that suggest establishing and transferring “best practices.”

James-Moore and Gibbons (1997) focus on the specific cases of industrial sectors characterized by highly differentiated low-volume and low-repetitive products. The authors outline certain areas of research, relevant for their case companies, like new product introduction, manufacturing, logistics, etc., and argue that lean approaches will not be applicable in every production setting. Therefore, companies of the aforementioned profile will often need to modify the applied lean methods or to look for totally different approach.

### *2.3 Benchmarking Toyota*

According to Marie *et al.* (2005) benchmarking is one of the approaches which can help companies improve their performance. The authors also refer to the fact that through benchmarking companies are able to observe and optionally implement those practices that are considered the most beneficial in the context of improving certain business processes. Moreover, benchmarking strongly relies upon the identification of the best practices.

Gurumurthy and Kodali (2009) claim that benchmarking is a tool used for continuous improvement and more frequently, for self-assessment and comparison. The authors claim that self-assessment in particular might prove to be very beneficial for the companies in the initial stages of any implementation projects. By being able to assess own weaknesses and strengths provides organizations with crucial baseline data on the current status of processes and performance. Moreover, benchmarking as a tool can even be applied to strategic levels of organizations.

According to Moriarty and Smallman (2009) also emphasize the increasing importance of benchmarking in any improvement processes that occur in organizations. The authors refer to benchmarking as a mean of abandoning the undesired state toward the desired state of improvement. Therefore, benchmarking addresses the transformation process that additionally encompasses organizational learning, since the focus should not be on bluntly copying others but rather learning and adapting. Moriarty and Smallman (2009) emphasize the fundamental assumption of benchmarking which is the existence of two parties: the exemplar which demonstrates the particular state of affairs that the anomalar would like to achieve. Such an approach to benchmarking suggests that it more than just a tool but rather a powerful concept that emphasizes change.

This paper utilizes a benchmarking approach in as a mean to emphasize the potential challenges of lean implementation, and Toyota was chosen as a benchmark for the study. Toyota is a company with long tradition and a broad expertise achieved mostly by investing in their employees and never ceasing to search for improvement opportunities (Liker, 1994). The obvious doubt that appears is that if small and

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medium companies that lack expertise and know-how, and often workforce can be any successful in implementing lean in the long run.

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### 3. The overview of the SMEs

SMEs are nowadays most common in organizations in European economy. According to the legislation European Commission (2003) micro, SMEs have immense impact on European since they represent 99 percent of all enterprises in the EU while providing jobs for around 90 million people. According to the European Commission legislation (2003) in order to be qualified as small or medium enterprise a company needs to comply with the regulations regarding the headcount or turnover. A company does not have to meet either headcount and turnover criteria simultaneously to be classified as small or medium. Table I presents the SMEs classification criteria according to the European Commission (2003). Companies with headcount less than ten are classified as micro enterprises.

According to Wymenga *et al.* (2011) European SMEs companies are still lagging behind the USA and Japanese SMEs, especially in terms of competitiveness. European SMEs are not innovative enough and their lack financial support from the government. Moreover, such organizations frequently lack motivation to study and implement new management methods. However, there are several advantages that stem from the company's size. According to Floyd and McManus (2005) small firms in particular are traditionally considered to be more flexible in terms of changing their manufacturing processes. Additional advantage that small enterprises have over large firms is the ability to respond quicker to changing consumers' needs by being able to address the request for greater variety better. Furthermore, Deros *et al.* (2006) claim that SMEs are more capable of offering of personalized service which can also be perceived as an opportunity for building a competitive advantage. The additional characteristic mentioned by Floyd and McManus (2005) is the increased willingness to become more innovative and take risks. This claim stems from the fact that SMEs are often young companies with generally younger staff, and less constrained by rigid norms or codes of conduct. Furthermore, the authors highlight the role of SMEs in bridging the productivity gap between the EU and the USA. Moreover, Seitz (2003) claims that SMEs are by its nature more capable of "becoming lean." The author justifies this claim by outlining organizational characteristics that might support the adoption of lean initiatives. Seitz (2003) highlights the following: centralized power, employee empowerment, reduced complexity of interactions, streamlined communication, rapid decision making, clear vision, and the ability to consider every opinion. The selected challenges are expected to be particularly important for SMEs in particular, since they reflect those characteristics of SMEs that might potentially hinder the implementation.

Table II presents the division of SMEs characteristics based on their potential influence upon the implementation of lean manufacturing.

Authors such as Alavi (2003), Ross and Francis (2003) claim that small and medium organizations might easy fall into a trap of eagerly stepping onto the path toward lean without realizing that following the steps of big automotive companies might not be

**Table I.**  
Classification criteria  
for SMEs

Enterprise category	Headcount	Turnover/balance sheet total	
Medium	Less than 250	€50 million or less	€43 million or less
Small	Less than 50	€10 million or less	€10 million or less

Supporting factors	Lean adoption Hindering factors	Lean manufacturing implementation
Faster communication	Inadequate financial resources	<b>993</b>
Quick decision making process	Shortage of skilled employees	
Unified organizational culture	Fluctuations in raw materials availability and prices	
Greater flexibility	Reliability upon one-person management	
Quicker response to customer needs	Inadequate education and training of entrepreneurs	
More authority and power to employees	Inadequate time and cash flow management	
Innovative environment	Intuitive rather than analytical decision-making	
Support to change initiatives	Reliance upon outdated, labor intensive technologies and traditional management practices	

**Table II.**  
SMEs characteristics supporting and hindering the adoption of lean

the best solution. Therefore, this paper aims at emphasizing the different conditions that SMEs face in comparison to big companies. Failure to do so might contribute to the difficulties in “doing lean” and in consequence, to abandoning the idea.

#### 4. Methodology

In accordance with the specifics of the aforementioned research question a qualitative approach was chosen and detailed case studies serve as a basis for the analysis. According to Eisenhardt (1989) the case study approach can be utilized for providing description, theory testing and theory building. This study aims at theory testing and addressing the broader context of lean in particular. The conclusions of the study have the potential of being replicated since the studied organizations display many similarities in terms of both internal and external challenges and overall characteristics (further discussed in the paper). The presented case study approach involves two organizations and focusses on qualitative data collection.

#### 5. Case companies

Two case studies, representing furniture and boating industry in Finland were selected. Even though the companies represent different industries, many similarities were discovered. Both companies are striving to improve their manufacturing processes and aim at higher effectiveness without compromising product quality. Since companies are unable to build their competitive advantage upon lowering wages or moving their production to low-labor cost countries, different alternatives need to be considered. The studied companies are non-lean implementers nevertheless, they are actively seeking for simple yet effective solutions that would not require extensive financial investment on the outset. The studied companies are considering the adoption of lean manufacturing as well as the improvement of manufacturing methods aimed at cost reduction.

##### 5.1 *Company A: a furniture manufacturer*

The company focusses on manufacturing of sofas and armchairs. Company cooperates with both local suppliers (e.g. plywood frames, foam) and foreign ones (e.g. fabrics). The actual manufacturing process comprises of assembling the pre-ordered components as well as cutting and sewing. Products are manufactured to order and an average lead time is about four weeks. The company maintains inventory of

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finished products, however, in recent years, the effort has been made to reduce it. The same applies to the inventory of components. The problem of unexpected delays in delivering the product due to shortage of sub components can be fairly easy to solve in the case of local suppliers in close proximity. The challenge arises in the case of components such as textiles that require about a week to be delivered. Company aims at shortening the lead times while maintaining high quality of their products. High quality and attractive design are the two most important differentiating features that the company emphasizes and builds its image upon. The increasing manufacturing costs are constantly a concern. Finland is commonly known as a country of fairly high cost of living but also high wages. That implies that competing with low-labor cost countries is impossible and competitive advantage should rather be built upon the superior quality and modern design.

#### 5.2 Company B: a motor boat manufacturer

The company produces motor small- and medium-sized motorboats (lengths from five to seven meters). The manufactured boats vary from small basic open boats to more luxurious, spacious versions with roof, a place to cook a meal and to sleep.

Manufacturing process is based on the spray lamination method. Once a boat's body is finished then the assembly of smaller components, such as metal railings and lights, is performed. Boats are made to order and distributed via dealers. Nevertheless, the company keeps high inventories of ready-made boat bodies for a quick assembly when needed.

The company does not manufacture engines for the boats. Those are purchased from manufacturers specialized in their production and then assembled. Customers are always informed about the boat price with and without the engine.

Table III presents a summary of the process based on in-depth interviews and shop-floor visits.

Both companies are facing similar challenges regarding the cost structure. The manufacturing/assembly as well as the relatively high wages that are being paid in Finland encourages companies to rethink their current operations. The studied companies also need to face their competitors from outside Finland, offering products of similar quality at a considerably lower price. Since moving production to low-cost countries is not considered a viable option by the case companies and therefore, the implementation of lean manufacturing is perceived as an interesting solution.

### 6. The challenges of lean adoption in case companies

This section focusses on outlining the discrepancies in the characteristics of SMEs (based on two case studies) and a lean benchmark – Toyota. Table IV presents the

	Company A	Company B
Industry	Furniture	Boating
Product (s)	Sofas, armchairs	Motorboats
Location	Ostrobothnia, Finland	Ostrobothnia, Finland
Sales model	Through distributors (authorized outlets)	Through distributors
Interviewees	CEO, production manager	Sales manager
Challenges	Shortening lead times, reducing manufacturing costs while maintaining high quality	

**Table III.**  
The overview of the case companies

	Case companies	Toyota	Lean manufacturing implementation  <b>995</b>
<i>Philosophy</i>			
Time perspective	“Short-termism”, focus on day-to-day operations, lack of clear vision in a long-term, resistance to change	Long-term orientation, focus on waste elimination and constant improvement of operations, building a learning organization	
Leadership	Leaders in SMEs often need to combine various organizational roles	Growing leaders internally, they need to understand company’s operations in great detail	
Employees	Challenge of fluctuations, it is not so easy to replace a skilled worker	Investment in employee development, building long-lasting company-employee relations	
Partners/suppliers	Focus on cooperation, companies dictating rules	Building long-lasting relations, suppliers seen as partners and an extension of the business Emphasis on supporting partners’ development	
Organizational learning	No tools, methods or routines that would support the process of developing a learning organization	Learning from past experiences and projects, standardizing best practices. Relentless reflection (hansei) and constant improvement (kaizen)	
Decision making	No specific decision-making process	Decisions are made slowly by consensus, implemented quickly	
Constant improvement	No specified learning process	Kaizen, hansei	
<i>Internal operations/tools</i>			
Processes/standardization	Lack of standard procedures	Processes standardized as much as possible, workers cross-trained to avoid the problems of absence	
Material replenishment	When finished- causes bottlenecks	kanban	
Workload leveling	No methods for workload leveling	<i>Heijunka</i>	
Quality assurance	Drawing conclusions from complaints made	Culture of stopping to fix problems, quality needs to guide the value creation process, no	
Visual control	No visual control	Visual control system (andon lights, etc.)	
Reliable technology	Reluctance to change technologies that have been in use for some time. Adherence to reliability rather than to effectiveness	Technology to support people, not to replace them. Quick implementation of new technologies after considering them thoroughly	

**Table IV.**  
Factors affecting lean  
implementation-case  
companies and Toyota

comparison of the most important characteristics that sets the conditions for lean manufacturing implementation. The chosen characteristics are based on TPS management principles as proposed by Liker (2004). The most relevant elements were chosen for comparison in order to emphasize the differences those features that might potentially hinder the lean implementation. The elements chosen for comparison form a framework for addressing the lean implementation challenges in SMEs. The selected criteria are expected to provide an exhaustive overview over the crucial aspects of the process of lean adoption.

The presented challenges to lean implementation form a conceptual framework. The criteria selected for addressing lean implementation were outlined on the basis

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of literature review and during the iterative process of gathering the empirical data. The research conducted by Achanga *et al.* (2006) conducted the research into the critical success factors for lean implementation. Based on their findings, as well as the research into the business process change framework for examining the lean manufacturing as presented by Motwani (2003) the critical challenges to lean implementation were outlined. The paper claims that the outlined challenges are particularly important for small and medium organizations. The claim is justified by the connection between certain characteristics of SMEs (discussed in Section 3) and their (negative) influence upon the process of lean implementation.

Even though the studied companies represent different industry sectors, there are several similarities that were observed. Both companies base their manufacturing on assembly and depend upon suppliers for various components. Both companies sell their products through dealers and rely on the make-to-stock philosophy. Such a “mindset” has proven to be particularly ineffective for the furniture manufacturer. Ultimately, the company managed to decrease the inventories and limit the space rented for storage. However, since the companies operate within broader supply chains, at a certain stage they will need to consider the lean improvements in a specific context of the whole supply chain. Those challenges and several more are discussed further in this section.

The tabular comparison of various dimensions characteristic for lean philosophy aims to outline the immediate discrepancies in business approaches as well as to show the span for lean improvements. The study of case companies has proved that lean improvements are the promising alternative to currently implemented manufacturing methods. According to Melton (2005), when implemented correctly and improved systematically, lean principles offer the wide array of benefits such as less process waste, reduced lead-time, and increased understanding of processes, financial savings and less rework. Nevertheless, the benefits of lean approach will only be attainable if companies devote enough time and persistence to the process of becoming lean and accept the fact that it is not a “quick fix” but rather a change of organizational mindset (Liker, 2004).

Table V presents the extended version of SMEs characteristics (both external and internal) regarding their influence on lean manufacturing implementation. The elements were chosen on the basis of their highest importance in lean manufacturing implementation, especially in their initial phase, as well as due to their immediate impact on the process. The chosen elements are then discussed in more detail.

The studied companies, as non-lean implementers, provide a valuable insight into the potential challenges regarding the initial stages of lean adoption. Based on the in-depth interviews and shop-floor visits certain characteristics, common for all case companies, were outlined. The presented characteristics provide an insight into their current situation. By contrasting the characteristics of the case companies with Toyota, the main challenges of lean implementation.

### *6.1 The challenge of long-term orientation*

After having studied TPS for years, Liker (2004) particularly emphasizes the importance of long-term orientation. Companies that seriously consider lean implementation should always value long-term goals more than short-term benefits. It is not uncommon for Toyota to give up short-term benefits for the sake of strategy planned beforehand. Nevertheless, short-term orientation which is a frequent case of European SMEs is a factor that seriously hinders any improved programs. The trap

Influencing factor	Lean context (hindering vs facilitating factors)	Lean manufacturing implementation	
<i>Internal factors</i>			
Philosophy	Short-term orientation ("short-termism") does not support lean thinking. Focus on short-term benefits and lack of long-term development vision might seriously hinder lean implementation. The paradox of seeing the need for change and being reluctant to introduce the new ways of thinking that might block the introduction of lean manufacturing	997	
Know-how	The size of case companies facilitates the knowledge sharing. Nevertheless, there is a lack of in-house specialists who would guide the process of lean implementation. The challenge of insufficient know-how for lean implementation might impose additional costs of e.g. hiring external lean consultants		
Employee relations	No cross-training of employees, no employee empowerment by assigning responsibility. Employees need to identify themselves with the organization and understand the importance of lean development efforts undertaken		
Communication	Smooth communication due to the small size of organizations, communication bottlenecks easily solvable		
Financing	Limited financial resources and resistance to invest in improvements that do not bring immediate benefits		
Value creation	Companies are not fully aware of the value they customers would want to receive. Companies are not fully aware of their value proposition and the meaning of value <i>per se</i>		
Organizational learning	Case companies have reached the level of "knowing organization". However, the attitude supporting constant improvement is still missing as well as the clear definition of core competences that a company should invest in		
<i>Heijunka</i> and just-in-time delivery	Necessary for creating a smooth production flow. Case companies are facing the challenge to reduce their inventories and arranging deliveries of components		
<i>Internal implementation facilitating/reinforcing factors</i>			
Communication	The size of case companies facilitates communication. Information flow fairly unrestrained by procedures and bureaucracy		
Partners/suppliers	Companies are aware of the importance of close cooperation with suppliers. Focus on building long-term relations		
Quality	Companies aim at making quality an important part of their value proposition. Introduction of the culture of stopping to fix the problems as well as achieving the right quality the first time		

**Table V.**  
Internal and external factors and their influence on lean manufacturing implementation

of short-termism often makes companies unprepared for the changes therefore their reactions would mostly be chaotic and inadequate. Moreover, it is quite common for the managers of SMEs to show unwillingness to change. Adherence to short-term policy will never encourage serious changes like lean principles implementation. During the course of the in-depth interviews it became clear that both studied companies are adopting the "short-termism," which can be explained by the drive toward immediate results rather than the investment that promises benefits within the longer timeframe. Such a company mindset can be seen as a serious constraint for the adoption of lean philosophy.



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### 6.2 The challenge of becoming a learning organization

A successful lean organization is simultaneously a learning organization. According to Flinchbaugh (2005) seeing lean as more than set of tools brings the understanding that those two concepts indeed have many intersections. The author highlights certain lean practices such as JIT and continuous improvement in particular, that underpin the importance of organizational learning in their successful implementation. Liker (1994) also emphasizes the importance of fostering the organizational learning process. Toyota spreads and shares lean knowledge but always highlights the importance of “learning by doing” instead of copying methods and tools without a deeper reflection. In the end, relentless reflection is a crucial element of TPS.

According to Hines *et al.* (2004) knowing organization means that a company already is on a lean awareness stage and efficiency is the key. Therefore, realizing that waste should be identified and removed seems to be fairly easy to implement. Nevertheless, the authors mention that organizations can only be successful in the case of operating in mature and static environment.

### 6.3 The challenge of leveling out workflow

According to Furmans (2005) the ultimate goal of leveling out workflow – *heijunka* is creating and maintaining continuous flow of products. *Heijunka* levels the production of different products over a given time period which can be a day, one shift or even less. Application of *heijunka* generates a constant demand for parts for the upstream process.

Lean philosophy outlines two other sources of waste apart from *muda-muri* (overburdening people and equipment) and *mura* (unevenness). According to Liker (2004) unevenness is a result of irregular production schedule or production volumes fluctuations that stem from internal problems such as downtime, missing or faulty parts. The author states that companies will not be able to eliminate *muda* or *muri* without tackling the challenge of *mura* in the first place. Leveling production and schedules should be done according to both volume and product mix. According to Liker (2004), the actual flow of customer orders should no longer be seen as critical. Instead, the total volume of orders in a given time period should be addressed. Therefore, the same amount and mix can be produced every day. Leveling production schedules is only achievable when a pattern of volume and mix can be outlined and based on that a schedule for every day can be prepared.

### 6.4 The challenge of supplier-buyer relations and JIT

JIT is a foundation of lean philosophy and it is intended to initiate and then facilitate waste elimination. The universality of JIT concept is supported by Gunasekaran and Lyu (1997) who argue that JIT is a philosophy that can be applied to any company regardless of its type of operations and business environment.

According to JIT principle elimination of waste is achieved by providing customers with exactly what they want and in the needed amount – no excess inventories, shortened lead times. According to Wafa and Yasin (1998) implementation of JIT is also expected to bring many additional benefits such as improving internal communication, reducing purchasing costs, reducing lead time, throughput time, fostering organizational discipline and managerial involvement, integrating different functional areas in the organization as well as to close the gaps between different functional areas.

The practical realization of the JIT principle requires the perception of the concept in a broader context. Authors such as Cooney (2002) outline the weaknesses of the concept such as its inability to address the influence various labor and product market factors upon the implementation of JIT. The author also emphasizes the importance of the relations with suppliers as JIT cannot exist without this prerequisite being fulfilled. SMEs might find it particularly difficult to establish and maintain long-term relations with their suppliers as the issue of power imbalance still plays an important role in buyer-supplier relations. Morrissey and Pittaway (2006) mention the issue of size asymmetry along the supply chain. Larger suppliers might tend to dictate the rules of cooperation and set the degree of closeness with the smaller buying company. This tendency is understandably valid in the reverse case – when the buying company is bigger than the supplier. The power is then shifted toward the bigger (and therefore more powerful) player. According to Morrissey and Pittaway (2006) another issue that might hinder the development of effective and “lean oriented” buyer-supplier relationships is the focus on immediate benefits. SMEs tend to value them above the stable and long-term relations even though they are fully aware of the benefits that stem from establishing and maintaining long-lasting, partner relations with suppliers.

#### *6.5 The challenge of employee empowerment and standardization of the work procedures*

The empirical research conducted both in furniture and boating case companies proves that adherence to “traditional” manufacturing methods is still strong. Line workers are enclosed within their assigned tasks and the practice of empowering workers and encouraging them to take responsibility and suggest improvements is practically nonexistent. Even though the assembly procedures are fairly uncomplicated (especially when compared with automotive production where lean thinking was initially developed) workers are unable to swiftly interchange between different manufacturing/assembly tasks (Table VI).

Implementation challenge	Managerial implications (Improvement suggestions)
Long-term orientation	Development of a long-term strategy Focus on constant improvement in a small scale
Learning organization	Building a company-wide understanding of lean Understanding that lean is a process that has virtually no end Seeing operations through the lens of constant betterment
Leveling out workflow	Reaching stability in terms of manpower, machine, materials and methods (Smalley, 2006)
Supplier-buyer relations	Early supplier involvement (Dowlatshahi, 1998) Close geographic proximity fostering supplier- buyer relations (Dowlatshahi, 1998) Limited number of suppliers as an additional motivation for building lasting relations Shifting focus towards mutual growth based on regular rather than as hoc transactions
Employee empowerment and standardization of work procedures	Clarification and simplification of procedures Focus on the development of a multi-skilled worker capable of handling various manufacturing or assembly tasks Encouraging people to find solutions on their own

**Table VI.**  
The summary of lean implementation challenges and suggestions for addressing them

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## 7. Conclusions and limitations

The paper discussed the conditions for lean manufacturing implementation in the specific context of SMEs. The main focus was given to the factors that strongly influence the process of lean implementation. Theoretical background for the study was based on outlining potential benefits as well as obstacles to the adoption of lean. Approaching the subjects from different viewpoints provided a broader perspective and deepened the understanding of the concept. The empirical part centered on the potentially challenging areas as well as outlining the main gaps that exist between the benchmark of the study – Toyota and the case companies. The implementation of lean manufacturing in specific conditions of SMEs was approached from the perspective of a number of implementation prerequisites. This paper does not claim that copying the ideas developed by Toyota will be beneficial for every organization. The discrepancies between lean giant and the studied companies were analyzed in order to identify the implementation challenges. During the data collection and analysis process the overall condition of case companies were examined in order to assess their readiness for the adoption of lean.

The most important assumption of this paper is that the successful adoption of lean requires long-term orientation and even the ability to sacrifice the short-term benefits in order to achieve sustainable lean improvements which should ultimately lead to the creation of the lean culture. The creation of a lean culture is one of the greatest challenges awaiting the prospective lean implementers, since a considerable degree of organizational learning skills are needed.

The challenges outlined in this paper are best addressed when lean is seen as a holistic concept that reaches beyond the manufacturing processes. Understandably, the implementation of lean is strongly shaped by the individual characteristics of a given company. Nevertheless, companies should always be aware of the assets they have at their disposal. The aforementioned benefits that stem from the fact of being an SME together with the awareness of challenges and the ability of overcoming them with the help of building culture of relentless improvement and waste elimination, should serve as conducive conditions for the adoption of lean and its further development into company's overall philosophy.

The findings presented in this paper also carry considerable managerial benefits. Managers considering the implementation of lean principles in their organizations should focus on ensuring that the company sees the adoption of lean as a long-term investment. Such approach moderates the risk of abandoning the process too early and thus losing a chance for reaping the full benefits that stem from lean improvement. The paper emphasizes the importance of the preparatory stages of lean, and the awareness of company's characteristics and the potential challenges that the process of lean adoption might bring.

The validity of the findings could be further improved by adding more empirical evidence which implies more study in SMEs to determine if the outlined challenges to lean implementation can be generalized. Nevertheless, the paper provides a significant insight into the specific context of the initial stages of lean, while opening the opportunities for further research into the following stages of lean implementations. The results of this paper might facilitate the initial stages of lean implementation in SMEs.

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## When a set of tools is not enough- lean placed strategically

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### Abstract

*This study aims at the identification of lean manufacturing implementation challenges in small and medium enterprises. The adoption of lean principles and ultimately a change into a lean enterprise is becoming more and more important for companies that are concerned about improving their overall performance. In current times of severe competition and pressure for shortening lead times while cutting production costs, lean manufacturing has become an interesting improvement opportunity. It can be stated that the reality of SMEs, to a certain degree, resembles the Japan's situation back in the days when the concept of lean was invented- the challenge of limited resources and the need for flexibility. Furthermore, the publications on lean deliver a clear message that reaching a lean enterprise is achievable regardless of company's profile. The promised universality of the concept combined with splendid results it might bring leaves SMEs in particular in a state of dichotomy. While being short on resources and having large "lean giants" as a benchmark, small organizations find it particularly challenging to initiate the process of lean implementation. Therefore, the aim of this article is to provide an overview of the current research in the field of lean, with Toyota case as a reference, and contrast it with the characteristics of SMEs as outlined during the course of empirical research. The comparison is further developed into the analysis of the crucial factors that affect the lean implementation. The study is based on Finnish manufacturing organizations however, the conclusions bear a certain degree of universality which allows claiming that they can be stretched to other types of SMEs.*

**Key words:** lean manufacturing, SMEs, strategic planning

### 1. INTRODUCTION

Lean as a concept can be seen growing in popularity and scientific literature presents numerous examples of the successful implementation. While success stories concern mainly the automotive industry, the research concerning lean implementation in small and medium enterprises (SMEs) is still being somewhat underdeveloped. Scientific resources often quote the success stories of major players, within the automotive industry in particular, while lacking the more complex perception that includes SMEs. Moreover, the existing research on lean tends to divide into two streams of lean seen as a toolbox and as a philosophy. This article presents different approaches to lean as well as the empirical evidence illustrating the weaknesses of seeing lean as a set of tools.

The benefits of lean philosophy have become widespread with the popularization of Toyota's success. Nowadays, in the conditions of economic downturn many companies, disregarding their profile, are seeking for solutions that would enable effective utilization of available resources as well as effective cost management. The scientific literature presents numerous examples of the successful adoption of lean. However, the presented success stories concern mainly automotive industry and are heavily dependent on quantitative results expressed mainly through increased profit [1]. The qualitative research concerning small and medium enterprises in particular, still remains somewhat underdeveloped. Moreover, the examination

of scientific literature proved that there exists a division in terms of classification of lean. Presenting and the perception of lean as a set of tools or as a philosophy is common, frequently contributing to false perception of organizational leanness as well to implementation failures. Moreover, the universality of the lean concept is still being questioned. The main critique being directed to lean's is the fact that it ignores the external factors to which management must respond when steering a business [2].

This paper presents different approaches to lean in more detail. The aim is to provide empirical evidence regarding the lean implementation in a manufacturing company. The paper highlights the weaknesses of the approach that assumes treating lean as a toolbox rather than a philosophy that encompasses both manufacturing and management systems. Moreover, the paper discusses the further development of the lean initiatives in the organization chosen for the study.

### 2. THEORETICAL BACKGROUND

The examination of scientific literature in the field of lean aims at briefly outlining the historical development of lean, presenting different approaches to the concept as well as emphasizing the importance of perceiving lean in a specific context of the overall management philosophy rather than a toolbox for manufacturing improvements.

## 2.1 A brief history of lean

Lean as a manufacturing and management concept has a history that goes back to Japan in post 2nd World War times and the manufacturing improvements ignited in Toyota. The importance of lean production in terms of its abilities to address the trade-offs between productivity and quality is emphasized by [3]. The author also refers to the very origins of the lean concept and its "critique" of the manufacturing methods of the West. The common flaws identified consisted of large-batches manufacturing (leading to the unnecessary inventory build-up) as well as the inability to translate customer requirements into a ready product that would offer a considerable range of variety. Having those inefficiencies as a starting point, the idea of lean manufacturing was established upon the small-lot concept and the elimination of waste. In order to be able to achieve the practical realization of the aforementioned concepts, lean gradually evolved towards a quick changeover techniques and just-in-time.

Bearing in mind all the benefits that stem from addressing the weaknesses of mass production as well as a change in customers' needs (request for greater variety), [3] emphasizes the dubious innovativeness of the lean concept. The author refers to the fact that lean might as well be seen as a result of mindfully addressing the aforementioned challenges. In the particular case of Toyota, the success can also be attributed to the characteristics of Japan particularly back in the post 2nd World War times. According to [4] the war-ravaged country with almost no natural resources at hand had little chance while competing with Ford. Therefore, based both on country's characteristics, economic situation as well as the mistakes made by Ford, Toyota was able to create and develop not only a manufacturing method but also management philosophy that became a paradigm shift and a new development path for many companies that decided to follow.

## 2.2 The holistic approach to lean

It is vital to recognize that the research into lean is not limited to manufacturing improvements. According to [5] the success story of Toyota is largely caused by its management system, based on the lean principles, which have been developing over the years. [5] emphasizes the importance of a long-term philosophy. Focus on a long-term perspective lies at the heart of the lean management system. Moreover, the principles of lean management refer to a broad context of operations, not only to manufacturing.

This paper emphasizes the importance of placing the adoption of lean in a broader context of company's strategy and development in a long-term perspective. [6] claim that the successful lean implementation in manufacturing companies should be considered as two-dimensional. Along with technical requirements the cultural requirements are equally important. The latter group of requirements is defined as a change in organizational culture that can be achieved by the improvements of such areas as:

- Decision making processes
- Specification of company's mission and vision
- Supporting a strategy of change and communication of objectives
- Assigning responsibility and employee empowerment
- Development of supplier relationships
- Creation and fostering of a learning environment
- Customer focus
- Lean leadership
- Focus on the regular assessment of lean initiatives

[6] outline yet another factor that should be addressed when developing the cultural environment fostering lean improvements. Long-term commitment and awareness of the fact that benefits of implementing lean might need time and iterations to achieve desired results is a crucial element of understanding lean. Such thinking is also supported by [7] who emphasizes the importance of the parallel introduction of lean manufacturing and lean management. The author emphasizes the importance of creating a lean culture that is an essential requirement for achieving sustainable results. According to [7] the lean culture refers to the way work is being done in an organization. Therefore, it is an intangible idea that remains unnoticed. [7] suggests that the identification of a lean culture within production can be explored by addressing the following issues:

- Inventory practices
- Controlling the production status
- The status of process improvement activities
- Typical responses when problems arise

[7] claims that recognition of the "old habits" and changing them is a necessary prerequisite for the introduction of sustainable lean improvements. The author focuses on the importance of lean management that should be introduced in parallel with manufacturing improvements. The principal elements of lean management comprise of the following:

- The role of leader and standardized work
- Visual controls
- Daily accountability process
- Discipline to execute the introduced lean elements

[8] focuses on the performance of organizations that treat lean as an ideology and emphasizes the importance of being able to distinguish between different forms of lean implementation. The author claims that the approach to lean that assumes its ideological traits, comprise of the following elements:

- Lean becoming a way of thinking
- Integration of lean into a complete system
- Lean as a profit generator
- The importance of developing people
- Tools that are considered to be means for seeing problems, not for solving them
- Lean extended to the whole value chain, including outsourcing
- The clarity of vision regarding lean is a must
- Cultural changes in terms of employee empowerment are needed



In summary, this paper emphasizes the importance of treating lean as a long-term commitment to organizational turnaround as well as strategic planning of the general lean development. This claim is further justified by the empirical part presented in chapter four. This article assumes that a sustainable lean implementation can be achieved by addressing not only shop floor improvements but also management systems of organizations. In other words, lean should be treated as a philosophy that guides even strategic planning.

The holistic approach to lean as presented in this paper promotes perception of lean in a broader context of organizational culture and strategy development in a long term. This paper aims at supporting the claim that lean implementation cannot be successful without the aforementioned approach.

### 3. METHODOLOGY

Case study approach was implemented in order to address the aforementioned research aims. Single case approach was chosen in order to address the depth rather than the breadth. [9] suggest that single cases are generally recommended for gaining an in-depth and detailed understanding. The study presented in this paper comprises of data collection through in-depth interviews and shop-floor visits. The emphasis was put on gathering qualitative evidence as well as providing description of the situation in a given point of time. The implemented approach aimed at theory testing and therefore, a deductive research approach has been utilized.

According to [10] case study method is particularly useful for providing answers to how and why questions, as well as for theory developing, testing and refinement. The case study method was chosen in order to study the phenomenon in its natural setting. Moreover, the method allows for exploration which was necessary to

sharpen the research objective. Theory testing was also an important for the presented research. [10] claim that the case study method is a suitable when complicated issues are being studied. The implementation of lean can be classified as a complex issue since it involves not only usually visible shop-floor improvements but also less tangible issues such as relationships with suppliers.

#### 3.1 Crafting and conducting the research

The research was conducted in based on a set of logical steps. Firstly, based on the author's experience from the previous projects, the potentially challenging area in the process of lean implementation was identified. Secondly, literature review was conducted in order to identify the different scientific approaches to the research in lean with particular attention being paid to the approach that assumes that successful lean implementation requires long-term commitment to the lean change as well as the awareness that becoming a truly lean enterprise requires a change affecting management systems, not only the introduction of several shop-floor improvements. The research into scientific literature facilitated the process of preparing the in-depth interview questions. The company chosen for the study was previously identified as a lean adopter. While simultaneously being a medium-sized, manufacturing company, the organization proved to be a suitable case for the further exploration. The in-depth interview was conducted with the company's lean leader responsible for planning, implementing and monitoring lean initiatives within the studied organization. Based on the identified implementation challenges, the conclusions and managerial implications were drawn. Figure 1 presents the logical flow of the research process.

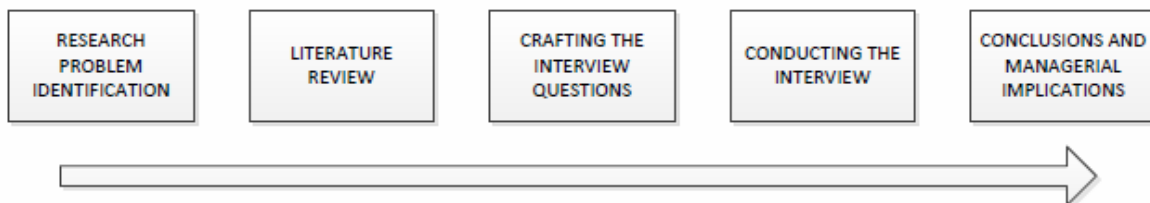


Figure 1. Logical flow of the research process

### 4. THE CASE COMPANY

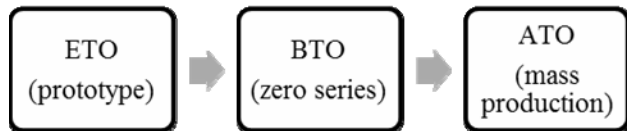
The company chosen for the study is a manufacturer and a supplier of megawatt-class permanent generator and full-power converters with headquarters in the Ostrobothnia, Finland. The company is active in wind power and other renewable energy sectors. The organization falls into the category of small and medium enterprises (SMEs) in terms of headcount and turnover. However, it has been consequently establishing its global presence (units in India, Germany, China, Spain, Korea and USA).

The products offered by the case company are highly complex and require a considerable degree of customization. Moreover, the company needs to face the challenge of unpredictable demand. The implementation of platform-based products and modularity is one of the means to address demand fluctuations as well as the degree of customization required by customers. In reality almost every customer order is different and therefore, the company does not keep inventories.

The company operates largely based on the engineering-to-order (ETO) and build-to-order (BTO) model. Moreover, it has an interesting model of

operating which is based on flexible factory model which is expected to be transferable to other parts of the world relatively easy. The company also relies on line workers employed indirectly through an outsourcing agency. Line workers are employed based on fixed-term contracts. The smartly standardized procedures enable them to start the assembly within a short time.

The specifics of the offered products determine the company's operating mode. The company based its manufacturing upon the three stages presented by Figure 2.



**Figure 2.** Manufacturing process in the case company

In the first stage, the company needs to be proactive in winning new orders and therefore invest in creating a prototype. Based on the principle of build-to-order company organizes the manufacturing of “zero series” that are sold to customers based on the previous orders ignited by the interest in prototypes. The “mass production” occurs a when customers order a product that can be assembled-to-order. The “mass production” series are fairly unpredictable and the company experiences moments when production lines need to be stopped since there are no orders. The next chapters will discuss the lean improvements undertaken in order to increase company's effectiveness as well as the challenges encountered.

#### 4.1 The adoption of lean

The adoption of lean occurred as an internal stimuli and strong belief that things can be done better and more effective. Moreover, the drive towards lean was also dictated by the need to facilitate the establishment of model factories. Standardization that lean promotes was the crucial issue determining the decision of becoming lean. The company began the adoption of lean five years ago and the benefits have become noticeable. However, they can be mainly observed in the context of manufacturing improvements. The factory tour, that occurred as a part of the data collection process, revealed that the principles of visual management, the logic of one piece flow, as well as 5s, have been adopted successfully. Still, the gradual diffusion of lean thinking needs to occur within the whole value chain of the studied organization.

The company focused introducing lean to manufacturing processes. Such approach has both its advantages and drawbacks. As it was mentioned in the early part of this paper, the adoption of lean should be seen as a holistic undertaking, otherwise a company cannot describe itself as a lean enterprise. However, the process of lean implementation requires dedicated leaders as well as a deep and thorough understanding of the changes that should occur. It can be stated that

the case company took the “safe and rational” route while making a best use of available resources and company's characteristics. Table 1 summarizes the lean improvements introduced in the case company. The improvements have been divided into two main areas that focus on standardization and visual presentation. However, it can be argued that the introduced improvements are the intersection of both.

[8] identifies seven consecutive stages of a lean journey, which starts with planning (where no implementation benefits are evident and no infrastructure and organizational decisions have been implemented) and ultimately reaches a stage in where lean becomes an ideology (where lean tools, culture and organizational practices are present, and lean thinking is applied to every component of the value chain). Based on the stages of the lean journey outlined by [8], the studied company can be classified somewhere half-way on its journey towards becoming a truly lean enterprise. The studied company can be classified at the enhanced stage of a lean journey, which defines an organization that has successfully implemented a pilot project in lean, lean initiatives manufacturing based, and the remaining need to address the cultural and organizational practices.

**Table 1.** Lean implementation in the case company

Lean initiative	Aim
<b>Standardization</b>	
Standardized work procedures with reduced setup time	Moderating the effects of high employee turnover; enabling the employment of outsourced workforce; newly employed workers capable of starting the assembly process after a brief training
Standardized documentation: <ul style="list-style-type: none"> <li>- Templates for internal documents and reports</li> <li>- Templates for product information</li> </ul>	Simplification of procedures and decreasing time needed for producing documentation; the idea based on Toyota's A3 reports
Streamlined sequence	Elimination of non-value adding and wasteful activities
Kanban system for suppliers (pull replenishment system) <ul style="list-style-type: none"> <li>- Kanban cards for components clearly marked</li> </ul>	Cutting costs and delivery times of components
Point of use storage	Eliminated wasteful activities like excess time needed for e.g. tool retrieval
One piece flow/cell manufacturing/small batch size	Easier distinction between value adding and wasteful activities
<b>Visual control</b>	

Lean initiative	Aim
Andon lights	Assigning responsibility to line workers; improved communication thanks to production figures updated weekly
5s (+ safety): <ul style="list-style-type: none"> <li>- Color coded tools</li> <li>- Unnecessary tools eliminated</li> <li>- Each item in a designated space</li> <li>- Floors clearly marked</li> <li>- Assembly instructions available on screen- focus on visual presentation</li> <li>- Identical workstations for each assembly line</li> <li>- Clearly marked shelves</li> <li>- Visual instructions</li> </ul>	Decreasing lead times; eliminating wasteful activities such as locating the right tool and the movement needed to retrieve it; simplification of assembly procedures in order to reduce setup times; increasing the workplace safety by eliminating risks of accidents

#### 4.2 Implementation challenges

[5] claims that lean manufacturing improvement initiatives should be supported by the lean management system based on several principles, out of which the most crucial are long-term orientation, choosing the right processes that produce the right results, adding value by developing people, as well as investing in the organizational learning. This paper highlights the importance of addressing lean from a strategic viewpoint that assumes that lean improvements needs to be embedded in company's strategic development plan. The lack of careful planning might result in the introduction of some random improvements that will ultimately result in a false impression of being a lean enterprise while, in fact, not being able to fully benefit from the improvements that lean potentially offers.

The lean initiatives presented in the previous section refer to the organization of the manufacturing processes. Nevertheless, the studied company is still experiencing difficulties in diffusing and sustaining lean initiatives. After five years of "doing lean" the reached development is noticeable but rather modest, especially in the context of gradually diffusing lean within the whole value chain. The company managed to introduce the aforementioned lean initiatives in their model factory visited during the data collection. Moreover, the interviewed lean leader stated that factories in other countries such as China (where the mass production takes place) have also reached a satisfactory degree of leanness. The studied company also gradually realizes that close collaboration with supplier is necessary for the further development of leanness. In summary, the studied organization has reached a stage in which lean journey needs to be continued and developed while lacking the clarity regarding the future state.

In the specific case of the studied organization, the most important implementation challenge stems from the fact that the company's operations are

characterized by high product mix, high variety and unpredictable demand. Many scholars claim that the principles of lean will not work in such conditions. Moreover, the company struggles with high employee turnover, which makes both the employee empowerment and assigning responsibility even more challenging. Workforce fluctuation also limits the opportunities for building team spirit and common understanding of what lean really is as well as the ultimate aim of the improvements. On the top management level, there is still a certain degree of reluctance regarding further development of lean, which means the creation of a lean organizational culture and the introduction of lean management. The insufficient communication of the benefits that lean would bring in a long- term could serve as the justification of such behaviours.

Even though the case company has been successful in improving manufacturing operations, the sustainability of the improvements still remains an open issue. The greatest challenge identified during the interviews was the lack of seeing lean in a long-term strategy of company's development. The introduction of lean is still perceived in terms of ad hoc set of tools, rather than a journey that requires a breakthrough in company's mind set. The change in terms how lean is currently being perceived and what are the expectations regarding the adoption of a new paradigm, needs to take place if the company is to develop lean improvements. During the process of gathering the empirical data, the reluctance regarding the ability of sustaining the lean improvements in a long term was identified. Even though the adoption of lean has been initiated around five years ago, the company is still somehow lacking the commitment and dedication.

The top management reluctance towards lean could also be caused by the lack of consistent key performance indicators that would clearly communicate whether the company is heading in the right direction or not. Moreover, the implementation of lean is too dependent upon the leader who is expected to guide the process and monitor the progress. Nevertheless, without the understanding and support even the most charismatic leader will not be able to guide the change process.

#### 5. CONCLUSIONS

The adoption of lean is nowadays becoming an interesting option for many companies as it promotes more effective utilization of resources, elimination of waste and focus on creating value to customer. This paper supports seeing lean in a broader context affecting not only manufacturing processes but also organizational culture.

The studied company decided to step upon the journey towards lean and according to interviewees the results are already visible. However, the observed results refer specifically to the manufacturing processes rather than to the way the company is being managed. If lean is to be treated as a journey it can be stated that the case

company still has a long way to go before it can call itself a lean enterprise. Nevertheless, the awareness of the need for change is already an important starting point for further development. Within the studied company the suggested future steps should comprise of focusing on the gradual conversion to lean management and seeing lean as a part of strategic development in a long-term. According to [7] the concepts of lean are easy to understand but nevertheless, in many cases the journey towards lean ends abruptly without success if there is a lack of understanding and dedication. The case company should focus on the creation of a shared working culture both on the level of line workers and top management. The gradual creation of intangible yet well understood "rules of conduct" could, according to [7], facilitate the process of creating a sustained lean culture within an organization. In the particular case of the studied company the workforce fluctuation is a serious constraint. Combined with too much responsibility assigned to the leader there is a risk that the lean conversions are not being built upon firm foundations. Ultimately, the company will have to face a situation when leaders are changed, and whether the adoption of lean would still be maintained remains an open question.

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## Kada niz alata nije dovoljan – strateški postavljen lean

Anna Rymaszewska

Primljen (05.10.2012.); Recenziran (14.05.2013.); Prihvaćen (03.06. 2013.)

### Rezime

Ova studija teži da identifikuje izazove implementacije lean proizvodnje u malim i srednjim preduzećima. Usvajanje lean principa i, kao konačan cilj, promena u lean preduzeće, postaje sve više značajno za kompanije koje teže da poboljšaju svoje sveukupne performanse. U vreme oštre konkurencije i pritisaka za skraćivanje vremena uz smanjenje proizvodnih troškova, lean proizvodnja je postala interesantna mogućnost za poboljšanje. Može se reći da realnost malih i srednjih preduzeća (MSP), u određenoj meri, liči na japansku situaciju iz dana kada je lean koncept nastajao – izazov ograničenih resursa i potreba za fleksibilnošću. Nadalje, radovi vezani za lean iskazuju jasnu poruku da je postizanje lean preduzeća ostvarivo bez obzira na profil kompanije. Obećana univerzalnost koncepta kombinovana s izvanrednim rezultatima koje može da donese ostavlja posebno MSP u stanju dihotomije. Dok im nedostaje resursa i dok imaju velike „lean džinove“ kao benčmark, poseban izazov za male organizacije jeste da pokrenu proces lean implementacije. Stoga, cilj ovog rada jeste da pruži pregled trenutnih istraživanja u oblasti lean, sa slučajem Tojote kao reference, kao i da to uporedi sa karakteristikama MSP koje su istaknute tokom niza empirijskih istraživanja. Poređenje se dalje razvija u analizu ključnih faktora koji utiču na lean implementaciju. Studija je zaslovana na finskim proizvodnim organizacijama, ali ipak, zaključci nose određeni stepen univerzalnosti koji dozvoljava tvrdnju da mogu da se primene na druge tipove malih i srednjih preduzeća.

**Ključne reči:** lean proizvodnja, mala i srednja preduzeća (MSP), strateško planiranje

## LEAN IMPLEMENTATION AND A PROCESS APPROACH- AN EXPLORATORY STUDY<sup>6</sup>

See printed thesis, pages 81-107.

This article may be published online after an embargo period.

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<sup>6</sup> Forthcoming in *Benchmarking: An International Journal*, vol.24, iss. 5

## **Towards a lean production ramp-up**

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### **Abstract**

This paper addresses the manufacturing ramp-up process and opportunities for its improvement in terms of desired quality and volumes. In highly competitive business environments of today, quick and seamless launch of new products to market determines company's success. This paper is focused on examining the process of manufacturing ramp-up from the perspective of lean improvements undertaken by the studied company. This paper addresses the question of whether lean initiatives have facilitated the manufacturing ramp-up. Moreover, the context of high variability and relatively low volumes adds value to research into both lean and ramp-up.

**Keywords:** lean, ramp-up, manufacturing

### **Introduction**

In any competitive environment the quick launch of new products determines successful operations and profitability. Being "fast" have long become a requirement for survival rather than a unique feature of an organization. Being "fast" also implies that companies will be able to experience the payback of investments.

The focus on this paper is on the production ramp-up process, which can be defined as the period in which normal production process moves from zero to full-volume, maintaining the targeted levels of cost and quality (Terweish et al., 1999). The importance of addressing that particular might be justified by the claim that frequently, an ineffective and lengthy ramp-up leads to limited market acceptance and therefore, financial difficulties. In other words, the crucial and awaited revenues are at risk of being pushed away. On the other hand, successful product ramp-up, is important as it considerably influences the market's acceptance of a new product. Terweish et al., 1999) highlight the importance of the fast and timely ramp-up process that enables companies to moderate the effects of the prices rapidly decreasing over time. Prices will

naturally fall as competitors accelerate their ramp-up processes and introduce their products. In this context, a successful and timely ramp-up process can significantly increase firm's chances of reaching the planned revenues. This holds especially true in the case of highly-competitive industries, characterized by accelerated rates of product introductions, high degree of innovativeness and therefore frequent new product introductions, as well as shortened production life-cycles.

The aim of this paper is to explore the opportunities for facilitating the ramp-up process. Facilitation implies that the process should be improved in terms of its timeliness and cost effectiveness. The aim is to examine the ramp-up process improved opportunities through the lens of lean principles. This is a fairly innovative approach that goes slightly against the widespread notion that lean approach works mostly for those high-volume and low-variety products, which implies the context of stability. The actual ramp-up process is far from stable nevertheless, there is a growing stream of research that expands the possibilities of applying lean principles to high-mix and low-volume environments.

The motivation for the research presented in this paper stems from the fact that the scientific literature does not provide many examples of the production ramp-up process examined from the perspective of lean improvements. The research presented in this paper is an attempt to address this gap. Moreover, the characteristics of the case company as, specifics of its operations as well as the business environment in which it operates, makes it an interesting example of the current challenges of a company offering highly complicating products in turbulent and volatile markets.

### **Theoretical background**

Mendelson and Pillai (1999) emphasize that one of the greatest challenges that companies are facing, is the constantly increasing velocity of change. The authors claim that companies remain competitive if they are able to release new product to the right market, at the right time, and with the right volume maintained throughout product's lifecycle. Terweisch et al., (1999) claim that the timing of revenues will greatly depend on time to volume. The investments in terms of product design and will, on the other hand, depend on product's time to market. Cooper and Kleinschmidt (1987) in their study aimed at determining the factors that separate successful product launches from the failures outlined several factors that influence product success and failure, proficiency of predevelopment activities being one of them, strongly correlated with new product success. Besides the seemingly obvious factors such as product superiority, the authors mention factors such as the synergy both marketing and technological. From the point of view of this paper, the technological synergy is particularly crucial. Technological synergy implies project-company fit in terms of R&D, engineering, production resources and skills. The actual production ramp-up process falls into the category of technological synergy. Therefore, it can be stated that the implications of the research by Cooper and Kleinschmidt (1987) also support the importance of production ramp-up process in the broader perspective of a determinant of a new product success.

Carillo and Franza (2006) studied the linkage between time-to-market and ramp-up time. The authors justify the need for their research by referring to shorter product life-cycles, more rapid product obsolescence, as well as increasing intensity of global competition, which have pushed companies towards rapid introduction of new products to market. The authors also emphasize the consequences of delays in bringing products to market, which can frequently result in sales loss. Carillo and Franza (2006) came to an important conclusion that managers should always consider time-to-market and

ramp-up decisions simultaneously rather than separately. From the model developed by the authors, the synergetic nature of investments in design and production capabilities became apparent.

Based on the aforementioned definitions of the production ramp-up process it can be stated that there are two important goals towards achievement of which the process should be aimed- quality and quantity. Quantity simply means reaching target volumes while quality can be assessed by examining the amount of faults that have been encountered as well as analysing the amount of time required for fixing and closing the delays.

#### *Learning curves and organizational learning*

Abernathy and Wayne (1974) describe the learning curve as cost reductions in a product through steady increases in volume. The authors claim that increasing a company's product volume and market share will additionally bring cost advantages over the competition. However, the authors also claim that apart from its obvious benefits, there could be negative implications of following the strategy blindly. Reduced flexibility, loss of innovative capability, and narrowly specialized workforce are mentioned.

According to Almgren (2000) organizational learning curve represents learning from experience as well as the benefits from moving from unknown to more routine. Experience is measured in terms of cumulative production volume or calendar time.

The theory of organizational learning can be perceived as a foundation to the idea of the learning curve. From the perspective of reducing costs, organizations should aim at shortening the time needed for turning new challenging tasks to those performed routinely (Cochran and Sherman, 1982).

#### *Manufacturing capability and lean*

Pufall et al., (2007) highlights the influence of manufacturing capability upon production ramp up. The authors define manufacturing capability as the ability to make things rapidly and efficiently. Moreover, the authors outline physical resource and organizational capability as the main determinants of manufacturing capability. Physical resources are those that are directly related to the actual manufacturing processes as well as moving a product through factory. Organizational capability is the response system of a factory. Organizational capability is particularly important from the perspective of the research presented in this paper since it is assumed that the applicability of lean manufacturing techniques starts with shop floor improvements such as 5s. Once manufacturing processes are addressed, the implementation of lean can move to a higher level of management systems.

### **Methodology**

The single case study approach was implemented in order to address the research question. The research approach is based primarily on qualitative data on manufacturing processes and the errors occurring throughout. The main input for data analysis were the fault reports generated by the Andon system throughout the production ramp-up period (April-September 2010). Moreover, the empirical part was further enriched by shop floor visits- observations of the manufacturing processes, as well as semi-structured interviews aimed at gaining a deeper insight into the product development process. Therefore, the empirical data gathering comprises of both qualitative and quantitative. Intensive case study research approach was implemented. The selection is justified by the fact that intensive case study research is focused on "understanding a unique case by



providing a thick, holistic and contextualized description” (Eriksson and Kovalainen, 2008: 118).

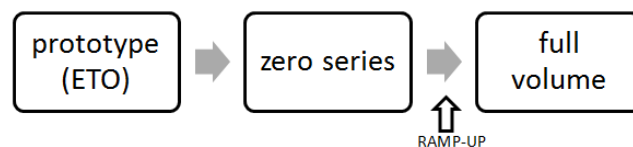
### *Case company*

The studied company is a manufacturer of permanent magnet generators and full power converters. Company’s headquarters is located in Finland but its global presence has also been established. The company has located a significant part of its manufacturing to China while maintaining the research and development processes within Finland. The Finnish factory is also responsible for testing the products. The manufacturing processes of the Finnish factory are studied in this paper.

The products offered by the case company are characterized by the high degree of complexity. Moreover, products are often engineered to order to fulfil very specific customer requirements. The company operates under the constant pressure of frequent product introductions as well as shortening its time-to-market. About five years ago the decision on the introduction of the lean improvements to the manufacturing processes was made. The main lean initiatives undertaken by the case company comprise of the Andon system, visualisation of assembly processes, 5s with added safety, point of use storage, Kanban system for just-in-time delivery of components as well as the zero inventories policy. The lean initiatives undertaken by the case company are currently bound to shop floor. The company is struggling with diffusing lean principles onto the whole value chain. However, its suppliers have not yet been able to implement lean. Moreover, the company is facing an internal challenge regarding the implementation of lean. Namely, the lack of consensus regarding the importance and necessity of the transition on the top management level.

Manufacturing and assembly processes within the studied company are aimed at standardization and maximum simplification as the company greatly relies on the flexible workforce outsourced seasonally. Moreover, the specifics of operations in the studied company and unpredictable demand in particular lead to situations where production is stopped. This applied in particular to the Finnish factory where the product development, testing as well as the manufacturing of zero series occur.

Figure 1 presents a generic view of the manufacturing process in the case company.



*Figure 1 - Generic manufacturing process in the studied company*

### **Data analysis**

The main source of data for the research presented in this paper was the fault reports from the Andon system utilized in the case company. The comprehensive report presents the types of faults encountered as well as time needed for immediate (fixing time) and corrective actions (closing time). The fixing times are usually shorter than the closing time as they not address the root cause of the problem. For the purpose of the analysis data from the beginning of April 2010 until the end of September 2010 were utilized. The period of analysis indicate the time needed for the production to move from zero to full volume. The main purpose of the analysis was to determine whether the company is actually learning from the past mistakes as well as whether the

undertaken lean initiatives have indeed contributed to the reduced numbers of faults. This aim is addressed by analysing the structure of the faults as well as the analysis of the average duration of fixing and closing the faults.

Table 1 presents a general overview of the most important faults.

Table 1- Faults and time needed for solving them

	ASSEMBLY FAULT	DEFECTIVE PART	BROKEN PART	DELIVERY FAULT
number of observations	252	224	67	43
avg. fixing time	6:24:40	5:20:27	11:31:04	12:04:10
avg. closing time	41:54:31	52:21:48	54:04:13	53:52:06

Fault analysis

The Andon system provides a comprehensive report on the faults encountered during the manufacturing process. Figure 1 presents an overview of the faults. The number of instances, encountered during the period of analysis is provided.

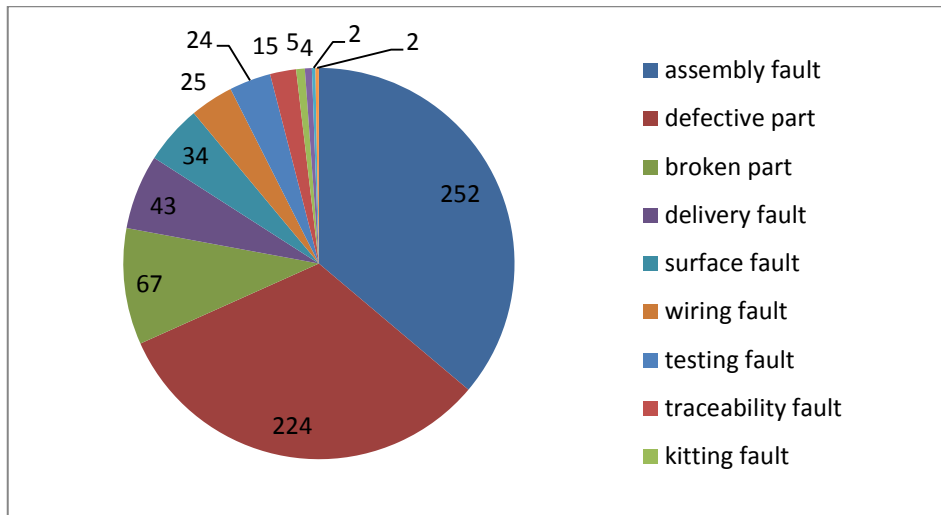


Figure 1- Breakdown of faults

As it can be observed the most common causes of production delays are the assembly faults, defective parts, broken parts or delivery parts. Figure 2 presents the amount of the most common faults during the period of analysis.

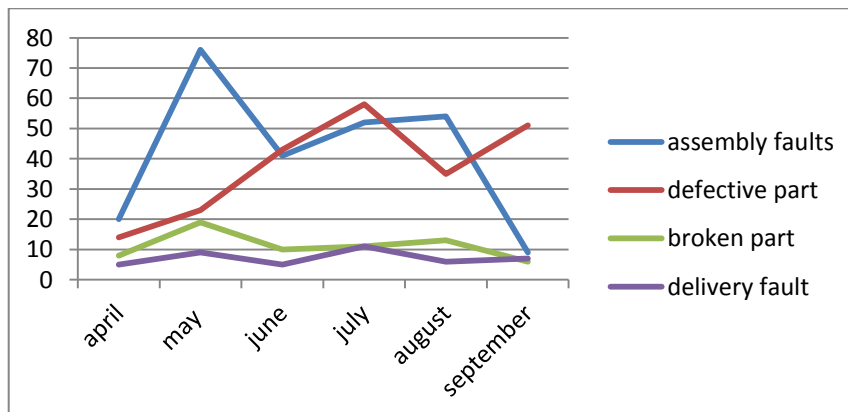


Figure 2- The amount of the most common faults April-September 2010

Assembly faults were identified as the most common. Such faults are bound to shop floor operations and therefore the preventative measures as well as the corrective actions can be taken immediately without the need to consult e.g. suppliers. The case company provides training for the employees as well as focuses on standardizing the assembly procedures whenever possible. The visualization of the assembly process was one of the main lean improvements undertaken in the case company in order to decrease the assembly faults and facilitate the learning process.

#### Time analysis

Fixing and closing times were the two categories reported with the main difference regarding the nature of the solution. Fixing times can be described in terms of immediate and short-term solutions while closing times involve addressing the root cause of the problem. Figure 3 presents the average time needed for fixing faults and closing them.

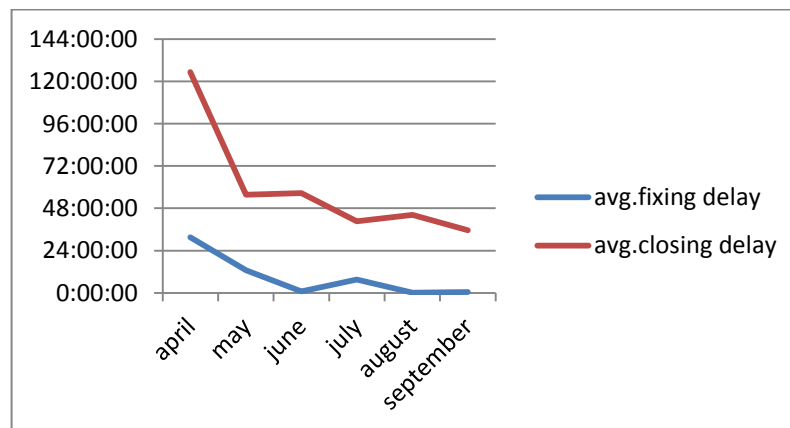


Figure 3- Average fixing and closing delays (hh:mm:ss)

Fixing delays are the time elapsed between the moments of acknowledging a fault and fixing it. Closing delays are the time elapsed between the moments when the fault was fixed until the moment a problem was ultimately solved. It is important to remember that in this specific case fixing does not guarantee that a problem is solved.

Figure 4 presents a comparison of the average fixing and closing delays for assembly faults (AF) and delivery faults (DF).

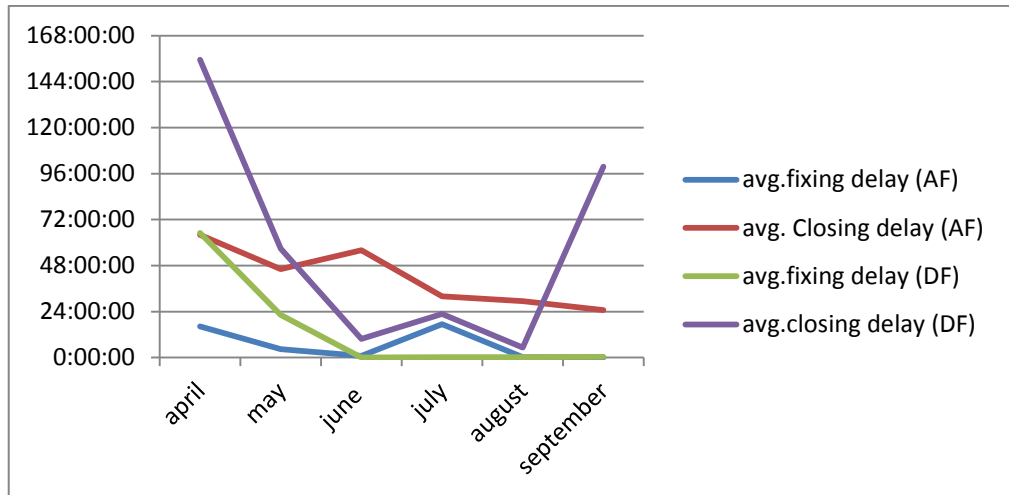


Figure 4- Average fixing and closing delays for assembly (AF) and delivery (DF) faults (hh:mm:ss)

Figure 5 presents a similar comparison of the average fixing and closing delays for defective parts (DP) and broken parts (BP).

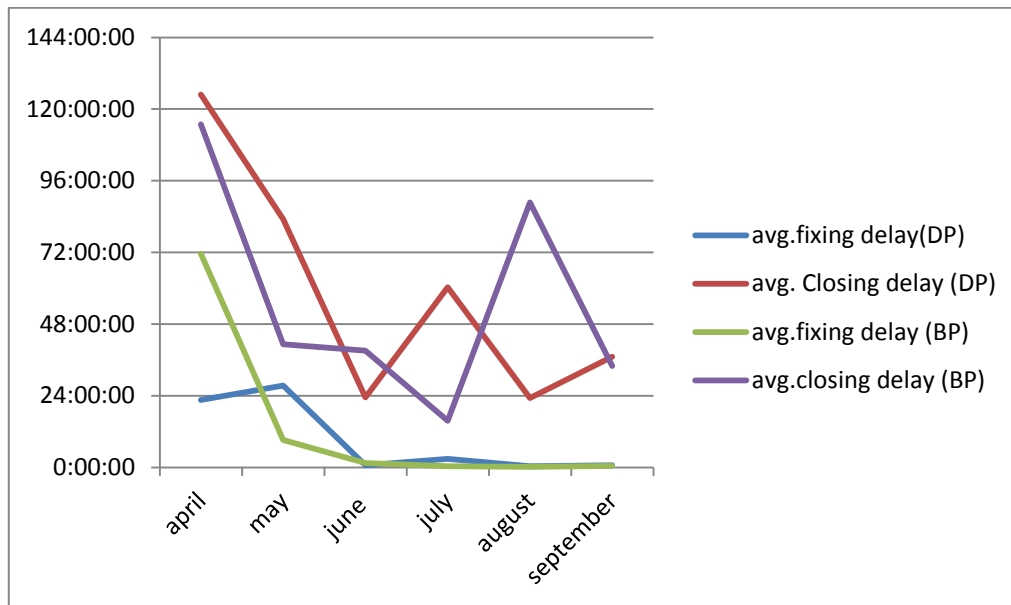


Figure 5- Average fixing and closing delays for defective parts (DP) and broken parts (BP) (hh:mm:ss)

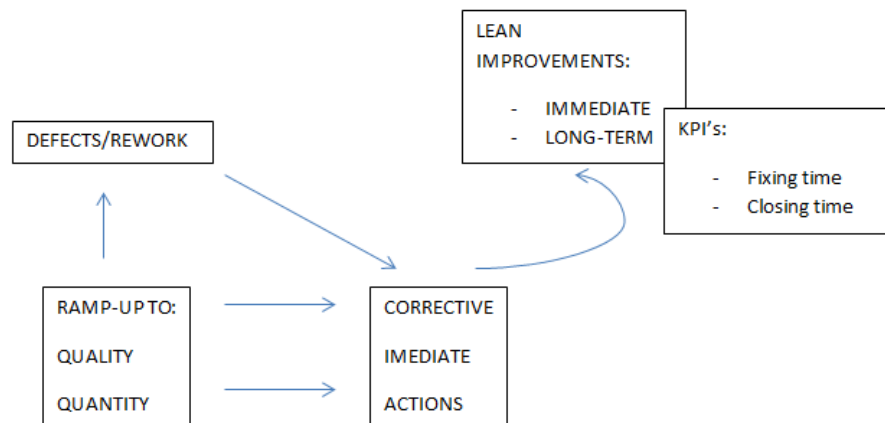
**Findings**

The presented data offer an ample opportunity to examine whether the manufacturing processes in the studied company are actually following the learning curve. Moreover, the empirical data analysed in this paper can also be utilized for addressing the question of whether the studied company should rethink its strategy for lean improvements. Based in the average duration of both fixing and closing delayed it can be stated that the company is following the idea behind the learning curve, However, as the two most time consuming faults identified are the assembly faults and defective parts a question arises whether the lean improvements undertaken by the company are facilitating the ramp-up process.

The production ramp-up can be considered from the perspectives of reaching certain levels of quality and quantity. In case of the studied company the desired volume was reached within the analysed time period (April - September 2010). Ramp-up to quality can be measured as a trend in the average time required for fixing and closing the delays encountered. Both fixing and closing delays can be described by the decreasing trend which implies that the company has been able to learn from the past mistakes and improve the operations so that the time needed for fixing and closing can be minimised. The main faults encountered during the production ramp-up process: assembly faults, delivery faults, broken parts and defective parts can also be considered from the perspective of its root cause. The studied company greatly depends on suppliers during its manufacturing processes. The company depends on its suppliers for the delivery of subcomponents as well as the preparation of cables and wirings necessary for the assembly. Once the products are developed, tested, its assembly procedures standardized, and large orders ensured, the company moves to a stage of mass production. The factories located globally are responsible for fulfilling the orders after the phase of engineering to order has been finished and target volumes have been achieved. Based on the analysed fault reports it can be stated that the case company should invest in closer collaboration with its suppliers in order to decrease delivery delays as well as eliminate the deliveries of faulty or broken parts. The implementation of lean principles cannot therefore be limited to the company's assembly operations. This holds particularly true in case of the company that relies on its suppliers to a great extent.

In the context of the main faults disrupting the production ramp-up the root causes of the problems should also be addressed. The assembly faults that were identified as the major obstacle to the production ramp-up process. Assembly faults should by definition take less time to fix and close as they usually do not require interactions with suppliers. The company has embraced the lean principle of investing in multi-skilled workers and therefore the majority of assembly faults can be tackled by any worker. Nevertheless, significant faults that were identified such as delivery faults, broken parts and defective parts signal the significant role of suppliers. The average closing and fixing times for those faults were significantly higher than the average closing and fixing times for assembly faults. In the context of the case company, the need for expanding the scope of lean improvements beyond the shop floor becomes crucial.

Based on the theoretical considerations as well as the analysis of empirical data, the following framework was proposed. Figure 6 demonstrates the proposed framework which is an attempt to summarize the theory and empirical research towards combining the concepts of production ramp-up and lean.



*Figure 6- The framework for lean improvements for production ramp-up*

The process of production ramp-up is a stage characterized by the increased amount of defects which, in turn, lead to increased rework that further delays. Faults can be solved by two types of actions- corrective and immediate. Lean improvements, both immediate aimed at elimination of waste, as well as the long-term such as working closely with lean suppliers, can help companies to break the “vicious circle” of waste and rework that slows down the production ramp-up process. The main performance measurements utilized in the research presented in this paper were average duration of fixing and closing the delays. Due to constraints in data availability conclusions had to be drawn based solely on those measures.

### **Conclusions, limitations and further research**

The empirical data on the faults affecting the production ramp-up proved to be an important input for analysing the manufacturing ramp-up process. The research presented in this paper is focused in particular on examining the ramp-up process from the perspective of the lean initiatives undertaken by the case company.

The diminishing number of faults as well as the decreasing times required for problem solving lead to a conclusion that the company is following the idea behind the learning curve. However, the question whether the lean improvements undertaken by the case company have contributed to the quicker and more effective ramp-up still remains open. The research presented in this paper supports the claim that lean initiatives need to reach beyond the shop floor of a single company. This is particularly valid in the case of the studied company that heavily relies on suppliers. Moreover, the case company has not been able to truly evaluate the undertaken lean initiatives. Therefore, it might be suspected that the top management’s reluctance towards expanding the scope of lean is caused by the inability to see the benefits of the undertaken lean initiatives. This paper might be perceived as an attempt to address the potential benefits of implementing lean in the specific case of high variability and low volume production, which usually is not considered as an ideal environment for lean.

Further research into the manufacturing ramp-up would be needed in order to increase validity of the findings presented in this paper. Due to the constraints in data access only one instance of production ramp-up was studied in this paper. Nevertheless, the findings presented might serve as a starting point to the further research in the subject.

From the perspective of managerial implications it can be stated that the company still needs to improve its production ramp-up as the number of faults as well as the time required for solving the problems is significant even though a trend towards decrease can be observed. Further improvements in terms of eliminating rework would have to be considered. More importantly, the diffusion of lean suppliers aimed at standardized procedures.

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**Lean Application to Manufacturing Ramp-Up: A Conceptual Approach**

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# Lean Application to Manufacturing Ramp-Up: A Conceptual Approach

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*This article provides a theoretical overview of the concepts of lean and manufacturing ramp-up in an attempt to conceptualize the strategic areas in which lean philosophy and principles can be applied for continuous improvements. The application of lean principles during the final stage of a new product development process, that is, the ramp-up process, is a critical, early enabler of lean manufacturing.*

*The manufacturing strategy literature conceptualizes a state of "leanness in operations," which can consolidate both the concepts of lean and manufacturing ramp-up, providing a dual perspective. Abstracting from the extant literature, the authors considered the competitiveness of manufacturing companies from two principal perspectives: the leanness of the ramp-up process and the new-value creation of quality managers. While much of the literature fails to acknowledge that the roots of lean actually lie in quality evolution and TQM, there is relatively sparse evidence on the subject of applying the lean philosophy to manufacturing ramp-up, so this study is an attempt to address this gap. This is achieved by providing a comprehensive outline of the two concepts and illustrating the areas in which mutual benefits can be drawn, as well as providing a conceptual framework for future studies in lean application to the manufacturing ramp-up process.*

*Key words: conceptual framework, lean, manufacturing ramp-up*

## INTRODUCTION

The increasing complexity of manufacturing environments and the pressure to deliver new products faster while continuously improving quality requires manufacturing organizations to frequently rethink their operations. Further, quality management practices contribute to operational and financial performance, allowing a firm to achieve a competitive advantage (Kaynak 2003; Lagrosen and Lagrosen 2005).

This article addresses how to include the application of lean, which is traditionally associated with stable, low variability, and high-volume production, to the process of ramping up production. It examines how lean assists during the transition phase from product development to mature manufacturing. The two concepts of lean and ramp-up are generally associated with dissimilar environments. Lean is seen as particularly applicable to high-volume and low-variability manufacturing, while the ramp-up phase is characterized by its short-term focus, unpredictability, and high complexity. Product developers responsible for the final stages of pilot- and ramp-up production need to constantly develop their process. Process development is typically tracked as reduced cycle times and reduced time buffers before reaching full-scale production. The success of these process development activities is measured according to predefined cost and quality requirements.

Taking the two concepts of lean and manufacturing ramp-up, the authors' framework centers on an appreciation of the intersubjectivity of embedded knowledge. It views quality management as a medium-level outcome, and time efficiency as a strategy-level outcome. This then is translated into the company's



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competitiveness. This perspective is broadly influenced by the work of Ferdows and De Meyer (1990); Flynn, Schroeder, and Flynn (1999); Roth and Miller (1990); and Rosenzweig and Easton (2010). The emphasis is on strategic decisions, whereby through structural, infrastructural, and integrative choices, ramp-up managers and manufacturers can acquire and maintain competitive capabilities.

The article is organized into four sections. The following section provides a theoretical overview of references in the context of manufacturing ramp-up and lean. Following that is a section about lean application areas during the ramp-up, with a particular focus on knowledge and quality management as enablers for lean implementation and thereby ramp-up time reduction. The final section concludes with a conceptual framework and implications for quality managers.

### THE CHALLENGING PHASE OF MANUFACTURING RAMP-UP

The earliest scholarly representation of ramp-up is at the new product level, that is, the launching of production. It begins when the process is scaled up from zero and ends at full-volume production. This agrees with Langowitz's classification of the initial commercial manufacture of a product (Langowitz 1988). Table 1 presents a chronological overview of the most important definitions of a ramp-up process.

These characteristics of manufacturing ramp-up are furthermore outlined by Fleischer, Spath, and Lanza (2003); Scholz-Reiter et al. (2007); and Surbier, Alpan, and Blanco (2014), suggesting that initially managers have a low level of knowledge about the product and processes. Then through a challenging and gradual learning process at low production output with high cycle time and low production capacities, they move to high-volume process, with supply chain and product quality, as well as planning reliability.

These characteristics are due to multiple causes, including insufficient product specifications and continuous product changes, which stem from late engineering changes and lack of product maturity. Technical processes such as long setups, unexpected bottlenecks, product manufacturability, and end-product quality, which may result in rework or scrap, are also complications (Surbier, Alpan, and Blanco 2014). Due to these characteristics, it is extremely difficult to systematize, control, and standardize the ramp-up process. This creates challenges for quality and lean managers in achieving continuous improvement. While there are multiple causes for the lengthy cycle times during ramp-up production, this article focuses on two of these: quality management and lead time.

### THE CONTEXT OF LEAN

The term "lean" originated in the Massachusetts Institute of Technology (MIT) study of Toyota

**Table 1** The chronological overview of the ramp up definitions.

Reference	Definition
Gustmann, Retschlag, and Wolff (1989)	The integration of innovation and industrial production
Wheelwright and Clark (1992)	"In ramp-up the firm starts commercial production at a relatively low level of volume; as the organization develops confidence in its (and its suppliers') abilities to execute production consistently and marketing's abilities to sell the product, the volume increases. At the conclusion of the ramp-up phase, the production system has achieved its target levels of volume, cost, and quality."
Almgren (1999)	During the production ramp-up, predefined indicators of cost and quality indicators are achieved.
Terwiesch and Bohn (2001)	The period following the product development phase during which a manufacturing process makes its transition from zero to full-scale production at targeted levels of cost and quality.
Romberg and Haas (2005)	Starts at the same time as the initiation of new product development; the reason is that the planning must take place before the actual execution.
Schuh, Stölzle, and Straube (2008)	The time span of the product creation of a firm. Ramp-up begins after product development with a first production run during which the product is manufactured on zero-series machinery and ends when full-scale production is reached.

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Production Systems. The system described there has been implemented by many major organizations around the world with the intention of reducing costs and improving responsiveness to customer demands. However, Bhamu and Sangwan (2014) point out that lean in different companies varies from a set of tools to an overall change of the organizational mindset. This variance may be due to an evolution in managers' perceptions and understanding of lean from seeing it simply as a means of eliminating manufacturing waste, toward viewing it as a more complex, enterprise-wide method of operating that can incorporate the entire supply chain.

The many definitions of lean indicate that over the years the understanding of the concept has become somewhat blurred. Modig and Åhlström (2012) attempt to provide a universally applicable definition of lean, hence distinguishing between two dissimilar approaches—resource efficiency and flow efficiency—and addressing the challenge of combining them. They suggest that a company's ability to combine these concepts is an opportunity for development and building a competitive advantage. Organizations should aim at the most beneficial combination of resource efficiency and flow efficiency, which often necessitates pushing performance frontiers further.

Lean exists at two levels, having both strategic and operational dimensions (Hines, Holweg, and Rich 2004). The term "discrete manufacturing" indicates a focus on isolated measures, such as individual improvement projects using the "lean toolbox." The term "continuous," however, suggests a process-oriented perspective, focusing on the continuous efforts, that is, the philosophy of "lean thinking," or the process of "becoming lean" (Karlsson and Åhlström 1996; Stone 2012).

Based on the review of the literature on lean, one can conclude that the concept of lean is universally applicable and extends into supply chains and even networks of enterprises. The conceptual research presented in this article builds upon the previous research conducted in the field of lean. The main assumption is that lean principles can also be applied to manufacturing ramp-up to increase the effectiveness of the process. The remaining sections of this article are devoted to addressing this assumption in more detail.

## LEAN APPLICATION TO MANUFACTURING RAMP-UP

The idea that applying lean thinking and principles to manufacturing ramp-up remains scientifically unexplored, although the application of lean beyond standardized and predictable environments is not particularly new. For example, Bowersox, Stank, and Daugherty (1999) address the lean launch strategy in a new product development process. They describe the lean launch strategy from the perspective of the implementation of response-based logistics. The research provides an important input into the wider field of applying lean in less predictable environments; however, to the best of the authors' knowledge, there is not much research that extends lean into the phase of manufacturing ramp-up (Rymaszewska, Christensen, and Karlsson 2015).

To extend lean, not only must the prior concepts be introduced, but a conceptual framework needs to be developed that gives insight about how manufacturing ramp-up can achieve faster time to market, along with increased volume and revenue.

While this article combines two different levels of abstraction, the overall philosophy and principals of lean and the ramp-up process, the scope is necessarily limited. This article focuses on the aspects of lean that can be easily applied to manufacturing ramp-up, such as waste elimination, moderating variation, and standardization, while also addressing the human factor of operations (employee empowerment), and a broader context of supply chains.

## LEAN MANUFACTURING RAMP-UP TOWARD A CONCEPTUAL FRAMEWORK

Seen in the context of the challenges of the global economy and increasing competitiveness, companies should aim to build their competitive advantage by alternating between trade-offs and pushing their performance frontiers further. There is little evidence that lean tools and techniques such as just in time (JIT), total quality management (TQM), and constraints

## Lean Application to Manufacturing Ramp-Up: A Conceptual Approach

**Table 2** The framework for applying lean to manufacturing ramp-up.

	Issues in manufacturing ramp-up	Lean implementation guidelines
<b>Quality</b>	An important determinant of a product's "market readiness." The desired level of quality should be reached in the shortest possible time. Simultaneously, the drive toward introducing a product fast often compromises the quality.	Promote a sense of continuous improvement among the production employees and encourage them to actively propose different types of experiments to reduce variations in the production process, which may cause deviation in product performance.
<b>Time</b>	Accelerating the speed of work to shorten cycle time and reduce time buffers during the ramp-up process increases the likelihood of human error and equipment failure.	Achieving the same or better results in less time lies at the core of lean thinking. Eliminate wasteful activities and focus on creating and delivering value to customers.
<b>Communication</b>	Lack of communication is one of the central reasons for the failure of manufacturing ramp-up.	Standardize communication and information flow with the help of lean techniques such as Obeya meetings, together with flattening the organizational structure and overcoming barriers in communication.
<b>Supply chains</b>	Successful application of lean to manufacturing ramp-up might in certain cases be dependent upon how a supply chain performs as a whole.	Lean tools implementation to manufacturing ramp-up results in supply chain members' awareness of their roles. Hence, before any actions are undertaken, managers need to ensure that the leanness spreads throughout a complete supply chain.
<b>Responsibility, empowerment, training</b>	The effective ramp-up can be achieved by assigning responsibility for certain actions, which helps improve the speed of the decision-making process.	Lean implementation happens at the shop floor; empowerment of the line workers is achieved through training and assigning clear responsibility.
<b>Product specifications</b>	Detailed and well-circulated product specifications might contribute to eliminating problems caused by unclear instructions.	Using standardized documents for product specifications and work instructions. The learning process should be embedded for continuous improvement and steady elimination of variability.
<b>Bottlenecks</b>	Process bottlenecks negatively impact the effectiveness of the ramp-up performance and, at the same time, are difficult to predict.	Lean aims at the elimination of bottlenecks and ensures swift and even flow as well as resource efficiency. This is achieved by systematic identification of wasteful activities and eliminating them.

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management have been applied to manufacturing ramp-up. This article addresses this issue from the theoretical perspective and lays the foundation for the practical application of the combined perspectives.

Table 2 presents the relevant areas where the lean tools and techniques can be applied to the manufacturing ramp-up process. The description provided within the "issues in manufacturing ramp-up" column is focused on explaining the importance of the chosen category to answer the question "Why?". The "lean implementation guidelines" column explains how the application of lean tools to manufacturing ramp-up could be perceived.

The proposed framework summarized in Table 2 is based on the existing literature (Rymaszewska, Christensen, and Karlsson 2015). In order to enhance the practical applicability of the proposed conceptual framework, a checklist of the issues to be addressed

while considering the application of lean to manufacturing ramp-up is proposed in the appendix.

Several enablers of lean application to the ramp-up process exist; however, the following section addresses two of those enablers, namely knowledge and quality management.

### Quality Management Value Creation

Strong ties between lean and quality imply that the application of lean tools and techniques to production ramp-up has implications for quality management. Failure to address the quality issues before full-scale production might result in ramp-up being an extended series of fire-fighting events. Early adoption of quality management tools might not only contribute to ensuring the efficiency of ramp-up but also provide

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considerable potential in the process of creating value to customer and companies. Customer value creation stems from the ability to understand the customer's perception of value, which often is perceived as a physical product or service offered ahead of the competitor. These attributes are directly related to the growth, cash flow, and profitability of the organization. Products that reach quality targets in considerably shorter time contribute to value creation within companies by ensuring that the ramp-up phase is executed swiftly, and by early detection and elimination of quality-related bottlenecks.

### Time Factor and Learning Curves

Time is a crucial factor and a lens through which a successful lean implementation and effective manufacturing ramp-up can be defined. This is especially true in today's highly competitive and complex business environment, where the pressure for seamless and frequent new product introductions is particularly strong. Time is a competitiveness factor that determines the success of manufacturing ramp-up. Combined with the short-term focused, unpredictable, and fuzzy nature of the ramp-up process, the ramp-up process needs to be revised to increase its effectiveness. The conceptual research presented in this article proposes the application of lean thinking and principles to the manufacturing ramp-up process. Terwiesch and Bohn (2001) outline the following time-related elements through which the success of a ramp-up process can be defined:

- Time-to-volume (time to reach full production volume)
- Time-to-market (time needed for the development of a new product, while achieving the desired quality level can be seen as a prerequisite of a "market-ready" product)
- Time-to-payback (time needed for reaching the initial financial goals)

Time is also an important characteristic in the case of lean. There is a plethora of definitions of lean, however, the importance of time can be observed from the

best known time-saving techniques such as JIT delivery, and single-minute exchange of die (SMED). Lean principals also focus on flow and resource efficiency, which, in the simplest terms, translates into ensuring that the customer receives the right product or service, at the right time, and with the right quality.

Decreasing the time required for reaching the planned volumes is closely connected to the learning processes. Terwiesch and Xu (2004) define learning as a "firm's accumulation of knowledge and its movement along a certain trajectory, called the learning curve." In another study, Terwiesch and Bohn (2001) similarly note that production ramp-up of "poorly understood" processes can be accelerated by putting in place approaches for "deliberate learning through ... controlled experiments using the production process as laboratory." The origins of the learning curve date back to the airframe industry and the famous publication by Wright (1936), who on a generic level observed the decrease in the cumulative time or cost per unit with the cumulative number of units produced. Therefore, the general assumption behind the C-shaped learning curve is that the time required to perform a task decreases as a worker gains experience, which implies that the time or cost of performing a task decreases at a constant rate as a cumulative output doubles.

The learning curve can also be expressed as an S-shaped curve, where the y-axis (vertical) expresses the number of products manufactured correctly (free of faults), which increases with the number of units produced (x-axis, horizontal) (Plaza, Ngwenyama, and Rohlf 2010; Jaber and Bonney 2011). Moreover, the learning process can be divided into three generic phases that differ in their steepness, which is a matter of expressing the speed of the process. In the initial phase (prototyping) the number of correct products increases relatively slowly compared to the next stage (zero series) where certain experience has been gathered and, therefore, the number of correctly manufactured units can rapidly increase. The zero series stage is where the learning process proceeds at the greatest rate, which is a consequence of extensive testing and improving. Both prototyping and zero-series production incur costs for companies; those are

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## Lean Application to Manufacturing Ramp-Up: A Conceptual Approach

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necessary steps that can be treated as an investment in the learning process. In the case of Volvo, the zero-series cars are driven by engineers and managers for testing and experimenting, and they are scrapped afterward, thus never getting commercialized, even if no nonconformities are detected (Almgren 2000). This is an example of deliberate learning.

The theory of organizational learning can be perceived as the foundation of the idea of the learning curve. From the perspective of reducing costs, organizations should aim at shortening the time needed for turning new challenging tasks into those performed routinely (Zangwill and Kantor 1998; Plaza, Ngwenyama, and Rohlf 2010; Karlsson 1989).

Almgren (1999) provides a useful understanding of the issue of learning curves and time required for learning processes. According to the author, an organizational learning curve represents learning from experience as well as the benefits from moving from unknown processes to more routine processes. Experience is measured in terms of cumulative production volume or calendar time.

According to Abernathy and Wayne (1974), a learning curve exists when costs are reduced as product volume increases. The authors claim that increasing a company's product volume and market share will additionally bring cost advantages over the competition. However, organizational learning is necessary for a permanent modification in the process to achieve quality, which is referred to as quality learning (Kanji 1996).

Learning will occur at different rates and, therefore, this phenomenon is largely organization specific. Argote and Epple (1990) refer to factors such as organizational forgetting, as well as turnover and transfer of productivity gains in particular. The authors emphasize that a lack of knowledge transfer might severely affect organizational learning, particularly when there are no standard procedures available, and when it is not possible to train employees in a short time. Fioretti (2006) claims that in some cases organizational learning might not occur at all. This is supported by a recent study showing that on one hand, the actors within the organization want to protect their competitive knowledge during the cooperation within the network; however, on the other hand, the distribution

of knowledge must be ensured within the network to develop potentials for value co-creation. This has been shown to have a direct impact on increasing competitive restraints; shortened ramp-up phases, product life cycles, and innovation cycles; and augmentation of product lines in manufacturing (Krenz et al. 2015).

## Conceptual Model

The conceptual framework offers a basis for future researchers to examine different problem-solving strategies in detail. This framework also provides a possible means of integrating lean practices into infrastructural strategic choices that are identified in the ramp-up and quality management literature. In addition, the authors' framework provides a means of organizing research to solve problems within the field of ramp-up process management.

The proposed conceptual framework is then extended with an application checklist intended to be useful for quality management practitioners. The proposed checklist specifically addresses the strategic choices to be considered in the case of lean implementation during manufacturing ramp-up. The checklist has been validated by three independent senior operations managers from the electronic and pharmaceutical industries to ensure its practical applicability (see Figure 1).

## CONCLUSIONS AND LIMITATIONS

This conceptual research article acknowledges the importance of the manufacturing ramp-up phase and seeks to propose a novel approach to improving the efficiency of the process, based on applying the lean philosophy and its principles to manufacturing ramp-up.

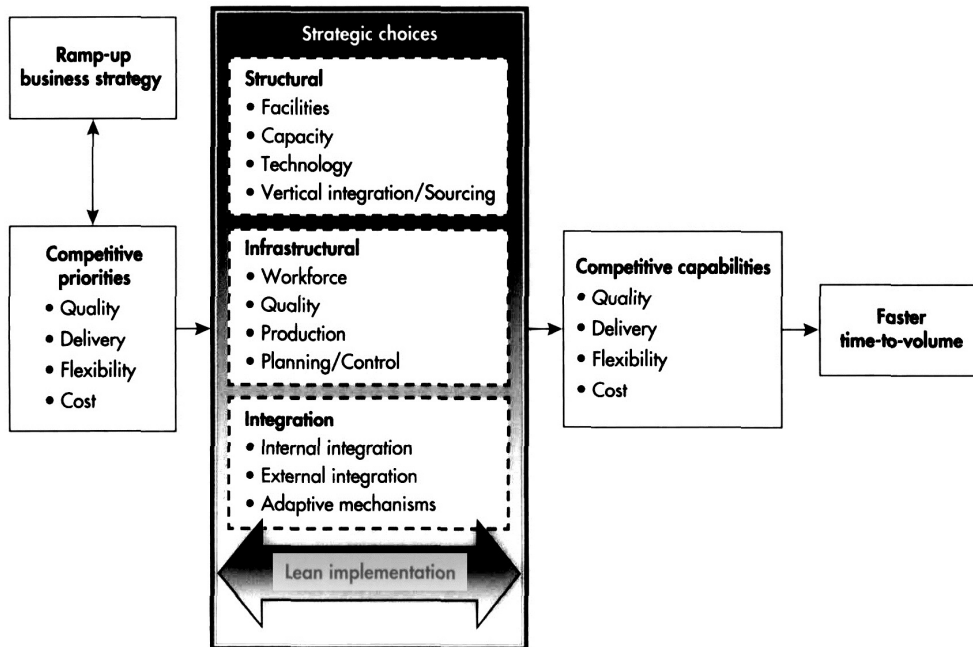
This article is expected to support the stream of research that assumes a development of lean that reflects the changes in the economic environment such as the growing complexity of operations and pressure for faster product introductions. The article systematizes the existing theoretical knowledge and, by synthesizing and combining it, the conceptual framework for applying lean philosophy to manufacturing

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**Figure 1** A holistic view of ramp up manufacturing strategy: Conceptual model of lean implementation.



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ramp-up. It is expected that the research presented in this article will lay the foundations for further examination of the so far sparsely researched topic of lean application to manufacturing ramp-up.

A focused literature review both in the field of lean and manufacturing ramp-up is provided, and critical research gaps are identified. This research is focused on providing an overview of the state-of-the-art, highlighting the scarce evidence of lean principles being applied to manufacturing ramp-up processes. The application of lean ideas to manufacturing ramp-up is a potentially promising approach, since it offers extending the scope of lean and addresses the important opportunity to improve the manufacturing ramp-up process, especially in terms of quality and time. Nevertheless, certain obstacles to the applicability of lean to manufacturing ramp-up need to be acknowledged. For instance, the greatest challenge to becoming a lean organization is variation. Here the authors focus on the need to eliminate, reduce, and manage variation to become lean. Otherwise, achieving both flow and resource efficiency will not be possible. On the other hand,

the inherent characteristic of the ramp-up process is volume increase and standardization of production methods, which are usually very new to an organization and very difficult to predict; therefore, planning ahead for success is limited. However, organizations might take certain measures and tools to moderate the effects of scaling up, starting from lean-related demand smoothing (heijunka), and evolving toward effective organizational learning.

This conceptual research provides a framework for exploring and readdressing the importance of the time factor. The time factor has been discussed in the context of being a determinant of a successful manufacturing ramp-up, as well as the aim of lean philosophy to achieve the same or better results in less time. However, time is also crucial for the idea of learning curves, which are frequently mentioned in the context of manufacturing ramp-up.

The framework focuses on improving the manufacturing ramp-up process by highlighting the areas where mutual benefits can be drawn. Moreover, the areas where the application of lean principles is

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## Lean Application to Manufacturing Ramp-Up: A Conceptual Approach

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challenging are also acknowledged and addressed from the broader perspective of variability and learning curves. The contribution of this article can be described in terms of building a deeper understanding of the concepts of both lean and manufacturing ramp-up. By bringing these ideas closer on a conceptual level, a foundation for further empirical research is provided.

### FURTHER RESEARCH

The following directions for further research are proposed. First, additional research into ramp-up factors where lean principles are challenging to apply is needed to explore the matter on the conceptual level. Second, the proposed research opportunities in the subthemes of discrete and continuous manufacturing could be empirically validated. Research in the industrial setting could contribute to manufacturing firms, when applying the principles and tools of lean and Six Sigma, thus offering an excellent way to improve the productivity and quality of the firm.

### Implication for Quality Managers

Lean applications focus on efficiency and aim at offering products and services at the lowest cost and as fast as possible. This information can be used to develop targeted interventions to improve the lean ramp-up process; this could start at the senior management level and could be operationalized within the various departments across the organization to improve flow and efficiency of the ramp-up processes. As an application, lean brings a set of tools and techniques to reduce lead times, inventories, set-up times, equipment downtime, scrap, rework, and other wastes in the pilot and ramp-up factory. Continued efforts are needed to make the application of lean in the ramp-up process more accessible, because it has the potential to incorporate leadership, customer focus, process capability, and process management to achieve process improvement. Often companies fail to integrate lean within their process and quality improvement initiatives and, therefore, such companies never achieve the breakthrough results they desire.

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### BIOGRAPHIES

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## APPENDIX

### Variables of ramp-up strategic choices to make (= measures)

#### Competitive priorities

**Quality:** capability of doing things right

**Dependability:** capability of doing things on time/when promised

**Speed:** capability of doing things fast; short cycle and lead times

**Flexibility:** capability of changing what is done: volumes, product mix, or to new products or services

**Cost:** capability of producing goods and services at relatively low costs

#### Competitive capabilities

**Qualifiers:** capability of being considered for tender

**Order winners:** capabilities that make buyers choose or have preference for product or service

**Orders:** capabilities of reaching deals

#### Integration factors

**Industry:** structure, technologies, development

**Suppliers:** structure, bargaining power

**Customers:** structure, bargaining power

**Rivalry:** numbers, sizes, development

**Size:** actual volumes, relative size

**Resources:** physical, human, externally available

**Technologies:** areas, levels, closeness to front, externally available

**Dynamic capabilities:** capabilities of developing and changing the above factors

#### Ramp-up strategies

**Competitive role:** not doing wrong, best practice, lean implementation, strategic factor, advantage

**Objectives priority:** trade-off choices in quality, dependability, speed, flexibility, and cost

**Processes:** workshop, batch, mass, flow

**Resources:** plant, equipment, staff

**Organization:** forms and managerial processes

**Systems:** capacity and process planning, quality control, maintenance

**Improvement:** rationalization, continuous improvement programs

# Executive Briefs

**Improving Production Ramp-Up Through Human Resource Methods** (pp. 7–19). Ina Heine, Aachen University; Patrick Beaujean, Aachen University; and Robert Schmitt, Aachen University

The performance of an organization in the ramp-up phase of manufacturing strongly impacts the quality of the serial production, contributing to important manufacturing performance measures that are relevant to both production and quality managers. Performance improvements in production ramp-up, however, are difficult to achieve, as there are numerous challenges to overcome due to unpredictable system behavior.

In order to improve the stability of production ramp-up, the authors of this article propose applying human resource (HR) methods. Based on theory and well-known concepts in the field, they developed a framework of HR methods for ramp-up management. These six methods include knowledge management, competency modeling, reward systems, leadership development, employee selection, and team development. This framework provides quality managers with methods for improving quality-related outcomes that are less technical and more human centered.

While the practical implications of these HR methods are not clear

since empirical research is limited, the authors expect that the result of applying the proposed framework is project teams meeting their ramp-up targets more probably. In the long term, they expect an increase in serial production stability.

**A Framework to Identify Best Quality Management Practices and Techniques for Diverse Production Ramp-Up Environments: Propositions for Future Research** (pp. 20–44). Zachary Moran Leffakis, Clemson University

There is great strategic and financial incentive for manufacturing firms to decrease their new product time-to-market and time-to-volume, as being the first to introduce new products to the market brings a firm a unique leadership sales position that enhances a firm's potential to sell at higher prices and volumes. This, in turn, results in greater market share, a competitive advantage, and greater profitability.

Over the years there has been much research regarding methods and approaches for decreasing new product development time. A rather new area of research is that of ramp-up management. Researchers are beginning to explore how the myriad relationship of competitive variables and operational factors can have an impact on the cost,

quality, and timeliness in the production ramp-up phase. This article aims to develop a framework to categorize four different types of production ramp-up environments across various manufacturing settings. The research framework seeks to identify the best quality management practices manufacturers can apply to prevent production ramp-up disturbances and improve yield rate performance. It is argued that each environment exhibits different levels of uncertainty, complexity, and operational characteristics, requiring a unique strategy with an exclusive set of quality management practices and techniques to improve production ramp-up performance.

**Lean Applications to Manufacturing Ramp-Up: A Conceptual Approach** (pp. 45–54). Irene Christensen, Copenhagen Business School, and Anna Rymaszewska, University of Vaasa

The two concepts of lean and ramp-up are generally associated with dissimilar environments, as lean is viewed as applicable to high-volume, low-variability manufacturing, while the ramp-up phase is noted for its short-term focus, unpredictability, and complexity. This paper attempts to suggest the benefit of applying lean principles during the final stage of the new product

## Briefs

development process—the ramp-up phase—as a critical, early enabler of lean manufacturing.

There is little research on the subject of applying the lean philosophy to manufacturing ramp-up, and in this article the authors aim to address this gap. They provide a comprehensive outline of the two concepts and illustrate areas in which mutual benefits can be drawn. Their research provides a framework for exploring and readdressing the importance of the time factor, which is often discussed as a determining factor in the success of manufacturing ramp-up, as well as the aim of the lean philosophy to achieve the same or better results in less time.

### **A Game-Based Approach to Raise Quality Awareness in Ramp-Up Processes** (pp. 55–69).

Philipp Brauner, Ralf Philippen, Antonia Fels, Marco Fuhrmann, Quoc Hao Ngo, Sebastian Stiller, Robert Schmitt, and Martina Ziefle, RWTH Aachen University

Shorter lead times, a growing number of product variants, and global supply chains are some of the reasons production planning is becoming increasingly difficult for firms, both on the technical level and on the human level. Production systems are highly volatile and uncertain, and human decision makers need to be properly trained for the ramp-up phase of production. To effectively understand how human and technical factors relate to ramp-up processes, an experiential framework is necessary.

This article proposes the use of a business simulation game to serve as such a framework. It is suitable for training managers before

the ramp-up process. It can be used to qualify ramp-up managers and decision makers for complex situations by enhancing their decision-making skills and improving their quality awareness during the ramp-up process. The simulation game the authors developed uses quality management principles to simulate humans' decision making during ramp-up and the associated effects on process and product quality.

To evaluate the efficacy of the business simulation game to convey the needed knowledge, the authors conducted an empirical user study and investigated the influence of the game intervention on several objective and subjective metrics. Results show a positive relationship between the game and all of these metrics, thus suggesting a benefit in the use of the game-based approach.

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## Development perspectives on improved environmental performance through lean philosophy

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**Abstract:** The aim of this paper is to examine the connections between lean and sustainable operations, with the focus on the environmental aspect of sustainability. All those aspects are presented in the supply chain context, as well as the process of value creation and delivering it to the end customer. The research contributes to the important challenge of expanding the applicability of lean, as well as supporting the claim that lean philosophy is valid even in today's rapidly changing economy, where pressure for improved environmental performance is increasing. Research contributions comprise of the development of knowledge in the field of lean by systematising the existing literature, outlining the areas of convergence, proposing a conceptual framework as well as suggesting future research directions. This study is conceptual in its nature.

**Keywords:** lean; green; value; supply chain; conceptual framework; literature review; environment; sustainability.

**Reference** to this paper should be made as follows: Rymaszewska, A. (xxxx) 'Development perspectives on improved environmental performance through lean philosophy', *Int. J. Sustainable Economy*, Vol. X, No. Y, pp.xxx-xxx.

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This paper is a revised and expanded version of a paper entitled 'The future of lean – a review of contemporary research perspectives' presented at International Conference on Innovation and Management ICIM 2014, Vaasa, 17–19 November 2014.

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### 1 Introduction

In today's rapidly changing global economy with increasing complexity, the theoretical underpinnings of operations management require constant revision in order to maintain its connection to real-life operations as well as to truly be able to stay on the forefront of creating new and applicable knowledge. The economic development cannot be discussed disregarding the challenges of the negative environmental impact that it causes. Dhingra

et al. (2014) refers to climate change, growing population, increasing poverty and inequality between and within societies as the most important burdens on the environment that need to be addressed. Therefore, the motivation behind the research presented in this paper is not purely theoretical as this paper is also an attempt towards emphasising the importance of rethinking and reconfiguring the concept of lean in the light of current economic and environmental challenges. This article focuses on lean seen in the wider context of greening and sustainability which should be achieved while delivering value to customers. Furthermore, the supply chain context and operations within networks are acknowledged.

The idea of lean thinking has been widely discussed in scientific literature and based on the five principles of lean it can be stated that the concept is universally applicable. Lean thinking is usually associated with the widespread success of Toyota manufacturing and management system and therefore, the development of scientific literature in lean has been mainly focused on large, automotive firms (Zhou, 2012). Furthermore, lean is usually associated with large scale, low variability production where achieving a relatively stable demand is a prerequisite to achieving the so desired flow. The diffusion of lean principles has also been occurring gradually with the widespread of scientific publications in the field. Nevertheless, the scientific literature that would aim at providing a comprehensive and holistic view on lean, rather than analyse the concept in separation, is still somewhat scarce. Therefore, this study is aimed at filling this gap as well as redrawing the attention to the idea of lean which, in the context of growing complexity of operations, might be considered obsolete. This study is an attempt towards revising lean philosophy in the context of the most relevant environmental challenges of operations. The paper summarises the recent developments in the literature concerning sustainable operations and lean philosophy, proposes a conceptual framework for combining these and proposes the directions of further development.

The conceptual nature of this paper implies its greatest utility to scholars and the researchers particularly interested in the aforementioned subjects. Since empirical evidence is not addressed in this paper the practical implications cannot be outlined directly. However, the potential value of the research can be drawn upon the outlined directions for future development as well as the proposed research topics. The proposed theoretical contribution is expected to serve as a background for further empirical research in the field of greening operations by bridging the gaps between those two areas of knowledge.

According to Hajmohammad et al. (2013), there are two separate paths that can be identified, namely the research addressing lean and green issues as well as the parallel stream of research addressing the supply and green issues. The research presented in this paper aims at providing a holistic view of lean in the context of green and sustainable operations as well as the subject of value creation in supply chains. Therefore, the main focus areas of this paper are:

- Combining the growing necessity of being green with lean thinking towards building a revised approach to wasteful activities, taking into consideration that lean and green do not always go hand in hand while acknowledging the sustainability context. Sustainability is seen in terms of respecting the environment as well as ensuring that the transitions are lasting.

- Acknowledging the supply chain context which serves as a frame of reference for operations management – organisations cannot be considered without the broader context of supply chains. As organisations rarely operate disconnected from one another, neither are the dyadic relationships valid in the light of high complexity. Therefore, the network approach is applied

Based on the aforementioned research focus areas, the following research questions were outlined:

- What is the current state of the research of the literature in lean and what are its deficiencies?
- What are the possibilities for developing the current state of the lean research into improved applicability and suitability regarding challenges of the future, how universal and applicable is lean in the light of changing economic landscape?

Changing economic landscape can be described in terms of globalisation which imposes increased competition, but also increases the accessibility of potential suppliers, as well as stricter regulations. The research presented in this paper takes a theoretical stance and proposes a framework for further development of lean. Therefore, the ultimate research objective of this study is to readdress lean thinking in the context of challenges of knowledge creation as well as the challenges of global economy.

The paper is structured as follows: scientific literature on lean in the aforementioned context is presented and conceptual framework is drawn as a summary of literature review. The paper closes with conclusions and directions for the future research.

## **2 Research background and methodology**

The concept of lean has been widely discussed in the scientific literature and lean thinking is usually associated with the success of Toyota and the publication of *The Machine that Changed the World* by Womack and Jones (1996). The success story of Toyota was an impulse for the widespread of the lean principles in the automotive industry in particular. Therefore, the lean approach has been mainly described as applicable in the high volume, low variety environments. With the constantly changing business conditions and growing complexity of operations, the research into lean has been shifting from being manufacturing focused, towards systems thinking and value creation within networks of companies.

Bhamu and Sangwan (2014) provide an overview of lean definitions spanning from year 1988 till 2012. Based on the authors' contribution it can be stated that the development of lean started with emphasising its difference from mass production, through gradually labelling lean as a process, production system or model, common paradigm, multi-dimensional approach, towards defining lean as a philosophy (production and management). However, the definitions of lean gathered and systematised by the authors do not directly address the issues of environmental impact of operations as well as the potential connections or lack thereof between lean and the aforementioned. This suggests that the connection between lean with sustainable, green operations in the context of value creation in supply chains, has not been well established yet.

4 *A. Rymaszewska*

A comprehensive literature review was performed as an essential step to creating a conceptual framework. According to Rowley and Slack (2004), conducting a literature review is particularly important in the cases of identifying the literature to which the research is expected to make a contribution, as well as contextualising the research within that literature.

The context of supply chains and operating within networks was chosen as a frame for reference and the lean philosophy is researched in the context of green and sustainable initiatives as well as revised from the perspective of value creation and delivery to customer, which tends to get more challenging as supply chains extend. The initial search for scientific publications was conducted by utilising major databases such as Emerald Journals, Science Direct (Elsevier), Business Source Premier (EBSCO), SpringerLink, Taylor&Francis Online Journal Library, Wiley Online Library. The keywords search was supported by utilisation of Google Scholar and Publish or Perish software. The selected references were manually checked for its relevance to the subject of this research.

The keywords used for the search process were: 'lean', 'green', 'sustainable', 'supply chain' and 'value' combined into phrases such as green lean, green supply chain, lean value, etc. with the help of Boolean operators ('and', 'or'). In order to avoid the inclusion of unreliable or partially available sources usable reference were limited to full-text, peer-reviewed papers published in scientific journals with focus on operations management. Moreover, in order to narrow the scope of the research, the issue of sustainability was approached from the environmental perspective.

### **3 Comprehensive literature review**

#### *3.1 The development of lean philosophy grounded in theory*

The literature on lean covers a wide range of application areas and this variety, apart from advancing the knowledge creation and sharing, poses a challenge in terms of identifying the prevailing theory. According to Leseure (2010), the Japanese management system challenged the seemingly impossible to avoid cost-quality and flexibility-costs. The Japanese management success that initially emerged in the automotive industry changed the perceptions of tradeoffs as an inevitable condition under which performance can be improved. Lean thinking is also strongly connected to the subject of ensuring the smooth flow of operations which is expected to improve productivity. Therefore, the theory of performance frontiers and the theory of swift and even flow were chosen as the most suitable theoretical reference for this study. Both theories are extensively discussed by Schmenner and Swink (1998). Modig and Åhlström (2012) indirectly refer to the theory performance frontiers.

Modig and Åhlström (2012) ground the discussion on lean in the inherent discrepancy between flow efficiency and resource efficiency. The authors claim that those two concepts are mutually exclusive in nature. Resource efficiency stipulates the use of resources as much as possible, and it has long been the most common way of defining efficiency. Flow efficiency, on the other hand, focuses on the 'unit' processed in an organisation. In case of manufacturing it is a physical product while in services a customer is often the referred 'unit'. The main assumption is that both products and customers flow through organisations and therefore, the aim is to ensure that this occurs fast and seamlessly. Understandably, effective flow does not automatically imply

resource efficiency. Therefore, Modig and Åhlström (2012) aim at defining lean at generic and universal level. The authors define lean as an operation strategy that is ultimately aimed at improving the flow which should also result in improving the resource efficiency. The considerations regarding combining resource and flow efficiency as expressed by Modig and Åhlström (2012) can be further explained in the wider context of the theory of performance frontiers.

Schmenner and Swink (1998) define performance frontier as the maximum performance that can be achieved by a manufacturing unit given a set of operating choices. The authors outline two types of performance frontiers – asset frontier, which is defined as the maximum performance under optimal asset utilisation, and the operations frontier, which represents achievable performance levels under current operations policies. The theory of performance frontiers also states that there are two strategies for reaching the higher performance frontier – improvement and betterment. Improvement strategy means adjusting processes to reach an operations frontier and betterment implies moving the operations towards the asset frontier. The authors claim that in the context of theory of performance frontiers, improvement is associated with removing inefficiencies from the systems, while betterment means moving or changing the shape of operating frontier.

The advent of lean thinking and its successful implementation changed the initial underpinnings of the theory of performance frontiers which were based on various tradeoffs. The success of Toyota proved that high quality and low price do not have to be mutually exclusive. Therefore, it is stated that the implementation of lean can actually help companies to reach new performance frontiers.

Furthermore, Seuring and Muller (2008) claim that the theory of performance frontiers should be revised especially in the context of greening supply chains. The authors claim that the quest of reaching new performance frontiers needs to include both environmental and social dimension. This study supports the claim made by Seuring and Muller (2008) and also emphasises the necessity to consider performance of the whole supply chains rather than individual actors.

Creating and maintaining flow has long been the foundational concept of lean, and named as one of the five main principles of lean (Womack and Jones, 1996). The idea of flow has been even discussed in the context of theory.

Schmenner and Swink (1998) propose a theory of swift and even flow that is closely related to lean manufacturing. The theory states that the productivity of a process will increase together with the improved swiftness and evenness of the flow. In other words, the productivity will rise with the speed of flow. On contrary, productivity will fall with rising variability which is associated with the demand fluctuations or with the steps in the process itself. The division of work into value-adding and non-value adding activities lies at the core of the theory of swift and even flow. Furthermore, Schmenner and Swink (1998) claim that material can move swiftly through a process if the wasteful activities are eliminated or greatly reduced.

The theory also assumes that a swift and even flow can only be assured if there are no bottlenecks. Bottlenecks can be identified with the help of the throughput time concept which measures the time lapsed from when materials are first worked on up to the point products are finished and ready to leave the warehouse. Measuring the throughput time facilitates identification of bottlenecks which are disruptive to swift and even flow.



### 3.2 *Value creation in the supply chain context*

Ahi and Searcy (2013) outline the following focal areas of supply chain management, based on the study of available definitions: flow, coordination, stakeholder, relationship, value, efficiency, and performance. This subchapter aims at addressing the value creation process with relation to lean principles.

The importance of value creation and systems thinking is currently being rediscovered and readdressed. The creation of value drawn from customer requirements is one of the basic, yet often overlooked, principles of lean thinking. Lean approach defines value as drawn from the final customer and, in simple terms, it represents what customer is willing to pay for (Hines et al., 2004).

Holweg and Pil (2005) justify the importance of considering lean and value creation in the supply chain context. The authors highlight the devastating consequences of disconnecting customers from the value chain, as well as the pitfalls of failing to diffuse lean principles within the whole supply chain.

This study postulates the focus on value creation and its delivery to customers' needs to be considered in the broader context of supply chains. According to Cox (1999), successful business operations will stem from maximising the total performance of supply chains rather than individual organisations. Therefore, in order to better fulfil customer needs, which translates into being more profitable, the focus should be put on building effective and responsible supply chains. Furthermore, Cox (1999) also states that companies are no longer competing against one another but the competition rather takes place between supply chains.

In the context of the claims stated by Cox (1999) the development of scientific knowledge in lean should acknowledge the supply chain context, and so is the aim of this study.

The main assumption underlying the concept of lean supply is that the flow from raw materials to final consumers should be treated as an integrated whole ultimately aimed at gradual value adding throughout various stages of the process. Such an approach recognises that also defects and costs that they incur span beyond the source (Cox, 1999).

According to Lamming (1996), the value adding process that lean thinking implies the total view of the process from raw material to final consumer and possibly even beyond. The lean supply also implies that the costs of delivering less than perfect value to customer are not necessarily bound to its source. Therefore, value creation should be seen as mutual undertaking of all the actors within supply chains. According to Wee and Wu (2009), lean supply chain seeks to identify all kinds of waste in the value stream and eliminate them. Waste identification and elimination is expected to result in extraction of value-adding activities and therefore, eradication of costs incurred by the delivery of less than perfect value to customers.

Martinez-Jurado and Moyano-Fuentes (2014) refer to the process of applying lean management principles to supply chain management which is known as lean supply chain management (LSCM). The authors claim that application of lean principles to supply chain management is crucial to achieving environmental sustainability across supply chains and this occurs through close and long-term relationships that enable the adoption of environmental practices, collaboration from the very first stages of the design process might result in products that are less burdening on the environment, and this holds true throughout their entire lifecycles. Martinez-Jurado and Moyano-Fuentes (2014), based on their literature review, also emphasise that the adoption of lean principles downstream

has not yet been sufficiently addressed. In other words, the evidence of lean adoption is more visible upstream, on the level of, e.g., manufacturing operations, while the closer to end customer, the more challenging the implementation of lean appears. This finding is particularly important also in the context of value creation and its delivery to the final customer.

When considering the value creation processes within complete value chains it is important to address the green value stream (GVS) as an important tool for the identification of the seven sources of waste. According to Marimin et al. (2014), GVS differs from the traditional in the way they define waste. GVS defines wasteful activities in terms of excessive use of energy, water, material waste, transport, emissions, and damage to biodiversity (Wills, 2009). Therefore, the value creation process should not only be perceived from the perspective of the efforts of all members of supply chain, but also from the perspective of waste elimination.

Table 1 summarises chronologically the most important publications that address the subject of value creation in the supply chain context.

**Table 1** The crucial references on value creation in the supply chain context

<i>Reference</i>	<i>Contribution/findings</i>
Lamming (1996)	Value creation should be seen as a mutual undertaking of all actors within a supply chain.
Cox (1999)	Value creation occurs within supply chains, competition occurs between supply chains rather than between individual organisations, in lean supply value adding should occur on every stage of the process.
Hines et al. (2004)	Value is drawn from the final customers and it represents what they are willing to pay for.
Holweg and Pil (2005)	Identification of the necessity to consider lean in the supply chain context.
Wee and Wu (2009)	Lean supply chain seeks to identify all kinds of waste and eliminate them which results in the extraction of value-adding activities.
Wills (2009)	Value creation addressed through the lens of green value stream (GVS). The definition of waste is different as compared to the traditional value stream mapping (VSM).
Govindan et al. (2014)	Addressing all three aspects (environmental, social and economic) of sustainability while value creation not addressed.
Martinez-Jurado and Moyano-Fuentes (2014)	In the context of lean supply chain management it is important to address the implementation of lean in the processes closer to the final customer (downstream). This is also important in the context of value creation and its delivery to the final customer.

### 3.3 *Lean, green and sustainability*

The environmental aspects such as move towards more green and sustainable operations have also become a crucial aspect to be addressed while discussing operations management and lean adoption.

Handfield et al. (1997) were among the first authors to address the necessity to rethink the link between value chain activities and company's environmental footprint.

The authors refer to the decisions regarding purchasing, operations management as well as distribution and logistics management in particular since they ultimately translate into the amount of waste that is generated.

The common approach to defining sustainability is the division into its social, economic and environmental aspects. In order to narrow the scope of the research presented in this paper the main focus is on the environmental aspects in particular, as the greening of operations is one of the three pillars of sustainability. According to Johansson and Sundin (2014), the concepts of lean and green have been developing independently from each other. Dues et al. (2013) provide a coherent classification of lean and green initiatives and focus on both the areas of synergy as well as on the areas where lean and green cannot be combined.

Hajmohammad et al. (2013) claim that the pursuit of waste elimination, inherent to lean, should translate into improved environmental performance. Nevertheless, the authors also state that the empirical research into the matter produced somewhat mixed results. In other words, the clear empirical evidence that proves that lean equals green is missing. Instead, it is safer to state that lean and green operations still imply certain tradeoffs.

The important issue to be addressed is whether lean, seen in the context of leading to superior manufacturing performance, also translates into the improved environmental performance. This research objective was addressed by Rothenberg et al. (2001) and King and Lenox (2001).

Lean thinking is strongly grounded in the identification of waste and according to King and Lenox (2001) the adoption of lean principles might lead to the improved environmental performance. The proponents of the 'lean equals green' approach will argue that the elimination of waste will ultimately lead to decreasing emission of pollution and toxins. However, certain assumptions of lean philosophy, such as manufacturing of small batches or just-in-time deliveries, are difficult or even impossible to marry with the idea of the improved environmental performance. Nevertheless, according to King and Lenox (2001) the adoption of lean might ultimately support organisations in the process of becoming green by the gradual spillovers of lean from e.g. manufacturing into environmental performance of organisations. The spillover of lean might start from acknowledging that less waste at the source will result in reduced need for end of pipe treatment.

There is another stream of research that takes a slightly different stance and supports the reverse relationship namely, the claim that the green practices might help companies become leaner. This led Dues et al. (2013) to a claim that while synergy between lean and green is possible, it is vital to acknowledge that there are areas where those concepts might even work against each other.

The differences in defining waste are probably the most significant discrepancy between the concepts of lean and green. According to Miller et al. (2010), while lean thinking sees waste as the actions that do not create value, increase costs and lead times, the green approach consider waste from the perspective of environmental impact.

Both Rothenberg et al. (2001) and King and Lenox (2001) highlight the necessity to further examine the connection between adoption of lean and the improved environmental performance since there has not been sufficient empirical evidence on the aforementioned. This claim is also supported by Seuring and Muller (2008) who look into the subject of sustainability in the supply chain context. The authors identify several weaknesses in the current state of research namely, the fact that sustainable development

is often reduced to environmental improvements, as well as the insufficient theoretical background.

According to Duarte and Cruz-Machado (2013) the concepts of lean and green share the strong component for process definition since both are aimed at improving processes at the operational level. Waste reduction lies at the core of both concepts even though the definition of waste might be dissimilar.

Seuring and Muller (2008) also state that the relationship between environmental concerns and economic performance still remains unclear and therefore, additional research in this field is needed.

**Table 2** Crucial references regarding the research into lean, green and sustainability

<i>Reference</i>	<i>Contribution/findings</i>
Handfield et al. (1997)	Necessity to rethink the link between value chain activities and environmental footprint.
Klassen (2001)	Increasing evidence that close supplier relationships can also improve environmental performance.
Rothenberg et al. (2001) and King and Lennox (2001)	The need to closer address the issue whether the improved performance thanks to lean also translated to the improved environmental performance. The existing empirical evidence is rather scarce.
King and Lennox (2001)	Adoption of lean might lead to the improved environmental performance.
Seuring and Muller (2008)	Sustainable development is often reduced to environmental improvements. The existing theoretical background is insufficient.
Miller et al. (2010)	Lean and green concepts do not share the same definition of lean.
Dues et al. (2013)	The adoption of green practices might help companies to become lean.
Duarte and Cruz-Machado (2013)	Waste reduction lies at the core of the concepts of both lean and green even though the definitions of waste might be dissimilar.
Kurdve et al. (2014)	Focus on the environmental aspects in manufacturing operations, more narrowed perspective on integrating production system models with environmental management. The issues of quality and safety are also addressed. The supply chain perspective is not addressed
Verrier et al. (2014)	Identification of the research development paths in the field of lean and green. Lack of focus on the entire product lifecycle which is partially compensated by addressing the supply chain context. Identification of the necessity to address lean in the supply chain context. Lack of resources that would be addressing the environmental issues within supply chains. Proposal of green performance measurements
Piercy and Rich (2015)	Empirical evidence of organisations successfully combining lean and sustainability.

The issue of lean is not often discussed in the context of sustainability and therefore, this paper is an attempt to address this deficiency. Sustainability is approached from a wider perspective that encompasses the triple bottom line principle, shifting away from

focusing solely on the environmental aspect and focusing more on the financial and social dimensions. For the purpose of this study, sustainability is also defined as the ability to maintain improvements over time.

Piercy and Rich (2015) address the issue of combining lean and sustainability in the empirical context of manufacturing companies. The authors identify two types of journeys – those that start from sustainability efforts which led to the adoption of lean improvements, and the opposite type of journey which assumes adoption of lean principles which then lead to the transformation into sustainable operations. The empirical evidence as presented by Piercy and Rich (2015) proves the important connection in between the concepts of lean and sustainability as well as proves that the evolution is possible both ways – from leanness to sustainability as well as from sustainability to leanness. Acknowledging the complexity of the change process, regardless of whether lean or sustainability comes first, facilitates understanding the journey-like nature of the aforementioned processes. Smeds (1994) highlights the fact that the results of lean initiatives usually require time to emerge. Bhasin and Burcher (2006) claim that lean failures often stem from the fact that an organisation failed to establish a common mindset which, in turn, can only be achieved with the cultural change. Table 2 presents a chronological summary of the crucial references regarding the research into lean, green and sustainability. Based on the overview of the various references it can be observed that even though there have been various attempts at combining the ideas of lean, green and sustainability, the further exploration of this broader field of knowledge is still missing.

#### *3.4 Transparency and responsibility as requirements for change*

In the context of lean improvements and their diffusion into whole supply chains it is necessary to address the issue of transparency of operations and transformations as well as the responsibility for them. While Piercy and Rich (2015) claim that transparency of information within a firm as well as across firm boundaries underpins sustainability, Lamming (1996) states that transparency is also crucial to successful implementation of lean. Womack et al. (1990) outline standardised work routines as well as clear communication channels to employees, suppliers and customers as the main elements of lean operations where transparency plays an important role. Piercy and Rich (2015) refer to the claims that transparency supports internal governance practices, and reduce waste within the firm's boundaries since only the needed resources are pulled into the firm.

Moreover, in the light of all the aforementioned dimensions, the challenge of assigning responsibility to the members of supply chains needs to be addressed. The issue of responsibility is usually associated with sustainable supply chain management. Seuring and Muller (2008) claim that when organisations are pressured on improving their environmental performance, the pressured is often passed onto suppliers. In other words, the responsibility for the actions is generally avoided and somehow dissolves throughout the supply chain.

Supply chain management acknowledges various elements that construct the supply chain responsibility. Spence and Boutilakis (2009) present the theoretical development from corporate social responsibility (CRS) to supply chain responsibility. The authors claim that the concept of CRS is unilateral which means that it lacks the important element that would acknowledge a focal firm having closer connections to their suppliers

than to any other stakeholders. Spence and Bourlakis (2009) propose a new theoretical framework for supply chain responsibility that comprises of the following elements:

- a complete supply chain committed to achieving social and environmental benefits
- legitimacy of all chain links and the right to voice their concerns
- a partnership approach
- acknowledgement of different approach to ethics by different organisational forms in a supply chain.

The authors emphasise the important requirement of the model, which states that all members have a contribution to make in terms of how the responsibility should be divided. The proposed framework emphasises partnership based on collaboration where each member commits to joint planning within a supply chain.

Moreover, the framework proposed in this study supports the research by Spence and Bourlakis (2009). The main assumptions put forward by the authors draw attention to the necessity of shifting perspective from a focal company to all members of a supply chain.

The proposed framework is expected to contribute to building a broader understanding of the lean concept that is traditionally associated with stable manufacturing environments and limited flexibility of operations. Such mindset might have occurred as a consequence of lean's emergence largely discussed in the context of automotive firms.

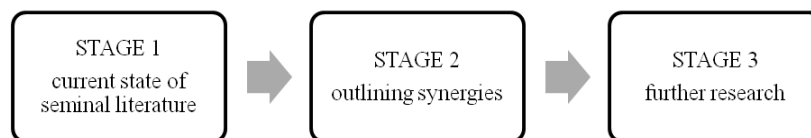
This paper taps into the recent developments of the research into lean that shifted from manufacturing towards all kinds of operations while preserving the cornerstone of lean thinking- elimination of unnecessary activities and all kinds of operational waste.

In order to overcome this kind of limiting mindset, the connections between relevant concepts have been re-examined so as to provide a sound theoretical and conceptual foundation for the future research into the topic of the lean thinking.

#### 4 Towards the conceptual framework

The proposed framework acknowledges the important findings from the literature, and it also aims at outlining the areas of potential synergy. The development of the framework as well as its expected contribution is explained by the three stages presented by the figure 1.

**Figure 1** The overview of the process of developing the conceptual framework

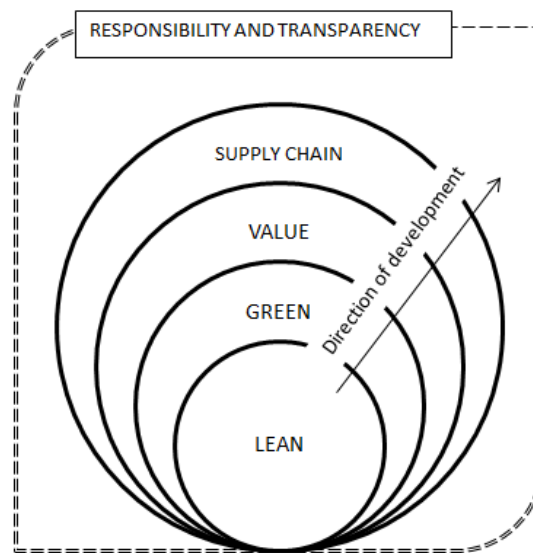


The proposed conceptual framework is a result of the aforementioned stages. Based on the essential references from literature areas of synergy are identified and directions of future development are proposed. The main focus is on exploring the applicability of lean philosophy and initiatives in the specific context of operations that are environmentally

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sound, as well as encompassing wider context of supply chains, and operating within networks. Figure 2 presents the proposed framework.

**Figure 2** The proposed conceptual framework



The main assumption of this study is that in order to be able to address the research objective, the concept of lean philosophy needs to be put in the right perspective. The right perspective is defined by the relevant and current topics such as greening of operations, value creation and delivery to the final customer in the supply chain context. Those areas of knowledge were identified not only as current and relevant to the operations management research but, most importantly, as vital to building an improved understanding of the lean concept.

The proposed framework is aimed at broadening the scope of lean application as well as supporting the claim that lean, as a manufacturing approach as well as management philosophy has not become obsolete, even though the concept in itself is not particularly new. Therefore, lean constitutes the core of the framework, followed by different layers. The different layers are the areas where lean principles should be introduced and developed towards mutual benefit.

The network approach guides the further consideration, and it is expressed by introducing the supply chain context while acknowledging the latest theoretical developments that emphasise the shift from dyads to triads and ultimately networks (Wilhelm, 2011).

The framework can be interpreted from the perspective of different stages that start with lean implementation and evolve towards other dimensions. The framework assumes evolutionary and dynamic nature of changes, and it suggests that the development should start with lean and then move towards green operations which are a necessary element of sustainability. The equivocal relationship between lean and green has been discussed in this paper. Even though Piercy and Rich (2015) quote both types of evolution: from lean to sustainable as well as from sustainable to lean, this study assumes lean improvements

as the starting point. Value creation within networks and delivery to final customer are the concepts that should guide the further development of what started as the implementation of lean. The challenge of value creation lies at the core of lean and it simultaneously becomes a task for the entire supply chain. Therefore, the element of value creation is introduced as the consecutive layer of the proposed framework.

Defining value to customer is challenging and lean thinking approaches it from the perspective of dividing activities into those that add value and those that do not. This is quite a narrow perspective which does not take into consideration the environmental aspect and the necessity for greening the operations. Therefore, the creation of value should be rather perceived from the perspective of the revised approach to value that redefines waste to encompass factors that affect not only productivity but also environment.

Furthermore, defining and assigning responsibility is easier to achieve within transparent supply chain. Therefore, those two aspects should be considered jointly.

## **5 Conclusions and further research**

The research presented in this paper acknowledges that the current complex, turbulent and changing economic landscape poses additional challenge on the universality and applicability of the concept of lean.

This research revises the literature in the field of lean and, in order to bring additional value to the current state of conceptual research, the focus is narrowed down to the issues of green and sustainable operations as well as value creation within networks. Such an approach is believed to not only contribute to providing an overview of the current state of the research in the aforementioned field, but also to the development of knowledge in terms of future research directions. The process of adding value to the current state of the research is realised by systematising the existing knowledge in the field of lean thinking and greening of operations, as well as by outlining the interfaces between those concepts, which is ultimately aimed at directing the research towards the new areas. The concept of lean is not so new anymore and seminal literature quotes many different contexts in which it has been applied. Therefore, in order to ensure that the concept of lean is not labelled as “obsolete”, the research presented in this paper takes a revised approach to lean by combining it with environmental performance of operations. This conceptual approach is expected to serve as a starting point for further considerations, either theoretical or empirical. The systematic literature review aimed at examining the current state of the research into lean in the context of greening and sustainability of operations, as well as value creation within supply chains and networks, resulted in the proposed conceptual framework. The framework highlights the context of lean development and it also outlines the directions of this development.

The study provides a helicopter view of the aforementioned field of knowledge. As it is conceptual in nature and it focuses on the theoretical development rather than on empirical contributions. During the research process it was discovered that there are several areas in which applying the lean approach and environmental aspects is a promising research perspectives. Therefore, based on the developments of this study the further research into the following aspects is proposed:



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- focus on further empirical research targeted at examining the connections between the essential concepts discussed in this paper
- examining the connection between performance measured not only in well-established terms of effectiveness, efficiency, quality, timeliness, productivity and safety, but also in terms of environmental impact and greening of operations
- focus on value creation in supply chain context regarding delivering value to end customer as well as attributing value to organisations within supply chains
- further research into the issues of responsibility and transparency as those are the crucial aspects of both lean and supply chain operations
- broadening the scope of sustainability and further research into its economic and social aspects as well as looking into establishing lean change that lasts.

The proposed areas of further research are expected to contribute to the further development of the research in lean. This is crucially important in the context of today's turbulent business environments, growing pressure for the improved environmental performance as well as fluctuating, unpredictable demand levels.

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