THESIS ON ECONOMICS H31

Critical Success Factors of Lean Thinking Implementation in Estonian Manufacturing Companies

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Declaration:
Hereby I declare that this doctoral thesis, my original investigation and achievement, submitted for the doctoral degree at Tallinn University of Technology has not been submitted for any academic degree.

/Aleksandr Miina/

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Introduction

Today, lean thinking is a very important and difficult topic. Lean thinking principles give companies an opportunity to increase efficiency and productivity and are, as such, in the circle of interest for them (Trombly, 2002; Trott, 2008). The importance of the improvement of manufacturing processes was greatly seen during the last financial crisis, and more and more companies around the world and in Estonia began their own lean implementation process following the crisis. Though lean ideas have been known and studied extensively for more than 30 years, there are still a lot of difficult and unclear aspects to be studied, and one of those is how to achieve successful lean thinking implementation.

Lean thinking (henceforth lean) is defined as the systematic elimination of waste (Santos et al., 2006). Ohno (1988) saw lean thinking as a time line, where a company must look to it from the moment the customer gives it an order to the point when the company collects the cash. Additionally, Womack et al. (1990) define lean thinking as shortening lead time by eliminating waste in each step of a manufacturing process, which in turn leads to the best quality and lowest cost, while improving safety and morale. And finally, Liker (2004) writes that a company must see the value from the customer's perspective, then remove all unnecessary activities and make the process better and better, producing as much as a customer wants, no more no less.

Under lean, waste refers to everything that does not contribute to the final product or service value and value is regarded from the customer's point of view. Customer value includes all the activities during the manufacturing of products that are paid for by the customer (Womack et al., 1990). The customer in lean thinking is internal and external. Internal customer is the next process within the same company or a next step within the same process. External customer is the next company in a chain that is using the product produced by previous company.

To define value, a company should know what the customer wants from that process (Liker, 2004). "Value is a capability provided to the customer at the right time at an appropriate price, as defined in each case by the customer." (Womack and Jones, 1996). Different sources express this idea using different terms – cost reduction, waste elimination or value non-adding activities elimination, though the same focus is apparent: to eliminate all the activities from the processes that do not increase the value of the product (from the customer's perspective), utilise resources for no outcome (thereby increasing costs) and waste operating time.

Customer value is the opposite to waste. Waste is all the activities that do not add value in the product manufacturing process. The lean concept brings 7 basic types of waste (Womack et al.,, 1990; Liker, 2004; Santos et al., 2006, Voss, 2007): overproduction – producing more than ordered, producing to the stock and producing unnecessary items; inventory – all materials and components, semi-finished goods (work-in-process or WIP) and all finished products standing in stock; transportation – any kind of movement of materials, components, WIP and finished products; excess motion – any activities during the process that are unnecessary (could be removed from the work method) to fulfil the goal; waiting – materials, components and WIP waiting to be processed, workers and machines waiting to start the job; over processing – making the products "too good" instead of "good enough"; defects – producing scrap or defective products, inspection and quality controls.

The roots of lean thinking lie in the Toyota Production System (TPS) – the system of organising production processes in an efficient and effective manner, which is used in Toyota Motor Corporation. The development of the system began at the end of nineteenth century at the time when the Toyoda family (the owner of Toyota company) owned Toyoda Automatic Loom Works company. System development continued in the twentieth century after the Toyota Motor Corporation was established. The focused development of TPS started after the Second World War and as a result bringing Toyota to the top of the automotive industry. After discovering the TPS and introducing the term lean in the famous bestseller "Machine that changed the world", the idea spread all around the world very fast, first from the automotive industry and then entering all other industries and sectors (services, healthcare, construction, public services) (Santos et al., 2006).

In academic literature worldwide, lean thinking is regarded as a cost reduction and productivity improvement technique (Achanga et al., 2004, 2005a, b; 2006; Bicheno, 2000, 2004; Womack et al., 1990; Womack and Jones, 1996), a new efficient paradigm for operations (Katayama and Bennett, 1996; Williams et al., 1992). Many companies use lean principles in developing their corporate strategies (Womack and Jones, 1996) and as a result it could be used as a powerful weapon in a more globally competitive world (Söderkist and Motwani, 1999). To conclude, lean thinking could be defined as a philosophy of manufacturing process organisation and management, which incorporates a set of tools and methods for waste elimination with the focus on people development and continuous improvement.

Though lean seemed to work very well in Toyota factories, companies outside of Toyota were not able to achieve the same results. Lean was developed in Toyota and therefore is a natural thing for Toyota. Other companies had to find their personal way of implementing those ideas in a successful manner and it turned out to be very complicated. Since then, the lean topic was studied very widely and different aspects of lean implementation were investigated, though still there is no standard framework or roadmap for successful lean implementation (Pepper and Spedding, 2010; Repenning and Sterman, 2001; Hogg 1993). Despite this unclear aspect of lean implementation, this concept is regarded as the method for processes, efficiency, productivity and quality improvement (Voss et al., 1995). Several problems regarding the lean implementation process in manufacturing companies and results of the process are identified in literature:

- about 10 per cent or less of companies succeeds at implementing lean manufacturing practices (Bhasin and Burcher, 2006).
- “only 10 per cent has the philosophy properly instituted” (Sohal and Eggleston, 1994, p. 8).
- new paradigms and best practices are often taken as a “black box”, which has many dangers inside (Voss, 2007).
- if companies use lean initiatives almost as a fad, most of their effort will fail to produce significant results (Repenning and Sterman, 2001).
- finally, there is evidence that “no standard framework for lean or its implementation exists. A systematic approach needs to be adopted, which optimises systems as a whole, focusing the right strategies in the correct places.” (Pepper and Spedding, 2010, p. 138).

Based on the above, the main problem for lean implementation could be formulated as follows: the standard framework for successful lean implementation is not studied enough and as a result manufacturing companies are either not starting a lean initiative or fail to implement it successfully. Companies are missing standard process for lean implementation and an overview of the critical steps they have to perform in order to achieve desired targets.

Lean thinking implementation is specified as an activity of following certain steps in order to achieve the manufacturing processes with the smallest amount of waste in them. Lean implementation consists of process, cultural and people aspects. Process aspect is the activity itself. Cultural aspect is connected with changing the culture of the organisation and people during the lean implementation process. People aspect is connected with people development and their reaction to the changes (Diefenbach, 2007; Teresko, 2002).

The simple view of process means there are inputs that are transformed into outputs. Manufacturing process means transforming tangible (materials, resources) and intangible (information) inputs into physical products throughout a sequence of steps (Taylor, 1911). Lean thinking is focusing on the elimination of waste from the manufacturing process (Voss, 1995a). Finally, implementing lean thinking principles in the manufacturing process is a process in itself, and this latter process is the focus of this current thesis.

Companies do not know where to start the process of implementation, which steps are critical for success and how to proceed with the whole process. Despite the high number of research papers and dissertations on the lean topic, the aspect of critical success factors during the lean implementation process is covered weakly and companies are missing clear, step-by-step guidelines for the successful implementation of lean. There are a lot of studies (Teresko, 2002; Bhasin, 2011; Olexa 2002a, b; Bateman, 2002; Moore, 2001; Voss, 2007; Liker, 2004) that have attempted again and again to rethink what lean is; and there are studies which highlight on which lean tools to focus during implementation and how to implement those tools, but still is there a deficiency of step-by-step process description for lean implementation. Additionally, several authors indicate that only small number of manufacturing companies succeeds with lean implementation (Bhasin and Burcher, 2006; Sohal and Eggleston; 1994). Additionally, other researches (Achanga et al., 2006; Oprime et al., 2011) point out that there are some critical aspects that mainly influence lean implementation process – factors that could secure sustainable and continuous lean implementation in manufacturing companies and guarantee them constant and fast growth in productivity

The potential solution for that problem would be the standard process model of lean implementation, where companies can see step-by-step instructions for the implementation of lean thinking principles. The model will also bring out critical factors for the success of the lean initiative. Critical success factors are the certain steps in the process that define the overall success of the lean implementation initiative. The fail of critical success factors brings the failure of the whole process.

According to the present statistics, the situation of productivity and value added per employee in Estonia compared with the European Union countries is weak. Based on data from Eurostat, the labour productivity per person employed in Estonia in 2005 was only 60.8% of the 27 countries European Union and almost two times smaller when compared to our neighbours Sweden and Finland – respectively 111.4 and 110.5 of GDP in Purchasing Power Standards (PPS) per person employed relative to the EU-27 (see Appendix 1). Though, the improvement in Estonia from 1999 to 2005 is almost 50%, the result is still weak and requires further and more rapid improvement. Furthermore, the improvement from 2005 to 2010 is only 13%. The comparison of value added per employee in the manufacturing industry in Europe in 2007 shows that there is long way for Estonia to go: value added per employee in Estonia is almost 3 times less than the EU-27 average and almost 5 times less than in Finland (Appendix 2).

We can conclude that compared to the EU average there is small labour productivity in Estonian manufacturing companies and the speed of productivity improvement is weak (Varblane, 2010). As a consequence, the author points out two main aspects. First, low labour productivity causes low wages and as a result weak consumer power, which, in turn, results in a smaller money flow to the manufacturing companies. Second, low productivity makes it very difficult to compete in foreign markets due to the inability of Estonian companies to offer considerably lower prices while entering existing foreign markets. Aspects connected with the efficiency and productivity of the manufacturing process are playing an important role in terms of the overall productivity and efficiency of companies, though there are many aspects and steps along a supply chain that influence those indicators. The concept of lean thinking is also used in Estonian manufacturing companies for the improvement of productivity and efficiency, and the number of companies is constantly increasing, though the results of lean implementation are scarce.

Based on all of the above, the author decided to investigate the situation regarding the lean concept in Estonia – how known is it and how widely is it used amongst manufacturing companies. The first attempt was done in the year 2006. It turned out that the adoption of lean management paradigms in Estonia was weak at that time. In May 2006, a small questionnaire (with 5 questions) about lean manufacturing was sent to 700 manufacturing companies in Estonia. Though the response rate was rather small (about 7%), the overall situation could be defined: only 30% of the responded companies were partially familiar with lean manufacturing and only 14% used only some of the lean manufacturing tools. Also, a small response rate is an indicator in itself – probably the questionnaire addressed an unknown and therefore strange topic. Another source proved the survey results. The Enterprise Estonia organisation funds training and consultancy programmes, among other initiatives. According to the data from their findings, only 4 training courses out of 575 (which makes 0.7%) concerned lean manufacturing during the first nine months of 2006, and only 2 out of 338 (0.6%) consultancy programmes focused on lean. Those two examples show a lack of proper information about the lean concept itself and the possible ways for lean principles utilisation in Estonia.

Furthermore, such small awareness was scary because one of the world's biggest and most well known concepts (as will be shown later in the paper) for operations improvement is practically unknown in Estonia, and interesting because such a situation opened the opportunity for the research, investigation and practical work of introducing that concept to Estonian business society. As was shown by the survey, companies were not aware about what lean is and consequently how to implement it – where to start, how to start, when to start, where to go, how to go.

Finally, it has been shown that there are two main problems identified. The first emerges from academic literature and is specified as missing a clearly defined step-by-step process for lean thinking implementation with an indication of the critical success factors of that process. The existence of the latter could ensure that time and money spent on it are not wasted and required tangible and intangible targets are achieved. The second problem is derived from the current situation in the Estonian manufacturing companies. It was shown based on present statistics that there are potential possibilities for higher productivity and efficiency of Estonian manufacturers. Furthermore, companies are trying to achieve those by the implementation of lean thinking principles, though results are scarce due to the unclear nature of the process of lean implementation.

The author proposes that in order to solve those two identified problems the successful and continuous implementation of lean thinking ideas and principles in Estonian manufacturing companies should be done. The process of the implementation of lean thinking will be successful if a clear step-by step path is present and the critical success factors are indicated.

The objective and the main aim of the current research is to develop a lean thinking implementation process model that could be adapted in manufacturing companies in order to secure the desired results of lean implementation.

Based on the previous discussion about problems and objectives, the following questions will be answered in the current paper:

1. How companies should perform the process of lean thinking implementation?
2. Why companies fail with lean thinking implementation?

To answer those questions, the following methodology will be applied. First, a comprehensive literature study of the theoretical aspect of lean thinking will be done and the process of successful lean thinking implementation process will be constructed. The latter will also indicate the possible critical success factors of lean thinking implementation. The second step is the choice of the companies based on the multiple case study method. The current investigation incorporates twelve companies from different industries and of different sizes. Furthermore, the data collection and analysis of the companies based on the content analysis method will be done. The final results of the analysis will show whether the developed lean thinking implementation process is suitable for its purpose or not, and which steps out of this process could be regarded as critical ones.

The main contributions of the current thesis to the theory are

1. The development of the model of lean implementation process;
2. Bringing out a company's own production system model in the form of lean house as a critical success factor of lean implementation process success;
3. The degree of adoption (DOA) analysing model was applied to assess the results of the lean implementation process of the studied companies;
4. The modification and application of the DOA model for the assessment of lean implementation process steps.

The existence of lean house is not possible without a good starting point and the subsequent steps together with the creation of the lean house itself. Such a step-by-step model approach to lean thinking implementation was not under looked in theory before and is therefore one of the important contributions to the current thesis. Additionally, current thesis discovered the importance of looking into lean thinking principles through the prism of company nature – companies are not similar and the same format of lean thinking principles might not suit all of them.

The practice is aided by a straight direction for companies who wish to or are implementing lean. Each company that is starting its lean road (or already going down that road) could take the model as instruction on what to do and how to do: guideline for assessing their current performance of lean implementation, understanding the process weak points and developing the next steps or the new loop of lean implementation – exactly as the model proposes. By this, the results of lean implementation in the companies could be higher and more successful.

The thesis is divided into three main parts. The first part "Theoretical framework of lean thinking implementation" builds up the framework of lean thinking for the thesis. This part starts with the history of lean development. Basic principles and philosophical aspects are explained further and are followed by a description of lean implementation aspects. Based on the study of literature, the process of successful lean thinking implementation is constructed. In the end of the first part, the author brings his view on lean and describes the lean situation in Estonia.

In the second part "Research methodology", the primary methodological aspects of the thesis are determined. This part describes in details all the steps of methodology from literature study and continuing with the selection of the companies, data collection and analysis methods. The second part ends with a description of the scientific perspective and approach.

The third part "Critical success factors and thesis results" describes the analysis of empirical data and exposes the thesis results. This part starts with an overview of the data collected during the empirical study in companies. Furthermore, the collected data are analysed and the company results of lean implementation process are assessed. Finally, the constructed model of lean thinking implementation is verified and the critical success factors of the lean implementation process are pointed out. To conclude the third part, the contribution to the theory**,** methodology and practice of the lean field is described as well as possible limitations of the study and further lines of the research.

The current thesis focuses on the production part of the supply chain and on the possibilities that could be used in production processes for efficiency and productivity improvement. Additionally, under current research the author deals with the process aspect of lean implementation and leaves aside cultural and people aspects. It is important to notice that such a choice (only of the process aspect) does not imply that the two other are of less importance or not worth investigating. All three aspects are of the highest importance and due to this all three topics are very wide. Since a doctoral thesis sets certain limitations in volume and narrowness of the topic, one of the three should be chosen. Also, the financial part of lean implementation is out of focus. Such a decision was made due to several reasons. First, the financial analysis of each lean initiative needs further investigation of each company's lean implementation process and therefore such an approach will be out of scope. Second, the financial results of each company are influenced by many internal and external aspects and due to this the degree to which lean results influence the financial results of the company should first be defined (Olsen, 2004). Third, the focus of current research lies in the lean implementation process itself and it is more important to be focused on that during the first approach to understand what and how should be done in order to secure successful lean implementation.

The author's presentations at conferences and publications in journals (see Appendix to CV) cover the thesis results and deliver these in greater detail to the field researchers.

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Abbreviations

4P – Philosophy, Process, People, Problem Solving
5S – Sort, Straighten, Shine, Standardize, Sustain
AVAA – Value Allowing Activity
C1 – Company 1
C2 – Company 2
C3 – Company 3
C4 – Company 4
C5 – Company 5
C6 – Company 6
C7 – Company 7
C8 – Company 8
C9 – Company 9
C10 – Company 10
C11 – Company 11
C12 – Company 12
CI – Continuous Improvement
CID1 – Continuous Improvement Determinant 1
CID2 – Continuous Improvement Determinant 2
DE – Decentralization
DED1 – Decentralization Determinant 1
DED2 – Decentralization Determinant 2
DED3 – Decentralization Determinant 3
DED4 – Decentralization Determinant 4
DOA – Degree of Adoption
EU – European Union
EW – Elimination of Waste
EWD1 – Elimination of Waste Determinant 1
EWD2 – Elimination of Waste Determinant 2
EWD3 – Elimination of Waste Determinant 3
EWD4 – Elimination of Waste Determinant 4
EWD5 – Elimination of Waste Determinant 5
EWD6 – Elimination of Waste Determinant 6
GDP – Gross Domestic Product
IF – Integration of Functions
IFD1 – Integration of Functions Determinant 1
IFD2 – Integration of Functions Determinant 2
ISO – International Standard Organisation
JIT – Just-In-Time
JITD1 – Just-In-Time Determinant 1
JITD1 – Just-In-Time Determinant 2
JITD2 – Just-In-Time Determinant 3

JITD3 – Just-In-Time Determinant 4
JITD4 – Just-In-Time Determinant 5
KG – Kaizen group
KPI – Key Performance Indicator
LHD – Lean House Development
LHDD1 – Lean House Development Determinant 1
LHDD2 – Lean House Development Determinant 2
LHDD3 – Lean House Development Determinant 3
LHDD4 – Lean House Development Determinant 4
LHDD5 – Lean House Development Determinant 5
LIE – Lean Implementation Execution
LIED1 – Lean Implementation Execution Determinant 1
LIED2 – Lean Implementation Execution Determinant 2
LIP – Lean Implementation Planning
LIPD1 – Lean Implementation Planning Determinant 1
LIPD2 – Lean Implementation Planning Determinant 2
LIPD3 – Lean Implementation Planning Determinant 3
LHT – Lean House Training
LHTD1 – Lean House Training Determinant 1
LHTD2 – Lean House Training Determinant 2
LHTD3 – Lean House Training Determinant 3
LKA – Lean Knowledge Acquisition
LKAD1 – Lean Knowledge Acquisition Determinant 1
LKAD2 – Lean Knowledge Acquisition Determinant 2
LKAD3 – Lean Knowledge Acquisition Determinant 3
LKAD4 – Lean Knowledge Acquisition Determinant 4
MT – Multifunctional Teams
MTD1 – Multifunctional Teams Determinant 1
MTD2 – Multifunctional Teams Determinant 2
MTD3 – Multifunctional Teams Determinant 3
MTD4 – Multifunctional Teams Determinant 4
MTD5 – Multifunctional Teams Determinant 5
NVAA – Value Non Adding Activity
OEE – Overall Equipment Efficiency
ODI – Organizational Development International
PDCA – Plan-Do-Check-Act
PM – Pull of raw Materials
PMD1 – Pull of raw Materials Determinant 1
PMD2 – Pull of raw Materials Determinant 2
PPS – Purchasing Power Standards
PS – Process Steps
PQ –Process Quality
PQD1 – Process Quality Determinant 1
PQD2 – Process Quality Determinant 2

PQD3 – Process Quality Determinant 3
PQD4 – Process Quality Determinant 4
PQD5 – Process Quality Determinant 5
PQD6 – Process Quality Determinant 6
REF – Reference Company
RQ – Research Question
SME – Small and Medium Enterprises
SMED – Single Minute Exchange of Dies
SP – Starting Point of lean thinkingimplementation process
SPS – Scania Production System
SRS – Scania Retail System
TPS – Toyota Production System
TRAIN – Training
QLEAD – Quality Leadership
WEMP – Worker Empowerment
WIP – Work-in-process
VAA – Value Adding Activity
VIS – Vertical Information Systems
VISD1 – Vertical Information Systems Determinant 1
VISD2 – Vertical Information Systems Determinant 2
VISD3 – Vertical Information Systems Determinant 3
VISD4 – Vertical Information Systems Determinant 4
VSM – Value Stream Mapping
XPS – Company’s X Production System
ZD – Zero Defects
ZDD1 – Zero Defects Determinant 1
ZDD2 – Zero Defects Determinant 2
ZDD3 – Zero Defects Determinant 3
ZDD4 – Zero Defects Determinant 4
ZDD5 – Zero Defects Determinant 5
ZDD6 – Zero Defects Determinant 6

1 Theoretical framework of lean thinking implementation

1.1 Roots of lean

After World War II, Japanese manufacturers had problems with shortages of material, financing and human resources. The country was decimated by two atom bombs, most industries had been destroyed, the supply chain was nil, and consumers had little money. (Liker, 2004). These hard conditions led to the birth of the Toyota Production System, or Lean Manufacturing.

Toyota needed to churn out low volumes of different models using the same assembly line, because consumer demand in their auto market was too low to support dedicated assembly lines for one vehicle. Toyota had no cash and operated in a relatively small country, so it needed to turn out cash quickly. There was no developed supply system. All of this was understood by Eiji Toyoda in 1950 when he visited U.S plants, including Ford's River Rouge complex. Also, he saw that the development of mass production techniques had not changed much since 1930. As a results of all this, the plant manager Taichi Ohno was assigned to understand Ford's production. This was a very hard task for him. Even before the war Ford was 10 times as productive as Toyota – Ford could produce 9,000 units per month, while Toyota only 900.

Ohno did what any good manager would have done in this situation – he continued to visit U.S plants and benchmark them. Also, he carefully studied Ford's book "Today and Tomorrow". (Liker, 2004). Toyota did not have space and money for extra inventory, and it didn't produce a large amount of one type of the car. But Toyota used the original idea of Ford's continuous material flow to develop a system of one–piece flow, which was very flexible and efficient. Practicing this idea in the factories, Ohno and his team through the years and decades developed the system now known as Toyota Production System. Womack et al. (1990, p. 19) shows that the origins of lean lie in the problems of mass production: "We take pains to describe the mature system of mass production as it came to exist by the 1920s, including its strengths and weaknesses, because the system's weaknesses eventually became the source of inspiration for the next advance in industrial thinking".

The TPS journey started with applying the principles of one piece flow – products are moved from station to station in batches of one piece, and jidoka – stop the production if there is a quality problem. Small batches helped to reach the flexibility, which was crucial to fulfil customer orders, and solving problems as they appeared helped to maintain the right level of quality. By the 1960s, TPS was a powerful philosophy and it developed further. Soon, it was realised throughout the world that the traditional mass production concept was to be adapted to the new ideas of lean manufacturing. In 1990, the world manufacturing community discovered "Lean production" – the term for what Toyota had learned decades earlier through focusing on speed in the supply chain. This happened through the work of the Massachusetts Institute of Technology Auto Industry Program. The bestseller based on this research, “The Machine That Changed the World”, defines lean as “shortening lead time by eliminating waste in each step of a process leads to the best quality and lowest cost, while improving safety and morale.”(Womack et al., 1990). The process means the process of manufacturing and delivering the products to the customer.

Voss (1995b, p. 20) describes the development process of lean as follows: “The convergence and rethinking of a number of core areas of operations management, together with the combination of new ways of organsing and managing has led to the ability to develop processes that are of high quality, predictable, reliable and flexible. This, in turn, has been a key enabler in the move from mass to lean production".

Going even a bit more back in a history, we can say that mass production was developed by Ford and Sloan (General Motors) due to the impossibility of craft production to supply a large amount of the same products; and, in turn, lean manufacturing was developed due to the impossibility of mass production to supply a large number of different cars in a small amounts without having big stocks due to money efficiency questions (Harbison and Myers, 1959). Toyota had no other choice but to develop lean manufacturing. It was a life or death question – either you will be very efficient and flexible and will satisfy customers fast or you will disappear from the market.

After discovering TPS and lean thinking, different researches as well as practitioners in manufacturing companies tried to understand lean thinking and define it. The next point develops the lean definition and the views of different authors on it.

1.2 Lean definition

The question of lean definition has been extensively studied by many authors such as Ohno (1988), Womack and Jones (1996), Womack et al. (1990), Liker (2004), Ahlström, (1997), Bhasin and Burcher (2006) and many others. The main focus of those studies are in four main aspects: defining customer value; eliminating all activities that do not contribute to the customer’s value (waste); as a result of waste elimination, processes take less time, quality, safety and moral is higher; and waste elimination process should be continuous. Those definitions indicate the general understanding about lean thinking amongst the researches and amongst manufacturing companies, as well as Estonian manufacturing companies.

Some other authors have created more straight forward definitions of lean and by this develop the main focus of lean even more: eliminating waste from manufacturing process. Slack et al., (2010) writes that lean aims to meet demand instantaneously, with perfect quality and no waste. Leseure (2010) says that lean means the ability to produce a product or service with only the resources that are strictly required to do so.

Santos et al. (2006) summaries the lean definition using a simple formula, making the understanding of lean even more simple for manufacturing companies. According to him, when the lean concept was developed, the Western world applied the following formula (Santos et al., 2006):

$$\text{Price} = \text{cost} + \text{profit} \quad (1)$$

Therefore, it was understood that the price of the product consists of cost for production and required profit. If the cost increases, the only way to maintain the same profit is by raising the price. Toyota proposed another way to approach to the same three components by pointing out that if the market fixes the price the only way to get profit is to reduce the cost (Santos et al., 2006):

$$\text{Profit} = \text{price} - \text{cost} \quad (2)$$

As can be seen, all the above definitions mentioned focus on eliminating waste from the processes, though lean thinking is not such a narrow discipline and incorporates other important aspects. Liker (2004) in his famous book “The Toyota Way” defines lean in a wider range than only a process and offers fourteen main principles divided into four different groups: long-term philosophy, process, value-adding and continuous improvement. Long-term philosophy expects managers not to think about possible short-term expenses, but instead to focus on possible future gains and to make decisions based on this. The process part consists of principles for maintaining continuous production flow with small batches (one-piece flow), levelled workload, standard tasks and fixing the quality problems as they appear. The next part explains how to develop the company’s workers, partners and customers and through this create more value for the organisation. Continuous improvement stands for the consistent solving of the root causes of problems by finding consensus through analysing all the possible alternatives that are based on real facts. Liker’s book brings the important aspect of lean thinking concept – the philosophy part. Companies cannot and should not see lean only as a tool, but they should understand the importance of the philosophical aspect and long-term thinking.

It is important to point out once more that by customer lean understands the next step in process of manufacturing goods. The next step could be internal (within the same company or within the same department) or external (next company that is using the product or the final consumer) (Hines and Taylor, 2000; Voss, 2007). Additionally, a very important aspect is that customer value in lean thinking does not equate to consumer value as such. Consumer value consists of many tangible and intangible aspects, where the intangible part might be of higher importance and monetary value than tangible. In lean thinking, customer value is all the manufacturing process steps that physically change the raw material into a final product according to the customer time, quality and quantity requirements, thereby adding value to the final product from the customer's perspective.

To conclude, lean thinking could be defined as a philosophy of manufacturing process organisation and management, which incorporates a set of tools and methods for waste elimination with the focus on people development and continuous improvement. Further points will give an insight into studies regarding philosophy and the long-term approach to lean thinking.

1.3 Lean philosophy

The question of whether we should view the lean concept as a philosophy of doing work or not is widely studied by different authors. They give ideas that lean should be viewed more as a philosophy or condition than as a process (Bhasin, 2011; Olexa 2002a, b; Bateman, 2002; Moore, 2001). The advice of Laureani and Antony (2011) is to accept lean more as a state of mind or philosophy than just a process improvement tool. Toyota Production System (TPS) did not happen overnight but through a series of innovations over 30 years (Ohno, 1988). The lean philosophy means that all the company lives and thinks based on the lean ideas (Teresko, 2002). As soon as the company and its personnel take lean as "a new innovative project", which is additional to the everyday work, then lean ideas do not work. Lean manufacturing is a philosophy because before the end of 19^{th} century craft production was the philosophy of doing work – companies and workers lived by it; then at the start of 20^{th} century mass production became a new philosophy – companies and workers also lived by it, while, yes, craft philosophy remained in some places; and then lean ideas came out and again this became the philosophy of doing work and exists in parallel with craft and mass production. The Toyota success is based on its philosophy.

The philosophical aspect of lean gives the idea that each company might have its own understanding of lean, or, we could say, their own lean philosophy. Indeed, Toyota went this path by describing the Toyota philosophy in the form of lean house (Liker, 2004). Lean house shows how the particular company understands the lean philosophy (Philips, 2000; Liker, 2004).

TPS house incorporates four basement blocks, or the foundation for the TPS: Toyota Way philosophy, Visual Management, Stable and Standardized Processes and Leveled Production. The next part of the Toyota house is two main pillars – Just-In-Time and Jidoka (In-station quality), also called right quality from the first time. Those pillars show very clearly why the Toyota way achieves their goals, which are the roof of the house. Best Quality, Lowest Cost, Shortest Lead Time, Best Safety and High Morale are achieved in order to focus on time delivery and best quality, which, as a result, allow for shorter production times by eliminating waste. Another good example of a similar lean house is the house of Scania Production System (SPS). Scania has its own vision and understanding of the lean philosophy and this particular understanding is expressed in the form of SPS house.

The sampled houses of lean are nothing other than companies' approaches to their daily operations based on long-term thinking, which is expressed by lean house. Changing the approach to the operations means changing the company's manufacturing paradigm (Santos et al., 2006) and many authors see lean as a new manufacturing paradigm. For example, James-Moore and Gibbons (1997), Cooney (2002) and Smeds (1994) discuss the relevance of lean manufacturing for all types of manufacturing. Harrison (1998) and Drickhamer (2000) study the concept of world-class manufacturing, its meaning and implication for manufacturing strategy development. Finally, Papadopoulou and Özbayrak (2005) and Drucker (1992) find that all new manufacturing paradigms and systems developed after lean are always assessed in comparison to lean. Also, their findings include an interesting fact: despite othe high interest towards the lean topic, the literature failed to follow the development of lean and therefore the big part of the literature relies on the antiquated view of lean.

Hines et al. (2004) gives a rather deep overview of lean paradigm development from 1980s until the 2000s (Table 1). Lean paradigm was consequently focusing on topics arising in the field of operations management and moving from improvement activities on the shop-floor (authors in the section 1980-1990 Awareness) through the lean supply chain (authors in sections 1990-mid 1990 Quality and Mid 1990-2000 Quality, cost, delivery) into the lean thinking system level (2000+ Value system). Despite this, the majority of the companies that are implementing lean thinking today are still stuck in the purely manufacturing process improvement part (shop-floor) and forget about the philosophy (value system). This may lead to the failure of lean implementation (Liker 2004; Voss, 2007). The focus of more recent researchers (Hilton and Sohal, 2012; Jeyaraman and Teo, 2010; Laureani and Antony, 2011; Oprime et al., 2011) is focused in the field of assessing the leaness of the companies and trying to identify the right process for lean thinking implementation; industry focus was also broadened from purely manufacturing into other sectors.

Finally, the philosophy creates the basis for lean thinking implementation and each company has to enter the continuous improvement process, also known as *kaizen* (Heizer and Render, 2011; Slack et al., 2010, Liker, 2004 and others).

The process of lean thinking implementation is of utmost importance since it brings the company to the desired results (Jeyaraman and Teo, 2010). Toyota has extensively implemented those for at least 60 years now (since the Second World War), but modern companies cannot accept the same approach due to it taking such a long time (Voss, 1988). Therefore, they need a faster, or we could say, more concentrated way (Fukuda, 1988; White and Trevor, 1983). Furthermore, the process view of lean thinking implementation is investigated.

Table 1. The evolution of lean thinking (Hines et al., 2004, complemented by author)

Phases	1980-1990 Awareness	1990-mid 1990s Quality	Mid 1990s-2000 Quality, cost and delivery	2000+ Value system	*2010+ Process view*
Literature theme	Dissemination of shop-floor practices	Best practice movement, benchmarking leading to emulation	Value stream thinking, lean enterprise, collaboration in the supply chain	Capability at system level	*Assessing the leaness of the company*
Focus	JIT techniques, cost	Cost, training and promotion, TQM, process reengineering	Cost, process-based to support flow	Value and cost, tactical to strategic, integrated to supply chain	*Process of lean implementation*
Key business process	Manufacturing, shop-floor only	Manufacturing and materials management	Order fulfilment	Integrated processes, such as order fulfilment and new product development	*Entire organisation*
Industry sector	Automotive – vehicle assembly	Automotive – vehicle and component assembly	Manufacturing in general often focused on repetitive manufacturing	High and low volume manufacturing, extension into service sectors	*Manufacturing, construction, healthcare*
	Shingo (1981, 1988), Schonberger (1982a), Monden (1983), Ohno (1988), Mather (1988)	Womack et al. (1990), Hammer (1990), Stalk and Hout (1990), Harrison (1992).	Lamming (1993), MacBeth and Ferguson (1994), Womack and Jones (1994, 1996).	Bateman (2002), Hines and Taylor (2000), Holweg and Pil (2001), Abbas et al. (2001), Hines et al. (2004)	*Hilton and Sohal (2012), Jeyaraman and, Teo (2010), Laureani and Antony (2011), Oprime et al. (2011).*

1.4 Process view of lean thinking implementation

Every company has to have a clear vision and target about the lean thinking implementation process (Voss, 1984). In other words, they have to answer the question “Why are we doing this?” Innovations and improvements create problems for the companies and therefore they have to be managed (Trott, 2008).

Literature gives us different strategies on implementing lean manufacturing principles, while no research about lean implementation results depending on the used methodology was identified in literature. For example, three main references are found (Cuatrecasas et al., 2007): Lean Thinking (Womack and Jones, 1996), Going lean (Hines and Taylor, 2000) and the Procedures Manual from lean Aerospace Initiative (Crabill et al., 2000). Those strategies give very general steps and are not pointing out the critical aspects of lean implementation process – the steps that define the overall success of lean thinking implementation. Womack and Jones (1996), for example, offer the following path for lean thinking implementation: defining customer value; eliminating all activities that do not contribute to the customer’s value; As a result of waste elimination, processes take less time, quality, safety and moral is higher; the process should be continuous.

Williams et. al (1992) says that despite the many positive comments about lean, there are still a lot of questions around this topic. Many authors (Womack and Jones, 1996; Liker, 2004; Womack et al., 1990; Ohno, 1988 and others) point out that the implementing of lean principles has to be continuous in order to bring desired results and therefore cannot be used as a fire fighting mechanism. This sets certain limitations on the process of implementation and requires a step-by-step planned approach (Söderkist and Motwani, 1999; Ohno, 1988; Olexa 2002a, b; Bateman, 2002; Moore, 2001). Additionally, there is evidence that “no standard framework for lean or its implementation exists. A systematic approach needs to be adopted, which optimises systems as a whole, focusing the right strategies in the correct places.” (Pepper and Spedding, 2010, p. 138). Also, organisations are realising the fact that it takes more than quality, cost, and delivery commitments to ensure survival. Organisations are recognising the need for extra efforts in terms of ability to adjust quickly and effectively to demand fluctuations as well as product diversification according to the requirement of customers (Mohan and Sharma, 2003). Those mentioned additional efforts mean than companies have to focus on certain steps of the lean implementation process more than others. Such steps are named as critical steps or critical success factors.

Achanga et al. (2006) in their research investigation have brought four main key factors that are fundamental or even critical for the implementation of lean manufacturing: leadership and management, finance, skills and expertise, and culture of the organisation. Leadership stands for 50%, finance for 30%, organisation and culture for 10% and skill and expertise for 10% on influencing the results of lean implementation. They suggest that, "leadership and management commitment are the most critical in determining the success of a lean project. A strong leadership ethos and committed management support is the cornerstone to the success of implementing any idea within an organisation." The output of management is a correctly organised and controlled process (Slack et al., 2012). Therefore, the strong management of lean implementation results in a correct and effective lean implementation process. Also, other authors show that management support and commitment to problem solving are the main factors for successful lean implementation (Antony and Banuelas, 2001; Coronado and Antony, 2002; Eckes, 2000; Henderson and Evans, 2000).

Oprime et al. (2011) in their study bring the summary of critical success factors of continuous improvement (Table 2). This study focuses on factors themselves and does not investigate the process of lean implementation. Factors of lean implementation are divided into three groups: organisational and operational, incentive systems and support tools. The process of lean thinking implementation is left aside and only factors facilitating the process or used during the process are considered (Table 2).

Hilton and Sohal (2012) in their investigation again rely on the factors of lean itself, not on factors of the process of implementation. They find that those success factors are: leadership, communication, behaviour and awareness of Six Sigma; policies, culture and organisational support and strategy; education, training and competency of the Six Sigma experts; project improvement teams and project management; and performance evaluations based on quality criteria, information systems, data and measurement.

To conclude that point, it is important to note that studies to date in academic literature mostly focus either on a very general lean implementation process (eg. Womack and Jones, 1996; Hines and Taylor, 2000, or Crabill et al., 2000) or on a general organisation's characteristics that should facilitate the process of lean implementation (eg. Achanga et al., 2006; Antony and Banuelas, 2001; Coronado and Antony, 2002; Eckes, 2000; Henderson and Evans, 2000, or Oprime et al., 2011). Additionally, companies are taking lean as a popular thing and do not properly study the issue. As a result, the process of lean implementation is not achieving the desired results, and resources are wasted for nothing. Based on this, the current thesis focuses on two identified gaps in the body of lean thinking theory: a missing step-by-step approach on the lean thinking implementation process and the non-defined critical success factors of this process. Consequently, the next point of the thesis is focused on the development of a successful lean thinking implementation process based on the critical issues identified in literature. Also, the definition of successful lean thinking implementation is given.

Table 2. Critical success factors of continious improvement (Oprime et al., 2011, complemented by author).

Categories	**Critical factors**	**Cited by**	***Connection to the process of lean thinking implementation***
Organisation and operation	New behaviours and values Leadership Employees' involvement Cooperation and integration Communication system Promotion of CI activities Problem solution models and skills Organisational support	Bessant et al. (1994); Savolainen (1999); Harrison (2000); Delbridge and Barton (2002); Hyland et al. (2003) Bessant and Caffyn (1997); Caffyn (1999); Bessant et al. (2001); Terziovski (2002); Dabhilkar and Bengtsson (2004); Bessant and Francis (1999); Murray and Chapman (2003); Abrahamsson and Gerdin (2006)	*Focus on cultural aspect (both employees and companies in general) of lean thinking implementation; creates the environment suitable for lean thinking implementation process development.*
Incentive systems	Personal characteristics Company skills for employees' involvement Motivation Formal and informal rewards	Dabhilkar and Bengtsson (2004); Delbridge and Barton (2002); Caffyn (1999) Bessant and Caffyn (1997); Atkinson (1994); Hyland et al. (2003); Davison et al. (2005); Lee (2004)	*Motivation for the process to be working on a continuous cycle*
Support tools	Problem solution models and skills Standardisation tools Problem identification tools	Bessant et al. (1994); Delbridge and Barton (2002); Atkinson (1994); Terziovski and Sohal (2000) Bechet et al. (2000) Bond (1999)	*Techniques and methods used in the process*

1.5 Development of successful lean thinking implementation process model

Deeper investigation of literature allows us to highlight the critical aspect of lean thinking implementation brought by different authors. First, as a basis for manufacturing process improvement, many authors (Oberg, 1963; Heizer and Render, 2011; Voss 1988; Santos et al., 2006 and others) point out standards. Taiichi Ohno (1988) stated very clearly: "You have to have standards, even if they are bad standards". Standard process means that the same process is performed each time exactly the same way, independent of who is performing the process. And if process is performed every time the same way, we can easily predict how much time it will take and what the result will be. We can also call such a process controlled or a quality process (Ainosuke, 1989; Slack et al., 2010; Heizer and Render, 2011). It is impossible to improve non-quality process due to the fact that it is not possible to measure it and therefore to define value non-adding activities. A lack of standard processes will make hard work to improve them (Flynn et al., 1994; Crabill et al., 2000; Hilton and Sohal, 2012).

Therefore, process quality is a starting condition for lean thinking implementation and its status in a company could be assessed by the following determinants (which have been developed by the author based on literature study): the amount of standardised processes and working instruction related to all the processes should increase; the number of deviations between standards and real life should decrease; the amount of scrap and rework costs related to the revenue should decrease; the responsibility of standards creation should move from functional managers to the multifunctional teams; the ratio of non-value added activities in processes is constantly decreasing; the number of process improvements per employee is constantly increasing.

Furthermore, many studies show that companies do not really understand what is lean and how it could be implemented. For example, only 10 per cent or less of companies succeeds at implementing lean manufacturing practices (Bhasin and Burcher, 2006). Furthermore "only 10 per cent has the philosophy properly instituted" (Sohal and Eggleston, 1994, p. 8). On the other side, new paradigms and best practices are often taken as a "black box", which has many dangers inside (Voss, 2007). Also, if companies use lean initiatives almost as a fad, most of their efforts will fail to produce significant results (Repenning and Sterman, 2001; Hogg 1993). Consequently, lean knowledge should be present in the company and disseminated, so that each employee understands what is lean thinking and for what it is used. Lean knowledge acquisition could be done in many different ways: books, articles, trainings, consultancy help, benchmarking other companies and many other ways. Lean knowledge acquisition assessment should be performed according to the following determinants: number of personnel trained in lean should increase; number of topics that personnel receive intensive training in should increase; number of benchmarked companies should increase; number of books mandatory for all employees to read should increase.

Based on gathered lean knowledge, a company has to construct their own model of the new production system it will take on – lean house (see point 1.3). As was mentioned previously, lean house is an interpretation of the lean theory for the current company in the form of values, principles and tools. Lean house means that the company is rethinking lean principles through the company activities prism and decides in which way and how they will implement lean (Philips, 2000). Lean house is the basis for the whole lean process and if it is missing, then the lean implementation process will not be continuous and sustainable in the long term (Philips, 2000; Liker, 2004; Santos et al., 2006; Voss, 1995b). Logically, a new form of lean knowledge should be spread around the company by the simple training of personnel. Lean house development results are assessed towards five determinants: attitude to lean implementation should move from project type (principle by principle) towards the company's own production system based on the lean principles approach; lean principles integrated into the company values are increasing; lean principles integrated into daily work is increasing; the attitude towards lean philosophy should move from waste elimination techniques to the way of working; as a result, lean house (or own production system) is created.

In lean house training, the company should focus on training in the way that the company understands lean (Abdullah, 2003). The determinants are as follows: the number of employees trained should increase; the number of employees able to train lean house to others should increase; the amount of information about lean house should increase.

As soon as lean house is created and communicated to the company, a lean implementation plan should be developed and executed. Without a long-term plan and its step-by-step execution, the whole lean implementation idea becomes a short project and it is inspired by momentary emotions (Sakakibara, 1993). As a result, nothing is achieved and the company is not changing its nature towards being lean (Achanga et al., 2004, 2006; Bhasin, 2011; Rother, 2010). Lean implementation could not be the project. Otherwise, the ultimate goal of continuous improvement will never be achieved – projects have their starts and ends; continuous improvement is endless (Ohno, 1988, Liker, 2004 and others). The current step shows the way in which lean is implemented in the company and the determinants are: lean implementation approach is moving from project type towards way of doing work based on lean house; the lean implementation plan is long term with clearly defined small steps and targets; continuous improvement, and the improvement of the lean implementation plan, is built in into the lean implementation plan.

The execution of plans constitutes a vital element for the success of the process (Heizer and Render, 2011; Slack et al., 2010). Determinants are as follows: the lean implementation execution approach is moving from project type towards way of doing work based on lean house; lean implementation follows the plan and is continuously improved upon based on the achieved targets.

The intended result of the discussed steps is successful lean thinking implementation. Several lean status or lean performance assessment methods could be identified in literature. One of those is offered by Little and McKinna (2005). They have called it Lean Assessment Tool and it is designed to investigate, evaluate and measure key areas of manufacturing within the company. Little and McKinna (2005) describe the tool as follows:

> *"Headings used in the Lean Assessment to gather information are: Management style and leadership; Culture and Teamwork; Quality; Waste elimination; Process/Continuous Improvement; Scheduling; Layout & Handling; Maintenance; Setups/Changeover. Taking the above headings, we use a radar plot that gives the company a visual map. This is the key output of this stage both for the consultant/facilitator and for the company. Informal discussions with workers may also take place to gather further information about the culture of the SME."*

Boyer (1996) was assessing the managerial commitment to lean production. He proposes that "plants which have a high degree of commitment to lean production simultaneously support this commitment with investments in the supporting manufacturing infrastructure, as measured by QLEAD, GROUP, TRAIN, WEMP" (Boyer, 1996, p. 50). QLEAD is respectively quality leadership, GROUP – group problem solving, TRAIN – training and WEMP is worker empowerment. These four criteria have determinants (each criterion has a different number of determinants) that are assessed by the company's employees as 1 = strongly disagree, to 4 = neither agree nor disagree, to 7 = strongly agree.

Karlsson and Åhlström (1996) have developed their own model of lean assessment and they call it Degree of Adoption (DOA). This method was also used by Soriano-Meier and Forrester (2002) for assessing the degree of leanness of manufacturing firms. The Karlsson and Åhlström (1996) method has nine criteria, which help assess the degree of lean adoption:

- Elimination of waste
- Continuous improvement
- Zero defects
- Just in time deliveries
- Pull of raw materials
- Multifunctional teams
- Decentralisation
- Integration of functions
- Vertical information systems

Each criterion has determinants that help to assess the criteria and calculate the score of criteria. The determinants are also developed by Karlsson and Åhlström. All of those three methods are similar: they have main areas of assessment (criteria) and corresponding determinants (sub-areas of assessment).

In the current thesis, the author has decided to use the model from Karlsson and Åhlström (1996) for the two main reasons: method is used more than once by different authors; the number of topics covered by the method is wider than by others – the Little and McKinna (2005) method also has 9 assessment areas, though they are assessed directly (radar plot); Boyer (1996) has only 4 areas for assessment and is focusing on managerial commitment. Criteria and their corresponding determinants focus on different aspects of lean thinking implementation.

A first criterion of lean success – elimination of waste – is defined by the following six determinants: the relation of work in progress to sales should decrease; lot sizes should be smaller; set-up time for machines should decrease; machines down time should be reduced; transportation in terms of parts and distance should decrease; value of scrap and rework related to sales should decrease (Karlsson and Åhlström, 1996).

The elimination of waste is based on seven waste types. Many authors (Bicheno, 2004; Harrison, 1998; Ohno, 1988; Rother, 2010; Slack et al., 2010) indicate that out of those seven wastes five could be totally removed from the processes – overproduction, unnecessary motion, waiting, over processing and defects. This means company can always produce exactly as much as ordered, with optimal motions sequence, without any waiting, over processing and defects.

The other two types of waste – inventory and transportation – cannot be totally removed (Womack and Jones, 2005). There always should be work-in-progress (WIP) inside the production line, at least one piece of semi-finished product on each workstation. If the production process is empty (there are no WIP), then it will take time to get the first ready product after the start of the process – one should wait until first product will pass all workstations. The "full" production line gives the possibility to obtain a ready product after one cycle – the time needed to perform activities on one workstation. The goal here is to minimise the inventory as much as possible. Also, there is the ultimate need to transport product and materials – we cannot manage entirely without transport. Therefore, the waste of transport could not be removed totally, but again should be minimised as much as possible.

According to the academic literature (Achanga et al., 2004; Cuatrecasas et al., 2007; Hines and Taylor, 2000; Singh and Khanduja, 2010; Seth et al., 2008), at first companies are implementing the following tools: 5S (efficient and visual workspace through five activities: sort out unnecessary items and materials, straighten or place everything in order, sweep or shine to keep everything clean, standardise and sustain the approach), values stream mapping (identifying waste in the processes (VSM)) and single minutes exchange of die (reducing set-up times (SMED)). Additionally, Ohno (1988) writes that with 5S, tool hidden waste is eliminated. Hidden waste refers to activities that do not add value but look like they add value: searching through the components or tools on the table, looking for components or tools on a nearby table or on the shop floor, sorting out components or materials during work time and so forth. Finally, according to Liker (2004) and Santos et al. (2006) quality, efficiency and work moral are better after 5S principles are integrated into work routines.

A second criterion for a successful lean approach – continuous improvement – is based on two main determinants: the number of suggestions per employee per year and the percentage of those that are implemented should increase; the way of organising the improvement activities: the company should have quality circles, multifunctional teams, a formal suggestion scheme and spontaneous problem solving (Karlsson and Åhlström, 1996).

Continuous improvement (CI) show a company's ability to endlessly analyse processes in order to searchi for new wastes – since there is no ideal process due to continuous changes in the people, company, technology, world and so on, one can find wastes again and again. In Japanese, it is called *kaizen.* The tool or formal structure used for kaizen in manufacturing companies is called PDCA – Plan-Do-Check-Act – circle, also known as Deming cycle (Heizer and Render, 2011; Slack et al., 2010, Liker, 2004 and others). PDCA is a simple framework for planning improvement activities in a continuous manner, not dependent on what kind of activity is being executed (Rother, 2010). It could be the implementing of 5S ideas, or solving a practical problem of too high a scrap amount, or improving space usage in a particular production group and so on. Also, within each of the steps, different tools such as VSM could be used. For example, if the target is to improve the space utilisation and time, the VSM could be used as the focus of the circle.

In addition to 5Why?, the technique of CI (to determine root cause, it is proposed to ask at least five 'why' questions after each answer) is used to find out the problem's root cause and eliminate the problem. Companies often deal not with the root cause of the problem but with the consequences of the problem and eliminate those (Crabill et al., 2000; Kobyashai, 1994; Leseure, 2010). As a result, it looks like a problem is solved now, but it is solved only for now – it could be repeated again and again since the root cause has not been eliminated (Murugaiah et al., 2010).

A third criterion is called zero defects and its main aim is to reduce quality cost and to improve the quality checking procedure. It is focusing on the next determinants: responsibility for identification of defective parts should move from the quality department to workers, and workers should be able to stop the line; responsibility for adjusting defective parts should move from the quality department to the worker responsible for the creating defect; the number of people dedicated primarily to quality control should decrease; products should be measured not only when they are ready but also at several stages within the process; the amount of control carried out by autonomous defect control should increase; the size of the adjustment and repair area should decrease (Karlsson and Åhlström, 1996). By achieving zero defects level, a company shows its ability to control process and thereby use the available production time more efficiently. Therefore, the tool of standard work should be used. The term standard work in lean thinking means the most effective combination of machines, people and materials at a certain moment of time (Ohno, 1988). The target of standard work is to build the process that is most effective and efficient at the certain moment of time and that gives the required quality (Wheelwright and Bowen, 1996). The focus is not on inspecting the manufactured parts but on the manufacturing process (Hayes, 1981).

Following on from continuous improvement is the just-in-time criterion and they are closely connected: zero defects is a prerequisite for just-in-time delivery. This fourth criterion consists of the following determinants: lot sizes should decrease; value of work in progress related to the sales should decrease; respectively order lead time should also decrease; the level of just-in-time should move from lots delivery just-in-time to the sequential just-in-time (Karlsson and Åhlström, 1996). Determinants are the same as in the bwaste elimination criterion and, therefore, the same tools are used.

The fifth criterion of DOA flows out from the previous one and defines the percentage of all the orders that are scheduled using the pull approach versus push. The determinants are as follows: the number of stages in the process that use the pull approach; degree of pull: value of annual requirements scheduled through the pull system (Karlsson and Åhlström, 1996). In a lean thinking, the pull approach is used instead of push: the starting point for manufacture in a pull system is not a forecast, but a customer order (Karmarkar, 1989). A prerequisite for pull scheduling is to reduce batch sizes (Schonberger, 1982a). The pull scheduling system in its ideal form will provide each operation in the manufacturing process with the right part, in the right quantity, at exactly the right point in time and therefore represent the very ultimate goal of process improvements (Shingo, 1985). On the other hand, the ideal one-piece flow is seldom maintained, but it is an objective to be pursued (Schonberger, 1982b).

Furthermore, the sixth criterion of degree of adoption – multifunctional teams – could be considered as fundamental as the waste elimination criterion and even maybe as a prerequisite for continuous and sustainable waste elimination: multifunctional teams of workers can generate and carry out a lot of ideas regarding waste elimination in processes (Monden, 1983). Determinants for multifunctional teams are next: the percentage of workers working in teams should increase; the number of tasks performed by a single team should increase; the number of job classifications should reduce; task rotation frequency should move from less than once a year to every hour or even more frequent; the number of training and amount of different working stages trained per worker should increase (Karlsson and Åhlström, 1996). The ability to create efficient and continuous improvements using multifunctional teams shows company culture and again is the basis for successful lean implementation (Wheelwright and Bowen, 1996 Krafcik, 1988).

The seventh criterion of DOA is closely connected to the previous one and could be regarded as a next step in giving more responsibility to the multifunctional teams. The determinants to analyse the level of decentralisation are, as follows: leadership level should move from a separate person within the organisation to the rotation within multifunctional teams; within a team, the number of employees who could and have accepted the responsibility for the leadership should increase; the number of hierarchical levels in the organisation should decrease; the number of areas of responsibility of multifunctional teams should increase (Karlsson and Åhlström, 1996).

As it stems from determinants, the result of decentralisation should be the decreasing number of hierarchical levels in an organisation. Lean thinking requres that responsibility and authority are consistently brought down to the lowest levels of the organisation (Hayes et al., 1988). The number of hierarchical levels in the organisation can as a consequence be reduced (Gunn, 1987). The way in which the tasks of management are transferred to the teams is decentralisation. Team leaders act as coaches by providing support to the teams instead of being classic managers (Hayes et al., 1988).

Another way of viewing the result of the decentralisation is the number of different direct and indirect functions integrated into the task list of multifunctional teams. The determinants of the eighth criterion of DOA are: the number of indirect tasks in teams should increase; the ratio of indirect personnel in relation to direct employees should reduce (Karlsson and Åhlström, 1996). Indirect tasks that could be performed by multifunctional teams could vary from material handling, planning and control to maintenance and quality checks. As a result, the support functions are not needed to such an extent in which they exist in the traditional production approach (Schonberger, 1986).

The final criterion of the lean approach is the status of information flow and information content provided to the teams. It should be continuous and in real time, and it should also consist of both strategic and operational information. Based on this, the determinants of the ninth criterion are: mode of information provision should move from no information to the employees towards the continuous displaying of the required information direct to the production floor; the number of strategic areas covered by information flow should increase; the number of operational measures in information flow should increase: the frequency of information to the employees should increase (Karlsson and Åhlström, 1996). Correct, timely, right content and mode of information are of utmost importance for the multifunctional teams to perform the tasks in the required measures of quality, time and costs (Wheelwright, 1985).

Finally, the success of lean thinking implementation as assessed based on the degree of adoption – sum of the scores of the nine criteria.

The conclusion and result of this point are, as follows. Based on a review of the literature, the author constructed the process of lean thinking implementation, which incorporates the important steps indicated above and leads to successful lean implementation (Figure 1). The steps regarded as critical are: process quality, lean knowledge acquisition, lean house development, training of lean house, lean thinking implementation process planning, execution of the plan and, as a result, successful lean thinking implementation. Since implementation should never end (Crabill et al., 2000; Kobyashai, 1994; Leseure, 2010), the step of continuous improvement closes the loop.

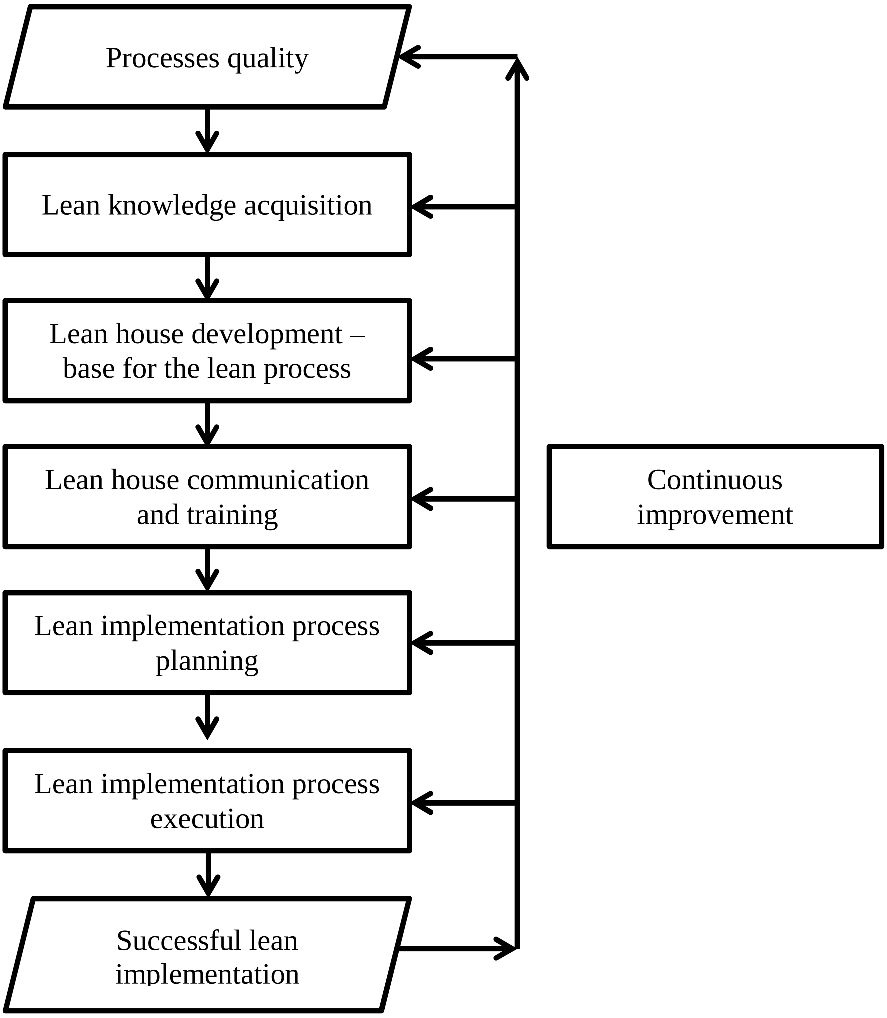

Figure 1. Lean implementation process model (constructed by author)

The developed process will be further used in the study for assessing the companies lean implementations in order to identify which step of the process influence successful lean thinking implementation more and thereby could be regarded as critical success factors lean thinking implementation. The performance at each step of each company is assessed against the determinants presented in this point prior to the literature review of corresponding step. The determinants of the process steps have been developed by the author. The result of the lean thinking implementation process in each company is DOA, which is also assessed against the presented determinants, which are derived from the Karlsson and Åhlström (1996) model. The methodology for the assessment of process steps and the degree of adoption is presented in part 2.

Also, the developed process model discussed above is not universal. According to the author, the initial proposal model is suitable for the batch type of manufacturing process. According to Slack, Chambers and Johnston (2010), there are five main manufacturing process types: project, jobbing, batch, mass and continuous. The main differences between the process type are on product variety and volume sides. In project type, the variety is very high – every other product is different from the previous product and the volume is very low – each product is produced in a single sample. Examples of project type process include manufacturing ships or nuclear plants. The totally opposite side is the continuous process type – variety is very low and volume is extremely high. Examples are usually from chemical production where there is one single product (for example, petrol) continuously produced in huge volumes. In between, we have batch type, which is most common. In the batch type of the process, both variety and volume are medium. We can say that most things we use in our everyday life are produced by the batch type of the process. Between batch and project type, we can find jobbing – the variety is higher than in the project type but smaller than in batch, and the volume is vice versa. The mass process type is located between batch and continuous process, with quite high volume and low variety.

The current research and proposed model focus area is batch type of the process without dependence on industry, company size, market or any other company parameter. The focus area is chosen for two reasons:

- Batch processes have very strong requirements in terms of being very efficient and at the same time offering a wide variety of products at an acceptable price level.
- Batch process type is represented in the biggest part of all manufacturing companies in Estonia.

It is important to note that by batch process type, the author is focused on the main manufacturing process in the company. In each company, in addition to the main process, one can find support processes that could be of another type. For example, product repairing is a project type; energy production is a continuous type, and so on. Project and jobbing processes have an even bigger variety than batch process though they could compensate that by higher price levels and being acceptable to customers. Mass and continuous process have less variety, and efficiency could be achieved by economies of scale. For batch process type, both approaches are not applicable: with rather high variety, small batch sizes and therefore with many product changeovers, price levels should be kept low. The only possibility to act like this is to continuously reduce operating costs.

Batch process type is a good representation of the main focus of lean thinking: if we take any kind of process, then according to the lean philosophy each process could be divided into three different activity types: value adding activities (VAA), value non adding (NVAA) activities and value allowing activities (AVAA) (Ohno, 1988; Liker, 2004; Rother and Shook, 2003; Heizer and Render, 2011 and others).

VAA requires resources and adds value to the product – in other words, we can say that the product is physically modified in some way and moved forward along the technological process toward its final state. NVAA also requires resources, but it does not modify the product – waiting, repairing, quality control and all other waste activities. AVAA again requires resources, but it also does nothing with value adding, but as specified in the name, they allow value adding – activities such as transportation. Finally, based on that idea we can say that the goal of lean philosophy implementation is to totally remove NVAA and reduce AVAA as much as possible (since it is impossible to remove them at all – we cannot produce anything without moving it from one station to another), thereby increasing the ratio of VAA in the process.

In the batch process type, the ratio of VAA in all the activities is quite small, usually representing only some hundredths or at best some tenths of all activities. This is due to the nature of batch processes: resources are organised by functions; products are produced in batches moving from one resource to another, thereby creating a lot of waste.

Since lean thinking ideas are just starting their journey in Estonian manufacturing companies, for the purposes of the current research it is much easier to find enough companies for the study when focusing on batch process type manufacturing companies. Finally, the proposed process model has no limitations in the focus area – manufacturing companies with batch process types. The main argument to support such a statement is outlined above.

Before moving on to the methodology part, the author would like to cover another topic related to lean thinking. The first one is criticism of lean. Nobody can say that there is a perfect manufacturing paradigm; therefore, lean thinking should have a negative side as well. Continuing this topic, the author outlines some alternatives to lean thinking that are used in manufacturing companies. Finally, the author discusses the situation regarding lean thinking in Estonian manufacturing companies. The focus of the two next points is the identification of other possible problems with successful lean thinking implementation (which could be found in critics) and to discuss in closer detail the problems of lean thinking implementation in Estonian manufacturing companies.

1.6 Criticism of lean and alternatives of lean

It is evident that critics of lean began as soon as lean thinking spread worldwide. Many authors (Carlisle and Parker, 1989; Fucini and Fucini, 1990; Garrahan and Stewart, 1992; Rineheart et al., 1993 and others) discovered major gaps in the lean approach and its suitability for process improvement. The main focus of the critics during different periods of time was on the matter of lean thinking as a new concept for manufacturing management (Hines et al., 2004). The gap of sustainable lean thinking process implementation, however, was presented throughout and (as it was also indicated before in the thesis) has not been solved yet (Table 3).

Table 3. Main gaps and criticisms of lean thinking (Hines et. al., 2004, complemented by author)

	1980-1990	**1990-mid 1990**	**Mid 1990-1999**	**2000+**
Key gaps	Inter-company aspects; Systemic thinking; Auto assembly only.	Mainly auto; Human resources, exploitation of workers; Supply chain aspects; System dynamics aspects.	Coping with variability; Integration of processes; Inter-company relationships; Still mainly auto; Integrating industries.	Global aspects; Understanding customer value; Low volume industries; Strategic integration; E-business.
Main critics	Carlisle and Parker (1989) Fucini and Fucini (1990)	Williams et al. (1992) Garrahan and Stewart (1992) Rineheart et al. (1993)	Davidow and Malone (1992) Cusumano (1994) Goldman et al. (1995) Harrison et al. (1999) Suri (1999) Schonberger and Knod (1997)	Bateman (2000) Christopher and Towill (2001) van Hoek et al. (2001)
Lean thingkig implementation process gaps	*Systematic process approach is missing; Not suitable for non automotive companies.*	*Lack of systematic process approach being able to cope with dynamic changes in the environment.*	*Lack of systematic process approach being able to cope with dynamic changes in environment; Still focus only on production.*	*Lean thinking implementation process not supporting company strategy (missing lean house)*

The first gaps began to appear in the early period of lean thinking implementation from 1980-1990 (Table 3). At that time, lean was mainly regarded as lean production, focusing only on shop-floor issues and not taking into account the intercompany aspect state (Womack and Jones, 1994; Womack and Jones, 2005). Therefore, the process of lean thinking that was able to make the whole company work towards the target of achieving lean status was not required. Furthermore, the need for coping with the dynamics of processes in a manufacturing company was discovered and the absence of a systematic approach to lean thinking implementation became apparent (Williams et al., 1992). Such a situation continued into the next periods and at present it is evident that lean thinking implementation should be able to support the overall strategy of the company (Bateman, 2000; Christopher and Towill, 2001). The transformation of the term lean went together with the usage of ideas: starting with lean production, continuing as lean factory and lean supply chain, and finally reaching lean thinking state – the start was in production only and now they are used in all other functions in the manufacturing company (Stone, 2012).

Cooney (2002) argues that overall the business situation, market conditions and company's external environment influence the adoption of lean principles and this influence is ignored. He adds that "lean production is dependent upon production levelling throughout the whole supplier chain to achieve just-in-time flow, and without this precondition being met the utility of lean factory practice is called into question" (Cooney, 2002, p 1134). Furthermore, high product variety and small volume production processes are considered to be hard for lean implementation (Bhattacharya and Walton, 1995).

Some studies prove that the lean implementation and adoption process is hard work, requires tremendous resources and needs the company's cultural change and acceptance on new working ways at all levels of the organisation (Drickhamer, 2000; Phillips, 2000). As a result, only about 10 per cent or less of the companies succeed at implementing lean manufacturing practices (Bhasin and Burcher, 2006). Other reasons for the failures include inappropriate understanding of the lean concept ((Sohal and Eggleston, 1994), taking the philosophy "black box", which has many dangers inside (Voss, 2007), and the usage of lean initiatives as a fad (Repenning and Sterman, 2001). The conclusion is that the sustainable and systematic approach of lean thinking implementation is required by manufacturing companies even more so now than before.

In addition to the critics, lean is quite often opposed or viewed together with other techniques such as agile manufacturing or six sigma. The topic of agile manufacturing is covered with papers comparing it to lean and trying to determine the best of two techniques by creating a new technique called *leagile* – lean plus agile. Authors such as Mason-Jones et al. (2000), Goldsby et al. (2006), Towill and Christopher (2002) and Hallgren and Olhager (2009) are some examples here.

Organisational Development International (ODI) offers 20 Keys® (Table 4) methodology developed by professor Iwao Kobayashi in the 1980s. ODI claims that, "some of keys have been used by world class companies since the 1970s

Table 4. 20 Keys® (Kobayashi, 1994)

Organizational Development International (ODI), 20 Keys® methodology		
-	Key 01	Cleaning and Organizing to Make Work Easy
-	Key 02	Rationalizing the System / Goal Alignment
-	Key 03	Small Group Activities
-	Key 04	Reducing Work-in-Process
-	Key 05	Quick Changeover Technology
-	Key 06	Kaizen of Operations
-	Key 07	Zero Monitor Manufacturing / Production
-	Key 08	Coupled Manufacturing / Production
-	Key 09	Maintaining Machines and Equipment
-	Key 10	Workplace Discipline
-	Key 11	Quality Assurance
-	Key 12	Developing your Suppliers
-	Key 13	Eliminating Waste
-	Key 14	Empowering Employees to Make Improvements
-	Key 15	Skill Versatility and Cross Training
-	Key 16	Production Scheduling
-	Key 17	Efficiency Control
-	Key 18	Using Information Systems
-	Key 19	Conserving Energy and Materials
-	Key 20	Leading Technology / Site Technology

Today, these tools and techniques are being widely used by companies and consultants alike. What makes 20 Keys® different from a set of tools and techniques is the framework in which it is presented. This framework ensures a holistic and sustainable implementation of best operating practices".

Santos et al. (2006) in their book "Improving production with Lean Thinking" bring lean philosophy and 20 Keys methodology together, clearly showing that the aim, tools and targets of both concepts are the same. This indicates that in terms of the present paper there should not be differences between those two.

On the other hand, the author believes that lean thinking has a part, which is missing in 20 Keys – the philosophical aspect. The 20 Keys methodology, based on the author's opinion, is a purely practical tool for process improvement. Lean thinking refers to the way of working – the philosophy of working. Based on this, the author believes that lean thinking is the optimal way for companies to operate improvements. Lean combines both the practical way and philosophical aspect, which is missing in 20 Keys.

Another alternative to lean thinking is agile manufacturing. Agile manufacturing tends to be a bit different from the lean concept, while focusing on almost the same targets – to be more efficient (Miina, 2008 (2)). While lean manufacturing focuses on the pursuit of process efficiency – getting the greatest outcome from the least input through the removal of wastes, agility refers to the effective, flexible accommodation of unique customer demands (Christopher and Towill, 2000). According to Naylor et al. (1997, p. 108), the agile company is one that "uses market knowledge and a virtual corporation to exploit profitable opportunities in a volatile marketplace".

Hormozi (2001) points out that the agility manufacturing concept came out around 1991. At that time, industry observed that the increasing rate of change in the business environment was quickly outpacing the ability of traditional manufacturing organisations to adapt. Due to this, organisations were unable to take advantage of opportunities that were presented to them, and this inability to adapt to changing conditions may result in the demise of their organisation in the long run. “An agile company is one that embraces change and adapts to it rapidly and easily. Agility means being able to reconfigure operations, processes, and business relationships efficiently while at the same time flourishing in an environment of continuous change” (Hormozi, 2001, p. 132).

Each article describes the phenomena of agility in a different way (Jin-Hai et al., 2003): response to change and uncertainty; building core competences; supply of highly customised products; synthesis of diverse technologies; intra-enterprise and inter-enterprise integration. Similarly, Goldman et al. (1995) suggest that agility consists of the four main components: delivering value to the customer; being ready for change; valuing human knowledge and skills; forming virtual partnerships.

In general, it could be said that agile manufacturing integrates design, engineering, and manufacturing with marketing and sales in such a way that the products are customised to the exact needs of the consumer (Hormozi, 2001). Its goal is to produce products that completely satisfy the consumer’s needs and wants (Nagel and Dove, 1991). Product lead times will be so short that they are virtually unheard of today (Blackburn, 1991; Youssef, 1992).

One of the examples of getting benefits out of agile ideas is Whirlpool Corporation. Problems in early 1980s, when Whirlpool's inability to meet the service requirements of long-standing customers like dealers and contractors began to undermine business, forced them to change their approach (Hormozi, 2001). As a result, cross-functional teams of employees at Whirlpool approached a total supply chain perspective and focused on an idea that a full dealer is a happy dealer. They used the network of strategically located, integrated regional logistics centres and a good transportation fleet. In the end, Whirlpool slashed its order cycle time from 14 days to 24 hours, significantly reduced costs, and took large quantities of inventory out of the supply chain (Gunneson, 1997).

As we can see, both the lean and agile concepts enable companies to achieve remarkable improvements. The next logical question will be what to choose? There are several articles that debate the advantages and disadvantages of both concepts. Some of them even discuss the possibility of marrying the ideas and creating a leagile paradigm in order to take only the positive aspects from both concepts (Mason-Jones et al., 2000; Goldsby et al., 2006; Towill and Christopher, 2002).

Hormozi (2001) provides us with a comparison of the lean and agile manufacturing concepts regarding the industry objectives (Table 5), which might be helpful in choosing between them. According to the author, it can be seen that agile manufacturing attempts to optimise the elimination of waste, production levelling, sensitivity to customers and other industry objectives while lean manufacturing techniques did not achieve this optimisation.

Table 5. Industry objectives in lean and agile paradigms (Hormozi, 2001)

Industry objectives	**Lean**	**Agile**
Emphasis on elimination of waste	High	High
Degree of production levelling	High	Flexible
Degree of organizational communication	High	High
Sensitivity to customer demands	Medium	High
Need for skilled employees	Medium	High
Degree of cooperation between companies	Low	High
Piece cost of small runs relative to large runs	Medium	Same
Lead times for existing products	Short	Short
Degree of product marketing required	High	Low

Another comparison about lean and agile paradigms is given by Naylor et al. (1997):

- Agile means using market knowledge and a virtual corporation to exploit profitable opportunities in a volatile marketplace.
- Lean means developing a value stream to eliminate all waste, including time, and to ensure a level schedule.

Agile concept came from the IT industry and is nowadays also used widely in all industry areas. In general, the target of both lean and agile is the same – to improve operations, while both focus on a slightly different aspects. Lean is more towards waste elimination and agile is more towards flexibility.

Nevertheless, there are many sources which prove that companies that apply lean initiatives and struggled through the implementation process are able to provide support for the system (Drickhamer, 2000; Liker, 1998; Rea, 2002; Teresko, 2002; Trombly, 2002; Zimmer, 2000). Strozniak (2001) marks that positive sides to lean ideas are also evident in a survey carried out by Industry Week whereby lean practices were mentioned as quite superb. Other authors (Drucker, 1992; Hogg, 1993; Mathews, 1994; Womack & Ross, 1990) suggest that manufacturing industry will move towards lean manufacturing and as a result will develop the operational advantage. Therefore, despite the different aspects discussed by commentators, lean thinking is a powerful tool if applied in systematic manner and is one of the approaches to be considered by manufacturing companies in their way to world-class manufacturing.

1.7 Lean in Estonian manufacturers

The idea that "everything you said about lean is nice, but we are already doing that and we call it common sense" was discovered during a pre-study discussion with Estonian manufacturers. It means that many Estonian manufacturing companies believe that by using "common sense" they deal with waste elimination from processes (Miina, 2008 (1)). This might be correct, but it also has to be noted that all this "common sense" has to be implemented in a planned and structured manner.

First, Estonia itself and manufacturing companies acting here are missing the long-term perspective due to the lack of experience of long-term acting. This comes due to historical aspects of having a short first republic and so far a rather short second one.

Second, as Estonia became independent, subjects such as Operations (production) management started to be, we can say, unpopular. Most of the studies in universities started to be focused on more popular subjects such as banking, finance, marketing and IT. As a result, Estonian manufacturing companies are currently lacking educated production or operations managers. Such a point of view is based on the author's own experiences and comments from the top managers of manufacturing companies. This all gives the situation in which Estonia is lacking the traditions of operations (production) management.

The third aspect flows from the previous two: the absence of a long-term perspective and operations management traditions create a situation whereby companies do not see the need for continuous process improvement. Such activity has a long-term outcome – companies are unable to see and understand this. Continuous process improvement as a basis requires a correct attitude and understanding of this – the lack of traditions makes this activity impossible.

All three mentioned aspects indicate to the author one of the reasons for the small productivity of Estonian manufacturing companies and also that the case of Estonia might be interesting for Estonian manufacturing companies themselves as well as for other former Soviet Union republics, such as Latvia and Lithuania, which are similar (from historical point of view) to Estonia.

The concept of lean is very wide, including different tools and techniques, focusing also on the philosophical aspect. The lean journey began from Toyota in the form of Toyota Production System and it was widely opened for others in the manufacturing world in the 1990s by Womack and Jones in the book "Machine that changed the world". Since then, it has been applied in different industries and companies.

The main idea behind lean is to eliminate waste. Waste is an activity that requires resources but does not add value to the end product. Value is defined by the customer. In other words, companies should not try to use their existing resources in the most efficient way from their point of view, but instead of this they should first clearly understand what is needed by customer – what is value for the customer, and then create a process for value creation in a low manner. The process is analysed using different tools, starting with process standardisation and continuing endlessly, resulting in continuous improvement. All this could be formalised as a company's improvement philosophy in the form of lean house.

Finally, lean is not an ultimate concept and there are critics of lean implementation. Additionally, alternatives to lean, such as the 20 Keys approach and agile concept are also widely used in the manufacturing world. Despite this, based on a number of successful stories, the author suggests that lean is one of the methods for improving the productivity and efficiency of Estonian companies.

1.8 Conclusion

The first part of the thesis focused on studying the lean thinking concept, its tools and aspects of its implementation in manufacturing companies based on academic literature. The main outcome of that part is that lean thinking, though it seems to be simple process improvement, is not such an easily applicable concept and there are certain complications in the process of lean thinking implementation. First, there is no clear understanding of what is lean and why it is needed. Companies see lean thinking as a fire fighting mechanism and as a panacea for low productivity and bad efficiency of manufacturing processes. Lean is neither but is rather a more complete philosophy of doing work and organising manufacturing process.

Second, to understand what is lean and how it tackles waste, research for the definition of waste elimination tools was done. Lean thinking incorporates a big set of tools and methods, though companies mainly start with easier and more often used tools. Those are 5S (sort, straighten, shine, standardise, sustain), VSM (value stream mapping), SMED (single minute exchange of dies), 5Why, standard work and continuous improvement.

Finally, even though the mentioned tools are well known and widely used, companies are still not achieving the desired results and gains proposed by the tools. The process of lean implementation is not defined as a step-by-step approach, critical factors of the process success are not uncovered, and each company is inventing its own path. As a result, less than one tenth of all lean implementation processes in the scope and targets of those are fulfilled. To cover that identified gap in the academic literature, the current thesis is investigating the process of lean implementation and is developing a step-by step process model for the lean implementation process with the focus on critical success factors. The following parts of the thesis give an insight into the methodology of research and bring out the results of the study.

2 Research methodology

In general, the two primary research paradigms are qualitative and quantitative studies. The process by which the researcher follows in studying the questions raised is shaped by those paradigms. Creswell (1994) defines qualitative study as a process of inquiry that is based on building a complex picture, formed with words and conducted in a natural setting. Creswell (1994) alternatively defines quantitative study as a process of inquiry that is based on testing a theory composed of variables, measured with numbers, and analysed with statistical procedures.

The purpose of the current research is to define the successful lean thinking implementation process in manufacturing companies. During the research, the company approaches to lean thinking implementation were analysed. The data for this study are qualitative in nature; therefore, a qualitative design is most appropriate to answer the research question of this study. Creswell (1994) lists six assumptions of qualitative research that should be addressed when conducting qualitative research. The following Table 6 lists the assumptions and how current research addresses them.

Table 6. Research characteristics (author's constructed)

Assumption	**Current research characteristic**
Process oriented	Study of the lean thinking implementation process in manufacturing companies
Focus on meaning	Focus on how the process of implementation is constructed and deployed in the companies
Researcher is the primary instrument	Researcher reviews literature, collect data in selected companies and analyses it
Involves fieldwork	Observations in the companies
Descriptive in nature	Purpose is to define a successful lean thinking implementation process
Inductive	There is no sufficient current theory on how companies should implement lean thinking in order to achieve success.

Part one of the thesis discovered two gaps in the theory of lean thinking: first, the lean thinking implementation process is not studied enough and therefore companies are missing the standard framework of lean thinking implementation; second, lean thinking implementation is relying on critical steps that define the overall success or failure of that process and respectively manufacturing companies have to be aware of those critical success factors for effective lean thinking implementation. Those discovered gaps allowed us to continue with the next steps of the research (Table 7).

Table 7. Research methodology (author constructed)

Research step	Methods	Result
Literature study	Domain-based for articles; Snow-balling for books and other sources;	Theoretical framework of lean thinking; Successful lean thinking implementation process constructed; Criteria and their corresponding determinants for assessing the process of lean thinking implementation and degree of adoption of lean.
Companies selection	Multiply case study method.	Twelve companies and reference company chosen.
Data collection	Observation, company documents study, semi-structured interviews.	Significant amount of data collected.
Data analyses and assessment of companies	Content analysis; Process step assessment; Degree of adoption model.	Critical success factors of lean thinking implementation defined.

The first step of the study was a review of literature based on two different approaches: domain-based for academic articles and snow-balling for books and other sources. The main results of that step included a comprehensive theoretical framework for lean thinking and the development of a successful lean thinking implementation process. Those results were presented in part 1 of the thesis.

The second step of the research was the selection of the companies for the study based on multiply case study method, and as a result twelve companies implementing lean were chosen. Additionally, one reference company was selected for double-checking the results of the study.

The availability of the companies allowed the research to move on to data collection through the usage of different approaches: the observation of daily activities of companies with a focus on lean thinking, semi-structured interviews of companies personnel and the study of company documents. Finally, the mass of collected data was analysed based on the content analysis method, the lean thinking implementation process steps and degree of adoption of lean thinking were assessed, and the final results of the thesis were determined – the critical success factors of lean thinking implementation were pointed out. A more detailed overview of the methods is presented further.

2.1 Literature study

Different authors focusing on performing a critical literature review are discussed at the beginning of the research project (Bell, 1993; Cooper and Schindler, 2003; Ghauri et al., 1995 and others), though some authors propose a well-defined process description of literature study (Welman and Kruger, 2001) while some others are less detailed (Cooper and Schindler, 2003). In general, all views on literature studies have in common that "perception that choosing the right strategy for the literature study is of critical importance as it has a definite impact on the research project, the constructs developed, the methods applied, and the conclusions arrived at" (Soerensen, 2004, p. 2), and they focus on five main steps: obtaining access to the source; material listing under selection criteria; relevance evaluation; validity evaluation; check for completeness (Soerensen, 2004).

The choice of the method depends on the purpose of the study and the researcher's experience in the field (Nemesio, 1999). In the current case, the main purpose of the literature study was to identify the gaps in the domain of lean thinking with the focus on the critical success factors of its implementation process. According to Soerensen (2004), some the appropriate methods include the domain-based method and snow-balling methods (Table 8). The main advantage of the domain-based approach is that the review is complete and that categories match the purpose of the research (Soerensen, 2004). Snow-balling strategy provides the least structured result, though it is very suitable for analysing books and other non-academic sources (Soerensen, 2004).

Academic articles for the current research were studied by using domain-based method. The starting point of the latter is a definition of what is under research. The definition of domain might consist of a list of (academic) journals, an index range in the library, a keyword for e-database searches, news databases etc. that is most often combined with a criterion on the date of publication (Soerensen, 2004). In the current case, the domain is a keyword for lean thinking. Furthermore, the listing of material based on the purpose of identifying the critical success factors of lean thinking was done and, according to the author, judgement relevance and the validity of the found sources were performed. The completeness check was done by a simple count of the contributions and a check on whether the famous articles are present, which is in accordance with the requirements of the study (Soerensen, 2004).

The snow-ball method was used for performing the literature study of books and other sources. The process of performing a study of this type starts with the identification of at least one book of relevance and then reading the sources referenced (Soerensen, 2004). The start was made by renowned books on lean (also referred being bestsellers on the topic of lean) and their references were studied further. In the case of the snow-ball method, the requirements are simpler than with the domain-based method and therefore relevance and validity were checked based on author judgement. A completeness check was not performed since it is not relevant for that method.

Table 8. Literature study methods and their application to the current study (Soerensen , 2004, complemented by author).

Method Step	**Domain-based**	***Current study***	**Snow-balling**	***Current study***
Selection of source	Domain in question	*Lean thinking*	Not precisely defined, starts from e.g. overview article or “well-known” book.	*All “well-known” books on lean thinking, e.g. “Toyota Way” (Liker, 2004), “The Machine that Changed the World” (Womack et al., 1990) and others.*
Material listing	Dependent on study	*Critical success factors of lean thinking implementation*	Not precisely defined	-
Relevance	“Fit” for purpose of the study.	*Fits with the purpose of the study*	“Fit” with purpose of the study.	*Fits with the purpose of the study*
Validity	The subjective evaluation of the researcher	*Found material is valid for the study according to the author’s evaluation*	The subjective evaluation of the researcher	*Found material is valid for the study according to the authors evaluation*
Check for completeness	Relevant.	*A count of the contributions in and the check on whether the well-known articles are present was performed.*	Not relevant.	-

The results of the literature study were presented in part 1 and they create the basis for the further research. The main output represent the successful lean thinking implementation process with the focus on critical success factors and criteria for those (process steps and results of the process) assessment.

2.2 Selection of the companies

The design of the research starts with the definition of questions and addresses the planning of scientific study (Babbie, 1998). The result is the master plan (Zikmund, 2000) or “blueprint” (Yin, 2003) that specifies the methods and procedures for collecting and analysing needed information. Research design allows for obtaining answers to research questions and control of the experimental part of the study (Kerlinger, 1965). In general, the research design is dictated by three main questions: first, the type of research question; second, the extent of control over actual events by a researcher; third, the degree of focus on contemporary events (Yin, 2003). Table 9 below represents an overview of the different approaches of the research.

Table 9. Overview of different research strategies (Yin, 2003)

Strategy	Form of research question	Requires control over behavioral events?	Focuses on contemporary events?
Experiment	How, Why	Yes	Yes
Survey	Who, What, Where, How many, How much	No	Yes
Archival analysis	Who, What, Where, How many, How much	No	Yes/No
History	How, Why	No	No
Case study	How, Why	No	Yes

Lean thinking implementation process in the companies selected is on going at the moment of study and therefore is contemporary event. The author cannot decide what to do and how to do it in the process of lean thinking implementation in the company and therefore does not have control over it – no control over the behavioural event. Additionally, as stated before, the main questions of the study are: how should companies perform the process of lean thinking implementation? Why do companies fail with lean thinking implementation? Therefore, the case study method was chosen for the purposes of current research.

The application of the other methods (experiment, survey, archival analysis, and history) would not be appropriate and would not produce relevant results. The experiment is a quantitative method that requires the researcher to manipulate the variables of a process to test a theory (Creswell, 1994). Due to the reason that current research is not testing the theory, but is explaining how companies are approaching the lean thinking implementation process and why they fail with it, the case study method is appropriate. Surveys are a quantitative method employing the questionnaires or structured interviews of a sample population for data collection to generalise across a population (Creswell, 1994). A survey approach could provide the general identification of critical success factors, but there will not be any explanation on why companies fail when dealing with those critical factors. Additionally, since it is stated that one of critical steps is the construction of company's own view of lean thinking (lean house), it would be difficult to correlate how each company approached this step. The archival analysis method requires the researcher to collect data from verbal, visual, or behavioural forms of communication (Horsey, 2003). This method precludes the researcher from directly interviewing participants or observing the process (Horsey, 2003), which, in general, could be used for the current study, but since the question why is not under the focus of the archival analysis the author disclaimed the usage of that method. The history method requires that there is no access to or control over the event being studied (Yin, 2003). This research focuses on a contemporary even; therefore, the history method is not appropriate.

According to Yin (2003), the case study has four main components: the study questions, study unit of analysis, the logic linking the data to the propositions, and the criteria for interpreting the findings. Therefore, the main reason for selecting the case study method is that it is the preferred method when attempting to answer "how" and "why" research questions about contemporary events over which the researcher has no control (Yin, 2003). The main research questions of the current thesis are: How companies should perform the process of lean thinking implementation? Why companies fail with lean thinking implementation? The author will focus on how the process of lean thinking implementation is constructed and deployed in the companies.

The problems of defining what is a unit of analysis and defining what the case is are in confrontation (Yin, 2003). Defining the context of the case requires that the study questions are defined to ensure that the scope remains in feasible limits, and due to this if the case is defined as a program, implementation process, or organizational change, there will be problems defining the beginning or end points of the case. (Yin, 2003). The unit of analysis of current research is a manufacturing company that has implemented lean thinking and a case timeframe start with the formal start of the implementation of lean thinking.

The logic linking data to propositions and criteria for interpreting the findings are the least developed components of case studies (Yin, 2003). The current thesis will use content analysis as the data analysis technique and degree of adoption (Karlsson and Åhlström, 1996) model for the interpretation of findings. A more detailed description of these is given later on in this part.

Since the number of the companies is more than one, the multiple case study approach is relevant. According to the multiple case study method, the appropriate number of the cases is 10 (Yin, 2003). The author has chosen 12 companies for the study purposes. The main criteria for the selection was based on a company's own statements on whether they are implementing lean practices and principles to improve their operations, and lean is not taken as a "popular thing" in those companies. According to many authors (Ahlström, 1997; Bhasin, 2011; Cuatrecasas et al., 2007; Hilton and Sohal, 2012 and others), the highlighted criteria are sufficient for the choice of the companies for the lean thinking implementation process study. Selecting companies from different industries and of different sizes will allow for generalisation of the results and the future development of theory. Additionally, all companies represent a batch type of their main manufacturing process.

Single case study requires usage of the theory; multiple case study analysis requires replication logic and the benchmarking of cases from different industries (Yin, 2003). The same exact tactics were used in current research, where companies from different industries were benchmarked against each other and the findings replicated.

In addition to the Estonian manufacturing companies, one reference company – Scania – was also assessed. Scania is known as one of the best examples of lean implementation outside of Toyota. Scania has it is own production system based on lean ideas. As a result, it would be interesting to see how the proposed model would work in the case of Scania. After the selection of the companies, the data collection step was performed.

2.3 Data collection

The targets of the data collection step were first to collect data in order to understand the initial (before starting lean initiative) company performance; and second to collect enough data to assess company performance change during lean implementation and lean implementation. Therefore, the main focus of data collection were:

- assessing process quality;
- assessing how and in what amount was lean knowledge acquired;
- assessing how lean knowledge was analysed and interpreted into lean house (and was it at all interpreted);
- assessing how the interpreted (if it was) lean knowledge was communicated to the personnel;
- assessing how lean implementation was planned and executed;
- and assessing results on lean implementation.

The types of data collected in the companies are shown in Figure 2. Main data types are text, narrative data and visual data. A detailed description of each data type and its collection method is given next.

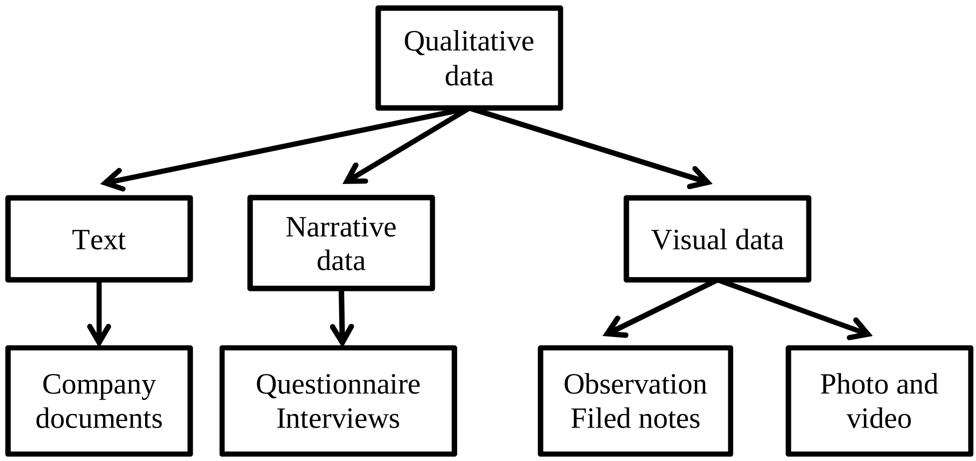

Figure 2. Data types (author's illustration)

Text data

Text data should be represented in the form of different company documents (Barley, 1990; Becker and Geer, 1957). The current study focused on different types of documents for each step of the lean thinking implementation process:

- assessing process quality:
    - process descriptions, working routines and standards;
    - processes key performance indicators (KPIs) measurement data (charts);
    - analysis of deviations in the processes and actions lists of corrective and preventive actions.
- assessing how and in what amount was lean knowledge acquired:
    - performed lean trainings description and participants lists;
    - lean thinking books obligatory to read for the personnel.
- assessing how lean knowledge was analysed and interpreted into lean house (and was it at all interpreted);
    - description of company's lean house or any other similar operational excellence model;
    - standards for implementing different lean tools (for example, 5S standard, SMED standard and others).
- assessing how the interpreted (if it was) lean knowledge was communicated to the personnel:

    - lists of performed internal trainings on the lean topic and participants lists.
- assessing how lean implementation was planned and executed:
    - lean implementation (long-term) plan;
    - fulfillment of plans and its corrections during the implementation.
- and assessing results on lean implementation:
    - process descriptions, working routines and standards;
    - processes key performance indicators (KPIs) measurement data (charts) and their dynamics during lean implementation;
    - analysis of deviations in the processes and action lists of corrective and preventive actions.

Not all types of documents described above were found in all companies and some documents were absent. Text data collection was retrospective.

Narrative data

The second data type was narrative data, which came from interviews, informal discussions and field observations. Mainly persons involved in the lean implementation process (questionnaire and discussions) and process performance (field notes) were under the focus of collecting narrative data.

Interviewing personnel outlined the main ideas of the lean projects in the studied companies and it allowed for an understanding of the view of personnel on companies' lean initiatives. The following questions were asked during semi structured interviews (adapted from Achanga et al., 2006):

- How do you understand lean thinking?
- What has motivated the company to implement lean thinking?
- Where has lean been implemented in your organisation?
- What were the criteria for choosing that area(s)?
- How many people were involved in the process?
- What training, if any, did the staff undertake? On-the-job-training?
- What were the difficulties encountered in training and how were they overcome?
- What were the difficulties during the implementation stage and how were they overcome?
- What do you think has been the result of implementing lean? Why?

Aside from the direct information about the steps proposed in the empirical model, the questionnaire and discussions also showed the ability or inability of involved persons to communicate and express their knowledge about lean implementation.

Visual data

Third type of data is visual data, which could be represented in the form of photos and videos (Barley, 1990; Becker and Geer, 1957):

- Photos of working area before implementing lean and after;

- Videos of processes before and after implementing lean.

Again, not all companies had visual data available, especially about the status before implementing lean, though in almost all cases some data was found anyway. After data collection, the author moved on to the data analysis step.

According to Yin (2003), the use of multiple sources of information is one of the major strengths in a case study design. The main qualitative data collection techniques and their pros and cons are defined below in Table 10.

Table 10. Overview of data collection methods (Creswell, 1994, complemented by author)

Data type	**Advantages**	**Limitations**	**Usage in current thesis**
Narrative	Useful when informants cannot be directly observed. Informants can provide historical information. Allows researcher "control" over the line of questioning.	Provides "indirect" information from interviewees' viewpoint. Provides information in a designated "place" Researcher's presence may bias responses Not all people are equally articulate and perceptive	Used for the collection of historical data of lean thinking implementation. Used for collecting the data (respondents opinion) about the present state of lean thinking implementation process.
Visual	Researcher has first-hand experience with interviewee. Researcher can record information as it occurs. Unusual aspects can be noticed during observation. Useful in exploring uncomfortable topics.	Researcher may be seen as intrusive. "Private" information may be observed that cannot be reported.	Used for proving or disproving the information from interviews and text about the present state of implementation and approach to it. Used to collect data about the present state of lean thinking implementation.
Text	Enables a researcher to obtain the language and words of the interviewee. Unobtrusive source of information. Saves time and the expense of	May be protected information unavailable to the public or private access. Requires the researcher to search out information in hard-to-find places.	Used to collect the historical data (when and why lean thinking implementation was started). Used to collect the data about the company's approach

	transcribing	Materials may be incomplete or not authentic.	to lean thinking implementation.

Data collection was performed in the companies during the period between 2009 and 2010. The subsequent step of data collection was data analyses and the assessment of the studied companies. The assessment focused on two main areas: the process of lean thinking implementation and the result of that process. The process of lean thinking implementation was assessed against the constructed model of lean thinking implementation: how well companies were following the requested steps. The next point first describes the method of lean thinking implementation results assessment and then describes the assessment of the lean thinking implementation process itself. Such an approach is chosen due to the reason that the assessment of the process is based on the same methodology as the assessment of process results.

2.4 Data analysis and assessment of the companies

Collected qualitative content (text, narrative and visual) was analysed by using the content analysis method. According to Neuendorf (2002, p.10) "content analysis is a summarising, quantitative analysis of messages that relies on the scientific method and is not limited as to the types of variables that may be measured or the context in which the messages are created or presented". The content analysis method could incorporate the various kinds of analysis where communication content is categorised and further classified (Krippendorff, 2004) and is a systematic, replicable technique for compressing many words of text into fewer content categories based on explicit rules of coding" (Stemler 2001).

Data analysis in the current thesis used the emergent coding approach with the application of recording units. In emergent coding, categories are established that follow some preliminary examination of the data: material is reviewed and a set of features in the form of a checklist is created, which is further applied for coding (Haney et al., 1998). Recording units are defined syntactically, that is, to use the separations created by the author, such as words, sentences, or paragraphs (Stemler, 2001).

Additionally, the question of validity is very important. As such, the validation of the inferences made on the basis of data from one analytic approach demands the use of multiple sources of information. This means that the researcher should try to have some sort of validation study built into the design, such as in the form of triangulation, which is often used in qualitative research. By triangulation, the credibility of the findings could be achieved by incorporating multiple sources of data. (Erlandson et al., 1993) In current research, three main types of data were used (see point 2.3).

Based on the method of content analysis, the data were naturally categorised into categories of lean thinking implementation process steps and into criteria of DOA of lean from Karlsson and Åhlström (1996) (see point 1.5), and were further subcategorised into categories derived from determinants of each criterion (process steps and criteria of DOA). Next, subcategorised data were analysed and overviews of the required information were brought out based on the data type – text (company documents), narrative (questionnaire and interviews) and visual (photos, video and field notes).

Furthermore, data in subcategories were assessed based on a model modified by Karlsson and Åhlström (1996). The used assessment grades for assessing process steps and DOA are: 2 – determinant is implemented; 1 – determinant is partly implemented; 0 – determinant is not implemented. Those grades were developed by the thesis author due to the fact that the Karlsson and Åhlström (1996) model is missing exact rules about the grades. The presented grades help to make a simple assessment of the result of companies' lean thinking implementation and are suitable for the Estonian case due to the same simplicity. Estonian manufacturers, as stated before in point 1.7, are just starting lean thinking implementation and therefore more a sophisticated assessment degree would be hard to apply due to results not being differentiated among the companies. In general, grade 0 means that the respective determinant is not applied enough in the company and has to be dealt with (subjectively representing 0-30% of possible activities and results of the determinant); grade 2 means that the determinant is being applied and at the moment of study no further developments are required (subjectively representing 70-100% of possible activities and results of the determinant); grade 1 represents the wider scale (subjectively representing 30-70% of possible activities and results of the determinant) and means that the determinant is being applied, though further development of it is highly recommended.

Assessment is done by comparing the status of each determinant before starting the lean thinking implementation process in the company with the status at the moment of study. Collected data (text, narrative and visual data) forms and amount varies from company to company and assessment is done partly by company representatives and partly by the author, though the final decision about the grade is done by the author following the rules of assessment and data derived from the categories of content analysis. Since each criterion has a different number of determinants, the maximum score for each criterion is different (Table 11 and Table 12). The row total is showing the level of degree of adoption of lean. The examples of content analysis and assessment of the determinants are shown in Appendix 3. Assessment of DOA and Appendix 4. Assessment of process steps.

Table 11. Maximum scores of lean adoption degree criteria (author's constructed)

Criterion	Number of determinants	Maximum score
Elimination of waste	6	12
Continuous improvement	2	4
Zero defects	6	12
Just in time deliveries	4	8
Pull of raw materials	2	4
Multifunctional teams	5	10
Decentralization	4	8
Integration of functions	2	4
Vertical information systems	4	8
Total	**35**	**70**

The row total is showing the level of degree of adoption of lean. The examples of content analysis and assessment of the determinants are shown in Appendix 3 and Appendix 4

Table 12. Maximum scores of starting point and five steps of the process (author's constructed)

Starting point/step	Number of determinants	Maximum score
Process quality	6	12
Lean knowledge acquisition	4	8
Lean house	5	10
Lean house communication and training	3	6
Lean implementation planning	3	6
Lean implementation plan execution	2	4
Total	**22**	**46**

The author's considered scientific perspective is hermeneutic since the main focus of the thesis lies in the interpretation of company processes of lean implementation and interpretation of their understanding of lean. The scientific approach used in the paper is inductive since the author makes the conclusions based only on the studied companies in the frames of the current research, which in fact is not eliminating the possibility that the conclusions in general are false.

Part two of the thesis described the methodological approach of the research. The final part of the thesis brings the results of the study and the final conclusions.

3 Critical success factors and thesis results

3.1 Overview of collected data of companies lean initiatives

The previous part of the thesis was dedicated to the introduction of research methodology and main proposals. The key proposal was the process model of the lean thinking implementation process, which is based on gaps identified in lean thinking literature. To prove or disprove that the field research was conducted, qualitative data was collected and then analysed based on the methodology described in part 2.

An overview of the studied companies is presented in Table 13 below and detailed information of their lean implementation processes is given further. In general, all the information presented in the table is about local companies (or local division) and information was gathered during interviews and observations. In total, we have 2 locally owned and 10 foreign owned companies, 4 of which are competing on the global market and 8 in both local and foreign. 6 have their own products and 6 are suppliers of customer-owned products. The represented industries are varied (though mostly metal treatment, assembly and plastic moulding). All of the companies are small or medium sized enterprises and the main production process is batch production (there might be supportive production processes in a company with different process types).

The companies' lean initiatives summary is showed in Table 14 where the main parameters of the lean thinking implementation process are introduced:

- When was the lean implementation process was started? Among the chosen companies, we have 4 categories of process length:
    - Started less than 1 year ago (5 companies)
    - Started less than 2 years ago (3 companies)
    - Started more than 2 years ago (2 companies)
    - Started more than 5 years ago (2 companies)
- Why was it started? Here are two main possibilities: local initiative (4 companies) or initiative from headquarters (8 companies).
- Usage of consultant help.
- What lean tools or methods were implemented?
- Does the company have its own production system (similar to the Toyota Production System)
- Targets of lean implementation
- Achieved results
- Problems, founded during observation.

In general, all the companies are using consultancy help, nobody has its own working production system and the implemented lean tools are almost the same. Ten out of twelve companies implemented 5S and for six out of the ten 5S was

Table 13. Overview of studied companies (author's constructed)

Nr	Industry	Business segments	Ownership (local/ foreign)	Market (only local/only global/ both)	Own product or supplier	Certificates/Mission/ Vision/Values
1	Electronics assembly	Electronics	Foreign	Global	Supplier	ISO9001, Mission, Vision
2	Wood	Furniture	Foreign	Global	Own	Vision, Values (global)
3	Plastic moulding and assembly	Plastic pipe systems	Foreign	Both	Own	ISO 9001, Vision
4	Assembly	Pharmaceutical facilities	Foreign	Global	Own	ISO9001/14001, Vision, Company's Way
5	Metal and assembly	Stainless steel products	Foreign	Both	Supplier	ISO9001, Mission, Vision
6	Metal	Steel products	Foreign	Both	Own	ISO9001/14001
7	Metal	Ventilation products	Local	Both	Own	ISO9001/14001, Mission, Vision
8	Plastic moulding	Plastic parts	Foreign	Global	Supplier	ISO9001, ISO14001, ISO/TS16949, Vision
9	Turning, Milling, Cold stamping, Assembly, Sheet metal	Automotive industry, Climate systems, Consumer products	Foreign	Both	Supplier	ISO9001, ISO14001, ISO/TS16949, Mission, Vision, Values, Business concepts

10	Metal and assembly	Steel products	Local	Both	Supplier	ISO9001
11	Plastic moulding	Plastic parts	Foreign	Both	Supplier	ISO9001/14001, Mission, Vision, Values, Ethical values
12	Metal and assembly	Lightning	Foreign	Both	Own	ISO9001, Mission, Vision, Values

Table 14. Overview of companies lean initiative (author's constructed)

Nr	When started?	Why started?	Using consultancy?	What was implemented?	Own production system?	Targets	Achievements	Problems
1	Less than 1 year	Initiative from headquarters	Yes, local	5S, VSM	No	No clear targets	5S and VSM seminars, things to improve identified, but no actions, mentioned tools are taken as formal thing without any practical outcome possible	No motivation on the shop floor – everything works fine, why to improve?
2	Less than 2 years	Initiative from headquarters	Yes, local	5S, KPIs, OEE	No	Tools are known and implemented, no measurable targets	5S, OEE and KPI work in one department (out of 7). Other departments planned	Owner change; there is no clear structure of lean implementation, process is not controlled
3	More than 2 years	Initiative from headquarters	Yes, local	5S	No	5S implemented in every factory across organisation	Best 5S implementation out of whole organisation (assessed against internal corporate standards), but stopped around 1 year ago	Implementation process is stopped due to large amount of customer orders
4	More than 2 years	Initiative from headquarters, Operations Improvement project	Yes, corporation level	Kaizen groups, Kanban and pull	No	Each Kaizen group sets its own targets for the next half a year	Project is active and everything goes well	People motivation

5	More than 5 years	Initiative from headquarters, clear project plan for the next 20 years	Yes, corporation level	5S, Operator's maintenance, kaizen groups	No	Clear targets from projects, certification of achievements from Group level	5S certified both in office and shop floor (internal corporate standard), well working kaizen groups.	Old traditions, no real improvement ideas, some person are not focused on any changes (improvements)
6	Less than 1 year	Initiative from headquarters	Yes, local	5S, Kaizen	No	No clear targets set	5S and kaizen started, but due to increased customer orders stopped for a while	Old ways to work seems fine – why to change?
7	Less than 2 years	Local initiative to improve operations	Yes, local	5S	No	5S works everywhere in the shop floor	5S implemented (assessed by local management), project handed over to the company	Personnel motivation, management commitment, project plan
8	Less than 1 year	Local initiative to improve operations	Yes, local	SMED	No	No clear targets	One SMED project were done, stopped due to recession – too less orders	Management motivation
9	Around 5 years	Initiative from headquarters	Yes, local and corporation level	5S	No	5S works everywhere in the shop floor	5S works, good company culture, key persons in production trained in lean principles	No yet clear vision from management, results in particular production groups depends on group manager
10	Less than 1 year	Local initiative to improve operations	Yes, local	5S	No	No clear targets	No clear results	Management motivation

11	Less than 1 year	Initiative from headquarters	Yes, local and corporation level	5S	No	Clear implementation project plan, clear targets for each step of implementation.	5S is working good enough, while some bigger problems must be solved.	Lack of resources for the lean project
12	Less than 2 years	Local initiative to improve operations	Yes, local	5S	No	No clear project plan, but company started to create production system	5S works good enough, all personnel is trained about basic lean principles, detailed training about waste types and methods of elimination, some results are measurable in money	Lack of time and resources for the project

the only method used. Amongst other tools, we can find Overall Equipment Efficiency (OEE), Key Performance Indicators (KPI), continuous improvement (*kaizen)* groups, Single Minute Exchange of Dies (SMED) and Operator's Maintenance.

During the observation and qualitative data collection, the author made a first attempt to assess the lean initiative performance of the companies, indicating it as low, medium or high (corresponding to grades of assessment 0, 1 and 2). This was made before applying the methodology described above for assessing the degree of adoption of lean and was made for the first grouping of the companies. Those groupings were needed for study purposes.

It was identified that the main parameters of lean implementation process that influence the results are identified from where the initiative came from, when the project was started and whether there are clear (quantitative or qualitative) targets. A summary of those parameters and their influence is shown in Figure 3. Below, an overview about first assessment is given.

Starting initiative

A lean implementation start from the headquarters significanty influences the result, as we can see from Figure 3. None of the companies with local initiative have achieved even a medium level of performance.

One of the explanations for such behaviour, found by the author, is that headquarters usually have already been implementing lean initiatives for years. Therefore, they have knowledge and structure behind those activities, which enables the local company to act efficiently. Also, an initiative from headquarters means that the process is controlled and reports regarding actions and results are written and checked regularly.

It is interesting to notice that one of the companies with high performance and initiative from headquarters only implemented lean for more than two years, while another for more than 5 years. It is hard to make general conclusions based on only two examples, but again within the current research we can say that length of the project does not influence the result if the starting initiative comes from headquarters. In other words, the main thing is not the quantity of targets achieved, but the quality of the achievements.

This conclusion is also proven by the fact that those two companies with high performance are the only ones that have a clear vision of why and how they would like to implement lean principles: one company has written an Operational Improvement project (which is based on lean principles), while the other confirmed an implementation plan for the next 20 years.

Length of implementation to date

The picture we can see in the "when started part" is somehow obvious, we could say. The longer the company is implementing lean principles, the better – results are located along the diagonal from bottom left to upper right, while the results may vary within the same range of implementation length, depending on other factors.

In our example, one of the longer-than-5-years companies has high performance, another only medium. As we discussed above, the company with high performance has a very long term plan and this gives good results. The company with medium performance also implements lean for more than 5 years, but there is a lack of clear vision from management; therefore, there is no clear plan and targets and achievements are small, as a result. On the other hand, there is commitment of management – the company still implements lean for many years.

What is the company's lean performance? (0% – 100%)	Starting initiative		When started				Targets	
	Local	HQ	>1 y	>2 y	<2 y	<5 y	Yes	No
70-100% - High	0	2	0	0	1	1	2	0
30-70% - Medium	1	3	1	1	1	1	3	1
0-30% - Low	3	3	4	2	0	0	1	5

Figure 3. Companies lean performance (author's illustration)

Targets

The target of lean implementation could be viewed as a tricky thing. For sure, one company could say that, "the target of lean implementation is to become a lean company". But what does it mean to become lean? To be as lean as Toyota? Yes, this is correct, but the ultimate target – the company has to implement lean for 100 years or more, as Toyota does. A question arises again, a bit detailed: what does it mean to be lean in the short term, let us say in 5 years? To answer that question, the company has to have certain targets.

As we can see from the preliminary analysis, the existence of certain targets leads to high or medium performance. An absence of targets leads to low performance. We could say that this is an obvious thing – if one knows where to go, he will reach it faster, and we get one more proof of that from our research. A good example of creating clear targets for lean thinking implementation is Scania company with its Scania Production System (SPS). Scania is known as one of the best examples of lean implementation in Europe and as a result the author uses Scania as a reference company for his study – applies the same degree in the adoption assessment model and compares results with studied Estonian companies. In other words, the author tries to control the proposed empirical model and assessment method – since it is a known fact (amongst lean researches and professionals) that Scania is one of the best examples of lean implementation outside of Toyota Corporation, then the proposed model and assessment method should prove that.

3.2 Companies assessment results and critical success factors of lean implementation.

3.2.1 Analysis of Scania production system

Scania was founded in 1891 and since then has produced more than 1.4 million buses and trucks around the world. At present, Scania operates in more than 100 countries and has 32,000 employees. Scania has three core values, which are maintained in all activities: customer first, respect for the individual and quality. As Scania says itself, Scania's objective is to deliver optimised heavy trucks and buses, engines and services, provide the best total operating economy for our customers, and thereby be the leading company in our industry. The foundation is core values together with a focus on methods and the dedicated people of Scania. (http://www.scania.com/scania-group/scania-in-brief/).

Scania is focused on continuous improvement in order to maintain strong, sustainable and efficient production. This is achieved via developed Scania Production System. SPS has been developed in-house by the company's employees based on the Toyota Production System. SPS together with Scania Retail System (SRS) are the parts of the philosophy at Scania – to focus on methods rather than results, and results will come as a consequence of doing right things right.

The general view of the SPS was presented before in this thesis in the form of lean house. Scania started to develop and implement a new approach to the trucks and bus production in the mid-1990s and still continues this way. This what Scania says on its webpage:

"In the early 1990s, when Scania had exhausted traditional production and management methods, it sent a team to the Toyota car company in Japan to study what was behind that company's high productivity and quality.

Scania engineers returned with important new knowledge that they had not been able to glean from the literature on Japanese car production methods. As it turned out, the success of the Japanese was primarily a matter of management and people rather than industrial robots. Toyota's leadership system was based on a few clear basic values shared by all employees. The company also worked with a set of principles that the employees knew and understood." Simply put, SPS is relying on values, principles and priorities.

There are three main values that are the foundations of the whole Scania Production System. All three values are equally important and are the foundation for everybody's work in Scania. They are:

Customer first – the customer is in focus during the work and when decisions are made. As says one of the workers, "the customer first means that we make sure we deliver with the right quality at the right time. The immediate customer to whom we deliver is the next link in the production chain. Scania's final customer is our joint customer."

Respect for the individual – everybody is respected by managers and colleagues and can have an influence. Everyone has the opportunity for development based on personal preconditions.

Elimination of waste – competitiveness is strengthened by the elimination of waste.

The principles of SPS help to make decisions and provide guidance on how employees should think in order to achieve the goals of efficient and sustainable production. SPS has four main principles: normal situation – standardised working method, right from me, consumption controlled production and continuous improvement. Standardised working methods come from TPS and were discussed earlier in the paper. This method is also described in SPS house by smaller blocks:

- Standardisation – create standards on manual work
- Tact – define customer need
- Levelled flow – even out the production volumes and distribute labour-intensive units across the working day
- Balanced flow – as far as possible the work is uniformly distributed between those resources that will be doing the work
- Visual – where we are in relation to the normal situation
- Real time – react and act here and now

Right from me is another interpretation of Toyota's *jidoka* principle – right quality from the first time. In Scania, right from me means that nobody accepts, provides or passes on a deviation to the customer. Each next step is regarded as a customer. If the problem occurs, then everybody is required to stop production, give quick feedback about the problems and deal with the problems.

Consumption controlled production is *kanban* – eliminating overproduction and starting things only when the customer (next step or final customer) gives a signal for need. Continuous improvement, as in lean thinking, is the head of everything and the ultimate target – constantly and continuously to examine the way the company works in order to define places for improvement via waste elimination.

In the centre of SPS house, one can find priorities – everybody has the same priorities in order to make right decisions quickly. Priorities are:

1. Safety/Environment
2. Quality
3. Delivery
4. Cost

Scania sees the priorities as a compulsory menu. Which is: priority is safety at the same time as right quality, correct delivery and competitive cost. But the order of the priorities comes into play as well – when one should prioritise abnormalities over each other.

Finally, we come to the practical application of the SPS. The general model of day to day working with the main parts of SPS is presented in Figure 4. SPS says that the company shares certain perceptions (values), agrees on basic ideas on how the work should be conducted (principles), therefore acting in a uniform way (methods) and achieving results.

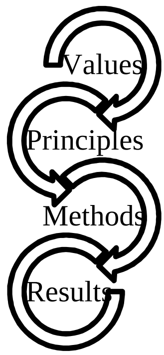

Figure 4. Practical application of SPS (SPS booklet, 20 March 2007 version 2)

The foundation of Scania's lean framework is that in all the activities the employees follow priorities from SPS and discuss those in the continuous improvement cycle in *kaizen* groups. They consist of 5-6 persons: the production group leader, *andon* person (*andon* person are registering signals from workers about the problems on line and helps to solve them immediately) and group members. They have a meeting every day for 10 minutes to discuss the problems based on the priorities list – did they have problems during the last day with safety/environment issues first, then with quality, delivery and cost issues. In the safety part, SPS distinguishes the problems that happened and those that almost happened. During the meeting group, they should decide on which issue they will work today. The schedule for the *kaizen* meetings is as follows:

- Production groups with group leaders (approximately 30 groups),
- then group leaders with production leader of the line (11 lines),
- then production leaders with workshop manager (11 lines divided into 3 workshops),
- then workshop managers with production manager

- and finally the production manager attends a meeting with the plant manager and other department managers (logistics, human resources, finance and engineering).

The same *kaizen* group meetings are held in other departments as well and end up in the same place – a meeting with the plant manager. Furthermore, if the decision of the meeting is to implement some improvement and it has to be done as soon as possible during the working time, the group leader takes the work of employee who proposed the improvement – this employee has to implement the proposed improvement and has to have time for it. Additionally, every week all lines stop for 20 minutes in order to implement other improvements – those that need input from all personnel.

In order to be sure that the standards are followed, the audit system is used. The audit questionnaire consists of 17 questions based on SPS values and priorities. Audits are performed by group leaders on the working places inside the group, by line managers to the groups, by workshop managers to the lines and by production manager to the workshops. Each manager performs one audit every day.

In general, SPS house is the same for all factories, while the methods used are a bit different. At the same time, all the factories are coming closer and closer regarding the methods, thereby creating the common standard of lean thinking implementation process.

To conclude, it is important to highlight that the implementation process of lean thinking principles at Scania follows exactly the path that is presented in constructed process of lean thinking implementation (see point 1.5). Everything starts with standards and ends with standards. The closed loop of the empirical model indicates the same: before the implementation of lean thinking principles, the standards of processes (in model it is indicated as a process quality) should in place. After the implementation, the next level of standards should be set.

The next step of the model is lean knowledge acquisition. This is exactly what Scania did. Scania went to Toyota and studied lean principles there and as a result developed their own understanding of lean thinking and named it Scania Production System. By this, the following step of the model is reached – lean house development. Also, further steps of the empirical model were also followed by Scania – training about SPS for all employees, thorough planning of lean thinking implementation and execution of that plan. The result is in place – successful lean thinking implementation. The result for Scania (also as it is proposed in empirical model) means less waste in the manufacturing process and the next level of process quality (standards). The closed loop of continuous improvement goes on.

A visit to Scania was followed by study in selected Estonian manufacturing companies for the purpose of proving or disproving the proposed empirical model. The amount and type of qualitative data collected within companies were different, though still allowing for conclusions regarding their lean thinking implementation process and its success. The results of the assessment of companies are given in the next point.

3.2.2 Analysis of manufacturing companies and critical success factors of lean implementation

The point presents the final results of the thesis. The assessment of twelve chosen companies was done based on the DOA model and methodology introduced in part 2. The examples of the assessment of large qualitative data with the content analysis method for calculating the grades of DOA and of process steps are presented in Appendix 3 and Appendix 4, respectively. During the study, the author focused on the assessment of the starting point (at what level of process quality company started their lean process), the lean thinking implementation steps (which steps of the proposed empirical model and how well were they performed) and finally on the results of the whole process (the degree of adoption of lean).

First, more detailed discussion is given and then a general overview of the results is presented. The structure for the detailed results is derived from the steps of the process model.

3.2.2.1 Process quality

The starting point of the lean thinking implementation model – process quality – showed interesting results, not only in terms of lean but also in term of general manufacturing process management. Process quality is an aspect that has to be in place in any company, and despite whether the company is going to implement lean or not. Standard processes are the foundation for controlled environment in production and are therefore a must for any manufacturing company.

In our case, 3 companies out of 12 got almost maximum scores (10, 11 and 11 respectively, maximum score is 12; see Appendix 5), another 4 companies got medium results (5-6 points) and others were on the lowest part of scores (1-4 points). Such result indicates that only one quarter of companies have their manufacturing environment under control; all others have minor or major disturbances with controlling the manufacturing process, thereby keeping those processes under standards. Also, those companies that are subsidiaries of foreign companies tend to have a better process quality level that local owned companies. The nature of starting point allows us to say that companies without good process quality are not able to improve anything. They just have nothing to improve due to the fact that most of the processes are performed differently each time they are done. Consequently, the unified base (standard process) for improvement implementation is missing. Ultimately, this means that companies with non-controlled manufacturing processes are not able to implement lean thinking by default.

In contrast, such a situation might not be hopeless. One of the tools within lean thinking is standard work, which adds a more controlled environment and therefore better manufacturing process quality. This means that lean thinking implementation could also be used to correct the process quality aspect. The first determinant of the process quality (further PQD1) aspect is to indicate whether the number of standardised processes increased or not during lean thinking implementation. Within this criterion, the results are almost the same as the general results of process quality aspect: 4 companies out of 12 get a score of 2 (implemented), another seven get a score of 1 (partly implemented) and one company gets 0 (not implemented). Score 2 in respect of process quality indicates that during the lean thinking implementation process quality (and therefore the number of standard processes) increased, score 1 means that it is more or less at the same level as before implementation and 0 means that either it became worse or the starting situation was bad and nothing significant happened during the implementation. The result of PQD1 indicates that 3 companies that get higher scores in process quality are using the standard work tool appropriately; also one company with medium results for process quality is using the latter tool for process quality improvement and others are not. It is important to note that the medium process quality score company that uses the standard work tool attained the highest score of the medium score companies.

Having standard processes in place does not yet mean that those standards are strictly followed in daily operations. The second determinant of process quality (further PQD2) is to indicate the number of deviations between real life and documented process standards. In this, the situation is that only two companies (those with the highest scores of process quality) have a good situation (score 2) – the number of deviations between real life and standards are decreasing during lean thinking implementation. With others (three companies with a score of 1 and seven companies with a score of 0), it means that either the set standards are not followed and there are deviations and the number is not decreasing or there is nothing to follow (no standard process as indicated in PQD1).

Deviations between standards and real life usually result in high scrap and rework costs (Heizer and Render, 2011) and this is indicated by the third determinant (further PQD3). Correspondingly, companies with good results in PQD1 and PQD2 also have a higher score in PQD3. In practice, it means that those companies that have standards in place and are following them are able to decrease the scrap and rework costs, and others (without any standards or having standards, but not following them) are not.

Furthermore, the overall process quality is also dependent on where and how process standards are created. The better (more practical and from different functions) input to the process standards creation, the better output – process standard is indicating real life and is therefore easier to follow. The forth determinant (PQD4) indicate that either standards are created by a functional manager (meaning one person is doing those) or the responsibility for standards is across cross-functional teams consisting of lower level managers and line workers. The assessment results show that responsibility for creating process standards in the studied companies is mainly dependent on functional managers (eight companies get score 8) or functional managers sometime discuss those standards with others (score 1 for another three companies). Only one company has implemented cross-functional teams for process standard creation.

Finally, all the above-mentioned activities showed results in a smaller amount of non-value added activities in processes (PQD5) and in a higher number of improvement suggestions per employee (PQD6). In the case of PQD5, the situation is different from a possible logical conclusion: six companies out of twelve have indicated a score of 2 and another six scored 1 or 0 (three companies each). Such a result indicates that despite not satisfying work with improving process quality, some companies are still able to improve the manufacturing process in terms of value adding, but this is done in a non-controlled manner, not saved in new process standards and is therefore of short-term nature. In other words, an improvement achieved in a non-controlled manner could soon be lost and the same work should be repeated (meaning, eliminating the same non-value adding activities again in changed processes, since the optimal process to date were not saved in process standard).

The situation with the PQD6 score are following the logical pattern: those companies with existing and followed standards, and with controlled and multi-functional approach to process quality improvement are increasing the amount of improvement suggestions from employees.

Scania as a reference company indicates excellent scores in all six determinants, showing that strong process quality is in place. Without that, it would be impossible for it to achieve such significant results in overall operations and in lean thinking implementation.

To conclude the analysis of process quality criterion (and starting point for lean thinking implementation), the following statements could be derived. Companies with good process quality have better possibilities to achieve the desired results in lean thinking implementation since they have good base to start the implementation process, they have already done improvements, thereby creating the next solid step for further improvements, and they get improvement suggestions from daily operations. Those companies with low process quality are missing (or not controlling) the ground to start the process of lean implementation and most likely planned results will not be achieved since they do not know what they are going to improve. Lean thinking implementation give the possibility to improve process quality by using the standard work tool, and taking this into account it could be said that companies with low process quality at the start also have the possibility to improve latter and achieve the desired results of lean thinking implementation. Therefore, good process quality as a starting point of lean thinking implementation is an important factor for companies, but it is not critical.

3.2.2.2 Lean knowledge acquisition

Gathering as much knowledge about lean as possible is a first step in lean thinking implementation process, and the received results from the study at this step are indicating the same pattern as in the process quality aspect. The same three companies get almost maximum scores: C4 get 6 points out of a maximum of 8, C5 – 7 points and C11 – 7 points (see Appendix 5). Another five companies get medium scores (3-5 points) and the other 4 were at the low level (2-3 points). The current step in general indicates how well the company and its personnel are trained in lean thinking knowledge. The gathered results show us again that only one quarter of the studied companies are investing time and money into lean training and the others are not perfect in this regard.

The lean knowledge acquisition step of the lean thinking implementation process focuses on four main determinants: number of personnel trained in lean should increase (LKAD1); number of topics intensively trained to personnel should increase (LKAD2); number of benchmarked companies should increase (LKAD3): and the number of books mandatory for all employees to read should increase (LKAD4). The detailed results of those four determinants indicate that in general all the studied companies are conducting trainings for personnel in different lean topics (LKAD1 and LKAD2), though benchmarking and book reading (LKAD3 and LKAD4) are at a weak position.

Eight companies of of twelve are constantly increasing the number of trained personnel (score 2 in LKAD1) and the other four are keeping it at more or less the same level (score 1 in LKAD1). This is a good result and gives strong opportunities for all companies to achieve successful lean implementation. The more employees that know what lean is and how to implement it, the easier it could be done. On the other hand, the situation with the number of topics trained is not so excellent. Only six companies are constantly training new topics to the employees (score 2 in LKAD2) and others stay on the same level (score 1 in LKAD2). The situation in which new topics are not trained to the employees means that the lean knowledge of the company is not developing and the lean thinking implementation process stays on the same level of progress (in terms of the ultimate goal to become as lean as Toyota).

In the two last determinants of this criterion, the situation is even worse. Only two companies are constantly benchmarking other companies that are implementing lean (score 2 in LKAD3), another five have done it to a degree and never repeated (score 1) and last five have never done it (score 1). On the one hand, there might be no need to benchmark others since no one company is similar to another and in each company one can find such a level of uniqueness that is enough for implementing lean in its own way, without any understanding of how it is done in others – the theoretical knowledge is required and that is it. Per contra, the logic of operations and lean remains the same, and transferring theoretical lean knowledge in a practical way for its implementation in the company requires hands-on experience and lessons learned, even if this is through the experience of others. Those latter aspects ultimately require benchmarking and an understanding of the experience of others. Through this insight, received results indicate weak points in lean knowledge acquisition.

Training and benchmarking is good, though even more additional knowledge could be received from the huge number of books on lean. At least the main, renowned bestsellers on lean have to be mandatory reading for employees towards understanding lean thinking in a wider context through examples from abroad. In the current study, only three companies have had some books to read (score 1 in LKAD4) and the other nine have never used this approach (score 0). In the case of Estonia, such a picture is explainable very easy: there is only one main lean book translated into the Estonian language and some articles in local magazines are available. All other literature is in English and is therefore usable only by top management with fluent English. On the other hand, a significant portion of the employees of Estonian manufacturers are native Russian language speakers, and for this reason the same lean literature translated into Russian could be used (all the main lean books have been translated into Russian). This is one way to improve the situation with the fourth determinant.

In regard to the reference company, the situation indicated that Scania is doing very well in terms of personnel training on different topics and is maintaining a moderate level on benchmarking and book reading. The need for constant training is very well placed there. The situation with benchmarking is so due to the reason that Scania itself is already the object of benchmarking for others and also has achieved a lot of self-experience in terms of lean implementation that could easily live with self-benchmarking (intra-company benchmarking).

Findings in the lean knowledge acquisition step show that companies are mainly dealing with personnel trainings, understanding that without these lean thinking implementation is not possible. However, in some companies the need for an extended number of topics is required. Furthermore, the situation with the benchmarking of other’s experiences as well as getting a more global view on lean from books could be improved significantly. Those last two determinants are defining the importance of lean knowledge acquisition in successful lean implementation. There is a need to hurry up a bit at this point and to say that lean knowledge acquisition (all four determinants) is critical in terms of the next step of the proposed model – lean house development. If a company has focused only on lean trainings, then the picture of lean house and the picture of successful lean companies interpretations of lean in the form of their own production system could be missed. Therefore, the studied companies will not be able to see this important next step and will not focus on creating their own lean house. In contrast, LKAD3 and LKAD4 might be covered by trainings, if trainers are aware about the need of the interpretation of lean into a company’s own production system in the form of lean house. On this point, it could be said that the lean knowledge acquisition step is one of the critical success factors for successful lean thinking implementation, as it ultimately gives the required base for lean house development.

3.2.2.3 Lean house development

The concept of lean house was introduced in point 1.3 and it represents the central part of lean thinking implementation. First, it is uppermost understanding and interpretation of lean thinking philosophy in a company. Second, it demonstrates the main road of lean thinking implementation in a company. And finally, it enables the move from add-on to daily operation lean principles implementation towards a way of working based on lean principles. In the current study, five determinants help to assess it: attitude to lean implementation should move from project type (principle by principle) towards the company's own production system based on lean principles approach (LHDD1); lean principles integrated into the company values are increasing (LHDD2); lean principles integrated into daily work is increasing (LHDD3); the attitude towards lean philosophy should move from waste elimination techniques to the way of working (LHDD4); as a result, lean house (or own production system) is created (LHDD5).

The result of the assessment of the studied companies represents the picture of where a good starting point in process quality and a strong focus on lean knowledge acquisition gives the possibility for lean house creation. Process quality indicates a structured approach to all processes in a company, including the lean thinking implementation process. This means that lean thinking implementation is also a process; therefore, it has to be standardised and constantly improved, but, again, should be started from a solid base – lean house. A good understanding on lean theory, insights into lean practices in other companies and a broad view of worldwide experience helps create a company's own interpretation of the lean theory that is suitable for it in the given conditions.

Companies C4, C5 and C11, which have the highest scores in process quality and lean knowledge acquisition, attained the highest scores in the lean house development step: all three received 8 points out of 10 maximum. The other studied companies have more moderate results: another three get medium results (4-5 points) and the remaining six are on the lowest level (0-3 points), where three companies get 0. Generically, the results indicate that only three companies understand what lean is and how they would implement it. The rest have either only some generic understanding of lean or have none at all.

The first determinant gives evidence about the overall approach to lean thinking implementation: whether it is a project type (the company is implementing one principle at a time, for example 5S, as a single project and does not have a longer insight about what is next) or it is the approach of step-by-step incorporation of lean principles into daily routines. When companies have a project approach to lean thinking tools implementation, then employees see them (tools) as some additional task to perform and therefore do not take them as necessary, but as a normal routine. “Tasks that are additional to the norm” are not performed and as a result lean thinking tools are not working properly. The results are as follows: four companies get 2 points, three companies get 1 point and the rest five get 0. Maximum points in LHDD1 indicate that the approach of companies is to achieve such a condition in which employees use lean tools as normal daily routines and do not see them (lean principles) as an addition to normal work tasks. In contrast, the lowest points mean that daily tasks and the usage of lean tools are separated and employees do it as some additional, thereby inconvenient, duty. The medium score indicates that companies are moving from one approach (add-on tools) towards another approach (incorporating tools into daily routines).

The outcome of activities assessed in LHDD1 is consequently graded in LHDD2, which is indicating the increase of the number of lean tools integrated into company values. In this field, scores are divided evenly between the companies: 2, 1 and 0 points are given each for four companies. The situation is logical compared to the LHDD1 scores: C4, C5 and C11 have being adding lean principles to company’s values due to existence of the long term plan for lean thinking tools implementation. The main tools discovered in company values are 5S, SMED, 5Why? and standard work. Consequently, the scores of LHDD3 are showing a similar path: the same three companies that get 2 points in LHDD2 also get 2 points in LHDD3. It means that tools added to the company’s values are also integrated into day-to-day operations as normal routines. Since the length of lean implementation to the date of study is not very big (maximum 5 years), then number of tools indicated in values itself is not big – 3 to 4 tools. Despite this, the important issue is that those three companies are constantly increasing the number and on the date of study had a clear plan on what is next.

Here, it is also interesting to look on two other companies: C6 and C12. In the case of C12, it has no consistent approach on moving from the project type of lean implementation towards “lean in daily routines” (LHDD1 score 1), though even with the project type approach it managed to keep the results of the performed projects on lean thinking implementation, thereby succeeded in increasing the lean tools integrated into values and day-to-day activities (LHDD2 and LHDD3 scores 2). So far, they have only tool of 5S (implementation length of lean is around 2 years) and the result of keeping it is due to the local initiative. Since the company itself (locally) decided to start the lean implementation process, it is not worthwhile to spent resources on implementing one or other tool and then throw away the achieved results. It could be said that C12 has strong potential for further lean implementation. The situation with C6 is vise versa. A strong initiative from headquarters directed it to create a vision of lean thinking implementation that follows the path of integration of tools, though it is lacking the passion of maintaining those as a “philosophy of doing the work”. C12 still has an approach of add-on lean tools to their normal operations. The tools of 5S and *kaizen* are present, but the real outcome has not been achieved yet. If the strong initiative from headquarters will remain, then the situation with LHDD2 and LHDD3 might become more positive.

The situation of other companies with LHDD2 and LHDD3 is weak. Due to the strong nature of the project type approach in lean thinking, implementation tools are not incorporated into companies values and are not the part of the daily routines. This indicates that a weak process approach in general and weak lean knowledge acquisition brings about weak results in the practical integration of lean thinking tools into a company's operations.

The fourth determinant submits the overall approach in the company towards lean thinking. Companies are either focused on pure waste elimination without a philosophical aspect or on building a strong system of being a lean company to the very heart of the operation. In other words, lean thinking has to be the way of working in a particular company, and not just the panacea against problems and faults. The ultimate result should be continuous improvement everywhere and always. Assessed scores in LHDD4 indicates that five companies – C2, C4, C5, C6 and C11 – get a medium score of 1 point and other seven get 0 points. The results of companies C4, C5, C6 and C11 are predictable based on the previous discussion and indicate that these are on their way towards achieving the situation in which "we, the company, act lean everywhere and always". The integration of lean tools into values and day-to-day operations on a constant basis should yield such a result. The more important is to look at the result of C2. It has medium results in all four determinants in the lean house development criterion, indicating that though it is not yet performing well with the integration of lean principles, the direction is right. C2 is a subsidiary of a foreign company and it is a lean initiative is from headquarters. It is using a lot of consultancy help and keeping already integrated tools working (5S, Overall Equipment Efficiency (OEE) and Key Performance Indicators (KPIs)), and the personnel attitude towards improving manufacturing processes is positive. This is a strong indication of the correct path and strong potential, but only if the company will keep on this path. In this case, it largely depends on how strong the initiative from headquarters will be in the future.

The last determinant (LHDD5) of lean house criterion is to summarise all the activities and indicate whether the company was able to transform all its knowledge, ideas and wishes about lean into one formal structure – lean house. The grading is simple: 2 points mean that the lean house is created; 0 points mean that it is not; and 1 point means that there is some structural representation of the company's view on lean and its implementation, but not exactly in the form of a lean house. The results indicate that companies C4, C5 and C11 get 1 point and others get 0 points.

Company C4 has very good formal approach to *kaizen* groups (KG) and continuous improvement (CI) – the system that describes in great detail how to apply KG and CI to all levels of an organisation, the responsibility of managers and other employees, and the results to be achieved. One important point is that approach has a start point but has no end point – the company is going to apply it as long as feasible. On the other hand, this approach is not a lean house as such, with clear values, priorities and lean tools. Employees are divided into KG, but each KG is free to choose which tool to use and what to improve. It looks effective, flexible and reasonable, but such an approach tends to be uncontrolled and does not give the same basis for the whole organisation. KGs rarely communicate with each other. Consequently, such a system could not be called a company's production system, but only some form of it.

Company C5 has a simpler approach than C4, but is as effective. C5 has a long term plan on which tools and when to implement and how to sustain already implemented tools. This approach is additionally supported by the corporation certification system. At the moment of study, C5 had implemented three tools (5S, *kaizen* groups and operator's maintenance) and was certified by the corporation on one of those. Conversely, this kind of approach does not fit into the picture of a lean house and actually is not a lean house. Company C5 is implementing tool by tool in a long-term approach, and by this it is building the foundation for a possible future lean house. A similar approach is used in company C6, which also has a long-term plan (at least next 10 years) for lean thinking tools implementation – not with a corporate certification system – but the plan is the same for all the companies within the corporation. Approaches of this sort allow companies to create the attitude whereby lean tools are implemented and sustained continuously. It could be assumed that companies with a discussed way of lean tools implementation are leaner than those without any long term view, but they are less leaner that those with an existent lean production system in the form of a lean house.

The approach of lean house is fully realised in the reference company Scania as is gets maximum points. Scania Production System's lean house was introduced in point 1.3. As it was highlighted during SPS analysis in point 3.2.1, lean house represents the foundation of work culture in the company. Every decision, every action and movement is based on values, priorities and tools derived from lean house at Scania.

As we see from result number 2, the DOA is largely dependent on the lean house development criterion score. This dependence is explained as follows: Lean house is the result of a good starting point and the first step of the lean thinking implementation process model. As was mentioned at the start of that point, without a systematic approach to process management, the process of lean thinking implementation will also not be addressed constitutionally, and due to this company will not see the requirement for elaborating the framework for the latter process. Thereafter, the reverse approach will naturally lead the company to the necessity of the company's lean framework either in the form of lean house (preferably), or in another analogous form. Furthermore, the requirement for lean house establishment will lead to the need for good comprehension of lean and such a need could only be realised via thorough lean knowledge acquisition. In future, the existence of lean house (or similar form of that) first guide the process of lean thinking implementation, towards the need for training about lean house, and next, together with a systematic approach to all processes, towards lean implementation thorough planning and execution of that plan. Correspondingly, the absence of lean house will not require the training of lean house. Additionally, the planning of lean thinking implementation is not needed to a great extent because of the deficiency of long-term vision about lean thinking, and without a plan there is no plan execution. In other words, good scores in the lean thinking implementation process start point and first step give a good score in the lean house criterion and consequently derives good scores in the next steps of the process. In the issue, DOA is high. The absence of lean house and good scores of process quality and lean knowledge acquisition might exist simultaneously, but the non-availability of lean house will certainly lead to poor scores in the next steps (meaning, weak lean thinking implementation), which will ultimately give an insignificant DOA score. Based on all of the above, the conclusion of the importance of the lean house step for successful lean thinking implementation could be made.

3.2.2.4 Lean house communication and training, lean implementation process planning and execution

It was explained in the conclusion to the last point that lean house existence directly influences the scores of the next steps of the model: lean house communication and training, lean implementation process planning and the execution of that plan. This influence exists because any kind of philosophy or production system concept is only valid when the whole organisation uses it as basis for daily work. For the attainment of such a condition, the philosophy has to be trained throughout the whole organisation and further implementation should be based on principles, values and priorities that are expressed in this trained philosophy.

Consequently, the lean house communication and training criterion indicates how well the company’s lean framework is spread among the employees by the usage of three determinants: the number of employees trained should increase (LHTD1); the number of employees able to train lean house to others should increase (LHTD2); and the amount of information about lean house should increase (LHTD3). After company personnel is aware of the company’s lean house and is well trained, the planning of the lean implementation process could start. This step of the empirical model is also defined by three determinants: the lean implementation approach is moving from project type towards a way of doing work based on lean house (LIPD1); the lean implementation plan is long term with clearly defined small steps and targets (LIPD2); continuous improvement, and improvement of the lean implementation plan, is built into the lean implementation plan (LIPD3). The last step of the empirical model, the execution of the lean implementation plan, is assessed with the help of two determinants: the lean implementation execution approach is moving from project type towards a way of doing work based on lean house (LIED1); lean implementation follows the plan and is continuously improved based on the achieved targets (LIED2).

Constitutionally, in the mentioned above three criteria, only companies C4, C5 and C11 get scores in all criteria and companies C6 and C12 in the lean house training criterion. Companies C4, C5 and C11 get maximum points in the lean house training criterion (6 points) and almost maximum points in the last two criteria (5 and 3 consequently). Companies C6 and C12 get only points from the LHTD1 – each company gets 1 point. Other companies get 0 points in all the three criteria mentioned in this point.

The interpretation of those results indicates that companies that are leading in our assessment (C4, C5 and C11, further LC – leading companies) mainly get high scores due to the existence of lean house. The absence of lean house immediately removes the need for its training – no lean house, no training. Therefore, since LC has lean house (or a similar form of it, as discussed in the previous point), they have to train the personnel to achieve practical use of it. Again, the existence of lean house does not necessarily mean that lean house is being trained in the proper manner. It is important to notice that the training of lean house is not the same as the training of lean principles. The training of lean house assumes that the principles used in it are already similar (or mostly similar) to the audience and is focused on explaining the way lean principles will be implemented and sustained in the company – exactly the thing that is coded in the lean house. Therefore, the results of LC in the lean house training step of the process show that those companies are constantly training personnel and achieving a situation whereby an increasing number of employees are able to teach lean house to others and due to the continuous development of lean house the more information about it is relayed.

Thereinafter, the existence of lean house allows the creation of the plan for lean thinking implementation. An important point is that within the plan the long-term plan for implementing and sustaining several lean principles, tools and approaches are meant. Without the lean house, the plan usually means the plan of the next project for some lean tools implementation (the case we have with other companies out of LC). As well, as it was shown in point 3.2.2.3 that LC has the form of lean house that is expressed as a long-term plan for introducing and using the tools and principles. Therefore, LC gets maximum points for the two first determinants of lean implementation planning criteria (LIPD1 and LIPD2) – the lean implementation plan incorporates the view that this is not only the plan for lean principles and tools implementation, but it is also the plan for changing the way of working with clearly set goals and targets for the long term and the short term. Since the lengths of the implementations of LC were not long to the date of the study, the plan was not much improved and, as a result, the last determinant (LIPD3) obtained one point.

In the end, the presence of the plan infers its implementation and the absence of the plan requires no actions. Therefore, LC gets 2 points for the LIED1 and the other companies 0 points. Again, due to the short history of lean implementations in LC, it is hard to assess the continuous manner of plan improvements, and based on this the score for LC for LIED2 is 1 point.

As for companies C6 and C12, they each get 1 point for LHTD1 and 0 points for LHTD2 and LHTD3, due to the fact that they had some training on their ideas and vision about lean thinking implementation, but this training was attended by a limited number of people, never repeated and had no major impact on the overall process of lean implementation to the date of assessment. Also, as it was discussed before, the lack of a long-term vision for lean thinking implementation deletes the need for latter planning and the execution of a plan. Therefore, results of C6 and C12 in last two determinants are 0 points.

All other companies get 0 points due to the situation highlighted in the previous point and the beginning of current point – the absence of lean house creates the condition where training and further planning together with implementation is not required. Due to the latter, the studied companies are not performing those activities and therefore achieve no points.

The reference company attained maximum points and the evidence of such a result is described in point 3.2.1. Scania has a department dedicated to the development of SPS, which has its main tasks as the training of SPS, follow-up of its implementation, continuous improvement of SPS and consequent planning for the implementation of new tools, value or principles from SPS and the execution of those plans. Those tasks fit ideally into the determinants of the last three steps of the model of lean thinking implementation, and accordingly maximum scores are awarded.

Relying on the discussion in the present point, the conclusion of the critical nature of the last three steps could be made. The presence of lean house is also critical but, as was pointed out earlier, lean house does not necessarily mean that training of it will be performed. Without the understanding of the lean thinking approach of the company, employees will not be able to achieve the way of working that relies on lean principles instead of the project type of lean application. Furthermore, without the thorough planning of lean house (and lean thinking) implementation and the execution of the plan, the existence of lean house is needless. Therefore, successful lean thinking implementation critically requires the understanding of lean house throughout the organisation, the thorough planning of its implementation and step-by-step execution with clear goals and objectives.

3.2.2.5 Degree of adoption

The performing of lean implementation process model steps resulted in a degree of adoption – the indication of how good the results were in each company in adapting the lean principles. The highest score out of studied companies in DOA is achieved by C5 (40 points) and it also has one of the highest scores in sum of model starting point and steps (40 points). The next two companies are C11 (with 38 points in DOA and 40 points in process) and C4 (respectively with 34 and 38 points). All other companies have significantly smaller results in DOA and also in the process steps (Appendix 5).

The degree of adoption is identified by nine criteria and the corresponding determinants of the criteria. In general, the twelve assessed companies are focused on waste elimination, zero defects, just in time deliveries, multifunctional teams and vertical information system criteria – almost all companies get points in those criteria, though the above mentioned three companies are certainly better than the others: C4, C5, and C11 achieve high or medium points, though the others are medium and low. The focus on the criteria referred to above is explained first by the nature and second by the length of lean implementation processes in the companies.

The studied companies are mostly dealing with pure waste elimination due to the starting kind of processes and not in building the system of continuous improvement and a way of working based on lean. Though our score leading companies have lean houses, which are actually focused on continuous improvement and building a sustainable lean system, they still have not been doing that for a long time and therefore significants signs could not be seen. Again, lean houses lead to better application of the first lean tools, meaning better results and assessed scores are higher.

Such things as reducing the set-up times of machines, decreasing the amount of work in progress, improving transportation due to changes in the layout, reducing the amount of scrap, creating a more focused quality control system, achieving higher delivery performance, creating improvement teams and providing more data for employees are the first results of 5S (Efficient workspace: Sort, Set on place, Shine, Standardise, Sustain), SMED (Single Minute Exchange of Dies), *kaizen* group, standard work and VSM (Value Stream Mapping) tools. All of those results are indicated in the respective scores. Furthermore, C4, C5 and C11 have much better, sustainable results in the mentioned improvements than the other companies. The latter – sustainability – is the main indicator of a solid system of lean implementation and it was found in only one of those companies that have understood lean and have created their own vision for implementing in the company. Lean house forms the visual basis for implementing lean; therefore, employees physically see what is lean for their company. The tangible nature of such a visual approach develops the attitude towards lean house in the company and the sustainability of the system arises.

Continuous improvement, the pull of raw materials, decentralisation and the integration of functions are criteria in which the assessed companies mainly failed to achieve scores. In two of these criteria – pull of raw materials and the integration of functions – all the companies achieved 0 points. The latter is an indicator that none of the studied companies is improving the supply chain (pull of raw materials) or eliminates the functional approach of the company structure (integration of functions). True, those two aspects of degree of adoption are rather difficult and require much more powerful lean systems, and therefore powerful companies, to start those. In the continuous improvement criterion, the only companies that get some points are the same: C4, C5 and C11. This is due to the existence of future perspectives in those companies – a long-term vision of how the company should implement lean. In the last criterion in this section – decentralisation – almost all the companies get points (except three) and mainly due to the fact that the companies create *kaizen* teams (multifunctional teams) and give them some responsibility.

Ultimately, it is important to notice once more that C4, C5 and C11 have a higher DOA since the creation of their vision of lean thinking implementation helps to achieve the sustainability of the results and enter into the loop of continuous improvement. In contrast, the absence of a vision in the other companies creates an unsustainable environment that merely deletes the first results of 5S, SMED and standard work tools, thereby not allowing the companies to achieve the high results of lean thinking implementation over time.

3.2.2.6 Final conclusions of the analysis

The summary of assessment of the lean initiative in the studied companies is shown in Table 15. The table with the results of each determinant of each criterion is shown in Appendix 5. The main results that we can see from the assessment are:

- DOA (or success of lean initiative) depends on how well lean implementation process steps were performed – Result 1 (R1);
- DOA depends on the existence of lean house (or own production system) – Result 2 (R2);
- Some criteria of DOA are not implemented in any company – Result 3 (R3).

Those results represent the main outcome of the study and prove the proposal made by the author, while introducing the empirical model of the lean thinking implementation process. In general, the results show that understanding about lean thinking should be inverted into a company's own language as a company's own production system (or lean house, or any other form of formalisation of lean thinking principles made especially for the company) and this is possible if the company has a good starting point (high process quality) together with effectively performed steps of the lean thinking implementation process. Also, the study indicated that despite the fact that some companies have good results in both the lean thinking implementation process and DOA, they have not implemented some of the lean thinking principles.

Result 1 – DOA dependence on process

This is the main result of the performed research and is the constructed model of lean thinking implementation: companies with higher scores for starting point and process steps will also have higher scores for the degree of adoption of lean. This result is seen by visual patterns of the sum of starting point and process steps (SP&PS) (Figure 5). DOA very much depends on how high the scores of starting point and process steps are.

This result gives an answer to the RQ1: the constructed model of lean thinking implementation could be regarded as a standard framework for the manufacturing companies that wish to implement lean. The companies that have a good starting point (process quality) and have performed all the steps within the model, or in other words have been following the standard framework, have better results that those who have not.

Result 2 – DOA dependence on lean house

Quite the same picture compared to the first result is seen by comparing the lean house and DOA (Figure 6) scores. Of that result, we determine the answer to the second research questions (RQ2) – the main critical success factor of all the steps is the creation of lean house as a basis for the whole lean implementation process and consequent steps. In other words, in order to have successful lean implementation and not to fail with it, each company has to understand and interpret lean thinking principles into intra-company knowledge and to create a company's own production system in the form of a lean house. XPS – Company's X Production System (analogically to the TPS – Toyota Production System and SPS – Scania Production System) – is the description of the general rules and values based on which the company works and implements lean.

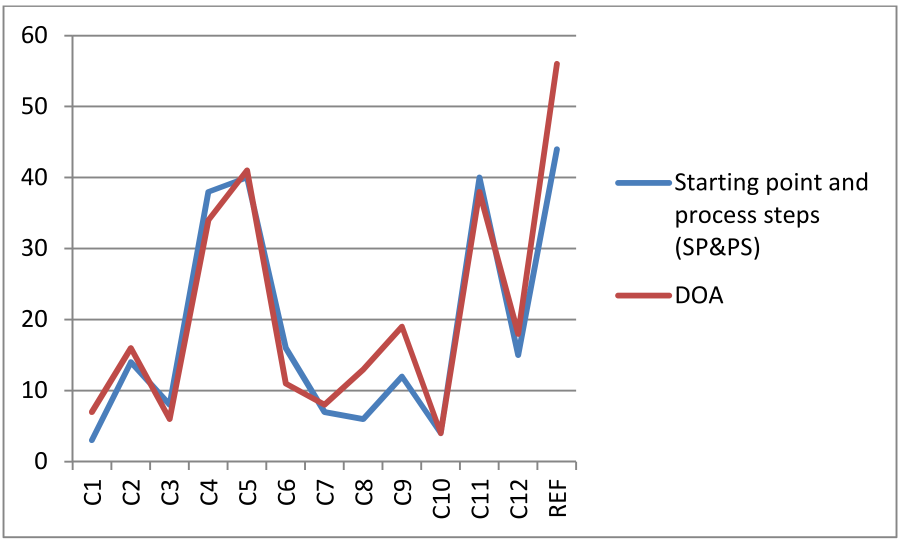

Figure 5. Visual patterns of SP&PS and DOA (author's constructed)

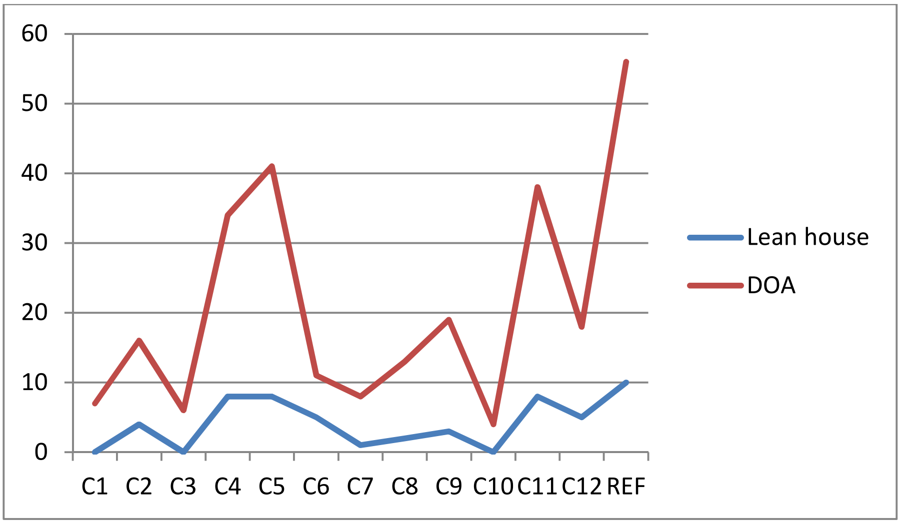

Figure 6. Lean house and DOA patterns (author's constructed)

Result 3 – Some DOA criteria are not implemented at all

From the results table, we can see that some criteria of DOA assessment are not implemented at all in any company, such as the pull of raw material and integration of functions. This result is quite interesting and shows that there is more to do even in those companies where lean initiative is implemented well and the results of the overall process are good.

As we see from the assessment results, companies C4, C5 and C11 have achieved high scores of DOA due to the good performance of the lean implementation process steps. All those three companies had their lean initiative started from headquarters (Table 14); they have a long term lean implementation plan resulting in the creation of their own vision of how lean should be implemented in the company. In other words, this vision of lean ideas implementation is the company's lean house. Exactly the same could also be said about the reference company that brings one more proof regarding the proposed hypothesis in the lean implementation process model. Other companies (with low DOA) scores do not have their vision regarding lean house in place, and are only implementing lean in terms of some tools and principles and do not have a long-term vision. Let us go into more detail regarding the results.

The proposed model for the lean thinking implementation process embodies the start point – good process quality – and five steps: lean knowledge acquisition, lean house development, lean house communication and training, lean implementation planning and execution of a lean thinking implementation plan.

Table 15. Assessment results of company’s lean initiative (author’s constructed)

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	REF
Process quality	**1**	**5**	**5**	**10**	**11**	**6**	**3**	**2**	**5**	**2**	**11**	**4**	**12**
Lean knowledge acquisition	**2**	**5**	**3**	**6**	**7**	**4**	**3**	**2**	**4**	**2**	**7**	**5**	**6**
Lean house	**0**	**4**	**0**	**8**	**8**	**5**	**1**	**2**	**3**	**0**	**8**	**5**	**10**
Lean house training	**0**	**0**	**0**	**6**	**6**	**1**	**0**	**0**	**0**	**0**	**6**	**1**	**6**
Lean implemenation planning	**0**	**0**	**0**	**5**	**5**	**0**	**0**	**0**	**0**	**0**	**5**	**0**	**6**
Lean implemenation execution	**0**	**0**	**0**	**3**	**3**	**0**	**0**	**0**	**0**	**0**	**3**	**0**	**4**
Starting point and process steps	3	14	8	38	40	16	7	6	12	4	40	15	44
Elimination of waste	*1*	*4*	*2*	*6*	*11*	*2*	*1*	*3*	*4*	*1*	*9*	*3*	*10*
Continuous improvement	*0*	*0*	*0*	*3*	*4*	*0*	*0*	*0*	*0*	*0*	*4*	*0*	*3*
Zero defects	*2*	*1*	*1*	*4*	*5*	*3*	*2*	*2*	*2*	*1*	*4*	*1*	*6*
Just in time deliveries	*0*	*1*	*1*	*4*	*5*	*1*	*1*	*1*	*2*	*0*	*5*	*2*	*8*
Pull of raw materials	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*3*
Multifunctional teams	*3*	*3*	*1*	*8*	*6*	*1*	*3*	*3*	*5*	*1*	*7*	*5*	*9*
Decentralisation	*0*	*1*	*0*	*2*	*2*	*0*	*1*	*1*	*2*	*0*	*2*	*1*	*6*
Integration of functions	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*3*
Vertical information systems	*1*	*6*	*1*	*7*	*7*	*2*	*1*	*2*	*4*	*1*	*7*	*6*	*8*
DOA	**7**	**16**	**6**	**34**	**40**	**9**	**9**	**12**	**19**	**4**	**38**	**18**	**56**

The argumentation hereinabove has indicated that process quality is important but not a critical factor, and all the process steps are critical success factors. On the contrary, it was clearly seen that the basis for the proposed lean thinking implementation process is the lean house step. In the case of the missing lean house, all the other steps could even remain as critical, but they lose their major purpose and are insufficient in achieving successful lean implementation. The latter was shown on the example of all other companies except LC (companies C4, C5 and C12). Therefore, it could be concluded that the main critical success factor for successful lean implementation in the proposed empirical model is the lean house creation step and the importance of the others are driven by it.

Finally it could be stated that the constructed model of the lean thinking implementation process is valid and could first be used by companies to analyse their current initiative and second for constructing their lean implementation process and incorporating an understanding of lean philosophy into it by creating their own vision in the form of a lean house. The initial idea says that the correct starting point and performing the steps in a certain sequence and to a certain depth are the critical success factors for successful and continuous lean implementation. By performing current research, the author has proved that if the above mentioned aspects are taken into consideration and are actually done then the company has all the prerequisites to achieve its desired targets in terms of lean – meaning successful lean implementation. At last, the creation of the lean house is the central part of the model; it drives all other steps and is therefore the main critical success factor for successful lean thinking implementation. By this, contributions to theory, methodology and practice are made and they are presented further.

3.3 Thesis contribution into the field of research

3.3.1 Contribution into theory

One of the main gaps of researched theory was the lack of a certain framework or step-by-step process for implementing lean ideas into manufacturing companies. This current thesis proposed one of the ways of approaching the lean implementation process by performing steps in a certain sequence and assessing those steps based on the determinants of each step. The proposed model is innovative, has not been implemented before, focuses very much on the existence of the lean house and gives a starting point for the further development of the current theory.

Also, the idea of importance of each company's own vision of the lean philosophy in the form of a lean house has not been discussed widely before and brings another important contribution to the development of academic knowledge regarding the lean implementation process. Quite often, companies see lean as a set of principles and start the implementation by just using those principles. In such cases, the implementation of lean looks like a set of small projects: 5S, VSM, SMED and so on. These projects by themselves might achieve the required targets, but in general they are not focused on a single target – changing the culture and philosophy of a company's manufacturing.

The current thesis discovered the importance of looking into lean thinking principles through the prism of company nature. Each company is unique and therefore lean thinking principles might not be suitable for all within the same format. Scania is one of the good examples – it went to Toyota, understood TPS, rethought it and created its own lean system. Three companies out of twelve have interpreted lean thinking into their own formats (though not in the form of a lean house) and thereby achieved better results in lean thinking implementation up to the date of the research. Finally, the existence of lean house is not possible without a good starting point and the subsequent steps together with the creation of the lean house itself. Such a step-by-step model approach to lean thinking implementation was not under looked in theory before and is therefore one of the important contributions to the current thesis. In addition to the theoretical contributions, the thesis has also contributed to the methodology and practice of lean.

3.3.2 Contribution to methodology

This is a difficult question: how to assess the results of lean implementation. Is a company lean or not? Such questions are always present in the lean thinking field and are of the utmost importance. Current research uses the model of the assessment of the degree of adoption of lean by Karlsson and Åhlström (1996), which was also used before by Soriano-Meier and Forrester (2002). Karlsson and Åhlström (1996) initially are not indicating the way of assessing the determinants, though Soriano-Meier and Forrester (2002) assess the same determinants by using the scale from 1 to 7: 1 – not adopted; 4 – partly adopted and 7 – fully adopted.

As one of the contributions into the methodology of assessing the leaness of the company in the current thesis, the author uses an approach similar to Soriano-Meier and Forrester (2002), though making the assessment grade simpler: 0 – not adopted; 1 – partly adopted and 2 – fully adopted. As was discussed in point 2.4, the used grades approach was developed by the thesis author due to the fact that the Karlsson and Åhlström (1996) model is missing exact rules about the grades. The presented grades help to determine a simple assessment of the result of the lean thinking implementation of companies and are suitable for the Estonian case due to the same simplicity. Estonian manufacturers, as stated previously in point 1.7, are just starting with lean thinking implementation and therefore more a sophisticated assessment degree would be hard to apply due to the fact that there are not significantly differentiated results amongst the companies. In general, grade 0 means that the respective determinant is not applied enough in the company and has to be dealt with (subjectively representing 0-30% of possible activities and results of the determinant); grade 2 means that the determinant is applied and at the moment of study no further developments are required (subjectively representing 70-100% of possible activities and results of the determinant); grade 1 represents the wider scale (subjectively representing 30-70% of possible activities and results of the determinant) and means that the determinant is applied, though further development of it is highly recommended.

Furthermore, the author applies the same approach to assessing the steps and starting point of the lean thinking implementation proposed empirical model. This new application of the model consists of developing the determinants for each step of the process and for the starting point, and for assessing those determinants based on the approach for assessing DOA. In the DOA part, only one aspect is assessed: Karlsson and Åhlström (1996) developed nine criteria for assessing the degree of adoption of lean and each criterion has its respective number of determinants. In assessing steps of the process, the author uses steps and starting points as criteria themselves and then develops appropriate determinants. Such an application of the assessment methodology has not been used before and also might be the starting point for the methodology application in similar situations. Additionally, the contribution into methodology allows for improvement of the practical aspect of lean thinking implementation.

3.3.3 Contribution into practice

From a practical point of view, the proposed model is a straight course for lean implementation for manufacturing companies with the batch process type. Each company that is starting its lean road could take the model as instruction on what to do and how to do it. What – is the steps of the model. How – focusing on the determinants of each step and on the determinants of the final result. There is a question in every company before starting lean – what should we do in order to secure the success of our activities?

The current thesis with its proven model is the answer and direction for the company that is again focusing on where to start – process quality, how to proceed – model steps and which step is critical in securing the overall success of the lean thinking implementation process – lean house. Also, each company already implementing lean in any status could take this current thesis as a guideline for assessing their current performance of lean implementation, understanding the process weak points and developing the next steps or the new loop of lean implementation – exactly as the model continuous improvement step proposes.

Though the presented research has its contributions to theory, methodology and practice, the limitations of those could still be identified. Also, since the field of lean thinking is of a complicated nature with many interrelated factors and conditions, further lines of research could easily be identified.

3.4 Work limitations and further lines of research

The possible limitation of the undertaken research is the small number of companies studied and the rather short period of lean implementation. Such issues do not giving many opportunities for the generalisation and therefore research results may not be applicable for a wide range of purposes or well applied according to the author's instructions and wishes.

On the other hand, the Estonian economy is rather young and the presented number of the companies and their lean status is as much as was possible to find in a period of study. Also, taking into account the fact that the main study was only possible to start in 2009, the author could say that the investigated number of companies is enough to achieve the targets of the present paper and to prove or disprove the proposals, while again a wider generalisation is limited; also, the results could be updated along with lean situation change in Estonia in the coming years. Further lines of the research could be indicated, such as: developing the model further by analysing the cost of the steps and possible financial gains; developing the model for the other types of manufacturing processes; developing the model further by incorporating the aspect of People and Culture. Next, the overview of each possible future option of research is given.

Costs of implementation and financial gains

In the current thesis, the author studied the process aspect of lean implementation. As was mentioned previously and will be discussed a little more, there are two more aspects – People and Culture. In all, these three are essential elements since there are interconnected with lean ideas and the changes that have to be undertaken in a company's processes, personnel and culture.

If we step away from those three aspects, we also should take into consideration the financial aspect of the changes. Though the main targets of lean are continuous improvement and the development of organisation through the development of personnel, it is important to remember the financial feasibility of those steps and changes.

One of the outputs of lean principles implementation (and basically why companies start lean) is the improvement of efficiency and productivity of the processes, and financial gains come from this. Based on this, the author proposes that one of the possibilities for further research is to analyse the financial part of the proposed lean implementation process – the possible costs and financial gains of each process step and the total for the whole process.

Model for other types of manufacturing processes

Companies with other manufacturing process types – such as project, job-shop, mass and continuous process – might also implement lean and a similar model could be developed for those process types as well. In general, the approach might be the same, though some specialities for each manufacturing type should be taken into account.

People and Culture

We still have the People and Culture part of lean implementation in place. Each company implementing lean has to keep in mind the critical aspect from those parts as well. Furthermore, the critical aspects of all three parts should be viewed together. It is not the people but rather the prevailing management system within which we work that is the culprit (Rother, 2010). The management system consists of all three mentioned aspects: process, people and culture. Therefore, we should view them together. On the other hand, all three aspects are wide and it would be rather hard to research all three in one dissertation.

If we take one series of Toyota books, we can see that they follow the same pattern of process-people-culture: The Toyota Way (Liker, 2004), Toyota Talent (Liker and Meier, 2007), Toyota Culture (Liker and Hoseus, 2008). We now have a new book where all these aspects are combined and which tries to encompass all the knowledge we have about lean and bring us to a new level of lean knowledge – Toyota Kata by Mike Rother. Up to the present, all known books of lean focused on the visible aspects of lean – practices, tools and principles; Toyota Kata looks into the invisible one – management thinking and routines (Rother, 2010).

We have new knowledge in place – Toyota Kata, and we can use it. On the other hand, Estonian experience with lean is rather small – focused and wide implementation started in 2006-2007. Therefore, the visible part of implementation is also important.

Finally, Toyota Kata proves the importance and right concept of the research undertaken from the point of view that we cannot specify the content of actions since that varies from time to time and from situation to situation. Instead of that, we can specify the form of thinking and behaviour (Rother, 2010). The proposed empirical model is the form of thinking and behaviour on a high-level of lean implementation. The content has to be designed and decided by each company itself, based on the current situation.

Conclusion

The field of lean thinking is one that has been extensively studied in recent decades. Along with different aspects under the loupe, numerous studies have focused on the question of defining lean, another great part is trying to clarify which tools and how should lean be implemented and used to achieve the status of being a lean company, and almost none of researches has attempted to create a clear path of lean implementation process. In other words, a defined, step-by-step guideline for successful lean implementation is absent. The consequence of that is an unwillingness to start the lean journey and anxiety about the results of it.

Based on current researches and statistics, the low productivity and efficiency of Estonian manufacturing companies should be improved and an appropriate way for that should be found. Along with the supply chain, many aspects and parts of that supply chain are contributing to productivity and efficiency, but the current thesis focuses on production. In production, lean thinking ideas are one of the ways for improving efficiency and productivity used in the global economy. Many companies in the Toyota Corporation and outside of it have proven that lean works and the improvements achieved might be very big. Still there is a question for non-Toyota companies – how can those desired results be achieved?

In literature, one could find different strategies about lean thinking implementation, but it is hard to see how lean implementation results depend on the used methodology. Those strategies (Lean Thinking (Womack and Jones, 1996), Going lean (Hines and Taylor, 2000) and the Procedures Manual from lean Aerospace Initiative (Crabill et al., 2000) give a very general overview on how to proceed with lean thinking and do not point out the critical aspects of the lean implementation process – the steps that define the overall success of lean thinking implementation. Organisations are realising the fact that it takes more than quality, cost, and delivery commitments to ensure survival, and that they need extra efforts in terms of ability to adjust quickly and effectively to demand fluctuations as well as product diversification according to the requirements of the customer (Mohan and Sharma, 2003). Those mentioned additional efforts mean than companies have to focus on certain steps of the lean implementation process more than on others. Such steps are named as critical steps or critical success factors.

According to many authors (Womack and Jones, 1996; Liker, 2004; Womack et al., 1990; Ohno, 1988 and others), the implemention of lean principles has to be continuous in order to bring the desired results and therefore cannot be used as a fire fighting mechanism. This sets certain limitations on the process of implementation and requires a step-by-step planned approach (Söderkist and Motwani, 1999; Ohno, 1988; Olexa 2002a, b; Bateman, 2002; Moore, 2001). Additionally, there is evidence that “no standard framework for lean or its implementation exists. A systematic approach needs to be adopted, which optimises systems as a whole, focusing the right strategies in the correct places" (Pepper and Spedding, 2010, p. 138).

Therefore, the objective and the main aim of the current research was to develop a lean thinking implementation process model that could be adapted in manufacturing companies in order to secure the desired results of lean implementation. The identified gaps in literature helped pose the following research questions: how should companies perform the process of lean thinking implementation? Why do companies fail with lean thinking implementation?

The author's experience as a practical consultant as well as his academic research allow him to draw the pattern for a successful and continuous lean implementation process, which incorporates certain steps, and they could be regarded as critical success factors in lean implementation. A lean road map should start with broad lean knowledge acquisition and communication of it to the whole organisation. Based on that, all the gathered knowledge should be transferred to the company's production system – lean house: the way a company understands lean and is going to implement it. Again, the created model of a company's lean house should be communicated to all personnel and only then implemented in real life. As a result, the degree of implementation of lean would be high. This approach only works when the company has process quality in place. Following this, the circle should be started again, creating a continuous spiral up to success and high productivity and efficiency. The importance of such a roadmap is mentioned by several authors since no certain way of implementing lean principles has been developed to date. There is evidence that "no standard framework for lean or its implementation exists. A systematic approach needs to be adopted, which optimises systems as a whole, focusing the right strategies in the correct places" (Pepper and Spedding, 2010 p. 138).

Based on the review of available literature, the author constructed the process of lean thinking implementation, which incorporates the important steps indicated above and which leads to successful lean implementation. The steps regarded as critical ones are: process quality, lean knowledge acquisition, lean house development, training of lean house, lean thinking implementation process planning, execution of the plan and, as a result, successful lean thinking implementation. Since implementation should never end (Crabill et al., 2000; Kobyashai, 1994; Leseure, 2010), the step of continuous improvement closes the loop. The developed process of lean thinking implementation was used further in the study for assessing the lean implementations of companies in order to identify which step in the process influences successful lean thinking implementation more and could therefore be regarded as a critical success factor in lean thinking implementation.

For the empirical part of the research, the author has chosen twelve manufacturing companies that are implementing lean. All of them are from different industries, but they represent the batch type of manufacturing processes. The multiple case study method for the selection of the companies was used due to the qualitative nature of the current study. The multiple case study method states that the sufficient number of the cases is 10 (Yin, 2003) and there are 12 companies in the current research. Furthermore, the case study method does not require control over the activity or process being studied and is focused on contemporary events (Yin, 2003); it is therefore suitable for the purposes of the current study. Also, the single case study requires usage of the theory; multiple case study analysis requires replication logic and the benchmarking of cases from different industries (Yin, 2003). Exactly the same tactics were used in the current research, where companies from different industries were benchmarked against each other and the findings replicated. Consequently, the collected data was analysed using the content analysis method: summarising, quantitative analysis of messages that relies on the scientific method and is not limited as to the types of variables that may be measured or the context in which the messages are created or presented (Neuendorf, 2002). The emergent coding approach with the application of recording units was used in current thesis. The validity question was addressed through usage of the triangulation of the data sources.

The assessment of data was done based on the proposed model from Karlsson and Åhlström (1996) for the assessment of degree of adoption of lean initiative. The DOA model consists of nine criteria of lean and they are assessed as 0 – not implemented, 1 – partly implemented and 2 – fully implemented. Those grades are given based on analysing the determinants of each criterion. The author developed the DOA model further and has used it or the assessment of critical steps from the empirical model.

The results of the assessment of the studied companies helps draw the conclusion that the proposed empirical model is valid and companies that implement lean by following these steps have a higher degree of adoption than others. We can particularly see that those companies that have created their own lean house – the interpretation of lean knowledge into a company's language – have achieved good results and are successful in their lean journey. The results were also proven by assessment of the reference company – Scania – which is known as one of the best examples for the implementation of lean outside of Toyota.

The research undertaken gives companies a clear path and the way of thinking to achieve higher results in terms of efficiency and productivity. The author believes that the wide introduction of the proposed empirical model in manufacturing companies will enable the widespread grow of productivity among Estonian manufacturers.

Newer field consultancy projects (started while finalising this thesis) show indications towards the same idea proposed and studied in this paper: if companies miss critical steps in lean implementation preparation, then with high probability they will miss the desired targets of lean implementation and the effect of their actions will be short term.

Additionally, many companies experience fear towards lean implementation – they are unsure whether the expenses of lean actions will give any tangible results and improve key performance indicators. The author admits that such a question arises in almost every lean project – how can we be sure that we will achieve the desired results. Again, the proposed empirical model offers more confidence regarding the achievement of results. The model proposes the critical steps company have to take in order to achieve success and to have continuous lean implementation, while the more detailed content of each step has to be decided by each company according to the situation. The model proposed the way of thinking and behaviour but does not propose the content of each step. Toyota has its own lean house, Scania – its own; some other company should have its own as well.

The positive aspect for Estonian manufacturing lies also in the fact that such research has been performed and the first results and ideas have been created. Now companies have at least some local material to rely on while thinking of or planning to introduce lean thinking ideas into their operations.

From a theory aspect, this thesis has begun to fill the gap of vague lean implementation framework. Lean philosophy as such and its tools have been widely examined, but a clear process description for successful lean implementation has been missing. The results of the current thesis contribute to the latter part of lean theory and create the basis for further development.

As a contribution to the methodology of assessing the leaneness of a company in the current thesis, the author uses the approach of Karlsson and Åhlström (1996), which is similar to that used by Soriano-Meier and Forrester (2002). One of the author's contributions is to make the assessment grade simpler: 0 – not adopted; 1 – partly adopted and 2 – fully adopted and another contribution into methodology is the application of the same approach to assessing the steps and starting point of the lean thinking implementation proposed empirical model. The latter was applied the first time and consists of developing the determinants for each step of the lean thinking implementation process and for the starting point, as well as of the assessing of determinants of those based on the DOA approach. In DOA, Karlsson and Åhlström (1996) developed nine criteria for assessing the degree of adoption of lean and each criterion has its respective number of determinants. In assessing the steps of the process, the author uses steps and starting points as criteria themselves and then develops appropriate determinants. Such an application of the assessment methodology has not been used before and also might be the starting point for methodology application in similar situations.

The research conducted is only the tip of the iceberg. There are a lot of questions that should be answered in this area. What is the best way to study the Toyota Production System? In Scania webpage, it is written that representatives from Scania went to Toyota to study the TPS in the 1990s – is this still relevant today? Are there other ways to study the lean system without visiting Toyota – traveling to Japan might be expensive for SMEs and what would be the output of such travel. Another question that might arise is how to create a company's own lean house – where and how to start. And there are more such questions. To answer all of them, the ultimate goal has to be achieved – the development of a general model for successful lean implementation. This model should incorporate Process, People and Culture aspects for all manufacturing process types with the possibility of assessing the financial feasibility of implementation.

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Appendix 1. Labour productivity per person employed.

(GDP in Purchasing Power Standards (PPS) per person employed relative to EU-27 (EU-27 = 100))

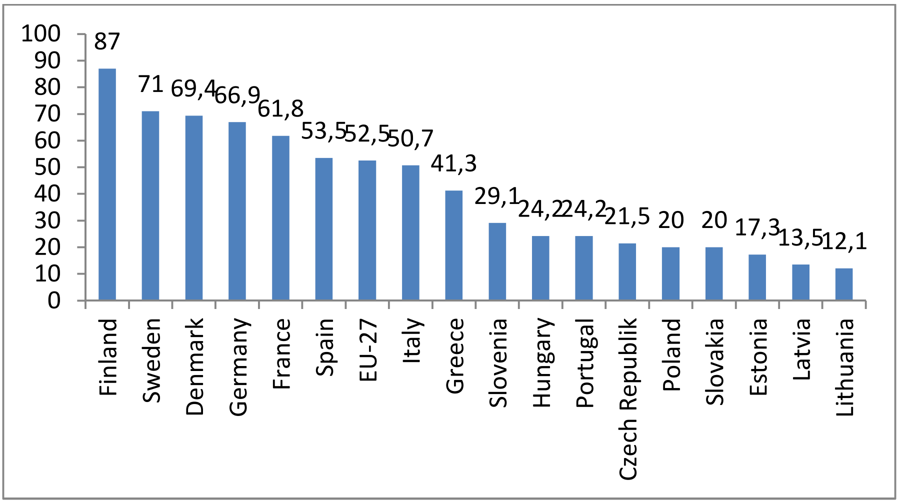
geo\time	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
EU27	100	100	100	100	100	100	100	100
Denmark	109.2	110.1	110.5	109.8	109.3	111.2	108.1	109.1
Estonia	***34.2***	***36.6***	***40.1***	***41.6***	***43.6***	***47.2***	***48.4***	***51.2***
Latvia	33.4	34.9	35.7	37	38.2	40.1	41.6	42.8
Lithuania	36.3	37.1	38.7	41.1	40.6	43	47.2	48.3
Finland	111.5	109.2	111.1	114.4	113.7	115.6	113.1	112.2
Sweden	111.4	112.7	114.2	113.4	114.9	115	109.2	109.3
Norway	115.6	121.6	122.9	114.7	120.8	139.6	137.3	132.3
USA	138.7	139.9	140.3	141.8	144.3	142.7	141.1	140.9
Japan	101.3	102	100.9	98.2	98	99.4	98.2	98.5

geo\time	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
EU27	100	100	100	100	100	100	100	100
Denmark	106.8	109.3	107.3	107.1	104.8	104.4	104.1	109.3
Estonia	***54.9***	***57.7***	***60.8***	***62.5***	***66.7***	***65.5***	***65.9***	***69.3***
Latvia	44.2	45.9	47.8	48.9	51.4	51.5	53.3	55
Lithuania	52.3	53.6	54.8	56.6	59.3	61.7	57.7	63
Finland	110.1	113.7	111.3	110.8	113.7	112.7	110.9	113.5
Sweden	112	115.6	112	113.2	115	113.5	110.7	113.3
Norway	135.7	143.2	153.4	157.5	150.9	156.9	144.9	149.2
USA	142.8	143.6	144.7	140.9	139.8	137.8	140.5	144
Japan	99.2	99.9	100	98	98.4	95.7	93.2	96.4

Source: Eurostat

Appendix 2. Value added per employee in manufacturing industry 2007 (thsd. EUR)

(Urmas Varblane, 2010, 9th BMDA Annual Conference presentation)



Appendix 3. Assessment of DOA

Company 1					
Criterion: ***Elimination of waste***					
Determinants	Data type			**Grade**	Comments
	Text – company documents	Narrative - questionnaire, interview	Visual – field notes, photo, video		
D1 Relation of work in progress to the sales should decrease	Company reports show no significant decrease of WIP related to sales	No focused redaction of WIP. Amount of WIP largely depends on particular situation in production	Photos. Observation showed that WIP amount was around 14 days.	**0**	
D2 Lot sizes should be smaller	Average lot size depends on order during some period of time and no focused actions to reduce those	No data	No data	**0**	
D3 Set-up time for machines should decrease	Set-up times statistics is missing	Set-up times are not measured	No data	**0**	
D4 Machines down time should be reduced	Machines down-time statistics is missing	Machines some-times are down and are repaired during reasonable time	No data	**0**	
D5 Transportation	No data	No data	To long distance to	**0**	

in terms of parts and distance should decrease			packaging area and then to stock. No changes during last times		
D6 Value of scrap and rework related to sales should decrease	No data in company documents regarding scrap percentage	Rework amount depends on components batch; 5S implemented in packaging reduced number of mistakes connected with missing or mixing packaging components.	Packaging station is organised better (photos), excluding possibilities of mixing two types on documents going into final package.	**1**	
Criterion: *Continuous improvement*					
D7 Number of suggestions per employee per year and percentage of those implemented should increase	No documents about employees suggestions	During implementation of 5S and Value Stream Mapping some suggestions from employees came, but only one or two were implemented	Photo	**0**	Though some suggestions were implemented, it is not a continuous trend, but single event
D8 The way of organizing the improvement activities: company should have quality circles, multifunctional teams, formal suggestion scheme and also	No evidence in documents regarding issues in the description of determinant	Improvement activities are not organized at all	No data	**0**	

spontaneous problem solving					
Criterion: ***Zero defects***					
D9 Responsibility for identification of defective parts should move from quality department to workers and workers should be able to stop the line	No data	Workers during manufacturing process are identifying defective parts and eliminating those from process. This is also partly due to the fact, that testing is a big part of the process.	No data	**1**	
D10 Responsibility for adjusting defective parts should move from quality department to the worker responsible for the creating defect	Company documents are not specifying this	Workers are not allowed to repair components and parts	No data	**0**	
D11 Number of people dedicated primarily to quality control should decrease	Number is not decreasing. Job descriptions and company structure.	No data	No data	**0**	
D12 Products should be measured not only when they are ready, but also in several steps inside the process	Product are measured also inside the process, but gathered data is not used properly	Products are measured during process.	Filed notes	**1**	

D13 The amount of control carried out by autonomous defect control should increase	No documents regarding the implementation of autonomous defect control	All controls are done by human	Photos	**0**	
D14 Size of adjustment and repair area should decrease	No data	Repair area was always the same	Photos	**0**	
Criterion: *Just-in-time*					
D15 Lot sizes should decrease	Average lot size depends on order during some period of time and no focused actions to reduce those	No data	Photos of WIP	**0**	
D16 Value of work in progress related to the sales should decrease	Company reports show no significant decrease of WIP related to sales	No focused redaction of WIP. Amount of WIP largely depends on particular situation in production	Photos. Observation showed that WIP amount was around 14 days.	**0**	
D17 Respectively order lead time should decrease also	VSM shows lead time around 25-26 days and not decreasing	Order lead time is quite long and not decreasing	No data	**0**	
D18 Level of just-in-time should move from lots delivery just-in-time to the sequential just-in-time	No data	Workers are not aware about just-in-time requirements	Photos of WIP	**0**	

Criterion: *Pull of raw materials*					
D19 Number of stages in process which use pull approach	No pull approach are documented	All stages are pushing	Photos of a process	**0**	
D20 Degree of pull: value of annual requirements scheduled through pull system	No data	No data	No data	**0**	
Criterion: *Multifunctional teams*					
D21 Percentage of workers working in teams should increase	No such data in documents	Workers dedicated to the assembly of certain product family are working as a team.	Field notes	**1**	
D22 Number of tasks performed by a single teams should increase	This is not documented, while partly is applied in a process	Workers dedicated to the assembly of certain product family are performing more tasks than before and number is slightly increasing	Photo	**1**	
D23 Number of job classifications should reduce	Number of jobs classifications is not changing	No data	No data	**0**	
D24 Task rotation frequency should move from less than once a year to the every hour of even more frequent	This is not documented, while partly is applied in a process	Workers are rotating. The frequency is decided by foreman	Photo	**1**	

D25 Number of training and amount of different working stages trained per worker should increase	Trainings are not planned in advance	Trainings are done according to the current needs, no planning ahead	No data	**0**	
Criterion: *Decentralisation*					
D26 Leadership level should move from a separate person within the organization to the rotation within multifunctional teams	Leadership is not moving towards rotation within multifunctional teams. Company structure	Foreman is a boss and his boss is a production manager	Filed notes	**0**	
D27 Within team the number of employees who could and have accepted the responsibility for the leadership should increase	Company structure	Foreman is a boss and his boss is a production manager	Field notes	**0**	
D28 The number of hierarchical levels in organization should decrease	Company structure. Number of levels is not decreasing	No data	No data	**0**	
D29 The number of areas of responsibility of	Areas of responsibility were always the same (company structure and job	Workers can do only what they are allowed to do. No increasing responsibility	Field notes	**0**	

multifunctional teams should increase	descriptions)				
Criterion: *Integrated functions*					
D30 The number of indirect tasks in teams should increase	Number of direct and indirect tasks is not documented	Teams are performing mainly direct tasks	Field notes	**0**	
D31 The ratio of indirect personnel in relation to direct employees should reduce	Not reducing. Finance and HR reports.	No data	No data	**0**	
Criterion: Vertical information systems					
D32 Mode of information provision should move from no information to the employees towards continuous displaying of needed information directly to the production floor	No description of information flows	Information about current and future orders is always available on information board. No other information	Photos	**1**	
D33 Number of strategic areas covered by information flow should increase	No description of information flows	Information about current and future orders is always available on information board. No other information	Photos	**0**	

D34 Number of operational measures in information flow should increase	No documents about displaying operational measures	Information about current and future orders is always available on information board. No other information	Photos	**0**	
D35 Frequency of information to the employees should increase	No data	Time to time	Filed notes	**0**	
DOA				**7**	

Company 11					
Criterion: ***Elimination of waste***					
Determinants	Data type			**Grade**	Comments
	Text – company documents	Narrative - questionnaire, interview	Visual – field notes, photo, video		
D1 Relation of work in progress to the sales should decrease	Based on finance reports, WIP is decreasing. Photos of WIP in a shop floor before implementation of Single Minute Exchange of Dies (SMED) tool.	After implementation of Single Minute Exchange of Dies (SMED) tool we are able to reduce set-up times for machines and as a result lot sizes and amount of WIP	Photos of WIP in shop floor	**2**	
D2 Lot sizes should be smaller	Lot sizes are decreasing based on data from ERP	After implementation of Single Minute Exchange of Dies (SMED) tool we are able to reduce set-up times for machines and as a result lot sizes and amount of WIP	Photos of WIP in shop floor	**2**	
D3 Set-up time for	Implemented SMED. Set-up	After implementation of Single	Filed notes. Video	**2**	

machines should decrease	times reduced up to 50%	Minute Exchange of Dies (SMED) tool we are able to reduce set-up times for machines and as a result lot sizes and amount of WIP			
D4 Machines down time should be reduced	Machines down time is reducing slowly. Data from machine working time tracking system	Machines some-times are down and are repaired during reasonable time	No data	**1**	
D5 Transportation in terms of parts and distance should decrease	Layout is not changed	Transportation distances are not changing	Filed notes	**0**	
D6 Value of scrap and rework related to sales should decrease	Company reports show improvement in quality	Scrap and rework is reduced do you more clear working instruction and implementation of 5S	Photos of scrap	**2**	
Criterion: *Continuous improvement*					
D7 Number of suggestions per employee per year and percentage of those implemented should increase	Number of suggestions is increasing due to 5S and SMED implementation	Workers can do suggestions and they are usually implemented (if appropriate) or feedback is given	No data	**2**	
D8 The way of organizing the improvement activities: company	Clear structure of department and team meeting is set up. Focus is on continuous problem solving	Company is continuously improving the way of solving problems in a shop floor	Filed notes	**2**	

should have quality circles, multifunctional teams, formal suggestion scheme and also spontaneous problem solving					
Criterion: ***Zero defects***					
D9 Responsibility for identification of defective parts should move from quality department to workers and workers should be able to stop the line	Workers are checking the quality of parts.	Workers during manufacturing process are identifying defective parts and eliminating those from process. They are also able to stop the process. This works only in a part of processes	Filed notes	**1**	
D10 Responsibility for adjusting defective parts should move from quality department to the worker responsible for the creating defect	Set-up workers can change set-up of machine is order to change the quality of product	Workers are not allowed to repair components and parts	Field notes	**1**	
D11 Number of people dedicated primarily to quality control should decrease	Number is not decreasing. Job descriptions and company structure	No data	No data	**0**	

D12 Products should be measured not only when they are ready, but also in several steps inside the process	Product are measured also inside the process	Products are some times measured during process	Filed notes	**1**	
D13 The amount of control carried out by autonomous defect control should increase	No documents regarding the implementation of autonomous defect control	All controls are done by human	Photos	**0**	
D14 Size of adjustment and repair area should decrease	No data	Repair area was always the same	Photos	**1**	
Criterion: *Just-in-time*					
D15 Lot sizes should decrease	Lot sizes are decreasing based on data from ERP	After implementation of Single Minute Exchange of Dies (SMED) tool we are able to reduce set-up times for machines and as a result lot sizes and amount of WIP	Photos of WIP in shop floor	**2**	
D16 Value of work in progress related to the sales should decrease	Based on finance reports, WIP is decreasing. Photos of WIP in a shop floor before implementation of Single Minute Exchange of Dies (SMED) tool.	After implementation of Single Minute Exchange of Dies (SMED) tool we are able to reduce set-up times for machines and as a result lot sizes and amount of WIP	Photos of WIP in shop floor	**2**	
D17 Respectively	Delivery reports show that	Lead time is faster	No data	**1**	

order lead time should decrease also	lead time is slightly decreasing due to smaller lot sizes				
D18 Level of just-in-time should move from lots delivery just-in-time to the sequential just-in-time	No data	Workers are not aware about just-in-time requirements	Photos	**0**	
Criterion: *Pull of raw materials*					
D19 Number of stages in process which use pull approach	No pull approach are documented	All stages are pushing	Photos of a process	**0**	
D20 Degree of pull: value of annual requirements scheduled through pull system	No data	No data	No data	**0**	
Criterion: *Multifunctional teams*					
D21 Percentage of workers working in teams should increase	Shop floor personnel is organised into teams	Worker and set-up worker are a team. Departments works as teams as well	Field notes	**2**	
D22 Number of tasks performed by a single teams should increase	Developed 5S and SMED standards increased teams responsibility and a number of tasks	After implementing 5S and SMED workers are responsible for more issues	Photos	**2**	
D23 Number of job	Number of jobs classifications	No data	No data	**0**	

classifications should reduce	is not changing				
D24 Task rotation frequency should move from less than once a year to the every hour of even more frequent	Task rotation is planned mainly in assembly	Workers are rotating. The frequency is decided by foreman	Photo	**1**	
D25 Number of training and amount of different working stages trained per worker should increase	Trainings plan available	Personnel is constantly participating in trainings: technology and lean	No data	**2**	
Criterion: *Decentralisation*					
D26 Leadership level should move from a separate person within the organization to the rotation within multifunctional teams	Within teams personnel could decide themselves	Teams can decide within bordered responsibility	Filed notes	**1**	
D27 Within team the number of employees who could and have accepted the responsibility for the leadership	Company structure	Formal leadership is in managers hand	Field notes	**0**	

should increase					
D28 The number of hierarchical levels in organization should decrease	Company structure. Number of levels is not decreasing	No data	No data	**0**	
D29 The number of areas of responsibility of multifunctional teams should increase	Developed 5S and SMED standards increased teams responsibility and a number of tasks	After implementing 5S and SMED workers are responsible for more issues	Photos	**1**	
Criterion: *Integrated functions*					
D30 The number of indirect tasks in teams should increase	Number of direct and indirect tasks is not documented	Teams are performing mainly direct tasks	Field notes	**0**	
D31 The ratio of indirect personnel in relation to direct employees should reduce	Not reducing. Finance and HR reports.	No data	No data	**0**	
Criterion: Vertical information systems					
D32 Mode of information provision should move from no information to the employees towards continuous	Information flow is described. Visual data available to the personnel in a shop floor	Online information is available about orders progress, planned orders, machine working times and key performance indicators (KPI)	Photos	**2**	

displaying of needed information directly to the production floor					
D33 Number of strategic areas covered by information flow should increase	Orders progress, planned orders, machine working times and key performance indicators. Information amount is increasing	Online information is available about orders progress, planned orders, machine working times and key performance indicators	Photos	**2**	
D34 Number of operational measures in information flow should increase	Number of KPI is slightly increasing	Number of KPI is slightly increasing	No data	**1**	
D35 Frequency of information to the employees should increase	Online	Online information is available about orders progress, planned orders, machine working times and key performance indicators	Filed notes	**2**	
DOA				**38**	

Assessment grades:
0 – determinant not implemented
1 – determinant is partly implemented
2 – determinant is fully implemented
Data presentation:
"No data" means that applicable data not found or that company does not have data regarding certain determinant and thus this determinant is not implemented.

Appendix 4. Assessment of process steps

Company 1					
Criterion: ***Process quality***					
Determinants	Data type			**Grade**	Comments
	Text – company documents	Narrative - questionnaire, interview	Visual – field notes, photo, video		
D1 Amount of standardized processes and working instruction related to the all processes should increase	Some working instruction were added during 5S implementation	Some working instruction were added during 5S implementation	No data	**1**	
D2 Number of deviations between standards and real life should decrease	No statistics about deviations between standards and real processes	Instructions are not fully followed and not renewed when needed	Field notes	**0**	
D3 Amount of scrap and rework costs related to the revenue should decrease	Statistics show no decrease	No data on workers level	No data	**0**	
D4 The responsibility of standards creation should move from functional managers	Standards are created by functional managers and situation is not changing	Standards are created by functional managers and situation is not changing	No data	**0**	

to the multifunctional teams					
D5 The ratio of non-value added activities in processes is constantly decreasing	According to Value Stream Mapping amount of non-value adding activities is high and not decreasing	Workers do not see value non-adding activities	Field notes	**0**	
D6 The number of process improvements per employee is constantly increasing	No statistics about improvements per employee	No statistics about improvements per employee	No data	**0**	
Criterion: *Lean knowledge acquisition*					
D7 Number of personnel trained in lean should increase	All employees were training on basic lean principles and that is it	All employees were training on basic lean principles and that is it	No data	**1**	
D8 Number of topics deeply trained to personnel should increase	All employees were training on basic lean principles and that is it	All employees were training on basic lean principles and that is it	No data	**1**	
D9 Number of benchmarked companies should increase	No benchmarking evidence	Employees are not visiting other companies	No data	**0**	
D10 Number of books mandatory to	No mandatory books	Why to read?	No data	**0**	

read to all employees should increase					
Criterion: *Lean house*					
D11 Attitude to lean implementation should move from project type (principle by principle) towards company's own production system based on lean principles approach	5S was implemented as a project and no other steps planned	5S implemented, but nothing will change	Field notes	**0**	
D12 Lean principles integrated into company values are increasing	No lean principles integrated into company values	Employees hardly can remember company values and lean principles	No data	**0**	
D13 Lean principles integrated into daily work is increasing	No lean principles integrated into company values	Employees hardly can remember company values and lean principles	No data	**0**	
D14 Attitude towards lean philosophy should move from waste elimination techniques to the way of working	Waste elimination is based on project type	No attitude towards elimination of waste	Filed notes, photos	**0**	
D15 As a result, lean house (or own	No lean house	No lean house	No data	**0**	

production system) is created					
Criterion: *Lean house communication and training*					
D16 Number of employees trained should increase	Since lean house is not existent, then no training	Since lean house is not existent, then no training	No data	**0**	
D17 Number of employees able to train lean house to others should increase	Since lean house is not existent, then no training	Since lean house is not existent, then no training	No data	**0**	
D18 Amount of information about lean house should increase	Since lean house is not existent, then no training	Since lean house is not existent, then no training	No data	**0**	
Criterion: *Lean implementation planning*					
D19 Lean implementation approach is moving from project type towards way of doing work based on lean house	Waste elimination is based on project type	5S implemented, but nothing will change	Field notes	**0**	
D20 Lean implementation plan is long term with	No lean implementation plan	No lean implementation plan	No data	**0**	

clearly defined small steps and targets					
D21 Continuous improvement, also improvement of lean implementation plan, is built in into lean implementation plan	No lean implementation plan	No lean implementation plan	No data	**0**	
Criterion: ***Lean implementation execution***					
D22 Lean implementation execution approach is moving from project type towards way of doing work based on lean house	Lean implementation is based on project approach	There is no need for continuous improvement, everything working fine	Field notes	**0**	
D23 Lean implementation follows the plan and is continuously improved based on achieved targets	No lean implementation plan	No lean implementation plan	No data	**0**	
Sum of scores				**3**	

Company 11					
Criterion: ***Process quality***					
Determinants	Data type			**Grade**	Comments
	Text – company documents	Narrative - questionnaire, interview	Visual – field notes, photo, video		
D1 Amount of standardized processes and working instruction related to the all processes should increase	Well introduced and working quality management system (ISO9001)	Employees are following working instructions	Photo, video, field notes	**2**	
D2 Number of deviations between standards and real life should decrease	Continuous working on deviation elimination, statistics is present	Workers are trying to understand deviation and improve processes	Field notes	**2**	
D3 Amount of scrap and rework costs related to the revenue should decrease	Based on reports, scrap is decreasing	Employees are trying to reduce amount of scrap	Field notes, photos	**2**	
D4 The responsibility of standards creation should move from functional managers to the multifunctional teams	Standards are mainly created by functional managers, though 5S and SMED standards were developed by workers	Opinion and suggestions of employees are counted when standards are created	Field notes	**1**	

D5 The ratio of non-value added activities in processes is constantly decreasing	Result of SMED implementation	We are working more efficiently	Field notes	**2**	
D6 The number of process improvements per employee is constantly increasing	Number of suggestions is increasing	Opinion and suggestions of employees are counted when standards are created	Field notes	**2**	
Criterion: *Lean knowledge acquisition*					
D7 Number of personnel trained in lean should increase	All employees were trained on basic lean and many on other topics. Further trainings are planned.	All employees were trained on basic lean and many on other topics. Further trainings are planned.	No data	**2**	
D8 Number of topics deeply trained to personnel should increase	All employees were trained on basic lean and many on other topics. Further trainings are planned.	All employees were trained on basic lean and many on other topics. Further trainings are planned.	No data	**2**	
D9 Number of benchmarked companies should increase	Other factories within the corporation are benchmarked	Employees can bring examples of other companies	Filed notes	**2**	
D10 Number of books mandatory to read to all employees should increase	There are mandatory books	Employees can read books on operations management and they are available in the company	No data	**1**	

Criterion: ***Lean house***					
D11 Attitude to lean implementation should move from project type (principle by principle) towards company's own production system based on lean principles approach	Company has long term plan on lean implementation	Employees are aware about next steps in lean implementation	Photos	**2**	
D12 Lean principles integrated into company values are increasing	Number of lean principles integrated into company values are increasing along lean implementation	Number of lean principles integrated into company values are increasing along lean implementation	Photo	**2**	
D13 Lean principles integrated into daily work is increasing	Number of lean principles integrated into company values are increasing along lean implementation	Number of lean principles integrated into company values are increasing along lean implementation	Photo	**2**	
D14 Attitude towards lean philosophy should move from waste elimination techniques to the way of working	Attitude towards way of working is moving, though principles implementation is taken as step by step approach (small project)	Lean thinking is additional issue, while helping a lot to improve processes	Filed notes	**1**	
D15 As a result, lean house (or own production system) is created	Lean house as such is not created, while clear lean implementation path is existent	Employees are aware about next steps in lean implementation	No data	**1**	

Criterion: ***Lean house communication and training***					
D16 Number of employees trained should increase	All employees were trained on basic lean and many on other topics. Further trainings are planned.	All employees were trained on basic lean and many on other topics. Further trainings are planned.	No data	**2**	
D17 Number of employees able to train lean house to others should increase	Number of employees able to train others is increasing	Line manager are able to train employees	Field notes, photos	**2**	
D18 Amount of information about lean house should increase	All information about lean thinking implementation is available	All information about lean thinking implementation is available	Filed notes, photos	**2**	
Criterion: ***Lean implementation planning***					
D19 Lean implementation approach is moving from project type towards way of doing work based on lean house	Company has long term plan on lean implementation	Employees are aware about next steps in lean implementation	Photos	**2**	
D20 Lean implementation plan is long term with clearly defined small steps and targets	Company has long term plan on lean implementation	Employees are aware about next steps in lean implementation	Photos	**2**	

D21 Continuous improvement, also improvement of lean implementation plan, is built in into lean implementation plan	Company has long term plan on lean implementation, though plan still has only first revision	Employees are aware about next steps in lean implementation and is taken it as a direction for the activities	Filed notes	**1**	
Criterion: ***Lean implementation execution***					
D22 Lean implementation execution approach is moving from project type towards way of doing work based on lean house	Lean implementation plan is moving towards continuous activity	Employees are continuously implementing lean principles	Field notes	**2**	
D23 Lean implementation follows the plan and is continuously improved based on achieved targets	Lean implementation plan is executed as planned, though plan still has only first revision	No correction of plan yet	Field notes	**1**	
Sum of scores				**40**	

Assessment grades:
0 – determinant not implemented
1 – determinant is partly implemented

2 – determinant is fully implemented

Data presentation:

“No data” means that applicable data not found or that company does not have data regarding certain determinant and thus this determinant is not implemented.

Appendix 5. Summary of assessment results

Criterion/*determinant*	Grading	Company
PQ -Process quality	**LOW (0-4 points)**	**C1 C7 C8 C10 C12**
	MEDIUM (5-8 points)	**C2 C3 C6 C9**
	HIGH (9-12 points)	**C4 C5 C11 REF**
PQD1 -Amount of standardized processes and working instruction related to the all processes should increase	*0*	*C7*
	1	*C1 C2 C3 C8 C9 C12*
	2	*C4 C5 C6 C11 REF*
PQD2 - Number of deviations between standards and real life should decrease	*0*	*C1 C2 C3 C6 C7 C8 C10*
	1	*C4 C9 C12*
	2	*C5 C11 REF*
PQD3 - Amount of scrap and rework costs related to the revenue should decrease	*0*	*C1*
	1	*C2 C3 C6 C7 C8 C9 C10 C12*
	2	*C4 C5 C11 REF*
PQD4 - The responsibility of standards creation should move from functional managers to the multifunctional teams	*0*	*C1 C2 C3 C6 C7 C8 C10 C12*
	1	*C4 C9 C11*
	2	*C5 REF*
PQD5 - The ratio of non-value added activities in processes is constantly decreasing	*0*	*C1 C8 C10*
	1	*C7 C9 C12*
	2	*C2 C3 C4 C5 C6 C11 REF*
PQD6 - The number of process improvements per employee is	*0*	*C1 C8 C9 C10 C12*

constantly increasing	*1*	*C2 C3 C5 C6*
	2	*C4 C11 REF*
LKA - Lean knowledge acquisition	**LOW (0-3 points)**	**C1 C7 C8 C10**
	MEDIUM (4-6 points)	**C2 C3 C6 C9 C12**
	HIGH (7-8 points)	**C4 C5 C11 REF**
LKAD1 - Number of personnel trained in lean should increase	*0*	-
	1	*C1 C3 C8 C10*
	2	*C2 C4 C5 C6 C7 C9 C11 C12 REF*
LKAD2 - Number of topics deeply trained to personnel should increase	*0*	-
	1	*C1 C3 C6 C7 C8 C10*
	2	*C2 C4 C5 C9 C11 C12 REF*
LKAD3 - Number of benchmarked companies should increase	*0*	*C1 C7 C8 C9 C10*
	1	*C2 C3 C4 C6 C12 REF*
	2	*C5 C11*
LKAD4 - Number of books mandatory to read to all employees should increase	*0*	*C1 C2 C3 C6 C7 C8 C9 C10 C12*
	1	*C4 C5 C11 REF*
	2	-
LHD - Lean house development	**LOW (0-3 points)**	**C1 C3 C7 C8 C9 C10**
	MEDIUM (4-7 points)	**C2 C6 C12**
	HIGH (8-10 points)	**C4 C5 C11 REF**
LHDD1 - Attitude to lean implementation should move from project type (principle by principle) towards company's own	*0*	*C1 C3 C7 C8 C10*
	1	*C2 C9 C12*

production system based on lean principles approach	*2*	*C4 C5 C6 C11 REF*
LHDD2 - Lean principles integrated into company values are increasing	*0*	*C1 C3 C7 C10*
	1	*C2 C6 C8 C9*
	2	*C4 C5 C11 C12 REF*
LHDD3 - Lean principles integrated into daily work is increasing	*0*	*C1 C3 C10*
	1	*C2 C6 C7 C8 C9*
	2	*C4 C5 C11 C12 REF*
LHDD4 - Attitude towards lean philosophy should move from waste elimination techniques to the way of working	*0*	*C1 C3 C7 C8 C9 C10 C12*
	1	*C2 C4 C5 C6 C11*
	2	*REF*
LHDD5 - As a result, lean house (or own production system) is created	*0*	*C1 C2 C3 C6 C7 C8 C9 C10 C12*
	1	*C4 C5 C11*
	2	*REF*
LHT - Lean house training	**LOW (0-2 points)**	**C1 C2 C3 C6 C7 C8 C9 C10 C12**
	MEDIUM (3-4 points)	**-**
	HIGH (5-6 points)	**C4 C5 C11 REF**
LHTD1 - Number of employees trained should increase	*0*	*C1 C2 C3 C7 C8 C9 C10*
	1	*C6 C12*
	2	*C4 C5 C11 REF*
LHTD2 - Number of employees able to train lean house to others should increase	*0*	*C1 C2 C3 C6 C7 C8 C9 C10 C12*
	1	*-*
	2	*C4 C5 C11 REF*

LHTD3 - Amount of information about lean house should increase	*0*	*C1 C2 C3 C6 C7 C8 C9 C10 C12*
	1	*-*
	2	*C4 C5 C11 REF*
LIP - Lean implementation planning	**LOW (0-2 points)**	**C1 C2 C3 C6 C7 C8 C9 C10 C12**
	MEDIUM (3-4 points)	**-**
	HIGH (5-6 points)	**C4 C5 C11 REF**
LIPD1 - Lean implementation approach is moving from project type towards way of doing work based on lean house	*0*	*C1 C2 C3 C6 C7 C8 C9 C10 C12*
	1	*-*
	2	*C4 C5 C11 REF*
LIPD2 - Lean implementation plan is long term with clearly defined small steps and targets	*0*	*C1 C2 C3 C6 C7 C8 C9 C10 C12*
	1	*-*
	2	*C4 C5 C11 REF*
LIPD3 - Continuous improvement, also improvement of lean implementation plan, is built in into lean implementation plan	*0*	*C1 C2 C3 C6 C7 C8 C9 C10 C12*
	1	*C4 C5 C11*
	2	*REF*
LIE - Lean implementation execution	**LOW (0-1 points)**	**C1 C2 C3 C6 C7 C8 C9 C10 C12**
	MEDIUM (2-3 points)	**-**
	HIGH (4 points)	**C4 C5 C11 REF**
LIED1 - Lean implementation execution approach is moving from project type towards way of doing work based on lean house	*0*	*C1 C2 C3 C6 C7 C8 C9 C10 C12*
	1	*-*
	2	*C4 C5 C11 REF*
LIED2 - - Lean implementation follows the plan and is	*0*	*C1 C2 C3 C6 C7 C8 C9 C10 C12*

continuously improved based on achieved targets	*1*	*C4 C5 C11*
	2	*REF*
SUM OF SIX CRTITERIA	**LOW (0-16 points)**	**C1 C2 C3 C6 C7 C8 C9 C10 C12**
	MEDIUM (17-32 points)	**-**
	HIGH (33-46 points)	**C4 C5 C11 REF**
EW - Elimination of waste	**LOW (0-4 points)**	**C1 C2 C3 C6 C7 C8 C9 C10 C12**
	MEDIUM (5-8 points)	**C4**
	HIGH (9-12 points)	**C5 C11 REF**
EWD1 - Relation of work in progress to the sales should decrease	*0*	*C1 C2 C3 C6 C7 C8 C10*
	1	*C4 C5 C9 C12*
	2	*C11 REF*
EWD2 - Lot sizes should be smaller	*0*	*C1 C2 C3 C6 C10 C12*
	1	*C4 C7 C8 C9*
	2	*C5 C11 REF*
EWD3 - Set-up time for machines should decrease	*0*	*C1 C3 C7 C10 C12*
	1	*C4 C6 C8 C9*
	2	*C2 C5 C11 REF*
EWD4 - Machines down time should be reduced	*0*	*C1 C7 C9 C10*
	1	*C2 C3 C4 C6 C8 C11 C12*
	2	*C5 REF*
EWD5 - Transportation in terms of parts and distance should decrease	*0*	*C1 C2 C3 C6 C7 C8 C C10 C11 C12*
	1	*C4 REF*

	2	*C5*
EWD6 - - Value of scrap and rework related to sales should decrease	*0*	*C6 C7 C8*
	1	*C1 C2 C3 C4 C9 C10 C12 REF*
	2	*C5 C11*
CI - Continuous improvement	**LOW (0-1 points)**	**C1 C2 C3 C6 C7 C8 C9 C10 C12**
	MEDIUM (2-3 points)	**-**
	HIGH (4 points)	**C4 C5 C11 REF**
CID1 - Number of suggestions per employee per year and percentage of those implemented should increase	*0*	*C1 C2 C3 C6 C7 C8 C9 C10 C12*
	1	*-*
	2	*C4 C5 C11 REF*
CID2 - The way of organizing the improvement activities: company should have quality circles, multifunctional teams, formal suggestion scheme and also spontaneous problem solving	*0*	*C1 C2 C3 C6 C7 C8 C9 C10 C12*
	1	*C4 REF*
	2	*C5 C1*
ZD - Zero defects	**LOW (0-4 points)**	**C1 C2 C3 C4 C6 C7 C8 C9 C10 C11 C12**
	MEDIUM (5-8 points)	**C5 REF**
	HIGH (9-12 points)	**-**
ZDD1 - Responsibility for identification of defective parts should move from quality department to workers and workers should be able to stop the line	*0*	*C2 C12*
	1	*C1 C3 C4 C5 C6 C7 C8 C9 C10 C11 C12*
	2	*REF*
ZDD2 - Responsibility for adjusting defective parts should move from quality department to the worker responsible for the creating	*0*	*C1 C3 C8 C9 C10*
	1	*C2 C4 C5 C6 C7 C11 C12*

defect	*2*	*REF*
ZDD3 - Number of people dedicated primarily to quality control should decrease	*0*	*C1 C2 C3 C4 C6 C7 C8 C9 C10 C11 C12*
	1	*C5 REF*
	2	*-*
ZDD4 - Products should be measured not only when they are ready, but also in several steps inside the process	*0*	*C2 C3 C7 C10 C12*
	1	*C1 C4 C5 C6 C8 C9 C11 REF*
	2	*-*
ZDD5 - The amount of control carried out by autonomous defect control should increase	*0*	*C1 C2 C3 C4 C5 C6 C7 C8 C9 C10 C11 C2 REF*
	1	*-*
	2	*-*
ZDD6 - Size of adjustment and repair area should decrease	*0*	*C1 C2 C3 C6 C7 C8 C9 C10 C12 REF*
	1	*C4 C5 C11*
	2	*-*
JIT - Just-in-time	**LOW (0-3 points)**	**C1 C2 C3 C6 C7 C8 C9 C10 C12**
	MEDIUM (4-6 points)	**C4 C5 C11**
	HIGH (7-8 points)	**REF**
JITD1 - Lot sizes should decrease	*0*	*C1 C2 C3 C6 C10 C12*
	1	*C4 C7 C8 C9*
	2	*C5 C11 REF*
JITD2 - Value of work in progress related to the sales should decrease	*0*	*C1 C2 C3 C6 C7 C8 C10*
	1	*C4 C5 C9 C12*

	2	*C11 REF*
JITD3 - Respectively order lead time should decrease also	*0*	*C1 C7 C8 C9 C10*
	1	*C2 C3 C5 C6 C11 C12*
	2	*C4 REF*
JITD4 - Level of just-in-time should move from lots delivery just-in-time to the sequential just-in-time	*0*	*C1 C2 C3 C4 C6 C7 C8 C9 C10 C11 C12*
	1	*C5*
	2	*REF*
PM - Pull of raw materials	**LOW (0-1 points)**	**C1 C2 C3 C4 C5 C6 C7 C8 C9 C10 C11 C12**
	MEDIUM (2-3 points)	**-**
	HIGH (4 points)	**REF**
PMD1 - Number of stages in process which use pull approach	*0*	*C1 C2 C3 C4 C5 C6 C7 C8 C9 C10 C11 C12*
	1	-
	2	*REF*
PMD2 - Degree of pull: value of annual requirements scheduled through pull system	*0*	*C1 C2 C3 C4 C5 C6 C7 C8 C9 C10 C11 C12*
	1	*REF*
	2	-
MT - Multifunctional teams	**LOW (0-3 points)**	**C1 C2 C3 C6 C7 C8 C10**
	MEDIUM (4-7 points)	**C5 C9 C11 C12**
	HIGH (8-10 points)	**C4 REF**
MTD1 - Percentage on workers working in teams should increase	*0*	*C3 C6 C10*

	1	*C1 C2 C5 C7 C8 C12*
	2	*C4 C9 C11 REF*
MTD2 - Number of tasks performed by a single teams should increase	*0*	*C3 C6 C7 C10*
	1	*C1 C2 C8 C9 C12*
	2	*C4 C5 C11 REF*
MTD3 - Number of job classifications should reduce	*0*	*C1 C2 C3 C4 C5 C6 C7 C8 C9 C10 C11 C12*
	1	*REF*
	2	*-*
MTD4 - Task rotation frequency should move from less than once a year to the every hour of even more frequent	*0*	*C6*
	1	*C1 C2 C3 C5 C7 C8 C9 C10 C11 C12*
	2	*REF*
MTD5 - Number of training and amount of different working stages trained per worker should increase	*0*	*C1 C2 C3 C8 C10*
	1	*C6 C7 C9*
	2	*C4 C5 C11 C12 REF*
DE - Decentralization	**LOW (0-3 points)**	**C1 C2 C3 C5 C7 C8 C9 C10 C11 C12**
	MEDIUM (4-6 points)	**-**
	HIGH (7-8 points)	**REF**
DED1 - Leadership level should move from a separate person within the organization to the rotation within multifunctional teams	*0*	*C1 C2 C3 C6 C7 C10 C12*
	1	*C4 C5 C8 C9 C11*
	2	*REF*
DED2 - Within team the number of employees who could and have accepted the responsibility for the leadership should increase	*0*	*C1 C2 C3 C5 C7 C8 C9 C10 C11 C12*
	1	*REF*

	2	-
DED3 - The number of hierarchical levels in organization should decrease	*0*	*C1 C2 C3 C5 C7 C8 C9 C10 C11 C12*
	1	*REF*
	2	-
DED4 - The number of areas of responsibility of multifunctional teams should increase	*0*	*C1 C3 C6 C8 C10*
	1	*C2 C4 C5 C7 C9 C11 C12*
	2	*REF*
IF - Integration of functions	**LOW (0-1 points)**	**C1 C2 C3 C5 C7 C8 C9 C10 C11 C12**
	MEDIUM (2-3 points)	**-**
	HIGH (4 points)	**REF**
IFD1 - The number of indirect tasks in teams should increase	*0*	*C1 C2 C3 C5 C7 C8 C9 C10 C11 C12*
	1	-
	2	*REF*
IFD2 - The ratio of indirect personnel in relation to direct employees should reduce	*0*	*C1 C2 C3 C5 C7 C8 C9 C10 C11 C12*
	1	*REF*
	2	-
VIS - Vertical information systems	**LOW (0-3 points)**	**C1 C3 C6 C7 C8 C9 C10**
	MEDIUM (4-6 points)	**C2 C12**
	HIGH (7-8 points)	**C4 C5 C11 REF**
VISD1 - Mode of information provision should move from no information to the employees towards continuous displaying of needed information directly to the production floor	*0*	*C10 C12*
	1	*C1 C3 C6 C7 C8*
	2	*C2 C4 C5 C9 C11 REF*

VISD2 - Number of strategic areas covered by information flow should increase	*0*	*C1 C3 C6 C7 C8 C10*
	1	*C9*
	2	*C2 C4 C5 C11 C12 REF*
VISD3 - Number of operational measures in information flow should increase	*0*	*C1 C3 C6 C7 C8 C10*
	1	*C2 C4 C5 C9 C11*
	2	*C12 REF*
VISD4 - Frequency of information to the employees should increase	*0*	*C1 C3 C7 C9*
	1	*C2 C6 C8 C10*
	2	*C4 C5 C11 C12 REF*
DOA - Degree of adoption	**LOW (0-24 points)**	**C1 C2 C3 C6 C7 C8 C C10 C12**
	MEDIUM (25-48 points)	**C4 C5 C11**
	HIGH (49-70 points)	**REF**

Appendix 6: Elulookirjeldus

1. Isikuandmed

Ees- ja perekonnanimi	Aleksandr Miina
Sünniaeg ja -koht	05.10.1979, Tallinn, Estonia

2. Kontaktandmed

Aadress	Tooma 8, Laulasmaa, Keila vald, Harjumaa, Estonia
Telefon	+372 52 699 10
E-posti aadress	aleksandr.miina@ttu.ee

3. Hariduskäik

Õppeasutus	Lõpetamise aeg	Haridus (eriala/kraad)
Tallinna Tehnikaülikool	2013	Ärikorraldus/Doktor
Tallinna Tehnikaülikool	2003	Tootmiskorraldus ja planeerimine/Inseneriteaduste magister

4. Keelteoskus (alg-, kesk- või kõrgtase)

Keel	Tase
Vene	kõrgtasemel
Eesti	kõrgtasemel
Inglise	kõrgtasemel
Saksa	algtasemel
Soome	algtasemel

5. Täiendusõpe

Õppimise aeg	Täiendusõppe läbiviija nimetus
21-25.02.2005	European Operations Management Association (EurOMA), „Research methods in Operations Management", EurOMA, Brussels

6. Teenistuskäik

Töötamise aeg	Tööandja nimetus	Ametikoht
alates 2007	MTÜ Lean Enterprise Estonia	Asutaja ja juhatuse liige
alates 2003	Tallinna Tehnikaülikool	Lektor

2009 - 2010	Glamox HE AS	Kvaliteedijuht
2004 – 2007	Stoneridge Electronics AS	Tootmisjuht
2002 – 2004	JOT Eesti OÜ	Projektijuht
2000 – 2002	JOT Eesti OÜ	Koordinatsiooni grupi juht

7. Teadustegevus

Juhendatud lõputööd:
Sarapik, M. (2011). *Opportunities for lean thinking implementation in the Flir Systems OÜ*. Magistritöö, Tallinna Tehnikaülikool, Tallinn.

8. Kaitstud lõputööd

Miina, A. (2003). *Engineering Change Management*. Magistritöö, juhendaja professor Rein Kyttner, Tallinna Tehnikaülikool, Mehaanikateaduskond.

9. Teadustöö põhisuunad

4. Natural Sciences and Engineering, 4.14. Industrial Engineering and Management (Lean manufacturing).

10. Teised uurimisprojektid

Puuduvad

Elulookirjelduse lisa

Konverentside ettekanded:
Miina, A. (2008). *Ideas on Implementing Lean Manufacturing in Estonia – Critical Success Factors*. The 15th International Annual EurOMA Conference, Groningen.

Miina, A. (2008). *Lean and Agile manufacturing - new possibilities for SMEs in Estonia*. 15th Nordic Conference on Small Business Research, Tallinn, Estonia, May 21-23, 2008 . Tallinn.

Artiklid:

Rahvusvahelised ajakirjad
Miina, A., Kolbre, E., Saat, M. (will be published in 2012). Critical success factors of lean implementation: example of Estonian manufacturing companies. *Business Development in Baltic Sea Region.* Berlin: Peter Lang Verlag. (ETIS 3.1)

Miina, A (will be published in 2012). Lean problem: why companies fail with lean implementation. *Management.* Scientific and Academic Publishing (ETIS 1.2)

Working Papers

Miina, A. (2007). *Lean in Service*. Research Perspectives in Service Engineering and Management (101 - 109). Helsinki University of Technology, Helsinki (ETIS 3.2)

Konverentsid

Zahharov, R., Bashkite, V., Karaulova, T., Miina, A. (2010). *Industrial building life cycle extension through concept of modular construction* . Proceedings of the21st DAAAM World Symposium, Zadar(Croatia) 20-23 October (805 - 806). Vienna: DAAAM International Vienna. (ETIS 3.1)

Miina, A. (2008). *Ideas on Implementing Lean Manufacturing in Estonia – Critical Success Factors.* In: Proceedings: The 15th International Annual EurOMA Conference, Groningen (the Netherlands), June 15-18, 2008. European Operations Management Association (EurOMA). (ETIS 3.2)

Miina, A. (2008). *Lean and Agile manufacturing - new possibilities for SMEs in Estonia.* In: Nordic Conference on Small Business Research : Challenges for Enterpreneurship and Small Business Development in the Context of European Enlargement : 15th Nordic Conference on Small Business Research, Tallinn, Estonia, May 21-23, 2008 . Tallinn. (ETIS 3.4)

Appendix 7: Curriculum Vitae

1. Personal data

Name	Aleksandr Miina
Date and place of birth	05.10.1979, Tallinn, Estonia

2. Contact information

Address	Tooma 8, Laulasmaa, Keila vald, Harjumaa, Estonia
Phone	+372 52 699 10
E-mail	aleksandr.miina@ttu.ee

3. Education

Educational institution	Graduation year	Education (field of study/degree)
Tallinn University of Technology	Expected 2012	Business Administration, Doctor of Philosophy
Tallinn University of Technology	2003	Industrial Engineering, Master of Science in Engineering

4. Language competence/skills (fluent; average, basic skills)

Language	Level
Russian	fluent
Estonian	fluent
English	fluent
German	weak
Finnish	weak

5. Special Courses

Period	Educational or other organisation
21-25.02.2005	European Operations Management Association (EurOMA), „Research methods in Operations Management", EurOMA, Brussels

6. Professional Employment

Period	Organisation	Position
Since 2007	NPO Lean Enterprise Estonia	Founder and senior consultant

Since 2003	Tallinn University of Technology	Lecturer
2009 - 2010	Glamox HE AS	Quality manager
2004 – 2007	Stoneridge Electronics AS	Production manager
2002 – 2004	JOT Eesti OÜ	Project manager
2000 – 2002	JOT Eesti OÜ	Coordination group manager

7. Scientific work

Dissertations supervised:
Sarapik, M. (2011). *Opportunities for lean thinking implementation in the Flir Systems OÜ*. Master thesis, Tallinn University of Technology, Tallinn.

8. Defended theses

Miina, A. (2003). *Engineering Change Management*. Master's Degree, Supervisor Professor Rein Kyttner, Tallinn University of Technology, Faculty of Mechanical Engineering, Department of Machinery, Tallinn.

9. Main areas of scientific work/Current research topics

4. Natural Sciences and Engineering, 4.14. Industrial Engineering and Management (Lean manufacturing).

10. Other research projects

None

Appendix to CV

Conference presentations:
Miina, A. (2008). *Ideas on Implementing Lean Manufacturing in Estonia – Critical Success Factors*. The 15th International Annual EurOMA Conference, Groningen.

Miina, A. (2008). *Lean and Agile manufacturing - new possibilities for SMEs in Estonia*. 15th Nordic Conference on Small Business Research, Tallinn, Estonia, May 21-23, 2008 . Tallinn.

Publications:

International Journals
Miina, A., Kolbre, E., Saat, M. (will be published in 2012). Critical success factors of lean implementation: example of Estonian manufacturing

companies. *Business Development in Baltic Sea Region.* Berlin: Peter Lang Verlag. (ETIS 3.1)

Miina, A (will be published in 2012). Lean problem: why companies fail with lean implementation. *Management.* Scientific and Academic Publishing (ETIS 1.2)

Working Papers

Miina, A. (2007). *Lean in Service*. Research Perspectives in Service Engineering and Management (101 - 109). Helsinki University of Technology, Helsinki (ETIS 3.2)

Conference Proceedings

Zahharov, R., Bashkite, V., Karaulova, T., Miina, A. (2010). *Industrial building life cycle extension through concept of modular construction* . Proceedings of the21st DAAAM World Symposium, Zadar(Croatia) 20-23 October (805 - 806). Vienna: DAAAM International Vienna. (ETIS 3.1)

Miina, A. (2008). *Ideas on Implementing Lean Manufacturing in Estonia – Critical Success Factors.* In: Proceedings: The 15th International Annual EurOMA Conference, Groningen (the Netherlands), June 15-18, 2008. European Operations Management Association (EurOMA). (ETIS 3.2)

Miina, A. (2008). *Lean and Agile manufacturing - new possibilities for SMEs in Estonia.* In: Nordic Conference on Small Business Research : Challenges for Enterpreneurship and Small Business Development in the Context of European Enlargement : 15th Nordic Conference on Small Business Research, Tallinn, Estonia, May 21-23, 2008 . Tallinn. (ETIS 3.4)

Abstract

The importance of the improvement of manufacturing processes was greatly seen during the last financial crisis, and more and more companies around the world and in Estonia began their own lean implementation process following the crisis. Though lean ideas have been known and studied extensively for more than 30 years, there are still a lot of difficult and unclear aspects to be studied, and one of those is how to achieve successful lean thinking implementation.

Lean thinking (henceforth lean) is defined as the systematic elimination of waste (Santos et al., 2006). Under lean, waste refers to everything that does not contribute to the final product or service value and value is regarded from the customer's point of view. Waste is all the activities that do not add value in the product manufacturing process. The lean concept brings 7 basic types of waste (Womack et al.,, 1990; Liker, 2004; Santos et al., 2006, Voss, 2007): overproduction – producing more than ordered, producing to the stock and producing unnecessary items; inventory – all materials and components, semi-finished goods (work-in-process or WIP) and all finished products standing in stock; transportation – any kind of movement of materials, components, WIP and finished products; excess motion – any activities during the process that are unnecessary (could be removed from the work method) to fulfil the goal; waiting – materials, components and WIP waiting to be processed, workers and machines waiting to start the job; over processing – making the products "too good" instead of "good enough"; defects – producing scrap or defective products, inspection and quality controls.

In academic literature worldwide, lean thinking is regarded as a cost reduction and productivity improvement technique (Achanga et al., 2004, 2005a, b; 2006; Bicheno, 2000, 2004; Womack et al., 1990; Womack and Jones, 1996), a new efficient paradigm for operations (Katayama and Bennett, 1996; Williams et al., 1992). Many companies use lean principles in developing their corporate strategies (Womack and Jones, 1996) and as a result it could be used as a powerful weapon in a more globally competitive world (Söderkist and Motwani, 1999).

Though lean seemed to work very well in Toyota factories, companies outside of Toyota were not able to achieve the same results. Lean was developed in Toyota and therefore is a natural thing for Toyota. Other companies had to find their personal way of implementing those ideas in a successful manner and it turned out to be very complicated. Since then, the lean topic was studied very widely and different aspects of lean implementation were investigated, though still there is no standard framework or roadmap for successful lean implementation (Pepper and Spedding, 2010; Repenning and Sterman, 2001; Hogg 1993). Despite this unclear aspect of lean implementation, this concept is regarded as the method for processes, efficiency, productivity and quality improvement (Voss et al., 1995).

Several problems regarding the lean implementation process in manufacturing companies and results of the process are identified in literature:

- about 10 per cent or less of companies succeeds at implementing lean manufacturing practices (Bhasin and Burcher, 2006).
- "only 10 per cent has the philosophy properly instituted" (Sohal and Eggleston, 1994, p. 8).
- new paradigms and best practices are often taken as a "black box", which has many dangers inside (Voss, 2007).
- if companies use lean initiatives almost as a fad, most of their effort will fail to produce significant results (Repenning and Sterman, 2001).
- finally, there is evidence that "no standard framework for lean or its implementation exists. A systematic approach needs to be adopted, which optimises systems as a whole, focusing the right strategies in the correct places." (Pepper and Spedding, 2010, p. 138).

Based on the above, the main problem for lean implementation could be formulated as follows: the standard framework for successful lean implementation is not studied enough and as a result manufacturing companies are either not starting a lean initiative or fail to implement it successfully. Companies are missing standard process for lean implementation and an overview of the critical steps they have to perform in order to achieve desired targets.

Companies do not know where to start the process of implementation, which steps are critical for success and how to proceed with the whole process. Despite the high number of research papers and dissertations on the lean topic, the aspect of critical success factors during the lean implementation process is covered weakly and companies are missing clear, step-by-step guidelines for the successful implementation of lean. There are a lot of studies (Teresko, 2002; Bhasin, 2011; Olexa 2002a, b; Bateman, 2002; Moore, 2001; Voss, 2007; Liker, 2004) that have attempted again and again to rethink what lean is; and there are studies which highlight on which lean tools to focus during implementation and how to implement those tools, but still is there a deficiency of step-by-step process description for lean implementation. Additionally, several authors indicate that only small number of manufacturing companies succeeds with lean implementation (Bhasin and Burcher, 2006; Sohal and Eggleston; 1994). Additionally, other researches (Achanga et al., 2006; Oprime et al., 2011) point out that there are some critical aspects that mainly influence lean implementation process – factors that could secure sustainable and continuous lean implementation in manufacturing companies and guarantee them constant and fast growth in productivity

The potential solution for that problem would be the standard process model of lean implementation, where companies can see step-by-step instructions for the implementation of lean thinking principles. The model will also bring out critical factors for the success of the lean initiative. Critical success factors are the certain steps in the process that define the overall success of the lean implementation initiative. The fail of critical success factors brings the failure of the whole process.

Finally, it has been shown that there are two main problems identified. The first emerges from academic literature and is specified as missing a clearly defined step-by-step process for lean thinking implementation with an indication of the critical success factors of that process. The existence of the latter could ensure that time and money spent on it are not wasted and required tangible and intangible targets are achieved. The second problem is derived from the current situation in the Estonian manufacturing companies. It was shown based on present statistics that there are potential possibilities for higher productivity and efficiency of Estonian manufacturers. Furthermore, companies are trying to achieve those by the implementation of lean thinking principles, though results are scarce due to the unclear nature of the process of lean implementation.

The author proposes that in order to solve those two identified problems the successful and continuous implementation of lean thinking ideas and principles in Estonian manufacturing companies should be done. The process of the implementation of lean thinking will be successful if a clear step-by step path is present and the critical success factors are indicated.

The objective and the main aim of the current research is to develop a lean thinking implementation process model that could be adapted in manufacturing companies in order to secure the desired results of lean implementation.

Based on the previous discussion about problems and objectives, the following questions are answered in the current paper:

1. How companies should perform the process of lean thinking implementation (RQ1)?
2. Why companies fail with lean thinking implementation (RQ2)?

To answer those questions, the following methodology is applied. First, a comprehensive literature study of the theoretical aspect of lean thinking is done and the process of successful lean thinking implementation process is constructed. The latter also indicated the possible critical success factors of lean thinking implementation. The second step is the choice of the companies based on the multiple case study method. The current investigation incorporates twelve companies from different industries and of different sizes. Furthermore, the data collection and analysis of the companies based on the content analysis method is done.

The proposed model for the lean thinking implementation process embodies the start point – good process quality – and five steps: lean knowledge acquisition, lean house development, lean house communication and training, lean implementation planning and execution of a lean thinking implementation plan.

The main results that we can see from the assessment are:

- DOA (or success of lean initiative) depends on how well lean implementation process steps were performed – Result 1 (R1);

- DOA depends on the existence of lean house (or own production system) – Result 2 (R2);
- Some criteria of DOA are not implemented in any company – Result 3 (R3).

Those results represent the main outcome of the study and prove the proposal made by the author, while introducing the empirical model of the lean thinking implementation process. In general, the results show that understanding about lean thinking should be inverted into a company's own language as a company's own production system (or lean house, or any other form of formalisation of lean thinking principles made especially for the company) and this is possible if the company has a good starting point (high process quality) together with effectively performed steps of the lean thinking implementation process. Also, the study indicated that despite the fact that some companies have good results in both the lean thinking implementation process and DOA, they have not implemented some of the lean thinking principles.

Result 1 – DOA dependence on process

This is the main result of the performed research and is the constructed model of lean thinking implementation: companies with higher scores for starting point and process steps will also have higher scores for the degree of adoption of lean. DOA very much depends on how high the scores of starting point and process steps are.

This result gives an answer to the RQ1: the constructed model of lean thinking implementation could be regarded as a standard framework for the manufacturing companies that wish to implement lean. The companies that have a good starting point (process quality) and have performed all the steps within the model, or in other words have been following the standard framework, have better results that those who have not.

Result 2 – DOA dependence on lean house

Quite the same picture compared to the first result is seen by comparing the lean house and DOA scores. Of that result, we determine the answer to the second research questions (RQ2) – the main critical success factor of all the steps is the creation of lean house as a basis for the whole lean implementation process and consequent steps. In other words, in order to have successful lean implementation and not to fail with it, each company has to understand and interpret lean thinking principles into intra-company knowledge and to create a company's own production system in the form of a lean house. XPS – Company's X Production System (analogically to the TPS – Toyota Production System and SPS – Scania Production System) – is the description of the general rules and values based on which the company works and implements lean.

Result 3 – Some DOA criteria are not implemented at all

From the results table, we can see that some criteria of DOA assessment are not implemented at all in any company, such as the pull of raw material and integration of functions. This result is quite interesting and shows that there is more to do even in those companies where lean initiative is implemented well and the results of the overall process are good.

As we see from the assessment results, companies C4, C5 and C11 have achieved high scores of DOA due to the good performance of the lean implementation process steps. All those three companies had their lean initiative started from headquarters; they have a long term lean implementation plan resulting in the creation of their own vision of how lean should be implemented in the company. In other words, this vision of lean ideas implementation is the company's lean house. Exactly the same could also be said about the reference company that brings one more proof regarding the proposed hypothesis in the lean implementation process model. Other companies (with low DOA) scores do not have their vision regarding lean house in place, and are only implementing lean in terms of some tools and principles and do not have a long-term vision.

The main contributions of the current thesis to the theory are

1. The development of the model of lean implementation process;
2. Bringing out a company's own production system model in the form of lean house as a critical success factor of lean implementation process success;
3. The degree of adoption (DOA) analysing model was applied to assess the results of the lean implementation process of the studied companies;
4. The modification and application of the DOA model for the assessment of lean implementation process steps.

The existence of lean house is not possible without a good starting point and the subsequent steps together with the creation of the lean house itself. Such a step-by-step model approach to lean thinking implementation was not under looked in theory before and is therefore one of the important contributions to the current thesis. Additionally, current thesis discovered the importance of looking into lean thinking principles through the prism of company nature – companies are not similar and the same format of lean thinking principles might not suit all of them.

The practice is aided by a straight direction for companies who wish to or are implementing lean. Each company that is starting its lean road (or already going down that road) could take the model as instruction on what to do and how to do: guideline for assessing their current performance of lean implementation, understanding the process weak points and developing the next steps or the new loop of lean implementation – exactly as the model proposes. By this, the results of lean implementation in the companies could be higher and more successful.

The research undertaken gives companies a clear path and the way of thinking to achieve higher results in terms of efficiency and productivity. The author believes that the wide introduction of the proposed empirical model in manufacturing companies will enable the widespread grow of productivity among Estonian manufacturers. Newer field consultancy projects (started while finalising this thesis) show indications towards the same idea proposed and studied in this paper: if companies miss critical steps in lean implementation preparation, then with high probability they will miss the desired targets of lean implementation and the effect of their actions will be short term.

Additionally, many companies experience fear towards lean implementation – they are unsure whether the expenses of lean actions will give any tangible results and improve key performance indicators. The author admits that such a question arises in almost every lean project – how can we be sure that we will achieve the desired results. Again, the proposed empirical model offers more confidence regarding the achievement of results. The model proposes the critical steps company have to take in order to achieve success and to have continuous lean implementation, while the more detailed content of each step has to be decided by each company according to the situation. The model proposed the way of thinking and behaviour but does not propose the content of each step. Toyota has its own lean house, Scania – its own; some other company should have its own as well.

The positive aspect for Estonian manufacturing lies also in the fact that such research has been performed and the first results and ideas have been created. Now companies have at least some local material to rely on while thinking of or planning to introduce lean thinking ideas into their operations.

From a theory aspect, this thesis has begun to fill the gap of vague lean implementation framework. Lean philosophy as such and its tools have been widely examined, but a clear process description for successful lean implementation has been missing. The results of the current thesis contribute to the latter part of lean theory and create the basis for further development.

Kokkuvõte

Tootmisprotsesside täiustamise tähtsust oli hästi näha viimase finantskriisi ajal. Pärast kriisi alustas üha rohkem ettevõtteid maailmas ja Eestis kulusäästliku tootmise juurutamise protsessi. Kuigi kulusäästliku tootmise põhimõtted on tuntud ja neid on põhjalikult uuritud juba rohkem kui 30 aasta vältel, on jäänud uurida veel palju raskeid ja ebaselgeid vaatekohti; üks neist on, kuidas edukalt juurutada kulusäästlikku mõtlemist.

Kulusäästlikku mõtlemist defineeritakse kui raiskamise süstemaatilist kõrvaldamist (Santos jt, 2006). Kulusäästlikus mõtlemises peetakse raiskamise all silmas kõiki tegevusi, mis ei lisa lõpptootele või -teenusele väärtust, kusjuures väärtust vaadeldakse kliendi seisukohalt. Raiskamine on kõik tegevused, mis ei lisa väärtust toote tootmisprotsessis. Kulusäästliku mõtlemise kontseptsioon toob välja raiskamise seitse põhilist liiki (Womack jt, 1990; Liker, 2004; Santos jt, 2006, Voss, 2007): ületootmine – tellitust suurema koguse tootmine, tootmine lattu ja mittevajalike esemete tootmine; laovaru – kõik materjalid ja komponendid, lõpetamata toodang (*work-in-process*, WIP) ning kogu valmistoodang, mis seisab laos; transport – igasugune materjalide, komponentide, lõpetamata ja valmistoodangu liigutamine; üleliigne töö – igasugused tegevused, mis ei ole protsessis vajalikud (neid on võimalik töömeetodist kõrvaldada) eesmärgi saavutamiseks; ootamine – töötlemist ootavad materjalid, komponendid ja lõpetamata toodang, töö algust ootavad töötajad ja masinad; üleliigne töötlemine – toote tegemine liiga heaks selle asemel, et teha piisavalt hea; defektid – defektse toodangu valmistamine, inspektsioon ja kvaliteedikontroll.

Maailma akadeemilises kirjanduses peetakse kulusäästlikuks mõtlemiseks kulude vähendamise ja tootlikkuse parendamise tehnikat (Achanga jt, 2004, 2005 a, b; 2006; Bicheno, 200, 2004; Womack jt, 1990; Womack ja Jones, 1996), kui tootmise uut efektiivset paradigmat (Katayama ja Bennett, 1996; Williams jt, 1992). Paljud ettevõtted kasutavad kulusäästliku mõtlemise põhimõtteid oma korporatiivstrateegiate arendamisel (Womack ja Jones, 1996) ja selle tulemusena seda võib kasutada võimsa relvana globaalselt võistlevas maailmas (Söderkist ja Motwani, 1999).

Kuigi kulusäästlik tootmine tundus väga hästi töötavat Toyota tehastes, ei suutnud teised ettevõtted saavutada samu tulemusi. Kulusäästlik tootmine arendati Toyotas, seega oli see nende jaoks loomulik. Teised organisatsioonid pidid leidma oma tee nende ideede edukaks elluviimiseks ja see osutus väga raskeks. Pärast seda uuriti kulusäästliku mõtlemise teemat laialdaselt ja vaadeldi kulusäästlike mõtete juurutamise erinevaid aspekte, ent ka praegu ei eksisteeri standardset raamistikku või teejuhti selle edukaks elluviimiseks (Pepper ja Spedding, 2010; Repenning ja Sterman, 2001; Hogg 1993). Vaatamata sellele, et kulusäästlike põhimõtete juurutamise protsess on veel ebaselge, peetakse seda kontsepti protsesside, tõhususe, tootlikkuse ja kvaliteedi parendamise meetodiks (Voss jt, 1995).

Kirjanduses identifitseeritakse järgmisi probleeme, mis on seotud kulusäästliku mõtlemise juurutamise protsessiga tootmisettevõtetes ja selle protsessi tulemustega:

- umbes 10 protsenti või vähem ettevõtetest juurutab kulusäästliku tootmise tavasid edukalt (Bhasin ja Burcher, 2006);
- ainult 10 protsenti on korralikult uurinud filosoofiat (Sohal ja Eggleston, 1994, p. 8);
- uusi paradigmasid ja parimaid teostusi võetakse sageli vastu kui „musta karpi“, kus on peidus palju ohtusid (Voss, 2007);
- kui ettevõtted kasutavad kulusäästlikke põhimõtteid peaaegu kui moenarrust, ei anna enamus nende pingutustest märkimisväärset tulemust (Repenning ja Sterman, 2001);
- on teada, et „pole olemas standardset raamistikku kulusäästlikuks tootmiseks või selle juurutamiseks. Peab rakendama süstemaatilist lähenemist, mis optimeerib süsteemi tervikuna, kasutades õigeid strateegiaid õigetes kohtades.“ (Pepper ja Spedding, 2010, p. 138).

Lähtudes ülalmainitust, võib kulusäästliku mõtlemise juurutamise põhilist probleemi formuleerida järgmiselt: standardset raamistikku edukaks kulusäästliku mõtlemise juurutamiseks on uuritud ebapiisavalt, mistõttu tootmisettevõtted kas ei alusta kulusäästlikke algatusi või ei suuda neid edukalt juurutada. Ettevõtted vajavad kulusäästlike mõtete juurutamise standardset protsessi ja ülevaadet olulistest sammudest, mida on vaja ette võtta selleks, et jõuda nõutud eesmärkideni.

Ettevõtted ei tea, kust alustada juurutamisprotsessi, millised sammud on olulised edu saavutamiseks ja kuidas kogu protsessi organiseerida. Vaatamata suurele uurimistööde ja dissertatsioonide hulgale kulusäästlikkuse teemal on kulusäästliku mõtlemise juurutamise protsessi oluliste edutegurite aspekti uuritud vähe ja ettevõtetel on puudu selged, samm-sammulised juhendid kulusäästliku mõtlemise edukaks elluviimiseks. On ilmunud palju uuringuid (Teresko, 2002; Bhasin, 2011; Olexa 2002 a, b; Bateman, 2002; Moore, 2001; Voss, 2007; Liker, 2004), kus püütakse ikka ja jälle mõtiskleda selle üle, mis on kulusäästlik mõtlemine; on uuringuid, mis tõstavad esile kulusäästlikke tööriistu, millele pöörata juurutamise käigus tähelepanu, ja räägivad, kuidas neid tööriistu rakendada; kuid ikka on puudu kulusäästliku mõtlemise juurutamise protsessi samm-sammuline kirjeldus. Lisaks sellele räägib mitu autorit sellest, et ainult väike osa tootmisettevõtetest saavutab edu kulusäästliku mõtlemise juurutamises (Bhasin ja Burcher, 2006; Sohal ja Eggleston, 1994). Teised teadurid (Achanga jt, 2006; Oprime jt, 2011) pööravad tähelepanu sellele, et on olemas olulised tegurid, mis mõjutavad kulusäästliku mõtlemise juurutamise protsessi – faktorid, mis võiksid kindlustada stabiilse ja pideva kulusäästliku mõtlemise juurutamise tootmisettevõtetes ja garanteerida kindla ja kiire tootlikkuse kasvu.

Selle probleemi potentsiaalne lahendus on kulusäästliku mõtlemise juurutamise standardsete protsesside mudeli olemasolu, kus ettevõtted võivad näha samm-sammulisi instruktsioone kulusäästliku mõtlemise põhimõtete juurutamiseks. See mudel tooks esile ka kulusäästliku algatuse edutegurid. Olulised edutegurid on protsessi kindlad etapid, mis määravad kulusäästliku mõtlemise juurutamise üldise edu. Oluliste edutegurite ebaõnnestunud rakendamine toob kaasa kogu protsessi ebaõnnestumise.

Lõpuks näidati, et on tuvastatud kaks põhilist probleemi. Esimene tuleb välja akadeemilisest kirjandusest ja seda iseloomustatakse kui kulusäästliku mõtlemise juurutamise protsessi selgelt määratletud samm-sammulise kirjelduse ja selle protsessi kriitiliste edutegurite määratlemise puudumist. Nende tegurite olemasolu kindlustaks, et protsessile kulutatud raha ja aeg ei ole asjata raisatud ning et on saavutatud nõutud eesmärgid. Teine probleem tuleneb praegusest olukorrast Eesti tootmisettevõtetes. Statistika näitab, et on olemas potentsiaalsed võimalused Eesti tootjate suuremaks tootlikkuseks ja tõhususeks. Pealegi, ettevõtted püüavad neid saavutada, juurutades kulusäästliku mõtlemise printsiipe, kuid tulemused on tühised, kuna kulusäästliku mõtlemise juurutamise protsess on ebaselge.

Autor teeb ettepaneku, et nende kahe tuvastatud probleemi lahendamiseks on vaja edukalt ja pidevalt juurutada kulusäästlikke ideid ja põhimõtteid Eesti tootmisettevõtetes. Kulusäästliku mõtlemise juurutamise protsess on efektiivne, kui on olemas selge samm-sammuline teekond ja on määratletud olulised edutegurid.

Selle uurimistöö põhiline eesmärk on välja arendada kulusäästliku mõtlemise juurutamise protsessi mudel, mida saab kasutada tootmisettevõtetes selleks, et kindlustada kulusäästliku mõtlemise juurutamise nõutud tulemusi.

Väljapakutud kulusäästliku mõtlemise juurutamise protsessi mudel sisaldab alguspunkti – protsesside head kvaliteeti – ja viit sammu: kulusäästlikust mõtlemisest teadmiste omandamine, kulusäästliku maja loomine, informatsiooni edastamine kulusäästliku maja kohta ja koolitamine, kulusäästliku mõtlemise juurutamise planeerimine ja kulusäästliku mõtlemise juurutamise plaani elluviimine.

Lähtudes eelmisest probleemide ja eesmärkide arutelust, leitakse selles töös vastused järgmistele küsimustele.

1. Kuidas ettevõtted peavad teostama kulusäästliku mõtlemise juurutamise protsessi (RQ1)?
2. Miks ettevõtetel ei õnnestu kulusäästliku mõtlemise juurutamine (RQ2)?

Nendele küsimustele vastamiseks kasutatakse järgmist metodoloogiat. Esiteks on põhjalikult uuritud kulusäästliku mõtlemise teoreetilist aspekti käsitletavat kirjandust ja on välja arendatud eduka kulusäästliku mõtlemise juurutamise protsess. Viimane määratles ka kulusäästliku mõtlemise juurutamise võimalikke olulisi edutegureid. Teine etapp on ettevõtete valik, mis tugineb mitmele juhtumi uurimise meetodile. See uuring hõlmab kahtteist ettevõtet, mis erinevad tegevusala ja suuruse poolest. Lisaks sellele on andmete kogumine ja ettevõtete analüüs teostatud sisuanalüüsi meetodit kasutades.

Hindamise põhilised tulemused on järgmised:

- DOA (kulusäästliku algatuse edukus) sõltub sellest, kui hästi olid teostatud kulusäästliku mõtlemise juurutamise protsessi sammud – 1. tulemus (R1);
- DOA sõltub kulusäästliku maja (või oma tootmissüsteemi) olemasolust – 2. tulemus (R2);
- mõnda DOA kriteeriumit ei ole juurutatud üheski ettevõttes – 3. tulemus (R3).

Need tulemused kujutavad endast uurimistöö põhilist resultaati ja tõestavad autori ettepanekut, tutvustades samal ajal kulusäästliku mõtlemise juurutamise protsessi empiirilist mudelit. Üldiselt näitavad tulemused, et arusaam kulusäästlikust mõtlemisest peab olema juurutatud ettevõtte enda keelde kui ettevõtte tootmissüsteem (või kulusäästlik maja või mõne teise kulusäästliku mõtlemise põhimõtte sobitamine spetsiaalselt ettevõtte jaoks) ja see on võimalik siis, kui ettevõttel on hea alguspunkt (protsesside hea kvaliteet) ja kulusäästliku mõtlemise juurutamise protsessi sammud on teostatud efektiivselt. Samuti näitas uuring, et kuigi mõni ettevõtte saavutas häid tulemusi nii kulusäästliku mõtlemise juurutamise protsessis kui DOAs, jäi neil rakendamata mõni kulusäästliku mõtlemise põhimõte.

1. tulemus – DOA sõltuvus protsessist

See on teostatud uurimistöö peamine tulemus ja kulusäästliku mõtlemise juurutamise väljaarendatud mudel: ettevõtted, kes saavad rohkem punkte alguse ja protsessi sammude eest, saavad ka rohkem punkte kulusäästliku mõtlemise omaksvõtmise eest. DOA sõltub oluliselt sellest, kui palju punkte saadakse alguse ja protsessi sammude eest.

See tulemus annab ka vastuse küsimusele RQ1: väljaarendatud kulusäästliku mõtlemise juurutamise mudelit saab käsitleda kui standardset raamistikku nendele tootmisettevõtetele, kes tahavad juurutada kulusäästlikku mõtlemist. Ettevõtted, kellel on hea alguspunkt (protsesside kvaliteet) ja kes teostavad kõik mudeliga määratletud sammud, teisisõnu kes järgisid standardset raamistikku, saavutavad paremaid tulemusi kui need, kes seda ei teinud.

2. tulemus – DOA sõltuvus kulusäästlikust majast

Esimese tulemusega sarnast pilti näeb, kui võrrelda kulusäästliku maja ja DOA punktide arvu. See tulemus annab vastuse teisele uurimisküsimusele (RQ2) – kõigi sammude peamine oluline edutegur on kulusäästliku maja loomine kui alus kogu kulusäästliku mõtlemise juurutamise protsessile ja järgnevatele sammudele. Teisisõnu, selleks et kulusäästliku mõtlemise juurutamine läheks edukalt, peab iga ettevõte saama aru kulusäästliku mõtlemise põhimõtetest ja viima need ettevõtte teadvusse ning looma oma tootmissüsteemi kulusäästliku maja põhimõttel. XPS – ettevõtte X tootmissüsteem (analoogne TPS-iga – Toyota tootmissüsteem – ja SPS-iga – Scania tootmissüsteem) on ettevõtte põhiliste normide ja väärtuste kirjeldus, mille alusel ettevõte töötab ja juurutab kulusäästlikku mõtlemist.

3. tulemus – mõni DOA kriteerium jääb juurutamata

Tulemuste tabelist on näha, et kõikides ettevõtetes jääb juurutamata mõni DOA hindamiskriteerium, näiteks toormaterjali tõmme ja funktsioonide integratsioon. See tulemus on päris huvitav ja näitab, et tegemist on ka nende ettevõtetega, kus on juurutatud kulusäästlik initsiatiiv ja üldise protsessi tulemused on head.

Nagu hindamistulemustest näha, saavutasid ettevõtted C4, C5 ja C11 suure DOA-punktide hulga tänu kulusäästliku mõtlemise juurutamise protsessi sammude heale täitmisele. Kõigis mainitud ettevõtetes algatati kulusäästlik initsiatiiv peakontori poolt; neil on pikaajaline kulusäästliku mõtlemise juurutamise plaan, mille tulemusena on loodud oma visioon, kuidas kulusäästlikku mõtlemist nende ettevõttes juurutada. Teisisõnu, see kulusäästlike ideede juurutamise visioon ongi ettevõtte kulusäästlik maja. Sama võib öelda ka võrdlusettevõtte kohta, mis jälle tõestab kulusäästliku mõtlemise juurutamise protsessi mudelis väljapakutud hüpoteesi. Teistel ettevõtetel (väikese DOA-punktide hulgaga) ei ole oma visiooni kulusäästlikust majast ja nad juurutavad kulusäästlikku mõtlemist ainult mõne tööriista ja printsiibi kaupa ega oma pikaajalist visiooni.

Selle uurimistöö põhiline panus teooriasse on järgmine.

1. Kulusäästliku mõtlemise juurutamise protsessi mudeli arendamine.
2. Ettevõtte enda tootmissüsteemi mudeli väljatoomine kulusäästliku mõtlemise juurutamise protsessi olulise edutegurina juhul, kui see on loodud kulusäästliku maja vormis.
3. Uuritud ettevõtete kulusäästliku mõtlemise juurutamise protsessi tulemuste hindamisel kasutati omaksvõtmise taseme (DOA) analüüsi mudelit.
4. DOA mudeli modifitseerimine ja rakendamine kulusäästliku mõtlemise juurutamise protsessi sammude hindamiseks.

Kulusäästliku maja eksisteerimine pole võimalik ilma hea alguspunkti ja järgnevate sammudeta koos kulusäästliku maja loomisega. Sellist samm-sammult lähenemist kulusäästliku mõtlemise juurutamisele ei ole varem teoorias uuritud ning seetõttu on see üks töö peamine panus. Lisaks sellele avastati selles uurimistöös, kui tähtis on vaadelda kulusäästliku mõtlemise põhimõtteid läbi ettevõtte olemuse prisma – ettevõtted ei ole sarnased ja kulusäästliku mõtlemise printsiipide sama formaat ei pruugi kõigile sobida.

Töö praktiline panus on kindla suuna andmine ettevõtetele, kes tahavad juurutada või juba juurutavad kulusäästlikku mõtlemist. Iga ettevõte, kes alles alustab oma kulusäästlikku teed (või juba liigub mööda seda teed), saab kasutada mudelit kui juhendit, mida ja kuidas teha; juhendit oma praeguse kulusäästliku mõtlemise juurutamise efektiivsuse hindamiseks, protsessi nõrkadest külgedest arusaamiseks ja järgmiste sammude või uue kulusäästliku mõtlemise juurutamise silmuse arendamiseks – just nagu mudel pakub. Selle tulemusena võivad ettevõtete kulusäästliku mõtlemise juurutamise tulemused olla paremad ja edukad.

Läbiviidud uurimistöö pakub ettevõtetele selget teed ja mõtteviisi efektiivsuse ja tootlikkuse paremate tulemuste saavutamiseks. Autor usub, et pakutud empiirilise mudeli kasutamine tootmisettevõtetes võimaldab Eesti tootjate tootlikkuse kasvu. Uuemad nõustamisprojektid (algatatud selle töö lõpliku vormistamise ajal) toetavad selles töös väljapakutud ja uuritud ideed: kui ettevõtted jätavad vahele olulisi samme kulusäästliku mõtlemise juurutamise ettevalmistamises, siis suure tõenäosusega ei jõua nad püstitatud eesmärkideni ja tegevuste toime on lühiajaline.

Lisaks sellele on mõnel ettevõttel hirm kulusäästliku mõtlemise juurutamise ees – nad ei ole kindlad, kas kulusäästlikule mõtlemisele kulutatud raha annab konkreetseid tulemusi ja parandab võtmemõõdikuid (KPI). Autor tunnistab, et see küsimus ilmub peaaegu igas kulusäästlikus projektis – kuidas saame olla kindlad, et saavutame nõutud tulemusi. Jälle võimaldab pakutud empiiriline mudel suuremat kindlust tulemuste saavutamise osas. Mudel kirjeldab olulisi samme, mida ettevõte peab astuma selleks, et saavutada edu ja kindlustada pidev kulusäästliku mõtlemise juurutamine; samal ajal peab iga ettevõte otsustama iga sammu detailse sisu vastavalt olukorrale. Mudel pakub mõtte- ja käitumisviisi, kuid ei paku iga sammu sisu. Toyotal on oma kulusäästlik maja, Scanial oma; teisel ettevõttel peab samuti olema oma maja.

Eesti tootmise jaoks on positiivne aspekt ka see, et selline uurimistöö tehti ning käsitleti esimesi tulemusi ja ideesid. Nüüd on ettevõtetel vähemalt mingi kohalik materjal, millele tugineda, mõeldes või planeerides kulusäästlike ideede juurutamist oma tootmises.

Teooria seisukohalt alustas see uurimistöö tühiku täitmist, mis esines kulusäästliku mõtlemise juurutamise raamistiku osas. Kulusäästlikku filosoofiat ja selle tööriistu on põhjalikult uuritud, kuid puudu oli kulusäästliku mõtlemise eduka juurutamise protsessi selge kirjeldus. Selle töö tulemused annavad oma panuse kulusäästliku mõtlemise teooria viimasesse ossa ja loovad aluse edasiseks arendamiseks.

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