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Utilization of lean construction principles and techniques in the Czech Republic

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In Prague, 07 January 2018 Jan Potužák

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Abstract

Title: Utilization of lean construction principles and techniques in the Czech Republic

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This master's thesis focuses on the innovative approach "Lean" and its utilization in the construction industry. First of all, the thesis introduces the current situation of the construction industry in both the Czech Republic and abroad. Further, the thesis introduces principles, techniques, and tools of the Lean Manufacturing. This part is used as the ground for the description of Lean Construction which is direct application of "Lean" principles to the construction industry. Furthermore, the results of questionnaire survey performed among the Czech construction companies, were analyzed. The level of Lean Conformance in the Czech Republic was found and discussed.

Keywords: Lean, Manufacturing, Questionnaire survey, Construction industry, Lean Conformance

Table of contents

Introduction 9

The thesis aims: 10

Research question No. 1 10

Research question No. 2 10

1 Current situation 11

1.1 Level of collaboration 13

1.1.1 Problems with the traditional procurement model 13

1.1.2 Benefits of collaboration 14

1.1.3 Subcontractors 14

1.1.4 Efficient collaboration 15

1.2 Problems reflecting a need for change 16

1.2.1 Tendering problems 17

1.2.2 Procurement problems 18

1.2.3 Design problems 19

1.2.4 Productivity problems 19

1.2.5 Material problems 19

1.3 Challenges 19

1.4 Construction industry in the Czech Republic 21

2 Lean Manufacturing 24

2.1 Origin of LM 24

2.2 What is Lean? 25

2.3 Toyota Production System 27

2.3.1 Heijunka 28

2.3.2 Just-in-time 30

2.3.3 Standardized Work 34

2.3.4 Kaizen 34

2.3.5 Jidoka 35

2.4 Summary of Lean Manufacturing 38

3 Lean Construction 41

3.1 What is Lean Construction? 42

3.2 Oddity of the construction industry 43

3.3 Lean Construction principles 44

3.4 Tools and techniques 47

3.4.1 Last Planner® System......48
3.4.2 Material Kanban Cards......52
3.4.3 Increased Visualization......52
3.4.4 Daily Huddle Meetings......53
3.4.5 First Run Studies......53
3.4.6 Fail Safe for Quality and Safe......53
3.5 Lean versus Traditional......54
3.6 Importance of measuring lean conformance......54
4 Measuring Lean Conformance......56
4.1 Methodology......56
4.2 Results‘ assessment......58
4.2.1 Respodents‘ attributes......58
4.2.2 Companies‘ ascpects......61
4.2.3 Analysis of single questions......63
4.2.4 Analysis of main principles......65
4.2.5 Overall Lean Conformance analysis of data sample......67
4.3 Discussion of questionnaire survey......70
Conclusion......73
List of figures......76
References......78
Addendums......82

Introduction

This diploma thesis deals with the quickly spreading trend which is the Lean Management and its utilization in the Czech construction industry. While other industries (especially the manufacturing one) have experienced substantial technical and operational booms over the past two centuries, the construction industry is still being criticized for its sluggish growth and stagnation. Despite the critics, the construction industry still remains stuck in using of wasteful practices, paralyzed by disputes, litigations and overwhelmed by infinite changes of acts. Nevertheless, some efforts begin to emerge after all and many researchers in cooperation with construction firms start to look for some suitable framework for the construction industry because the economic and the industrial influences of this industry are indisputably significant.

One of the most success approaches past few decades is so-called “lean” thinking. This “ideology” which was developed by car manufacturing industry became a revolutionary practice with its extensive attempts to be applied not only in manufacturing, but also in every other industry such as services, retail, healthcare, construction, and even government. The promising ideas of maximizing value while minimizing waste, turned many construction practitioners to developing researches and case studies about implementing this approach to the construction industry. Some countries took the chance and try to be on the top of the Lean applicators, some still strive to push the ideas into the industry and the companies taking part of the industry.

The thesis starts with the analysing of the current situation in the construction industry as the whole. Discussing the level of collaboration which is crucial for the application of “lean” ideas. Further, it deals with the main problems and discussing the major opportunities which could lead to the overall growth of the industry, and suiting of the industry for application of new innovative approaches. At the end of the first chapter, the essential description of the general situation of the Czech construction industry is performed.

The second chapter is related to the Lean Manufacturing which is the foundation for the further advancement. The beginning reveals the origin of this thinking which caused the revolution in manufacturing and the elementary principles developed by the car makers in the America and Japan. The second chapter ends by explaining the basic tools and techniques used in the manufacturing industry.

Chapter 3 focuses on the Lean Construction, which is the term developed to separate classical Lean Manufacturing and its application to the construction industry. This chapter, at first, discusses the differences between the construction and manufacturing industries. The other part of the chapter is focused on the tools and techniques coming from the manufacturing, but transformed for the construction. By the end of this chapter, the importance of measuring lean conformance is explained in general.

In the last chapter all theoretical principles are applied in form of the questionnaire survey and its assessment. The survey was performed amongst the construction companies in the Czech Republic. Respondents were asked to answer the questions related to the main principles of the Lean Construction and collected data are further used as the basis for the final discussion.

The thesis aims:

- To provide information about lean thinking principles and techniques and its utilization in construction projects
- To determine interest of Czech construction companies in usage of lean principles
- To help the contractors understand their internal practices better from the lean construction perspective

Research question No. 1

How does the implementation of lean construction principles and techniques affect project performance?

Research question No. 2

Are Czech construction companies using the advantages of lean construction principles?

1 Current situation

As the name of the thesis indicates, this work presents an innovative direction called Lean Management and its utilization in the construction industry. But the question arises, why there is an effort to change the long lasting, traditional construction practice? In this chapter, I am going to reveal why the construction industry falls behind the other sectors and what are the criteria for success and development in such a various, comprehensive and beautiful industry, such as the construction one.

The construction industry is concerned with plenty of definitions describing what is arguably the development of a product such as a new building or the refurbishment of an existing one (Ferry & Brandon, 1999). Nowadays, construction process is strictly determined by boarders using technological improvements, however without any deeper philosophy. Although manufacturing industry has change the whole thinking approach during the past several decades, the construction industry still lacks developing enthusiasm.

„*The construction industry as a whole is dominated by small and medium-sized enterprises (SMEs), with small and micro businesses accounting for approximately 95 percent of the sector. Large construction companies are typically major contractors on largescale building and infrastructure projects, with many smaller companies working in a subcontracting capacity. Larger companies, although constituting a very small proportion of the number of enterprises operating in the sector, conduct a disproportionate share of the work by "value"* (UK commision for employment and skills, 2013). As the construction is an environment burduned by many disputes about cost and responsibilities, it causes a frequent problem of bringing an added value into projects. The construction business is a tough game where the stronger one wins and the weaker one loses.

Typically, a traditional construction practice can be described as a process where the customer sets requirements for the final product and passes it to the architect/designer (hereinafter A/D). To develop a final design including all the drawings, technical specifications etc., many kinds of engineers are working together, trying to meet the customer's requirements. The following stages of the project execution are showed hereunder. This Plan of Work was originally published by. The Royal Institute of British Architects in

1964 as a standard method of operation for project execution and has become widely accepted as an operational model throughout the building industry. The Plan of Work provides a procedure suitable for traditional procurement methods. Throughout many years, the Plan of Work has been transformed into the contemporary form, which is defined in figure 1.

Figure 1 – RIBA Plan of Work (source: ribaplanofwork.com, 2013, self adaptation)

As the Figure 1 shows, 5 of 8 stages are related to the pre-construction phase, thus the pre-construction is seen as considerably important. The planning in construction projects is crucial, because further steps are done in accordance with the plan. These 5 stages also cover the risk management, implemented techniques and procedures. Although the frequent communication between customer and A/D is essential in pre-construction phase, the contractor joins the game when the whole project has been taken down in the papers. This traditional practice, as I like to call this approach, lacks added value from the contractor. The added value regarding contractor‘s ideas and choice of technology causes that the contractor is no longer beneficial to the project’s intention. The current innovative approaches point to the pre-construction phase the most and they are based on a high level of collaboration amongst all parties involved in the project from the very beginning.

1.1 Level of collaboration

The term collaboration comes from the Latin words for “work” and “with” and refers to shared effort or interests as well as work or activity by a group of people who individually contribute to the efficiency of the whole project. Ironically, collaboration can also mean “traitorous cooperation with an enemy” (especially during a time of war), and that definition more often reflects the competing situation on traditional construction job sites (Aziz & Hafez, 2013).

1.1.1 Problems with the traditional procurement model

Traditionally, construction projects are built in a competing environment. Each member of the construction team is forced to compete with the others to earn a reasonable profit; delays, conflicts and disputes are common. Progress is made difficult by poor coordination between trades, incomplete drawings and specifications, and underfunding by the owner that slows cash flow and causes further conflict and delay. Subcontractors are rarely treated as equal partners in the process, and sneaky contract clauses abuse trust between team members. The project owner expects a team that works together to produce a good-quality product, builds according to plans and specifications, and delivers the product in time and for the in price within the budget. The project team comprises of a group of strangers with competing interests who may never work together again. It is like trying to win the Stanley Cup with a team that has never played together. Project designers and builders work together for owner‘s satisfaction, but that aim can easily fall apart as relationships are getting worse during works execution (Baiden, et al., 2006).

Another issue is fragmentation of the sector. It occurs when the number of small and medium-sized firms increases, and the number of large firms decreases. This fragmentation can lead to an unclear role of learning in construction, because organization reduces mutual knowledge of capturing and sharing, inhibits knowledge production, limits learning and innovative solutions. It occurs due to the industry’s unique characteristics and due to other reasons, such as client dependency, location dependency and weather influenced activities. As a critical barrier to change, fragmentation can inhibit knowledge information production that lead to a low level of productivity. The impact generally includes (Alashwal, et al., 2011):

- Elimination of learning and innovation solutions
- Slowing down the useful experience and know-how to be used sufficiently during the planning process
- Lowering the intention to invest in innovation and reduction of the mutual sharing of information and knowledge
- Inhibiting knowledge production that lead to low level of productivity
- Numerous contracts leading to unclear liability.

During the preparation and planning phase, it is important to create a bespoke construction-process which reduces time and costs and increases quality.

1.1.2 Benefits of collaboration

The success of a collaborative model of a project depends on communication and performance. Good communication can improve plan, specify imperfections and reduce delays. In theory, an improved communication also leads to innovations and technical solutions that improve quality. Cooperation and coordination of activities through interpersonal and group communication support a better decision-making and prevent final product defects, ensuring that the owner is satisfied. The benefits of collaboration include reduced project costs for the owner, higher profits for contractors, earlier completion, and fewer contract disputes. The stress on relationships rather than transactions can establish support for continuous improvement and long-term relationships that extend to future projects (Vondruška, 2016).

1.1.3 Subcontractors

Construction work has become so specialized that even a small subcontractor can make innovative contributions to a project using its particular expertise. When all team members have share of the outcome and are included in decision-making, the resulting synergy can produce higher quality of the products more efficiently. Commitment to a common vision supports creative solutions to problems that arise during construction (Johnston, 2016).

However, published research on collaboration has revealed several obstacles that must be overcome for its full potential to be realized. General contractors are not always interested in developing cooperative relationships with subcontractors, especially those who prefer to shift risk and delay payment to maximize their own profits. They often doubt the managerial competence of their subcontractors and interfere with their site operations, creating avoidable conflicts. Subcontractors are dismissed as a job cost instead of a resource. Subcontractors mirror that lack of trust and do not agree with the system that delay payments and with the approach of authority in ways that undermine their performance. They also complain that their expertise is not used when problems arise on projects and then they are forced to accept decisions they consider wasteful and ineffective (Johnston, 2016).

1.1.4 Efficient collaboration

Collaboration is still a relatively new approach to project delivery and its value is still being discussed. Architects, engineers, general contractors, subcontractors and suppliers all bring their own goals and ideas to the team, and self-interest dominates the construction process.

„Coming together is a beginning. Keeping together is a progress. Working together is a success.“

→ HENRY MARTIN FORD

When carmaker Henry Ford said these words, he could have been foreseeing the intended outcome of collaborating on construction projects.

If the company's project execution philosophy follows a traditional model, characterized by punishable contract terms, slow payments, logistical obstacles on the site and distrust of customers and other sub-contractors, they might need to update their values and culture. Although there can be a good learning system, it would not be out of question to incorporate employee training at levels on how to communicate, build trust and solve problems in a collaborative environment. On the other hand, companies, that have already been successful with negotiating optimal contract terms, collecting receivables quickly and maintaining good relationships, can be instrumental in pushing this approach through the whole industry by helping the others to realize the benefits of using collaboration on the projects for the good of all participants.

1.2 Problems reflecting a need for change

Construction management and technology are two key factors influencing the development of the construction industry. While most of industries have carried out tremendous changes over the past few decades and have enjoyed the benefits of process, product and service innovations, the construction sector has been hesitant to fully embrace the latest innovation opportunities and its productivity has stagnated or even decreased over the last 50 years, although several new and advanced technologies have been applied to construction projects. For example, the productivity of the USA construction industry has been declining since 1964 (UK Commission for Employment and Skills, 2013).

Competition over the world is increasing rapidly. In 2007 construction contracts won by Chinese companies increased in the United States and Europe by 160% and so domestic companies are being challenged on its home field. Construction sales are moving east to China, India, the Middle East, and Africa (CRIMEA) and only the most competitive players can benefit from this trend. Simply said, new approaches are recalled to heal the construction's industry illnesses. Several obstacles to the USA competitiveness have been revealed (World Economic Forum, 2017):

- Declining productivity
- A pursuit of minimum cost
- Prescriptive standards and codes that decrease productivity

UK commission for employment and skills has described poor construction performance in a different way. They have recognized, that a construction is not always able to manage commercialization of the technologies and innovations developed by researchers in an effective way. In the Construction Industrial Strategy, there is apparently a 'low level of innovation' and it notes that "investment in intangible assets such as new processes (particularly in the contracting sub-sector) is low due to uncertain demand for new goods and limited collaboration" (UK commision for employment and skills, 2013). According to UK Commission for Employment and Skills (2013), there are 2 main general obstacles in construction industry:

- Skills:

In construction there is a significant low training among the self-employed and skills shortages among trade and professional occupations which can inhibit in technology deployment and low innovation.

- High degree of fragmentation:
  It is very common in construction that too much competitiveness leads to huge fragmentation. Other sectors grow on levels of collaboration, innovation and ability to access foreign markets.

The main reason for the above-mentioned problems seems to be that the new technologies cannot effectively reduce the costs of design and construction while, at the same time, improving the management of the construction process. For example, the Computer Aided Design (CAD) technology has improved the efficiency of drawing but it cannot reduce design errors and these can cause the need for rework. Such reworks can increase the level of difficulty for construction engineers, especially to optimize construction process to reduce costs. Design/Build (D/B) is a perfect example of the most common project delivery system, where the aim is to reduce costs and to increase quality by an improved constructability of the building design. However, the new technologies still appear to struggle with providing an effective support for implementation of D/B projects. Therefore, the combination of both new technology and contemporary management approach seems to be an effective approach to improve construction industry efficiency (Aziz & Hafez, 2013).

1.2.1 Tendering problems

The ‘traditional‘ method of competitive tendering has many limitations and weaknesses including for example (Construction Task Force, 1998):

- It eliminates the mutual Exchange of technical knowledge and information.
- It tends to create an atmosphere of hard negotiating, which does not lead to the development of good relationships.
- It provides poor opportunities for integration of the construction team because it prevents the contractor from becoming involved at the design stage.

- Tender periods are often very short compared to the design or construction stages which put bidders under pressure to meet deadlines often resulting in errors in costing and high level of risk.
- The tendering process itself is expensive, with eighty percent or more of the companies' bidding being unsuccessful and which leads to having to cover these costs or pass them on the next client.

Despite the effort of governments, trying to set the rule that the lowest price should not determine the choice of contractor, the majority of work is still won on this basis, especially in the public sector (Construction Task Force, 1998).

1.2.2 Procurement problems

The procurement of construction largely follows the traditional approach. In this approach, the customer separately hires three key service providers for three key services of design, measurement and cost advice, and construction. The problems of traditional procurement can be summarised as follows:

- The need for fully developed design before tenders are prepared increases the overall project duration as well as project cost.
- The ability to organise and control the work of nominated subcontractors usually is less loyal to the contractor (or customer) than to the architect who nominated them.
- The separation of design and construction tends to foster a 'them and us' attitude between designers and contractors, thus reducing team spirit that is essential for project success.
- The traditional system has been proved to be insufficient for some large and complex projects, which require advanced management systems, structures and skills.
- The sequential nature of this system often results in lengthy design and construction periods, poor communication between customers and the project team (especially contractors), and bad problem-solving capability.

Contemporary construction practice creates alternative procurement strategies such as Design and Build and partnering, but it is just impossible to put together a universal guide for all the kinds of project – many of the alternatives have their particular ‘problems‘ (Proverbs, 2000).

1.2.3 Design problems

Over-specification has been a common problem for contractors for years, but the problems has become even more serious at the tomes of economic boom. The point of reducing specification level is about cutting out wastes and unnecessary cost. It has been suggested, that over-specification adds almost fifteen percent to the cost of construction work. Atkinson (1995) reported that many offices are designed to be occupied with sixty percent more staff than occupy the building eventually. Buildings have been also found to have an unnecessary number of lifts, toilets, and escape routes. A comparative study between UK and US building costs in 1993, found that lower specification, more prefabrication, and higher reliance on standard components could lead to significant savings in the construction costs (Atkinson, 1995).

1.2.4 Productivity problems

An average construction worker is productive only for 40 percent of the time, the rest of the time is spent by moving from one task to another or waiting for materials and/or instructions. Productivity can be impaired by numerous factors including: poor management and supervision, disruptions to work, unfavourable weather conditions, low and discontinuous demand, frequent changes in specification, inefficient construction methods, and over-manning. As time passed by, the fragmented culture of the industry caused that parties involved have become less trusting, mores self-interested and bad-tempered (Construction Task Force, 1998).

1.2.5 Material problems

Materials represent a significant part of the cost of construction. It was reported that at least ten percent of all raw materials delivered are wasted through loss, damage and over-ordering (CIRIA, 1999).

1.3 Challenges

The Above-mentioned problems are describing certain parts, crucial for companies‘ success. The construction industry is nowadays at the crossroads and companies not taking underlying challenges into consideration could become struggling for viability. On the other hand, companies that address these challenges head-on and try to innovate its business processes, will be prepared for growth. The challenges below represent summarization of the main problems in the construction industry (Constructingexcellence.org.uk, 2013):

1. **Productivity and profitability**

Currently, the growth and modernization of the construction industry is decelerated by heavy competition. This competition is shrinking profit margins and constraining essential reinvestment in new technology and better business practices. Stagnated construction labor productivity makes this problem even more complicated. The lack of productivity is reflected by the bottom line, where typical margins for construction companies are between two and eight percent. Therefore, construction companies are found to be trapped between shrinking profit margins and stagnant productivity, incapable to generate reasonable profits necessary for innovation of critical technology (Soares, 2013).

2. **Project performance**

The opportunities in construction industry are growing, but so is project complexity. Companies handling very thin profit margins can be literally crushed by a single production surprise. Design complexity makes the problem more complicated. As design requirements become larger, it requires greater efficiency, thus contraction companies struggle to survive. The number of projects finished on-time and/or on-budget nowadays is just desperate. In 2012, it was found that only 30 percent of large projects in the energy industry are delivered on-budget and only 15 percent of projects are completed on-time (Accenture, 2012).

3. **Lack of skilled labor**

Prior to the recent recession, the US construction market consisted of two generations: the traditionalists and baby boomers. Nowadays, the workforce is split into four generations: Traditionalists, Baby Boomers, Generation X and Millennials. This labor fragmentation is about to be a huge challenge because each generation has its own work ethic, attitude and collaboration spirit (Pwc.com, 2011). Traditionalists are almost gone, and Baby Boomers are quickly following. The recession caused that many skilled craftsmen have left the industry and never returned. In 2020, Millennials are expected to represent half of the global labor workforce – many without reasonable experiences or interest in the industry. Finally, combination of complexity and lack of skilled labor increases the risk of delays, construction problems and employee safety concerns (Constructionbusinessowner.com, 2015).

4. **Sustainability**

Climate change and water management are two environmental issues that pose a growing challenge to the construction industry. Achieving targets for global carbon dioxide emissions reduction will be a major challenge for the construction energy. Smart planning and sustainable design could reduce energy consumption and pollution, but require a new approach to project management – an approach that the construction industry is not yet prepared to undertake (Constructingexcellence.org.uk, 2013).

The construction industry provides new opportunities in the name of digitalization. Challenges such as poor profitability and productivity, project performance, lack of skilled labor and sustainability can show us the new way of how digitalization and innovate thinking approach can increase productivity, “Eliminate waste” and avoid on-site surprises.

1.4 Construction industry in the Czech Republic

The construction production is considered one of the most important indicators of economic development. The greatest changes in the Czech Republic construction industry have occurred since 1948 up to the present.

In the years 1947 and 1948, when the former Czechoslovakia started to recover after World War II, the construction production increased four times. Significant industrial and engineering constructions were done, the whole cities were built. However, in 1961 the construction production became stagnant and since from 1963 onwards started to decrease. The contradictions in the investment plan and disproportionate number of new constructions and buildings resulted in increasing unfinished amount of work and extension of construction period.

In the middle of the 1960s, reformative efforts were introduced again. The 70s became so-called “normalization“ [1] period when changes in

[1] Name commonly given to the period since violent repression of the Prague Spring in 1968 by the Warsaw Pact armies up to 1989 when communist regime was replaced by democracy.

construction productivity reflected investment policy and its focus. Relatively large proportion recorded residential housings and industrial constructions. After that in the first half of the 1970s, a volume of the construction production was rapidly increasing. Construction firms had a lot of contracts on the highway and subway constructions, oil and gas pipelines.

The end of the 70s recorded significant deceleration of growth rate. It proceeded to the beginning of the 80s when the plan of residential housing production was not fulfilled. Consequently, government accepted motivational measures. The positive impact of measures came between 1983-1985, when losses were balanced and plans almost fulfilled. Those reformations of the central planning did not bring significant economic improvement. Lasting economic stagnation and low standard of living, falling behind modern world resulted in the fall of Communist regime in 1989.

The Czech economy experienced essential transformation in the 90s, and the building industry was the one that changed the most. Huge national organizations were divided into middle and small size companies, many of them were owned by international subjects. However, a lope number of the construction production greatly decreased consequently to the transformation. In 1991, recession caused a sixfold decrease in the number of construction of residential housings compared to 1990. The construction production increased in 1992 again especially due to the increased billing before implementation of the Value Added Tax. Though production was increasing, the construction production reached an imaginary bottom in 1993. The closer to the middle of the 1990s, the more stabilized the industry was getting. Construction companies, mainly in private holding, disposed of a wide range of building materials. More and more often, we could see engineering companies almost without any labor workers of their own. In 1995 the growth of the prices exceeded 8 percent, nevertheless, industry turned to the other direction again very soon. The period in 1997-1999 can be called as recession almost the crisis, which affected not only construction industry but the whole economy of the Czech Republic. The construction industry in those years was characterized by excess labor workers and bad financial situation. To sum up the 1990s, the construction industry was also characterized by great portion of a brand new construction.

After the year 2000, the crisis of the 90s was overcome and the dynamic of the growth of the Czech construction industry was successfully restored. There was an obvious effort to modernize industrial, commercial and administrative buildings, especially in the form of “intelligent buildings“. Thus, a number of construction works kept the fluent growth. Throughout the years

2000-2007 the construction production in the Czech Republic recorded an overall growth of 61 percent. This extraordinary growth was boosted by several influences:

- Influx of foreign investments
- Relatively fast economic growth
- Growth of public purchasing power
- Influx of cash from european funds

Besides the above-mentioned things, growing demands of functional and modern transport infrastructure provoked another impulses for growth.

The peak was reached in 2008, the number of the procurements was still growing, but the economic growth started to slow down. Decrease was recorded especially in building constructions, which reflected the deterioration of population's social situation. Developers stopped to build for speculative reasons, but started to take contracts only from real clients. The construction industry did not grow again until 2014. Despite the fact that the construction industry started to grow, public procurement decreased by 21 percent in 2016 compared to 2015.

The Forum of Czech Construction Industry 2017 took place in March 2017 where the key barriers of the growth were discussed. The experts agreed that the main problems slowing down the development of the construction industry are:

- Non-existing unified management system for public procurement
- Unpredictable public demand
- Excessively long process of projects‘ approval
- Lack of interest among young people to enter the industry
- Resistance of the firms to innovative changes

The above-mentioned reasons indicate that the Czech construction industry has to make a big step to reach the level of European highly developed countries. The industry is not trusted by firms and population, thus it is necessary that each ´has to begin with himself. Politicians have to simplify the laws related to construction industry and firms have to open their mind to innovative approaches such as Lean and BIM to rebuilt the trust and growth.

2 Lean Manufacturing

As the theme of this master’s thesis indicates, the main technique or approach and its utilization discussed is Lean Manufacturing, also known as Lean Management or Lean Production (hereafter LM). For a better general comprehension, it is necessary to explain what LM represents.

2.1 Origin of LM

The very first signs of something which can be called production process integration could have been seen in the USA in 1913. The American businessman and innovator of automotive industry Henry Ford integrated the entire production process into something what he called a flow production. He lined up fabrication steps in process sequence wherever possible using special-purpose machines and go/no-go gauges to fabricate and assemble the components going into the vehicle within a few minutes, and delivering perfectly fitting components directly to line-side. The problem of Ford’s system was its inability to provide variety. Not only variety of colors but also the variety of specifications (Womack, Roos, Jones, 1990).

And then, there comes the Japanese Toyota Production System invented by Kiichiro Toyoda, Taiichi Ohno, and others in 1930. They used Ford's original idea to make a series of simple innovations to provide both continuity in the process flow and a wide variety in products offering (Womack, Roos, Jones, 1990).

„*Toyota concluded that by right-sizing machines for the actual volume needed, introducing self-monitoring machines to ensure quality, lining the machines up in process sequence, pioneering quick setups so each machine could make small volumes of many part numbers, and having each process step notify the previous step of its current needs for materials, it would be possible to obtain low cost, high variety, high quality, and very rapid throughput times to respond to changing customer desires. Also, information management could be made much simpler and more accurate.“ (*Lean Enterprise Institute, Inc., 2012)

2.2 What is Lean?

As lean thinking spreads to every country around the world, each industry has adapted the tools and principles beyond manufacturing according to its needs, to logistics and distribution, services, retail, healthcare, construction, maintenance, and even government. The idea is to maximize customer value while minimizing waste. To put it simply, “Lean” means creating more value for customers with fewer resources. In other words, LM consists of analyzing the manufacturing and nonmanufacturing processes of the company in order to identify activities with significant reserves. With the so-called “Lean“ tools, they can be edited for greater efficiency, eventually removed and replaced by others, more efficient activities. The result is “Lean Manufacturing“ which eliminates waste (Lean Enterprise Institute, Inc. 2012).

Another way to look at lean manufacturing is to view it as a collection of tips, tools, and techniques (i.e. best practices) that have been proven effective for driving waste out of the manufacturing process (Leanproduction.com 2011).

Lean is a method that improves processes using continuous improvement (4.2.3. Kaizen) and elimination of waste. Technically it is the North American equivalent of the Toyota Production System. Nevertheless, the very foundation of Lean Manufacturing is leveling of production (4.2.2. Heijunka). Heijunka as the foundation brought forth the two main pillars which represent “Just-in-time production“ and “Automation with a human touch“.

Womack and Jones (1996) summarized the five basic principles of lean thinking in their book “Lean Thinking: Banish Waste and Create Wealth in Your Corporation“:

1. **Define value precisely from the perspective of the end customer in terms of a specification product with specific capabilities offered at a specific price and time.**

   - While it seems very straightforward, this step is actually very hard to carry out. For highly complex products or services, the value must flow a very long journey across many companies and departments of each company. Consequently, failure to specify value correctly before applying lean techniques can easily result in providing a wrong product or service in a highly efficient way, which is considered as a pure *muda – a* Japanese term for waste.

2. **Identify the entire value stream for each product or product family and "Eliminate waste".**

    - The value stream is all the specific actions required to take a specific product through three critical activities of any business:

        a. Product definition – from the concept through detailed design and engineering to production lunch.
        b. Information management – from order taking through detailed scheduling to delivery.
        c. Physical transformation – from raw material to a finished product in the hands of the customer.

3. **Make the remaining value-creating steps flow.**

    - Making steps flow means working on each design, order, and product continuously from the beginning till the end so that there is no waiting, downtime, or scrap within or between steps. This usually requires introducing new types of organization or technologies and getting rid of the old-school machines which are very complex technologies requiring operating in batch mode. When processes flow correctly, products that required years to design, now only take a few months, orders that required days to process are completed in a few hours, and the throughput time for physical production shrinks from months or weeks to days or minutes.

4. **Design and provide what the customer wants only when the customer wants it.**

5. **Pursue perfection**

    - As the lean techniques begin to be applied throughout the whole value stream, it might seem that there is no end to the process of reducing effort, time, space, costs and mistakes. It happens because the four initial steps are caught in a circle. A more precise definition of value always challenges the steps in the value stream and gets value to faster flow. Consequently, the continuous process of improving always exposes hidden muda (wastes).

2.3 Toyota Production System

While forming Toyota Production System (hereafter TPS), Toyota and others had in mind that the system has to provide products at world class quality levels to meet the expectations of customers, and to be a model of corporate responsibility within industry and the surrounding community. Based on these ideas, the team established four basic aims (Monden, 1998):

1. To provide world class quality and services to customers.

2. To develop each employee's potential, based on mutual aspect, trust and cooperation.

3. To reduce costs through the elimination of waste and to maximize profit.

4. To develop flexible production standards based on market demands.

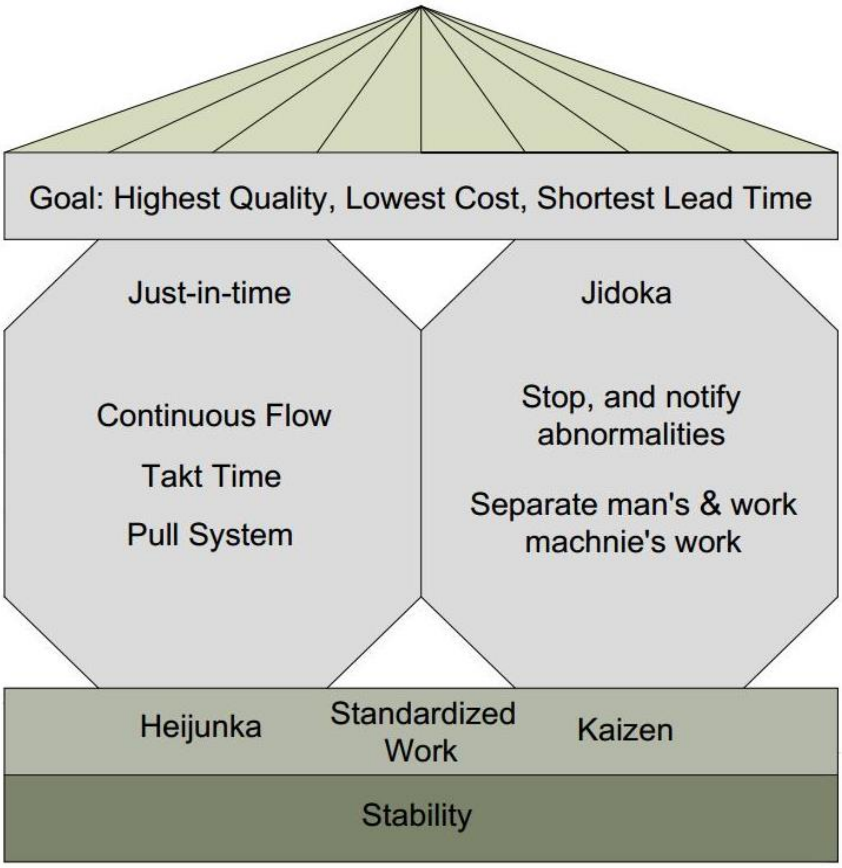

Figure 2 Toyota Production System "House" (source: lean.org, 2014, self adaptation)

The figure 2 presented above shows the TPS. It describes the major sub-systems that compromise TPS, it also explains the key concepts and tools associated with the system.

As you can see, TPS House shows many kinds of tools utilized during the main development of TPS. For a better understanding I am going to describe the major tools and techniques.

2.3.1 Heijunka

Heijunka (pronounced hi-JUNE-kuh) is a Japanese word that means "leveling". Proper implementation helps organizations meet demand while reducing wastes in production and interpersonal processes (Coleman, 1994).

Lean Lexicon, 4th Edition defines (2008) *heijunka*: "Leveling the type and quantity od production over a fixed period of time. This enables production to efficiently meet customer demands while avoiding batching and results in minimum inventories, capital costs, manpower, and production lead time through the whole value stream".

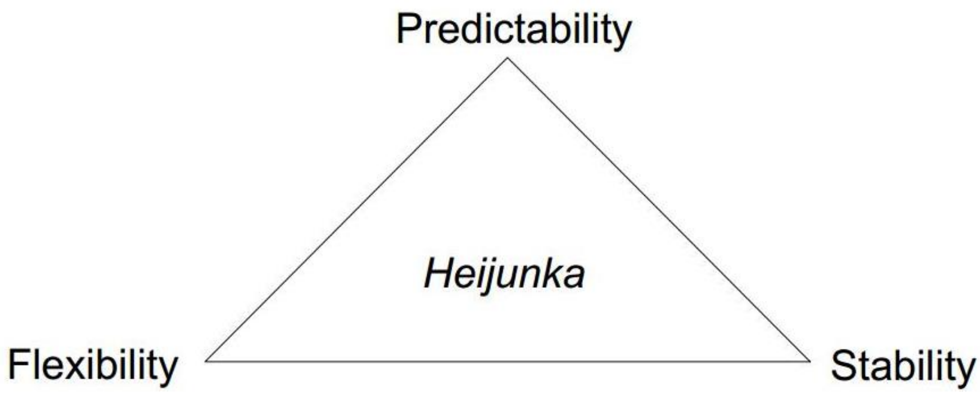

Figure 3 Relationship Among Predictability, Flexibility and Stability (source: isixsigma.com, © 2000-2017, self adaptation)

Figure 3 shows the relationship among predictability, flexibility and stability. When implemented correctly, *heijunka* provides predictability by leveling demand, flexibility by decreasing changeover time and stability by averaging production volume and type over the long term (Friddle, © 2000-2017).

Heijunka is a technique to facilitate Just-In-Time (JIT) pruduction. It i salso imporatant when it comes to sequecing production. For example, saya glass producer recieves orders for 500 of the same glass per week: 200 orders on Monday, 50 on Tuesday, 150 on Wednesday, 50 on Thursady, and 50 on

Friday. Instead of trying to meet the demand in the sequence of the orders, the glass producer would use *Heijunka* to level demand by producing an inventory of 100 glass near shipping to fulfill Monday's orders. Every Monday, 100 glasses would be in the inventory. For the rest of the week, the production would make 100 glasses per day – a level amount. What if the situation involved multiple types of glasses? Imagine that orders are being placed for glass models A, B, C and D. A mass producer would want to minimize waste around equipment changeovers. Its production schedule could look like this: AAAAABBBCCDD. The TPS uses *Heijunka* to solve above-mentioned examples by assembling a mix of models within each batch, and ensuring that there is an inventory of product proportional to the variability in demand.

Heijunka depends significantly upon putting a percentage of capacity into changeover flexibility. Lean expert Ballé (2017) wrote “If you want to make every product every day, which is kind of the Lean first goal, you need to reduce changeover time accordingly“. Demand forecasts are often not quite right, and sometimes completely wrong. Increasing changeover flexibility and efficiency protects a production line from demand ambushes. The frame of any *heijunka* implementation is supposed to begin with “takt time“ and end with a *heijunka* box.

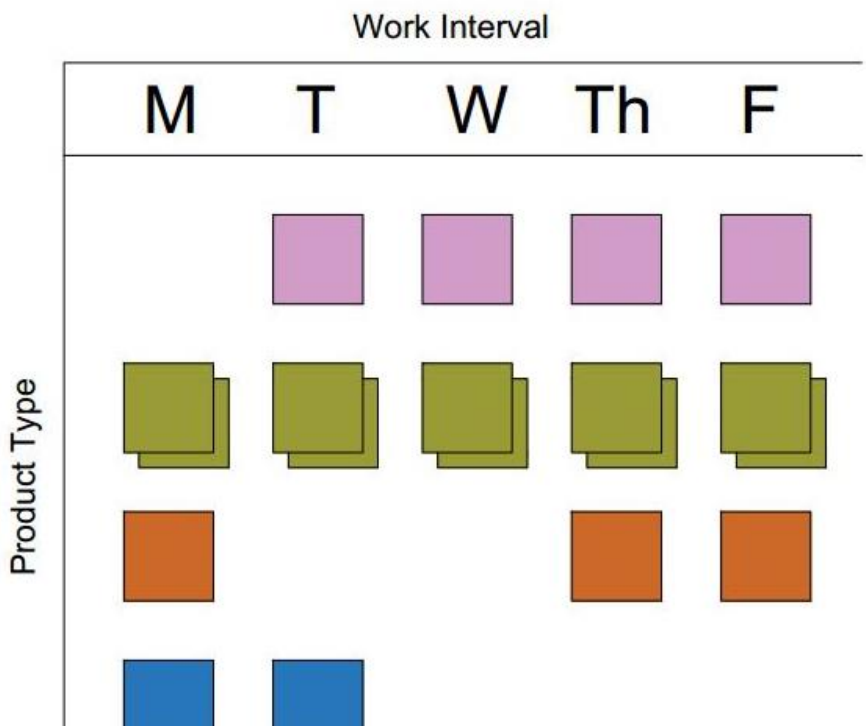

Figure 4 Heijunka box (source: isixsigma.com, © 2000-2017, self adaptation)

Takt time is simply the time it takes to complete a product in order to meet customer demand. It will be described later on.

A *heijunka* box is a simple visualization of production using kanban cards[2] to signal production according to a specified interval of work (e.g., per day). It is used by production staff on the floor and is highly regarded in visualizing processes (Friddle, © 2000-2017).

Figure 4 presents an example of simple *heijunka* box. It helps to visualize the optimized production schedule. Each square on the board represents a kanban to signal production of a single product. Each square on a given day represents one product to be made. For example the plan for Monday comprises of two green types, one orange and one blue type of product.

2.3.2 Just-in-time

Just-in-time (hereafter JIT) is a method originated in Japan. The author of the JIT concept is Toyota. The very first foundations were laid in 1926, but the biggest boom came in the 1980s in the Japan and the USA. JIT deals with production supply and inventory control. The underlying philosophy organizes logistic flows in order to minimize transport and storage costs.

The main principle of JIT is to ensure the inventory is available just in the time of need. It is highly used for the material delivery when supplier deliver material supplies to the site or factory, right in the time then the material is about to be used. This approach can reduce carrying costs of inventories, maximize the use of space and in some cases, improve the quality of results.

Implementation of JIT places demands on the perfectly accurate coordination of all the related processes and flows.

Another advantage of this approach is that purchase and production can be accomplished on a small scale and no earlier than necessary. However, extra caution is needed because without the use of backup inventories, the arrival of material must be accurate and continuously fine-tuned. In addition, the material must be of usable quality and workers must use this material properly in the production process (Cimorelli, 1996).

[2]Kanban cards – they mostly have the form of squares on the board (schedule), to signal steps in manufacturing process. It allows teams to communicate more easily on what work needed to be done and when.

Nevertheless, not even JIT can work properly without a wide range of special support. Essential examples of the factors below can ensure a smooth execution of the works and result in a high quality:

- High quality supplies
- Manageable supplier network
- Geographic concentration (short transit times for vendors or suppliers)
- Efficient transportation and materials handling
- Strong management commitment (Schermerhorn, 1996).

Following subchapters present a shortlist of the most important supportive techniques that facilitate JIT.

Push vs. Pull

One of the key characteristic of the lean production is the Pull system. But the question arises why the Pull system takes precedence over the Push system? There are many definitions of Pull and Push and many articles describing the difference, but each explains the differences in a slightly different way. Not even the very own name of the systems “Pull and Push” manage to describe the systems perfectly.

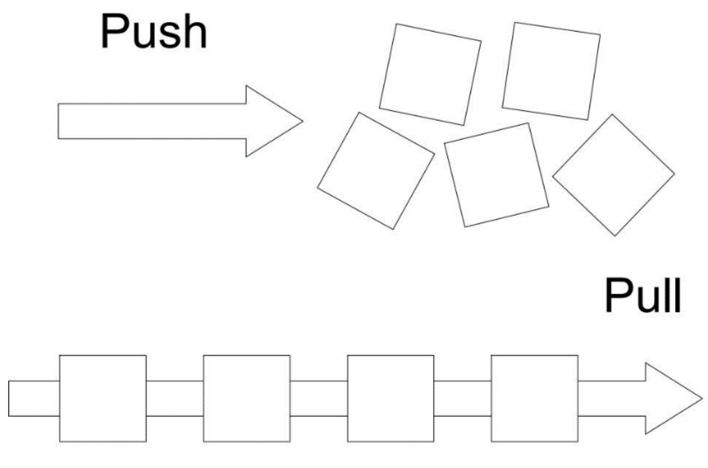

Figure 5 Push vs. Pull (source: AllAboutLean.com, © 2015, self adaptation)

It is important to start with the definitions and its explanation. For each system there is a chosen definition found on the internet.

Definition: *"Push system means the Make-to-stock production, in which the production is not based on the real demand. Pull system means the Make-to-order production, in which the production is based on the real demand".* (Lean Manufacturing Japan, ©2008).

Push and Pull are often explained using the Make-to-stock and Make-to-order, Push production system makes products without any specific customer's demand and Pull production system makes only products based on a specific customer's demand. This simple point of view might cause many misunderstandings. Even the Toyota company itself, major representative of the lean philosophy, makes some of its cars without specific customer's demands, and creates inventory of popular models for "random" customers. It is possible to make-to-stock even in Pull production system (Roser, 2015).

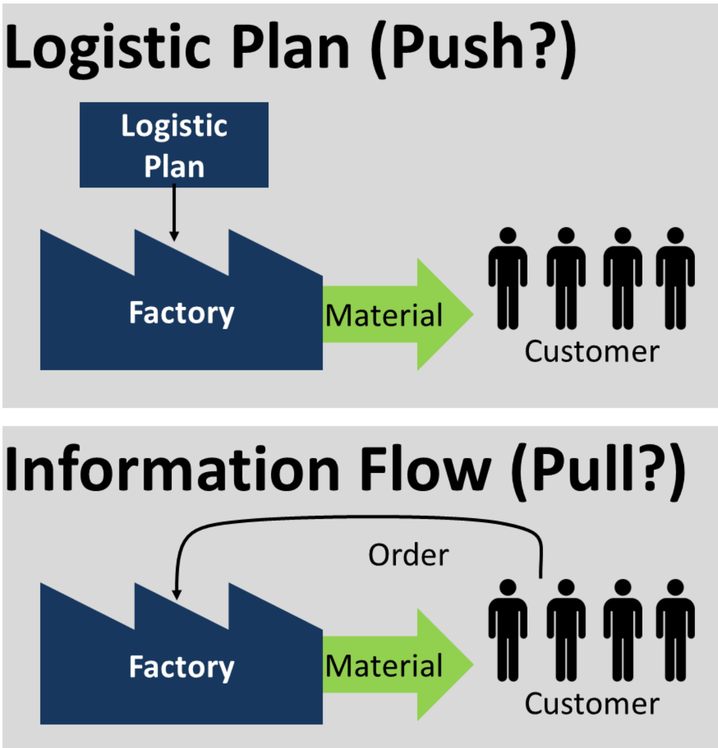

Figure 6 Push vs. Pull (source: AllAboutLean.com, © 2015)

As the Hopp and Spearman (2004) wrote in their article "To Pull or Not to Pull", the Pull production system is the one, limiting the amount of work in progress that can be inside the system. The Push production system is the one, not limiting work in progress. It means that if you do limit work in progress, it is Pull system, otherwise it is about Push. There is no toll for dealing with pulling or pushing material or information. The main difference is the limit of work in progress. If the company has set the limit for work in progress, they use Pull system and advantages of lean philosophy.

Takt Time

Takt Time is the rate at which a finished product needs to be completed in order to meet customer demand. It comes from the German word, *Taktzeit*, which is often referred to as the heartbeat or drumbeat of production in Lean Management.

If a company has a takt time of ten minutes, it means a complete product, assembly or machine is produced off the line every ten minutes. The takt time is set according to average customer demand, customer is buying a finished product every ten minutes. Takt time is highly used in all kinds of industry a it does not have to be necessarily driven by the demand, In case of constructions, “takt” can mean the time a team of workers has to finish certain repetitive process.

Takt Time described mathematically can look as follows:

$$Takt\ Time = \frac{T_A}{D_R} = \frac{Available\ Work\ Time\ /\ Unit\ of\ Time}{Customer\ Demand\ Rate}$$

The unit of time in the numerator and denominator must bet the same. The numerator, Available Work Time, is often referred to as Minutes/Shift, Seconds/Day, Minutes/Day and so on. The denominator, Customer Demand Rate, is often referred to as Parts/Min, Units/shift, Pieces/day, and so on.

It is important to note that the Available Work Time should reflect the total number of time unit employees work minus time spent on any breaks or meetings. Customer Demand Rate (sometimes replaced by Required Units of Production) is a measure – how many products a company expects its customer to buy in a certain time period (Millstein, 2014).

Continuous Flow

Continuous Flow can be explained as producing and moving one item at a time (or a small and consistent batch of items) through a series of processing steps as continuously as possible, with each step making just what is requested by the next step. Implementing Continuous Flow in the manufacturing operation improves productivity, increases process flexibility, and reduces defects, production lead time and WIP inventory. It is also called *one-piece flow, single-piece flow,* and *make one, move one.*

Lean practitioners should relentlessly strive for continuous flow through the reduction of waste. Any time a process stops, lead time is prolonged, the customer has to wait for the product or service, and it is costing more money than if the flow was continuous in nature (Marchwinski, 2003).

2.3.3 Standardized Work

Standardized work means that production processes and guidelines are clearly defined into very details to eliminate variation and incorrect understanding of work execution. The goal is that production processes should be executed the same way every time. Instead of a long written manual, the visual guides are prepared to provide easier understanding for workers. Processes are designed as simple and as lean as possible in order to keep them easier to understand and to be easily managed. Standard processes are monitored and updated in constant periods.

2.3.4 Kaizen

Kaizen is uses philosophy of continuous improvement which is the very basic core element of the lean production system. There are two types of continuous improvement; gradual improvement and periodic big leaps. The form of continuous improvement in the lean philosophy has been gradual (Kaizen) since very beginning (Ohno, 1998). It is about being unsatisfied with the current situation, correcting defects right away, experimenting with the new ideas, eventually implementing these ideas immediately, finding opportunities during unfavourable time, searching for the real reasons and believing in the infinite nature of development.

Kaizen comes from the Japanese words Kai = better and zen = change. The literal translation is “better change“, but over the years it has taken up the more famous meaning “continuous improvement“ which is described above. Kaizen is based on certain principles such as:

- Good processes bring good results.
- Look at yourself and try to understand current situation.
- Keep yourself informed and follow the facts.

- Accept the measure to prevent, eliminate and solve core problem causes
- Work as a team.
- Kaizen is everyone's concern.
- Etc.

One of the very interesting feature of kaizen is, that the big changes come after the sequence of many small changes made over the course of time. Theoretically, Kaizen means that everybody makes an effort to make company better (IMAI, 2007).

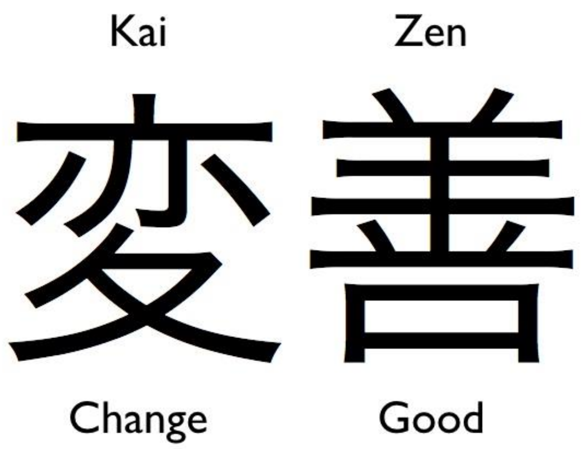

Figure 7 Kaizen = Continuous Improvement (source: © Kaizen Institute, 1985-2017)

2.3.5 Jidoka

Jidoka is the often forgotten pillar of the Toyota Production System and lean manufacturing. The whole story of *Jidoka* started in 1896 when Sakichi Toyoda inventsed a simple device that could stop the shuttle on an automatic loom if the thread broke. It prevented the machine from not only creating defects but also alerted the operator about a problem which meant that one operator could operate several looms instead of watching just one in case something went wrong. This principle became known as Autonomation or automation with a human touch. Later toyoda sold patent for this invention to a UK mill. And so the world boom started.

Jidoka is a principal that helps to increase quality of production processes. It is about the quality at source, or the built in quality, and the main principal is the quality monitoring of production process within the real time. If any abnormality is detected, the production process must be stopped until the abnormality is discovered, problems highlighted and actions taken.

The principle of *Jidoka* can be divided into a few steps:

1. Discover an abnormality
2. STOP
3. Fix the immediate problem
4. Investigate and correct root cause

This principle does not just point to use within machines through autonomation, *Jidoka* is highly visible in every aspect of lean manufacturing. It is about bringing quality into a process rather than inspecting for it at the end of the process (Baudin, 2007).

Lean relies on *Jidoka* principles across the various tools and makes us use visual management techniques to highlight whenever an abnormality occurs for us to take action. Below, some tools which facilitate Jidoka are described:

Genchi Genbutsu

The idea hidden behind the term *Genchi Genbutsu,* which is the best way to make sure a production line is working at the maximum efficiency is "Go and see it for yourself". *Genchi Gebutsu* (English: Go and see for yourself) is the part of the Toyota Production System. It requires a high level of management presence on the factory floor to make all the locations quickly available for management personnel. The best practice is to go and see the location or process where the problem exists in order to solve that problem more quickly and efficiently. The fact is that any report about certain problem is mostly simplified and abstracted from its context. This is often one of the key reasons why solutions designed away from the process seem inappropriate. The existing problems should be first of all correctly understood before being solved, and the presence of the managers helps to grasp problems, confirm the facts and analyse root causes.

Andon

Andon in manufacturing is one of the most common forms of visual management that is in used Lean. It is a very effective tool because of its ability to enable the operation to run smoothly without any [3]bottlenecks. *Andon* was first utilized by the Toyota Production System as a quality control method. Jidoka might mean “empowering the employees“. We are rather talking about machine operators which are directed to the assembly line to identify the status of the process and to take proper actions with proper significance.

“Andons are the lighted signal like the traffic lights with three colors on top of each level of production assembly line. Whenever a worker detected any problem in the production line, or found himself unable to keep pace with the line, he could stop the operation by pulling a cord called Andon cord, which would set off an alarm system and illuminate the color coded andon electric light board. If the problems detected were not rectified within a specified time period then the entire production line would stop, either manually of automatically. And if there is no problem the Andon illuminates a green signal signifying that process can continue with the operations“ (Whatissixsigma.com, 2017)

Color Cord	Condition	Action
Green	Production is normal or smooth	Proceeds to next level
Yellow	Problem appeared	Operator takes help of concerned authority to fix the problem
Red	Production Stopped	When problem is not identified and needs further investigation

Figure 8 Example of Andon signals (source: Whatissixsigma.com, 2017)

Poka Yoke

Poka Yoke is the Japanese term, that might be translated as “fail-saving“ or “mistake-proofing“. It is often called a mechanism or a tool in manufacturing, which helps the employee/operator to avoid (Yoke) mistakes (Poka). The idea behind is the elimination of defective products by prevention and notifying human mistakes, which cause these defects. The simple example is a mechanical or electronic device or machine, which prevent from

[3] Bottleneck in Lean approach means there is one process, station, step etc. That is limiting factor that will prevent greater throughput. The power of knowing its bottlenecks helps us to increase the flow by improving the process.

making defects at 100 percent efficiency. Machine prevents for example the exchange of the components, exchange of the processes sequence. To put it simply, it stops the operator from montage or further production unless something is missing or badly installed.

2.4 Summary of Lean Manufacturing

The people who sympathize with Lean Manufacturing have developed many useful tools so far, but above-mentioned practices left the biggest impact on this innovative approach. To summarize all the most important techniques and tools, Picchi (2001) made a summarization of techniques and its usage sorted according to each Lean principle.

Objectives	Principles	Core elements		Examples of related techniques
Permanently improve company's competitiveness by:	VALUE	Enhanced product / service package value	Solution that enhances value for the client	Identification of what is value for the client, services aggregation, business re-structuring
			Product variety	Modular design, interchangeability, fast set-up, planned variety compatible with production system
		Time based competition	Production lead time (order to delivery)	Small batches, product family factory lay-out, JIT
			Product development lead time	Black box system, heavyweight manager, set based design, concurrent engineering
- eliminating waste	VALUE STREAM	High value adding in the extended enterprise	Value stream redesign eliminating waste	Mapping, combining activities, eliminating non-adding value activities, supporting and promoting suppliers lean implementation
			Suppliers involvement in production and product development systems	Partnership, supplier training, black box system, JiIt supply
- consistently attending client's requirements in variety, quality, quantity, time, price	FLOW	Dense, regular, accurate and reliable flow	Dense flow , with height adding value time, clear pathways and communication	Mapping, work cell, one piece flow, multifunctional worker, autonomation, product lay-out, design for manufacturing
			Regular flow - paced by client / next process demand	Takt time, kanban, one piece flow
			Accurate and reliable flow	TQC, statistical process control, poka-yoke, jidoka, Total Productive Maintenance (TPM)
		Standard work	Work “Standardization”	Work instructions, work content, cycle time and standard inventory definition
			Transparency	Visual management, 5S
			Low level decision	Delegation, training

Figure 9 Lean Core Elements (source: Picchi, 2001)

Objectives	*Principles*	*Core elements*		*Examples of related techniques*
	PULL	JIT production and delivery	Pull versus push system	Kanban, takt time
			No overproduction, WIP (Work In Process) reduction	Kanban, standard inventory, FIFO: firt-in-first-out, small batches, one piece flow
			Demand smoothing: harmonizing market variations and production flexibility	Anticipation (Master plan), Peaks negotiation (Dealers system)
			Reflecting product variation in short periods of production	Heijunka, fast set-up, small batches
		Flexible resources	Information flexibility	Flexible information systems
			Equipment flexibility	Fast set-up, low cost automation, redundant equipment
			Workers flexibility	Multi-skill training, work cell
	PERFECTION	Learning	Fast problem detection	No buffer, no stock, kanban, small batches, one piece flow, first-in-first-out (FIFO), visual management, 5S, decision in operator level
			Fast problem solving in lower level and solution retention	Empowerment, teamwork, Quality Control Circles (QCC), 5 Whys, quality tools, kaizen
			Evolutionary learning	Kaikaku (dramatic changes), benchmarking
		Common focus	Leadership and strategy	Strategic planning, Policy deployment, Hoshin management, managers in workplace
			Structure	Teamwork, hierarchy levels reduction, cross functional structure
			Client and production focus diffusion	Training, day by day coaching, leadership example
			Human respect	Laying off as the last resort, Job system, work meaning enrichment, participation, empowerment, recognition, ergonomy, safety
			Total employee involvement	Suggestion system, QCC, kayzen, job system, training system
			Total system diffusion	Techniques “Standardization”, simplicity in communication, system and techniques application in all processes and in whole company

Figure 10 Lean Core Elements (source: Picchi, 2001)

3 Lean Construction

As well as in the other industries, a growing number of construction firms are embracing the lean methodology that should result in maximizing costumer value while minimizing waste. The lean principles are easy to apply to an industry where budgets, timeframes, and safety are all crucial. But the lean approach to construction project delivery is totally different from traditional methods where it is hard to implement lean methodology properly. Simply said it is much easier to produce repeatable forecastable results in a controlled environment of a factory than in a more unpredictable construction site. So, a question arises how to apply lean production methodology to the construction. Construction projects are a very complex and highly uncertain environment, many ideas that came from manufacturers have been rejected due to its unsuitability. The key of proper lean approach implementation to traditional construction practise is to know the differences. Managing construction using lean thinking is different from traditional construction practice because it:

1. has a clear set of a objectives for the delivery process,
2. aims to maximize performance for the customer at the project level,
3. concurrently designs the product and process and it
4. applies production control throughout the whole project.

The above-mentioned differences are presented in the lean perspective. It is true that the traditional approach tends to first break the project into pieces such as design, which should identify customer value, and construction, then put those pieces in a logical sequence, estimate the time and resources required to complete each activity and therefore the project. Once any key activity along the critical path falls behind, the risk of increase in cost and duration is critical. Then, construction managers are forced to take certain steps, for example to trade cost for schedule by working out the best sequence of work. These arrangements may result in cumulation of waste due to mismatch of continuing activities and arrival of needed resources. Thus, lean thinking points out that traditional approaches to construction project delivery, focus on activities and ignore flow and value considerations (Koskela, 1992, Koskela and Huovila, 1997, Tommelein and Ballard, 1999).

3.1 What is Lean Construction?

Lean construction has been defined in several ways. Greg Howeell and Glenn Ballard, the co-funders of the Lean Construction Institute (LCI), describe lean construction as management-based production system. The package of the objective, principles, and techniques, provides the foundation for an operations-based project delivery system (Ballard, Howell, 1998).

Definition according to Lauri Koskela indicates that lean construction pursues the same goals as lean production, especially to “Eliminate waste” of materials, time and effort in order to maximize customer value. This Koskela’s point of view is called TFV (Transformation-Flow-Value generation) theory. (Koskela, 2000). Whereas LCI strives for direct application of industrial approaches in manufacturing to construction.

These two core above-mentioned approaches together introduced some implementations of manufacturing methods to construction. The best known is The Last Planner System (LPS) approach to the planning and management of construction process. It aims to improve the predictability and reliability of construction production with emphasis on managing relationships, conversations and commitments amongst all parties, to collaboratively create foundations for work execution. In other words, the discussion between site staff and planning ensures that work is not waiting for workers, and that workers and not waiting for work (Ballard, Howell, 1994).

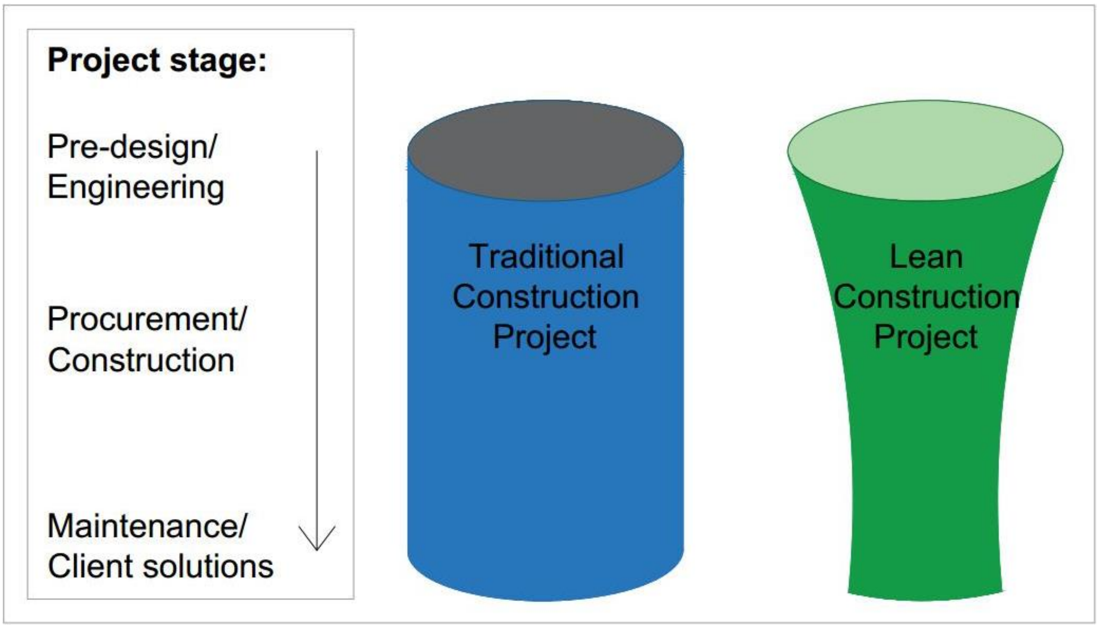

Figure 11 Project’s resources demands (source: manageit.cz, © 2016, self adaptation)

As the Figure 10 indicates, project using lean methods is of the same resources demands volume, in the first project’s stage. However, in the next stages is seen a great decrease in resources volume within the lean project. The principle is choice of the right and professional methods and techniques which are applied properly, and accepted by subcontractors. On the other hand, the idea of applying each and every tool and method blindly to every project is absolutely wrong. Each construction project is unique, and the combination of approaches is mostly always different.

3.2 Oddity of the construction industry

Construction is very complex sector, with strong fragmentation. In the production cycle several parties are involved, such as owners, designers, general contractors, sub-contractors, and suppliers. Lean thinking proposes that the company should be analysed through their flows (from order to cash, from raw materials to delivery, etc.) and not through departments (Picchi, 2001). The unique and complex environment of the construction industry represents a challenge for production management. Riley and Clare-Brown (2001) said that it would not be possible to transfer management practices to construction unless necessary effort had been taken to modify the management tools or the culture in the construction industry. According to Winch (2010) to create a proper model of manufacturing for the construction industry, requires the analysis of the construction subsector, which can be generally grouped into four categories:

1. Large infrastructure works, typically civil engineering
2. Prestige building projects,
3. “Routine” building projects that provide the bulk of new buildings
4. Housing production

The first three categories are on-site, project-oriented construction projects (the majority of the work is site-based), so the production in volume can be hardly achieved. Winch (2003) argued that the last category the Housing production is the most similar to lean production. While first three categories mostly include the huge employment of the sub-contractors, designers, consultants, etc., the housing production company often takes care about the whole construction process, from design to the factory production of a of a complete house. This not has to mean that lean construction principles can only be implemented in the housing sector. Winch (2010) has outlined that lean-inspired improvement activities such as TQM[4] and JIT[5] have their place in effectively managing construction projects, because they provide a valuable tool set for improving process capability

The construction project can be also understood as a virtual, multi-company and temporary organization. The application of lean thinking application opportunities, if limited to each company involved, will not focus on the major potential of waste reduction, considering the whole flows within the project (Picchi, 2001).

Many differentiate factors of the construction industry from other industries were explored. Koskela (1992) called them inherent peculiarities of construction; they are summarized in Figure 11.

3.3 Lean Construction principles

Lean construction practice, as well as Lean Manufacturing, developed basic principles to demonstrate fundamentals of the Lean thinking in construction industry. These principles come from Manufacturing principles which have been described in chapter 4.2. In 2016, US company ConstructConnect™ summarized lean principles for construction industry. The principles shown below can guide firms and help them to achieve lower costs, reduced construction times, more productivity and efficient project management. They represent a holistic approach to the construction process.

1. **Identify value from the customer's point of view**

What the client truly values in a construction project typically goes hand in hand with the plans and specs. Customer's value is not just about the quality of project execution, completing a project on time and within budget. It requires customer-focused approach that can best be achieved by building relationship with the client. In lean construction, this should include all stakeholders: owners, architect, engineers, general contractor, subcontractors and suppliers. Identifying client values should begin early in the conceptual planning phase of a project and be carried on through construction. It's about understanding not only what your client wants, but why they want it, so the project team can manage expectations and best advise the client. A deep level of trust must be established between all parties involved in order to successfully implement lean practices (Jones, 2016).

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[4]TQM – Totally Quality Management – it is a complex technique which put emphasis on quality management in all dimensions of project's/company's life cycle.

[5]JIT – Just–In–Time (4.3.2)

Aspects	Construction industry	Manufacturing industry
Duration (life time)	Short	Long
Nature	On-of-a-kind nature	Repetitive
Work Station	Transient	Stable
Material components	Non-standardized	Standardized
Material supply	Schedule-driven	Order-driven
Safety provision	Less enforced	Highly enforced
Labour force	Seasonal, low job security	Not seasonal, higher employment security
Wages	Vary depending on skill, experience, and employers	More stable wage policies
Environment	Final production is assembled in situ	Within the factory
Technology	Low level of automation, prefer not to use	Better and advanced
Quality	Related to product conformance; rework is common	More closely to process control; rework is generally avoided
Owner involvement	Highly involved	Less involved
Culture	Ill-defined, site personnel know nothing of company's management philosophy	Clearly defined so that staff are conscious of it
Regulatory intervention	Design solution and many work phases in a construction project are subject to checks and approvals by regulatory authorities	Less subject to checks and approvals

Figure 12 Difference between construction and manufacturing industry (source: Gao, Low, 2014)

2. Identify processes that deliver the value stream

The value stream means what the client values. Right after identifying value from your client's perspective, it is necessary to identify the processes needed to deliver the value stream. All steps in the process should be carefully mapped out to determine what activities are involved. Labor, information, materials, and equipment needed for each activity should be taken into account. Any non-value adding step in a process should be eliminated (Jones, 2016).

3. Eliminating waste

Lean construction is characterized by cutting out waste. Waste represents the eight major types in construction process. All of them result in downtime.

- Defects
  Defects are anything not done correctly the first time which results in rework. This wastes time in having to make the repairs and materials needed to correct the work.

- Overproduction
  In construction, overproduction occurs when a task is completed faster than scheduled or before the next task in the sequence is ready to start.

- Waiting
  It is a wasted time where workers must wait for work because delivery of material failed, or preceding work is not completed as scheduled. The workflow is disrupted.

- Not utilizing talent
  This means that labor with some skills and experiences are matched to the wrong job. It is complete waste of their talents, skills and knowledge.

- Transport
  This waste occurs for example when a equipment, materials, or workers are transported/delivered to a jobsite before needed. It can also refer to the unnecessary transmission of information.

- Inventory
  In lean construction, inventory only means wasting time, money, and human resources. The idea is to move toward “just-in-time” inventory.

- Motion
  Waste of motion is created by unnecessary movement, such as distance between workers and tools or materials.

- Over processing
  Over processing is mostly caused by dealing with too many features or activities having no value to the client, such as taking steps to eliminate the other types of waste.

4. **Achieving flow of work processes**

The idea hidden behind the lean construction approach is to achieve a continuous workflow that is reliable, predictable, and uninterrupted. The whole construction process should be divided into single stages going in sequence. In order to achieve flow all parties have to communicate and work together to avoid wasting (principle 3). Contractors are helping themselves to ensure they have the capacity to finish each task on schedule, by dividing a project into separate production zones. If on stage of production gets behind or ahead of schedule, it is important to communicate and make adjustments to avoid workers waiting for work (Jones, 2016).

5. **Using pull planning and scheduling**

Pull planning or scheduling means the work is released based on downstream demand in order to create reliable workflows. Because work is done sequentially, and the tasks are done one after another, it requires starting from a specific milestone or target completion date and plan work backward. Subcontractors are the best suited to determine their capacity for performing given task. To achieve smooth progress, all parties should communicate explicitly and work handoffs to coordinate schedules (Jones, 2016).

6. **Perfecting the process through continuous improvement**

The term Continuous improvement explains principle itself. As the old projects are being completed, new projects are coming, and a lot of experiences were gained throughout the time. To be aware of the mistakes made before is critical. It allows companies to make adjustments, to better identify and reduce waste, but also continually innovate new ways of lean thinking implementation (Jones, 2016).

3.4 Tools and techniques

To move lean production to lean construction, researchers have tried to identify differences between each industrial direction and develop some set of practices for construction one. The classification according to Paez (2005) is summarized in figure 13:

1. First level: Direct application of the techniques from lean manufacturing.
2. Second level: Modification of the techniques from lean manufacturing.
3. Third level: Brand new lean construction techniques.

Level	Lean construction technique	Related lean production techniques
I.	Material Kanban Cards	Kanban System
II.	Visual Inspection Quality Management Tools Concurrent Project Engineering	Visual Inspection (Poka-Yoke) Multi-functional Layout TQM Standard Operations Single Minute Exchange of Dies
III.	Last Planner Plan Conditions of Work Environment (PCMAT) Daily Huddle Meetings	Kanban System Production Levelling Toyota Verification of Assembly Line (TVAL)

Figure 13 Comparison of Lean Techniques (source: Paez, 2005)

Paez (2005) also sorted techniques according to its goals, through a real-world case study (figure 14).

Goal	Flow Variability	Process Variability	Transparency	Continuous Improvement
Lean Construction technique	Last Planner	Fail Safe for Quality	5S Increased Visualization	Huddle Meetings First Run Studies

Figure 14 Goals of Lean Construction techniques (source: Paez, 2005)

All of these above-mentioned can be applied separately or combined. Nevertheless, combined utilization will increase leaned of a construction organization. It would be explanatory to take a glance at these techniques.

3.4.1 Last Planner® System

The Last Planner® System (hereafter LPS) is a tool that simplify and conversation between trade foremen and project management at appropriate levels of detail, and before issues become critical. The LPS' development began in 1980s, but the formal development occurred in 1990 when Glen Ballard and Gregory Howell started to do consulting work in the industrial sector. Over this period, the LPS demonstrated its dynamism by constantly combining practice with theory through research. Further research showed its integration with other elements such as BIM, Location-Base Planning, and Visual Management. Many researchers from around the world are actively conducting research on the LPS and new findings are continuously integrated into the LPS (Daniel, Pasquire, 2016).

LP was developed to make planning processes and work flow highly reliable, and to build necessary trust within a collaborative team environment. It helps to make plan detailed by those whom execute the work. LPS also follows lean construction principles such as Just-In-Time delivery, value stream mapping, Pull Planning and it not only helps to improve conversation flows but it is also highly used as a system for planning, monitoring and control. Its main motives are time and cost. Time control is managed by monitoring work progress and cost control is managed by monitoring efficiency and productivity of the necessary resources. The primary function of LPS is the collaborative planning proves that involves planners for planning in greater detail as team gets closer to doing the work. Ballard and Howell (1994) said that LPS refers to the person that creates tasks for direct workers to perform. While the conventional 'push scheduling' principles are looking for work the SHOULD be done and is planned in weekly meetings, LPS incorporate 'pull planning' principles where only the work that CAN and WILL be done is considered and promised by Last Planners (leanconstruction.org, 2013).

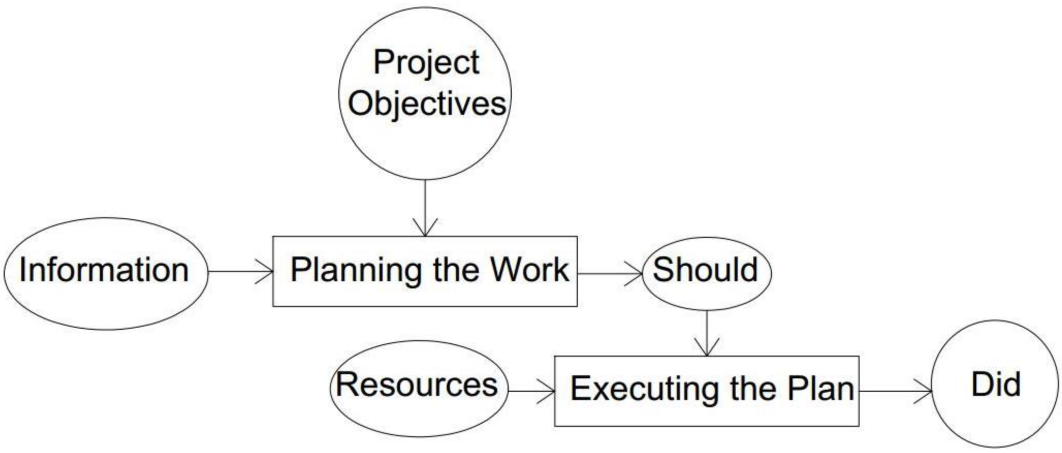

Figure 15 Traditional management practise (source: Ballard, Howell, 1997, self adaptation)

The LPS transforms SHOULD be done, which surfaces from the requirements of a master schedule, into CAN be done (Ballard, 2000b). CAN be done is determined by considering applicability of SHOULD be done, taking the constraints into the account. The weekly or daily WILL be done activity plan is formed from CAN be done activities. The person who makes decisions whether the work is ready to be physically executed at the operational level, in what sequence over what durations using what resources and methods is the Last Planner. Last Planners is mostly some foreman or a head of design.

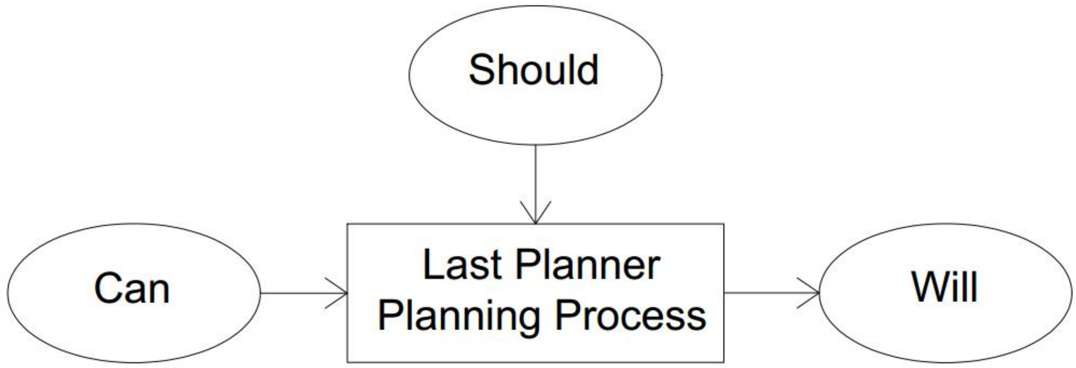

Figure 16 Last Planner planning process (source: Ballard, Howell, 1997, self adaptation)

Last planner is the last in the chain because the output of his/her planning proves is not a directive for a lower level planning process, but results in production (Figure 16) (Ballard, Howell, 1997). The seven main stages of the LPS are (Pellicer, 2015):

1. The first planner (the construction site manager) reviews the contract and the design project, and consequently develops an initial schedule. This schedule is going to be used by the construction site manager only as a reference for the second step and it does not have to be distributed to the other stakeholders.
2. The construction site manager summons the last planner for a meeting ("pull session") where the construction schedule is discussed among the participants. As an output of the pull session a master plan is approved with the commitment of all parties and distributed to the stakeholders if necessary.
3. Within the master plan, the look-ahead plan is produced by the construction site manager assisted by the last planners if needed. The look-ahead plan identifies the constraints and it proposes a path to avoid or delete bottlenecks. This plan forecasts six weeks in advance approximately, and identifies the work that has to be cleared of any constraints. It looks forward to increase construction flow.
4. The weekly plan is produced every seven days (weekly meeting) with the involvement of the last planners. The weekly plan established the detailed work that will be done during the following week (assignments) through promises of the last planners.

5. During the weekly meeting, the last planners check the compliancy of the weekly plan, and identify the reasons of non-compliancy.
6. Weekly results are made public (visibility) in the construction site, indicating the performance of every party for each task implicated. This publicity of results (either good or bad) is a key factor to reinforce the commitment of the last planners.
7. There is feedback in every step of the process to update the master plan and to het lessons learned.

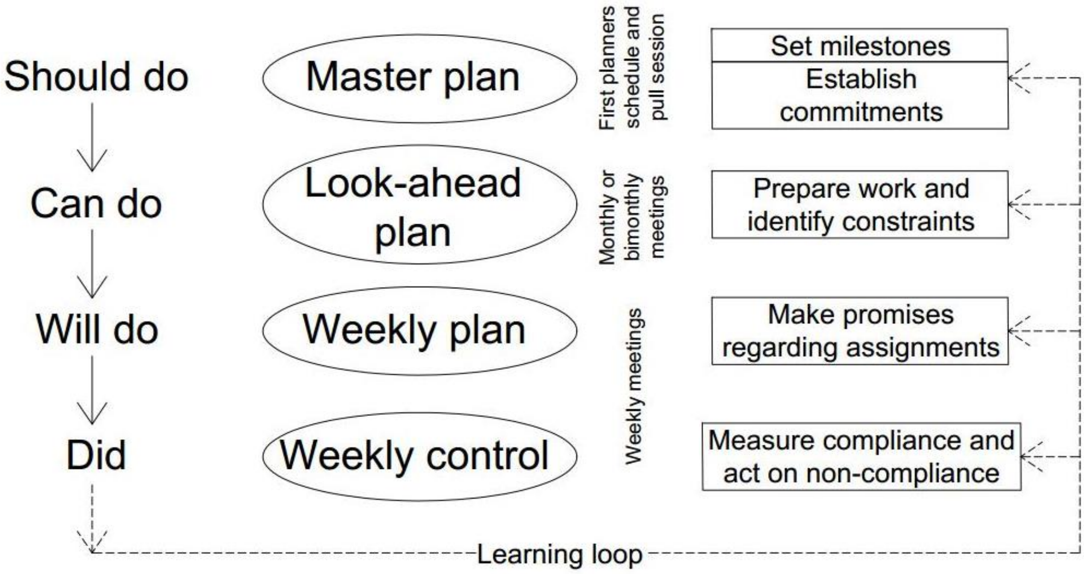

Figure 17 Summary of the Last Planner System (source: Pellicer, 2015, self adaptation)

A key stage of the process is the pull session because a committed group of decision makers define milestones and perform planning as a team. They have face to face discussions of every important tasks; the plan is composed starting from its final deadline, backwards forcing the participants to think out of the box. The participants in the pull session, not only have to be invited formally, but also coached on the rules and what is expected from them on the meeting in order to identify tasks, including time and resources needed, and identify constraints to perform those tasks (Pellicer, 2015).

It is a baseline expectation that all work in progress have at minimum a Weekly Work Plan, which is collaboratively created by each Production Team. Minimum weekly output requirements are (leanconstruction.org, 2013):

- Percent Plan Complete Chart (PPC)
  - A basic measure of how well the planning system is working and calculated as the 'number of promises/activities completed on the day stated' divided by the 'total number of promises/activities

made/planned for the week'. It measures the percentage of assignments that are 100% complete as planned.

- Variance Pareto
- Constraint Log w/timing ID Gauge
  - A list of Constraints with identification of an individual promising to resolve the item by an agreed date. Typically developed during a review of the Six Week Look-ahead Plan when it is discovered that activities are not constraint free.

To use LPS effectively, it is a must follow underlined principles (leanconstruction.org, 2013):

- Plan in greater detail as the work execution is getting closer
- Produce plans collaboratively with those who will do the work
- Reveal and remove constraints on planned tasks as a team
- Make and secure reliable promises
- Measure promises kept (planning capabilities, PPC) in order to improve by learning from variance (work flow disruptions)
- Continuously improve as a team, remove waste and adjust performance based on what has been learned as a means to optimize work flows

3.4.2 Material Kanban Cards

Material Kanban cards in lean construction represent the same tool as the Kanban system in lean manufacturing. It is used in a just-in-time environment to authorize the movement of parts and supplies from one work center to another or from raw stock to a workstation. key stage of the process is the pull session because a committed group of decision makers. The visual form contains product name, product identification, lot size and routing process , name, and destination of the subsequent process (Figure 18) (Schniederjans, 1993; Singh, 1996).

3.4.3 Increased Visualization

The increased visualization lean tool is about communicating key information effectively to the workforce through posting carious signs and labels around the construction site. Workers can remember elements such as workflow, performance targets and specific required actions if they visualize them. This includes signs related to safety, schedule, and quality. This tool is similar to the lean manufacturing tool, Visual Controls, which is a continuous improvement activity that relates to the process control (Salem, 2005).

3.4.4 Daily Huddle Meetings

Two-way communication is the key of the daily huddle meeting process in order to achieve employee involvement. As part of the improvement cycle, a brief daily start-up meeting was conducted where team members quickly give the status of what they had been working on since the previous day's meeting, especially if an issue might prevent the completion of an assignment. This tool is similar to the lean manufacturing concept of employee involvement, which ensures rapid response to problems through empowerment of workers and continuous open communication through the tool box meetings (Salem, 2005).

3.4.5 First Run Studies

First Run Studies are used to redesign critical assignments, part of continuous improvement effort; and include productivity studies and review work methods by redesigning and streamlining the different functions involved. The first run of a selected craft operation should be examined in detail, bringing ideas and suggestions to explore alternative ways of doing the work. A PDCA cycle (plan, do, check, act) is suggested to develop the study. Plan refers to select work process to study, assemble people, analyse process steps, brainstorm how to eliminate steps, check for safe, quality and productivity. Do means to try out ideas on the first run. Check is to describe and measure what actually happens. Act refers to reconvene the team, and communicate the improved method and performance as the standard to meet. This tool is similar to the combination of the lean production tool, graphic work instruction, and the traditional manufacturing technique, time and motion study (Salem, 2005).

3.4.6 Fail Safe for Quality and Safe

Chapter 4.3.5 described Poke-yoke devices as a tool that prevent defective parts from flowing through the process. Fail safe for quality relies on the generation of ideas that alert for potential defects. This approach is opposed to the traditional concept of quality control in which only a sample size is inspected and decisions are taken after defective parts have already been processed. This is similar to Visual inspection from lean manufacturing. Fail safe can be extended to safety but there are potential hazards instead of potential defects, and it is related to the safety risk assessment tool from traditional manufacturing practice. Both elements require action plans that prevent bad outcomes (Salem, 2005).

3.5 Lean versus Traditional

Traditional construction is too activity focused, control begins with tracking cost and schedule and efforts to improve productivity lead to unreliable work flow, further reducing project performance. Protecting activities leads to adversarial relations and planning systems cannot coordinate the work between crews. Figure 18 shows a comparison of the differences between lean construction and traditional construction (Kim, 2002).

3.6 Importance of measuring lean conformance

As the lean rapidly spreads among scholars and practitioners, a huge amount of literature has been presented since the early 1990. A need for lean conformance or level of "leanness" measuring, has increased. Measurement of lean conformance in this thesis will provide us information in general whether are construction companies ready for the applications of the lean construction methodologies and tools or even they already made an effort to transform its approach to Lean direction. Lean conformance investigates lean attributes and applicability of lean construction at various firms.

Lean Construction	Traditional Construction
Control	
Causing events to conform to plan - Steering	Monitoring against schedule and budger projections - Tracking
Optimization	
The entire project	Aspecific aktivity
Scheduling Viewpoint	
- Pull work schedule - Based on when its completion is required by a successor activity	- Push work schedule - Based on emphazing required start dates for activities
Production System	
Flow production system	Conversion production system
Production process	
Effectiveness	Efficiency
Performance Measurement	
Percent Plan Complete (PPC)	WBS, CPM, Earned Value
Customer Satisfication	
Successor proces satisfication	Owner or final consumer satisfication
Planning	
Learning	Knowing
Uncertainty	
Internal	External
Coordination	
Keeping a promise	Following orders
Goal of Supervision	
Reduce variation & Manage flow	Point speed & Productivity

figure 18 Comparison of Lean and Traditional practice (source: Kim, 2002)

4 Measuring Lean Conformance

The first part of this chapter, will present methodology for measuring lean conformance for contractors, with its limitations. The second part will be focused on the data gathered by this methodology and its analysis. To show results in a greater detail, some statistical tests and indicators will be performed, such as the average lean conformance value, ANOVA test, etc. As a conclusion, this chapter will be summarized, and the necessary discussion of the analysis will be presented.

4.1 Methodology

The whole methodology was prepared according to the document Measuring Lean Conformace, written by Diekmann and co. (2003). The document was prepared for Construction Industry Institute (CII) who was interested in the applicability of lean thinking to the construction process. As a solution for measuring lean conformance the team developed Lean Construction Wheel model (Figure 19) and prepared questionnaire based survey to acquire necessary data from various construction companies. To measure lean conformance in the Czech Republic, I have decided to perform a very similar questionnaire which contains the total of 31 questions. The first 4 questions deal with respondents' professional and occupational attributes. The questions 5 to 10 clarify operational characteristics of the firms.

The CII team developed the Wheel on the basis of using the same model to measure Value Stream Management. The Lean Construction Wheel has 5 main principles which are further divided into 16 sub-principles. Main principles are "Standardization", "Culture/People", "Continuous improvement/Built-in-quality", "Customer Focus", and "Eliminate waste". The number of sub-principles varies for each main principle, but as Diekmann (2003) said, all important lean principles (for construction) are included in this wheel. Each sub-principle is, in turn, represented by one or two questions. The number of questions for each sub-principle may vary questionnaire from questionnaire. I have decided to represent the most of sub-principles by one question and some of them by two questions.

The main principle "Standardization" deals with the visual management, workplace organization, and defined work processes as its sub-principles. Another main principle "Culture/People" is represented by training, people, involvement, and organizational commitment as sub-principles. Sub-principles "Error proofing", "Response to defects", "Metrics", and "Organizational learning" represent the main principle "Continuous improvement/Built-in-quality”. The next main principle “Customer Focus” as its sub-principles have flexible resources, and optimize value. The last main principle “Eliminate waste” deals with supply chain management, optimize production system, reduce process cycle time, and optimize work content.

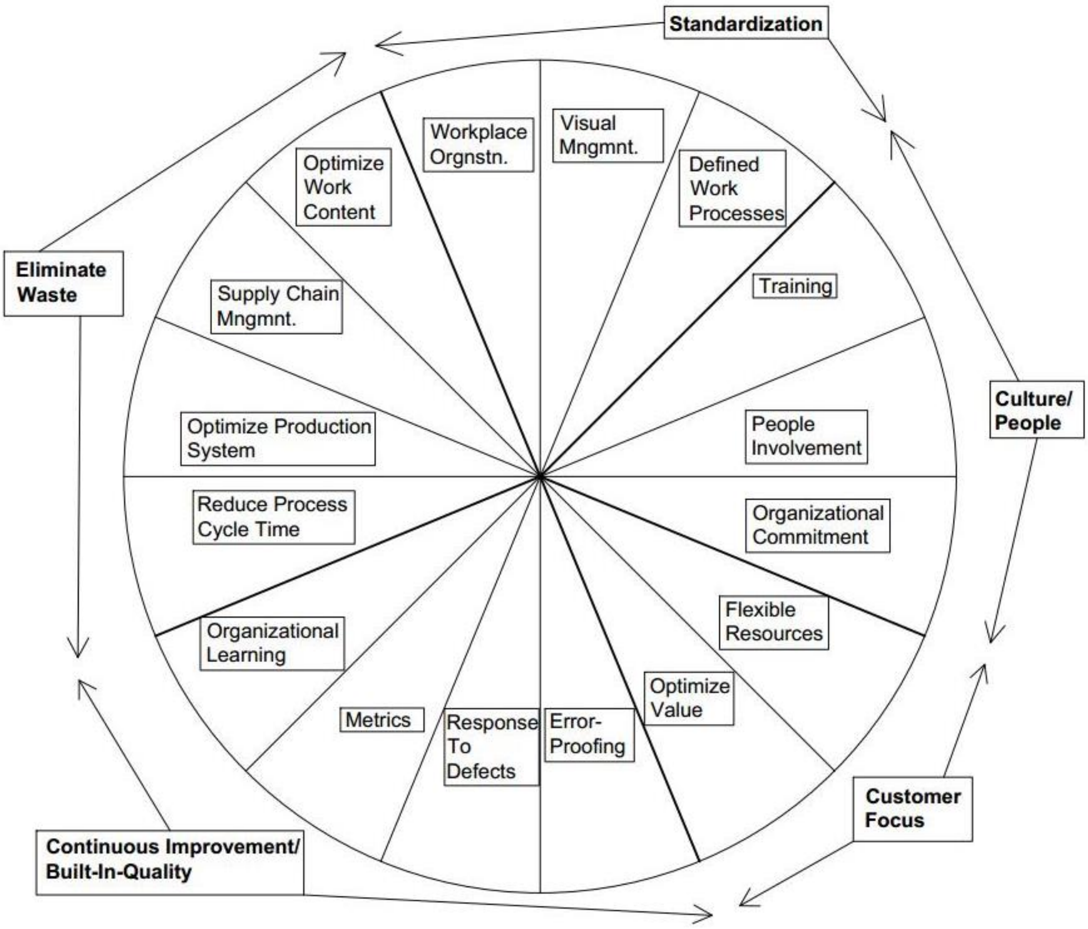

Figure 19 Lean Construction Wheel (source: Diekmann, 2003, seld adaptation)

This questionnaire survey has couple limitations. First, the questionnaire was prepared to be filled in only by contractors. Second, all of the respondents were chosen among lower, middle or upper level managers. Third, the questionnaire was not only used to the Czech contractors, but to the foreign ones operating in the Czech Republic as well. It is a survey majorly focused on internal operational aspects of contractors, rather than environmental aspects.

The form of questions is shown in Figure 20. Respondents are asked to evaluate the practices within their company. Besides, each question has two statements and the respondent is asked to identify proximity or conformance of the practices to one of these two statements. The system of answering is very simple, if the practice within their company completely fits to the statement on the left, respondent should mark number one. If the practice is closer to the statement on the left than on the right side, the number 2 to be marked. The principle on the right side for number 4 and 5 are totally the same as on the left side. For answers 50/50, the number 3 is prepared. Nevertheless, the fact that the person has no idea or thinks that these statements are irrelevant, then N/A choice is marked. As you can see in Figure 20, the statement on the right side represents leaner practice. This system is the same for each question. This questionnaire was first carried out to be easily filled in on paper or in an interactive PDF version. Later it turned out that this way is highly ineffective, and respondents are more willing to answer right in the internet browser. So, the questionnaire was reworked to an online version by using Google Form. As the survey was made in the Czech Republic, the whole questionnaire was in Czech language. The English version can be provided on inquiry.

There is no posted information regarding schedule, quality, safety, productivity, or job status.	1 2 3 4 5 N/A	The jobsite uses visual devices that communicate job status and requirements on schedule, quality, safety, and productivity to everyone.

Figure 20 A sample question (source: Diekmann, 2003)

4.2 Results‘ assessment

To assess the Lean Conformance in the Czech Republic, 100 contractors were chosen and asked to participate in the questionnaire survey, which is explained above. First, 33 of the contractors were chosen on the basis of the Czech journal “Stavebnictví” which evaluates construction companies in the Czech Republic. The rest of 67 contractors were chosen among the members of Association of Building Entrepreneurs of the Czech Republic (ABE). Out of all 100 attempts, 41 respondents agreed to contribute to the survey and filled the questionnaire form. It corresponds to a response ratio of 41 percent. All the answers were collected by using Google Forms online application.

4.2.1 Respodents‘ attributes

First of all, respondents were asked four questions related to their professional life. In the first question, respondents answered what kind of position they hold (Figure 21).

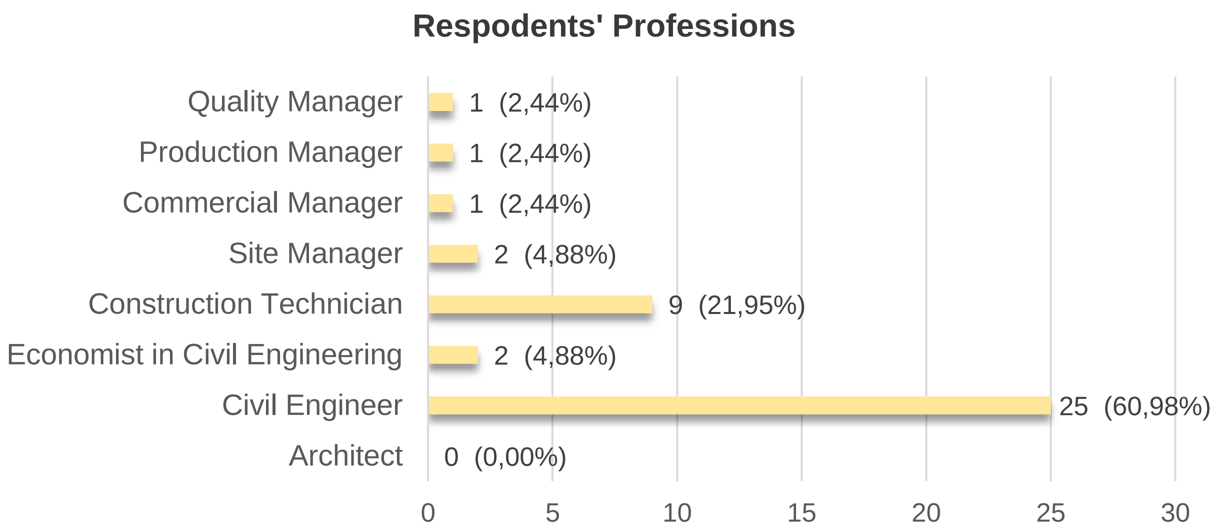

Figure 21 Respondents' Professions

As Figure 21 indicates, more than a half of respondents is represented by Civil Engineers. The second largest group of respondents are Construction Technicians and the rest of respondents is divided into small groups of one or two persons.

In the second question, respondents were asked about their level of education. Only one respondent achieved a PhD. degree, 33 of them achieved Master degree and 7 respondents started their professional life right after the high school graduation.

The third question aimed at finding out respondents' managerial positions. As I have mentioned before, only respondents of the lower, middle or top management were asked to contribute to the survey. As Figure 22 shows, 19 respondents represent middle management position, and both lower and tom management positions are represented by 11 respondents.

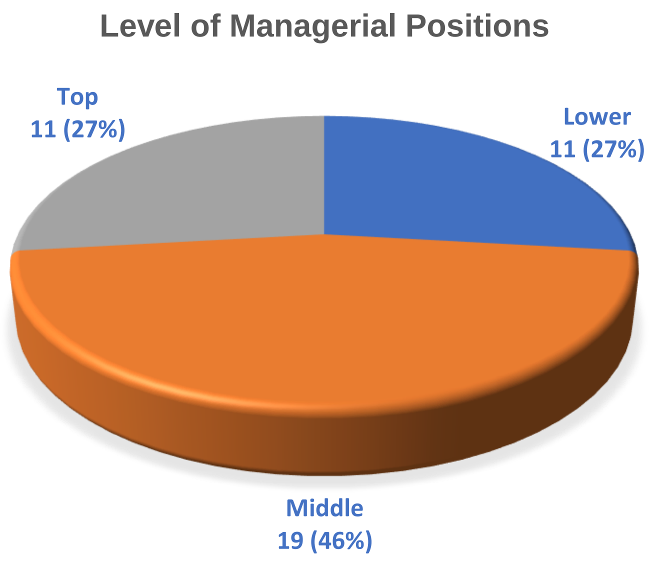

Figure 22 Level of Managerial Positions

The last question is related to the level of experiences in the current respondent's position. Figure 23 shows that respondents' experiences are approximately evenly distributed to all levels. This fact grants to the survey a better informative value.

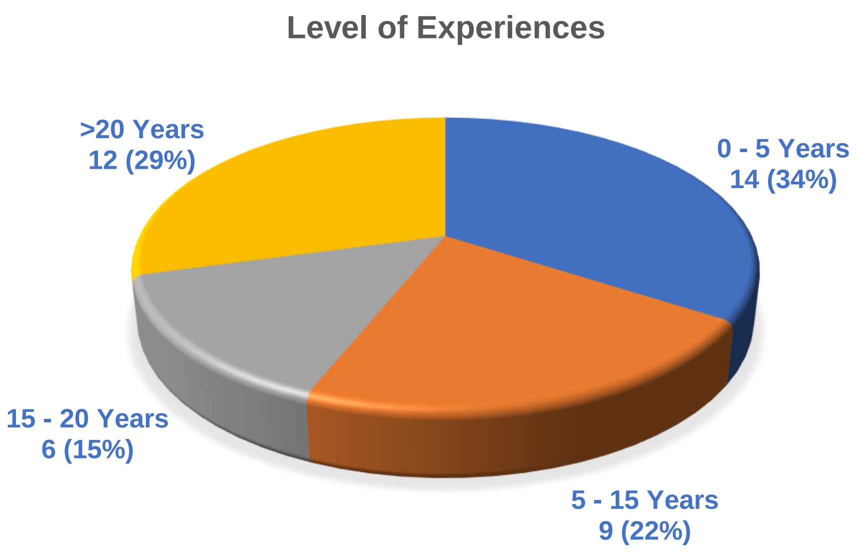

Figure 23 Level of Respondents' Experiences

4.2.2 Companies‘ ascpects

The second part of the questionnaire is focused on the aspects of the whole company. By answering the question 5-10, respondents provided information about the area of expertise, operational time since its foundation, average number of employees, average annual turnover, major clients, and about geographical operations.

The results of the areas of expertise are shown in Figure 24. As we can see respondents are mostly employees of the companies focused on commercial and residential buildings. A very small proportion of respondents are employed by companies focused on civil engineering or design. This question is a multi-answer, so the sum of the numbers in Figure 24 does not fit the number of responses because some companies are multi-expertise.

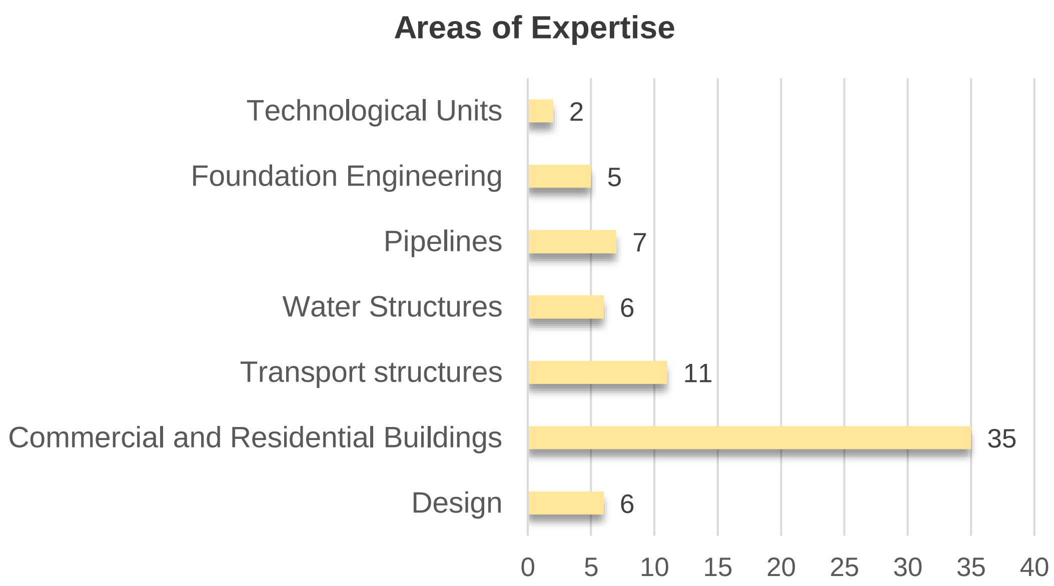

Figure 24 Areas of Expertise

Another question is related to operational time since its foundation. Almost three quarters of all companies have more than 20 years of experiences. A much smaller part of the companies, represent the group of 15-20 years of experiences and the rest is divided into the groups under 15 years (Figure 25).

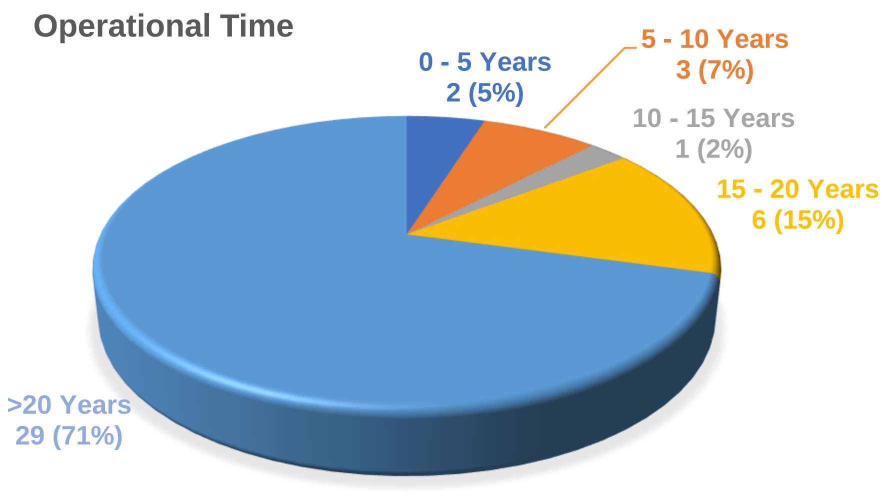

Figure 25 Operational Time

Question number 7 provides an information about the average number of employees in respondent's company (Figure 26).

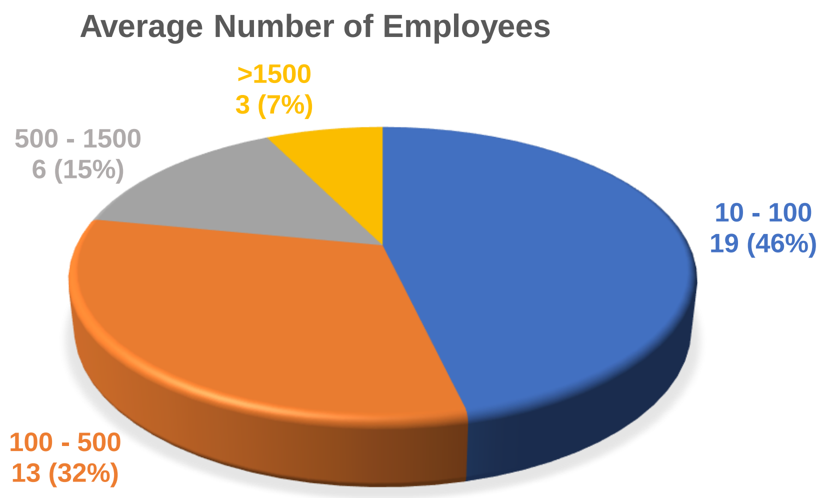

Figure 26 Average Number of Employees

The question related to average annual turnover is the last that will be displayed (Figure 27). As we can see, none of the respondents is employed by a small-size company with average annual turnover under 10 million Czech crowns.

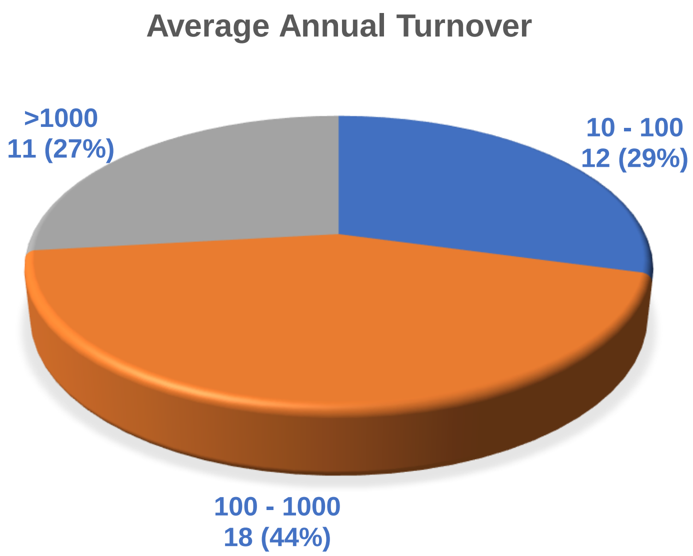

Figure 27 Average Annual Turnover

Question number 9 provides and information about their major clients. Almost 83 percent of the companies cooperate both with the public sector and the private sector. Almost 15 percent are only focused on the private sector and only 2 percent (1 company) is only focused on the public sector.

The last questions concerning company aspects asked respondents about the companies' geographical operations. More than a half of the contributing companies operate only in the Czech Republic, the rest operate both in the Czech Republic and abroad.

4.2.3 Analysis of single questions

Figure 29 shows the frequency of the answers for each question in Lean Conformance questionnaire. In total 41 respondents answered 21 questions, it equals 861 answers. Figure 28 indicates answer ratios for each choice.

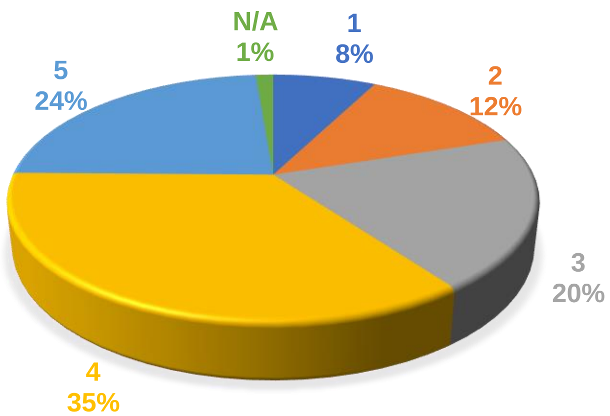

Figure 28 Answer Ratios

Type of question	Answer frequency					
	1	**2**	**3**	**4**	**5**	**N/A**
“Standardization”						
Visual Management - 1	8	8	7	12	6	0
Visual Management - 2	7	10	8	10	5	1
Workplace Organisation	1	3	6	16	15	0
Defined Work Processes	12	14	4	7	3	1
People/Culture						
Training	1	4	7	8	21	0
People Involvement	0	6	11	15	9	0
Organizational Commitment	0	0	8	20	13	0
“Customer Focus”						
Optimize Value	1	0	3	16	20	1
Flexibility	0	1	8	18	14	0
“Eliminate waste”						
Supply Chain Management - 1	1	3	7	20	10	0
Supply Chain Management - 2	0	4	3	24	10	0
Optimize Work Content - 1	18	2	5	5	10	1
Optimize Work Content - 2	0	0	9	20	12	0
Reduce Process Cycle Time - 1	0	1	9	20	10	1
Reduce Process Cycle Time - 2	1	5	14	17	4	0
Reduce Process Cycle Time - 3	5	7	12	10	4	3
Optimize Production System	1	9	10	14	7	0
Continuous Improvement/ Build-In-Quality						
Error-Proofing	0	6	13	15	7	0
“Response to defects”	4	8	10	11	7	1
“Metrics”	4	12	8	11	5	1
“Organizational learning”	1	4	10	15	10	1
Total	**65**	**107**	**172**	**304**	**202**	**11**

Figure 29 Answers’ Frequencies (source: self-performed questionnaire survey)

As we can see, each choice has a different answer ratio. The highest answer ratio is achieved by choice number 4. The second rank is taken by number 3 and the third, by number 5. As number 4 means “Rather yes”, we could assume that the sample of companies is oriented rather to the Lean than to the Traditional practice. On the other hand, this assumption would be too hasty, because we do not know what the overall numbers are.

Type of question	Mean
Flexibility	2,81
Optimize Work Content - 2	3,14
Visual Management - 1	3,14
Optimize Work Content - 1	3,24
“Organizational learning”	3,24
Optimize Production System	3,48
Supply Chain Management - 1	3,52
Optimize Value	3,67
“Response to defects”	3,71
Visual Management - 2	3,71
Error-Proofing	3,76
Organizational Commitment	3,76
Training	3,76
People Involvement	3,81
Reduce Process Cycle Time - 2	3,90
Defined Work Processes	4,00
Workplace Organisation	4,00
Reduce Process Cycle Time - 3	4,24
Supply Chain Management - 2	4,29
“Metrics”	4,52
Reduce Process Cycle Time - 1	4,67

Figure 30 Mean values of each question, sorted ascending (source: self-performed questionnaire survey)

As we can see in Figure 30, there is the lowest mean achieved by question Flexibility. This fact can indicate the problem with flexible acting, caused by some issues or demanded by customers. On the other hand, the best score been achieved by question Reduce Process Cycle Time – 1 which can mean that the companies are really employing some measures to reduce construction time.

4.2.4 Analysis of main principles

As explained in the Methodology part (4.1), the questions are divided into the 5 general groups which represent the 5 main fields of focus (main principles) in Lean Construction. Nevertheless, each principle differs by the number of questions (Figure 29). Due to this fact, each principle forms the different value of the final overall Lean Conformance (value ≠ weight). The most valuable principle is “Eliminate waste” which produces 38% share of the final Lean Conformance value. The rest of values for each principle are shown in Figure 31.

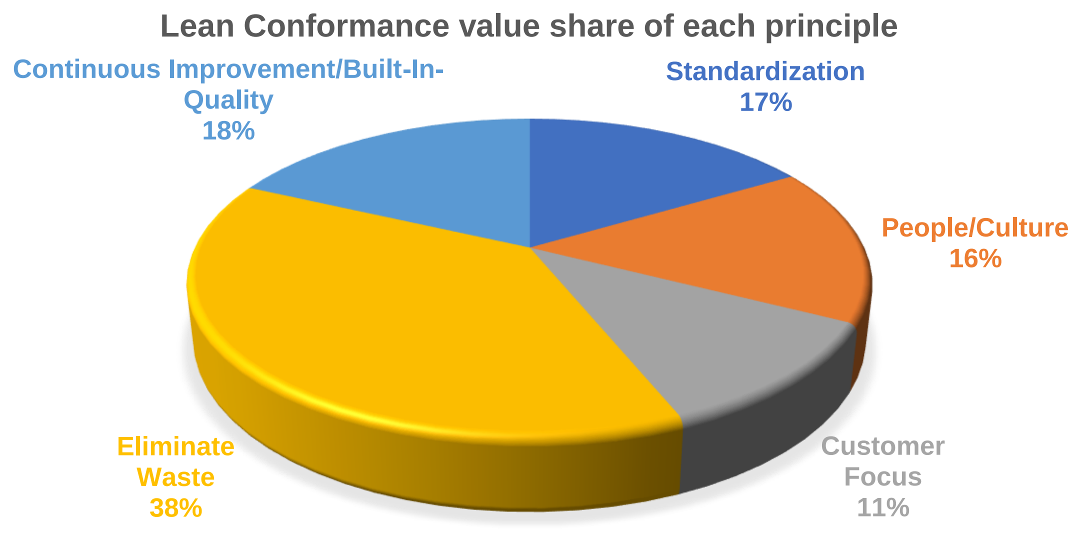

Figure 31 Lean Conformance value share of each principle

As well as we can determine the final Lean Conformance value of the data sample which will be performed later, we can also determine the Lean Conformance value for each main principle. The "leanness" of each principle can be determined according to the following formula:

$$Leanness\ (\%) = \frac{Real\ Value\ (of\ the\ principle) * 100}{Maximum\ Possible\ Value}$$

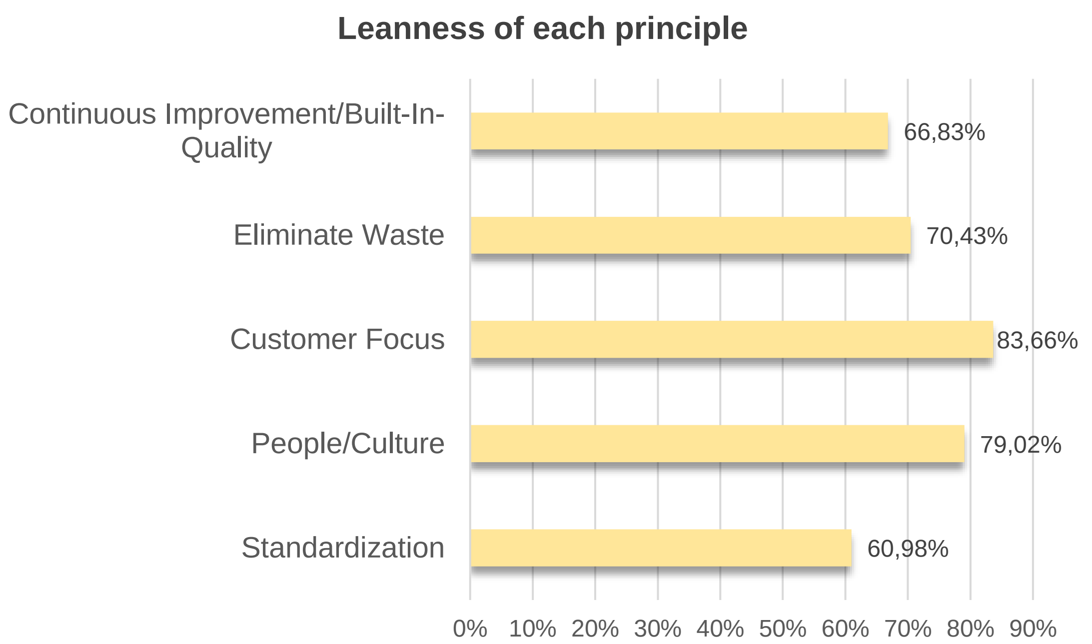

Figure 32 Leanness of each principle

Figure 32 shows quite clearly that companies are opened the most to the principle "Customer Focus", which aims at the client's satisfaction. On the other hand, the least lean is the principle "Standardization". This could be caused by the complicated regulations for standards' utilization.

Type of principle	Mean
"Standardization"	3,05
Continuous Improvement/Build-In-Quality	3,34
"Eliminate waste"	3,52
People/Culture	3,95
"Customer Focus"	4,18

Figure 33 Mean values of each principle (source: self-performed questionnaire survey)

4.2.5 Overall Lean Conformance analysis of data sample

This part of results' assessment is going to present descriptive statistic values and results of some statistical tests which are going to provide us with relevant conclusions. First of all, the assessment of the overall Lean Conformance value must be performed to get both the basic data for survey conclusions and the ground for further statistical tests. Lean Conformance is expressed as a percentage value which indicates a "lean" behaviour, whereby the higher number, the leaner behaviour of the company. Overall numbers are going to reveal the general situation in the Czech construction industry and possibilities for further lean construction studies and the for the applications of the lean methodologies/tools.

Lean Conformance formula:

$$Lean\ Conformance\ (\%) = \frac{\sum Answer\ Value}{105} * 100$$

The Lean Conformance of both data sample and each company was performed by the above-mentioned formula. Each question, which can be of a value 1, 2, 3, 4, 5 or N/A have the same weight. The N/A answer is considered as 1, because if the respondent does not know what to answer it means, that he or she has no idea about the practice in his/hers company or has no idea about the lean statement mentioned in the question. The descriptive values of the data sample's Lean Conformance are shown in Figure 34.

Min	Max	Mean	Median	Mode	Standard Deviation	Kurtosis	Skewness
39,05	93,33	70,43	70,48	69,52	10,37	1,50	-0,46

Figure 34 Data sample's Lean Conformance descriptive values (source: self-performed questionnaire)

As we can see in Figure 34, the mean of the Lean Conformance is 70,48%. The skewness indicates that the Normal Curve is slightly skewed to the right side. (Figure 36). Due to this fact it is a must to perform the normality test which will find out, whether the data sample follows the normal distribution, and is convenient for further testing or not (Engineering Statistic Handbook, 2006). The normality test is performed using the statistical software Minitab®.

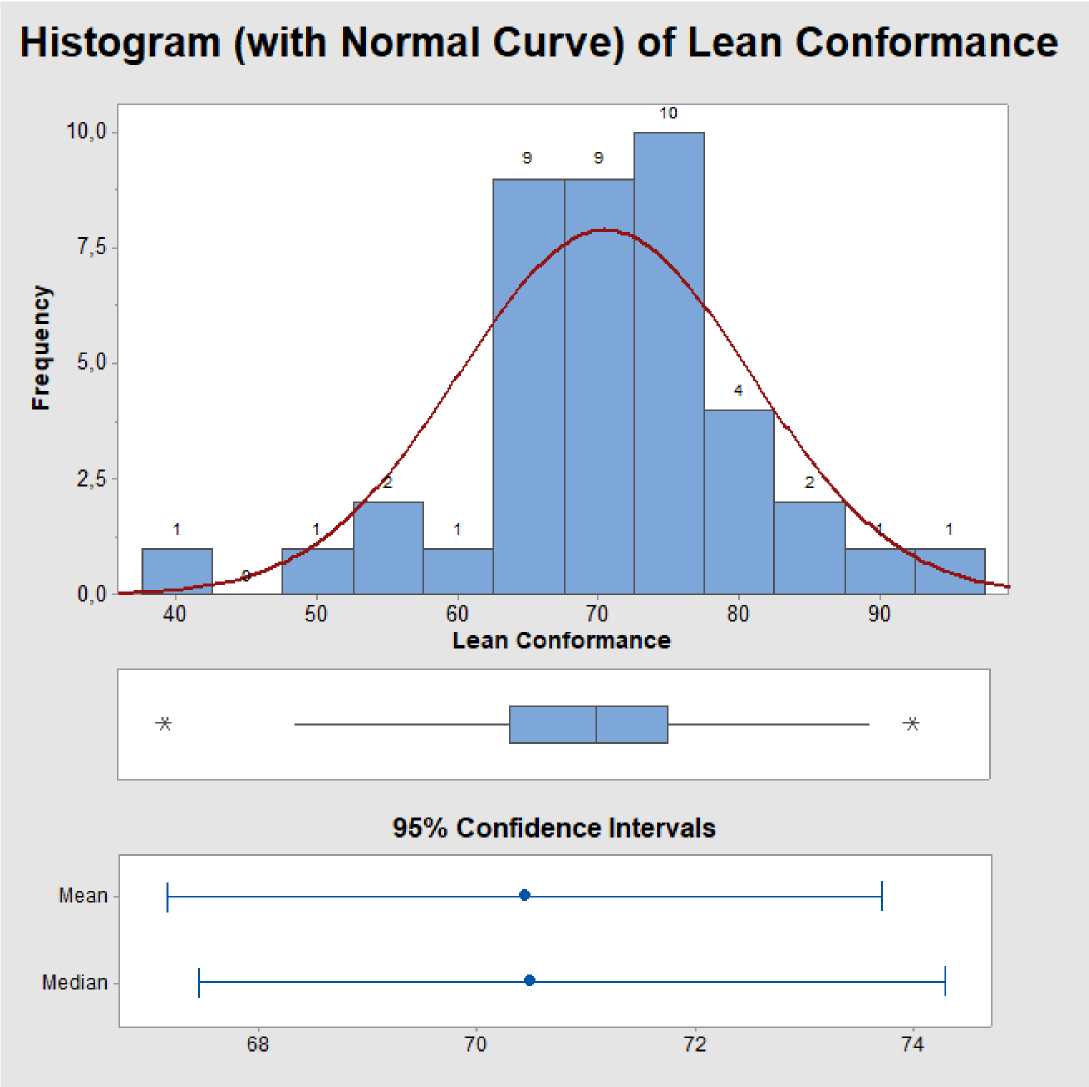

Figure 35 Histogram of Lean Conformance (source: self-performed questionnaire, Minitab® 18)

P-value in Figure 36 means a probability that measures the evidence against null hypothesis. A smaller p-value than the significance level (0,05 is commonly used), provides stronger evidence against null hypothesis. To put it simply, if the p-value is higher than 0,05 the data sample follows the normal distribution (Engineering Statistic Handbook, 2006). In our case, all the tests proved a higher p-value. We can say that our data sample follows normal distribution.

Type of Normality Test	P-Value
Anderson-Darling	0,347
Ryan-Joiner	> 0,100
Kolmogorov-Smirnov	> 0,150

Figure 36 Normality tests (source: Minitab® 18)

As mentioned before, the data sample is convenient for further analysis. As the most commonly used test available is one-way ANOVA test, which is used to compare the means of two or more groups to determine whether they differ significantly from one another. This test is only an addition which could point at the interesting questions, beneficial to the final discussion performed at the end of this chapter. The ANOVA test would only show that the Lean Conformance results are dependent on certain factor (Minitab® 18 Support, ©2017). For our testing, I sorted companies according to the average number of employees and the average annual turnover. This sorting can be seen in Figures 26 and 27. The two ANOVA tests were performed using Minitab® 18. Each of them tried to find a dependency on sorting factors. The results are presented in Figure 37.

	P-Value
ANOVA 1	0,347
ANOVA 2	> 0,100

Figure 37 ANOVA test results (source: Minitab® 18)

To explain results of ANOVA tests, the principle is very similar to the normality test. The p-value (probability that measures the evidence against the null hypothesis) is calculated according to an extensive algorithm and then compared to significance level (commonly used 0,05, which indicates a 5% risk of concluding that a difference between the means exists, when there is no actual difference). If the p-value is equal to or lower than 0,05, the difference between some of the means in statistically significant. Otherwise, there are no significant differences. In our case both p-values were determined as higher than significance level (Minitab® 18 Support, © 2017). We can say that is no dependency neither on the number of employees, nor on the annual turnover. The whole tables with results can be found in addendums.

4.3 Discussion of questionnaire survey

As the results of the questionnaire survey have been presented above, there is the time to discuss conclusions. The most important result of the survey is that the overall average Lean Conformance value of the sample is equal to 70,43 percent. This mean and median equal to 70,48 percent indicate that the contractors are at least promisingly open to the new approaches and its application including all the principles, methods, and tools. Having the potential interest of the contractors in the Czech Republic, other attempts to spread “lean ideology” could be systematically performed.

Nevertheless, back to the questionnaire structure. If we take a closer look at the Lean Construction Wheel (Figure 19), we can see five main principles and for each of them, a certain amount of sub-principles which are almost correspondent with the amount of the questions in the questionnaire.

The first group of questions is related to the principle “Standardization”. “Standardization” and its sub-principles aim at finding, for example, whether the company is open-minded to sharing relevant information concerning schedule, cost, and productivity with all the staff and manager. Or if the company’s priority is clean, organized, and logical operational jobsite, which can lead to a shorter cycle and an increased productivity. As we can see in Figure 33, the average choice within the question related to this principle is 3,05 which means “50/50”. This fact can be caused by complicated regulations for standards’ utilization or by the financial demands of the proper “Standardization”. On the other hand, the overall leanness of this principle is very close to 70 percent (Figure 32), which looks more promising to a further commitment of the companies in the “Standardization”.

Another group of questions is “Culture/People”. This principle is focused on the environment inside the company. Respondents are asked about the employee training, commitment of the staff to the company’s goals, and about the degree of commitment to the principles and practices of lean execution by managerial employees. This principal is crucial for the success in lean utilization because without a solid chain of employees, from top management to the last labourer, the full lean behaviour of the company cannot be reached. Fortunately, both average choice and leanness of this principle, is signalized by the answer “Rather Yes”, which means that companies realize the importance of the healthy environment within the company.

The third group focuses on the customer. Due to this fact, it is called “Customer Focus”. This principle comprises of two sub-principles. The first is Flexible Resources which is focused on the ability to adapt to customer requirements and to change to meet their needs. This includes the capability not only to order material and equipment immediately, but also to quickly inform the personnel about the scope of change and to help them adapt to the new requirements.

The second sub-principal is Optimizing Value. As the name indicates by asking question related to optimizing value, the survey is trying to find out, whether the company concerns maximizing the outcome of the project by understanding the requirements of the customer. While assessing the survey results, the Customer Values scored the best among all the main principles. By achieving the leanness value at the almost 84 percent, this principle is the only one considered as “Yes”, which means perfect lean behaviour. However, 84 percent is very close to the 80 which is the border value of “Rather Yes” answer. Besides, the mean of the choice ended up as 4,18 which is in “Rather Yes” level as well. The above-mentioned facts indicate that companies strive for satisfaction of the customer as their highest priority.

The main principle with the largest number of questions is “Eliminate waste”. It is clear, that the principle aims at eliminating construction waste. Types of construction waste are described in chapter 3.3 Lean Construction principles. This field of performance is divided into four sub-principles: Supply Chain Management, Optimize Production System, Reduce Process Cycle Time, and Optimize Value. So far, the questions of the above-mentioned principles, except one, were represented by only one question. However, the principle “Eliminate waste” is such an extensive field, that it deserves to be asked in a more detailed manner than the others (Figure 29). Combination of the leanness at the almost 70 percentage value and mean of the choices for this principle at 3,52 indicates, that the companies make an effort to “Eliminate waste” efficiently, but still struggle with the utilization and fulfilment of the Lean Construction principles.

The last principle is related to continuous improvement which is another topmost principle that represents a part of the lean wheel. The lean ideology is not something that could be considered as a formed methodology within set boundaries. The other way around, lean is based on the continuous improvement which ensures the most possible advancement of the methods/tools. The Czech construction companies in our data sample presented themselves as opened to the ideas of continuous improvement, but not successful with using the methodology. This fact is supported by mean of the choices at the 3,34 value and principle leanness at approximately 66 percent. This reality could be caused be the nature of the construction industry which is more “stay-backward” related, rather than “open-minded”.

Conclusion

The primary aim of the diploma thesis was to analyse lean thinking principles and techniques in detail, in order to help contractors, understand their internal practices better from the lean perspective. Last but not least, another aim was to determine the interest of the Czech construction companies in the usage of lean principles. Based on these aims, two research question were asked:

No. 1 How does the implementation of lean construction principles and techniques affect project performance?
No. 2 Are Czech construction companies using the advantages of lean construction principles?

First of all, I have analysed the current situation in the construction industry. The results of this analysis reveal that the construction industry is paralyzed by the overall demand stagnation. This fact is caused by the problems such as the blind pursuit of the lowest price in an exchange for the project quality. That is mainly caused by the incorrect setting of the public procurement system. Another obstacle considered for inhibiting the growth is the excessively long process of projects' approval which decreases productivity, and last but not the least, it is the lack of skilled labor workforce especially among craftsmen. This fact is supported by the lack of interest among young people, who do not favour the crafts to be ranked too high among other professions. The way how to support the overall growth is to challenge ourselves by our own mistakes, to accept them and to try to transform them into a propulsion power that will help us not only to follow successful western countries, but even to outrun them. A highly effective way is to forget about the traditional practices which predestine our way of thinking making it hard to accept anything else. Nevertheless, as well as the government, the construction firms have to change the way of thinking and focus on their internal values. The turn ahead to the innovative approaches such as Lean or BIM is a trend of increase in efficiency.

The middle part of this thesis is focused on the lean thinking at the whole. Starting with the Lean Manufacturing principles, and ending with the principles and methodology of the Lean Construction that answers the research question No. 1. One of the improvements resulting in shorter cycle times and increased productivity. This can be caused simply by keeping things consistent for workers, for example clean, organized and logically operated job site. By putting the clients onto the highest level of priority, the company ensures clients' satisfaction. It leads to a willing cooperation that avoids further disputes slowing down project execution and avoids problems with client's liabilities fulfilment. By applying the principle dealing with the waste elimination, the company tries to eliminate as much downtime as possible. And again, downtime results in decreased productivity, which leads to failure to meet deadline, cause the loss of money and reputation. The implementation of the lean principles also means accepting philosophy of continuous improvement. None of the projects, companies, institutions, governments would never be able to grow and improve its performance, without learning from their mistakes. although, not every lean principle is focused on projects' performance, each supports the others. Without a smooth project execution, the company cannot grow, but a sick internal environment of the company will surely not improve project performance either.

The final part of the thesis introduced the survey intention and its results. The survey was done in a questionnaire form and asked the questions related to Lean Conformance. Simply put, Lean Conformance means whether a company is using or is at least opened to the lean principles and techniques. 100 companies in total, were asked to contribute in the survey. The result of the collecting the filled in questionnaires is 41 forms which leaves us with 41 percent answering ratio which is rather satisfactory. Respondents had a choice to answer the question by choosing numbers from 1 to 5 or N/A, whereby 5 means that they agree with the statement and 1 means that they do not agree. N/A is for those who do not understand the question or have no clue what it means. After searching for the best way to assess the results, I decided to sort them according to the single questions, main principles, and the overall Lean Conformance results. Each part of the results' assessment gives us a different scope of view. The Analysis of single questions shows how the companies scored in using the single sub-principles and techniques stated in the questionnaire (Addendums). The best score recorded the question Reduce Process Cycle – 1. The ratio is 4,67 and it reflects a very high interest of the companies to avoid downtime and to decrease process time as much as possible. The most chosen answer was number 4 which gives the ground to answer research question No. 2 that the companies included in the data sample are using the lean principles rather than principles of traditional practice. On the other hand, the assessment of the main principles, show us the "leanness" of the companies. The leanest principle overall is "Customer Focus". This fact indicates that the client is the highest priority of the companies. Finally, the overall results of the Lean Conformance were carried out. Before, the results assessment, the fact that the data have a normal distribution (found by normality tests) gave us a chance to find out whether the size of the company plays and important/decisive role or not. To find out, ANOVA tests were performed, but none of them proved any dependency at all. The mean of the Lean Conformance in our data sample is 70,43 percent. Due to this value, the contractors can be considered as at least promisingly opened to the new approaches and its application including all the principles, methods, and tools. Having the potential interest of the contractors in the Czech Republic, other attempts to spread “lean” ideology” could be systematically performed in order to restore and increase the growth and prosperity of this diverse, comprehensive and beautiful industry, as the construction definitely is.

List of figures

Figure 1 – RIBA Plan of Work (source: ribaplanofwork.com, 2013, self adaptation) 12
Figure 2 Toyota Production System "House" (source: lean.org, 2014, self adaptation) 27
Figure 3 Relationship Among Predictability, Flexibility and Stability (source: isixsigma.com, © 2000-2017, self adaptation) 28
Figure 4 Heijunka box (source: isixsigma.com, © 2000-2017, self adaptation) 29
Figure 5 Push vs. Pull (source: AllAboutLean.com, © 2015, self adaptation) 31
Figure 6 Push vs. Pull (source: AllAboutLean.com, © 2015) 32
Figure 7 Kaizen = Continuous Improvement (source: © Kaizen Institute, 1985-2017) 35
Figure 8 Example of Andon signals (source: Whatissixsigma.com, 2017) 37
Figure 9 Lean Core Elements (source: Picchi, 2001) 39
Figure 10 Lean Core Elements (source: Picchi, 2001) 40
Figure 11 Project's resources demands (source: manageit.cz, © 2016, self adaptation) 42
Figure 12 Difference between construction and manufacturing industry (source: Gao, Low, 2014) 45
Figure 13 Comparison of Lean Techniques (source: Paez, 2005) 48
Figure 14 Goals of Lean Construction techniques (source: Paez, 2005) 48
Figure 15 Traditional management practise (source: Ballard, Howell, 1997, self adaptation) 49
Figure 16 Last Planner planning process (source: Ballard, Howell, 1997, self adaptation) 50
Figure 17 Summary of the Last Planner System (source: Pellicer, 2015, self adaptation) 51
figure 18 Comparison of Lean and Traditional practice (source: Kim, 2002) 55
Figure 19 Lean Construction Wheel (source: Diekmann, 2003, seld adaptation) 57
Figure 20 A sample question (source: Diekmann, 2003) 58
Figure 21 Respondents' Professions 59
Figure 22 Level of Managerial Positions 60

Figure 23 Level of Respondents' Experiences 60
Figure 24 Areas of Expertise 61
Figure 25 Operational Time 62
Figure 26 Average Number of Employees 62
Figure 27 Average Annual Turnover 63
Figure 28 Answer Ratios 63
Figure 29 Answers’ Frequencies (source: self-performed questionnaire survey) 64
Figure 30 Mean values of each question, sorted ascending 65
Figure 31 Lean Conformance value share of each principle 66
Figure 32 Leanness of each principle 66
Figure 33 Mean values of each principle (source: self-performed 67
Figure 34 Data sample's Lean Conformance descriptive values (source: self-performed questionnaire) 68
Figure 35 Histogram of Lean Conformance (source: self-performed questionnaire, Minitab® 18) 68
Figure 36 Normality tests (source: Minitab® 18) 69
Figure 37 ANOVA test results (source: Minitab® 18) 69

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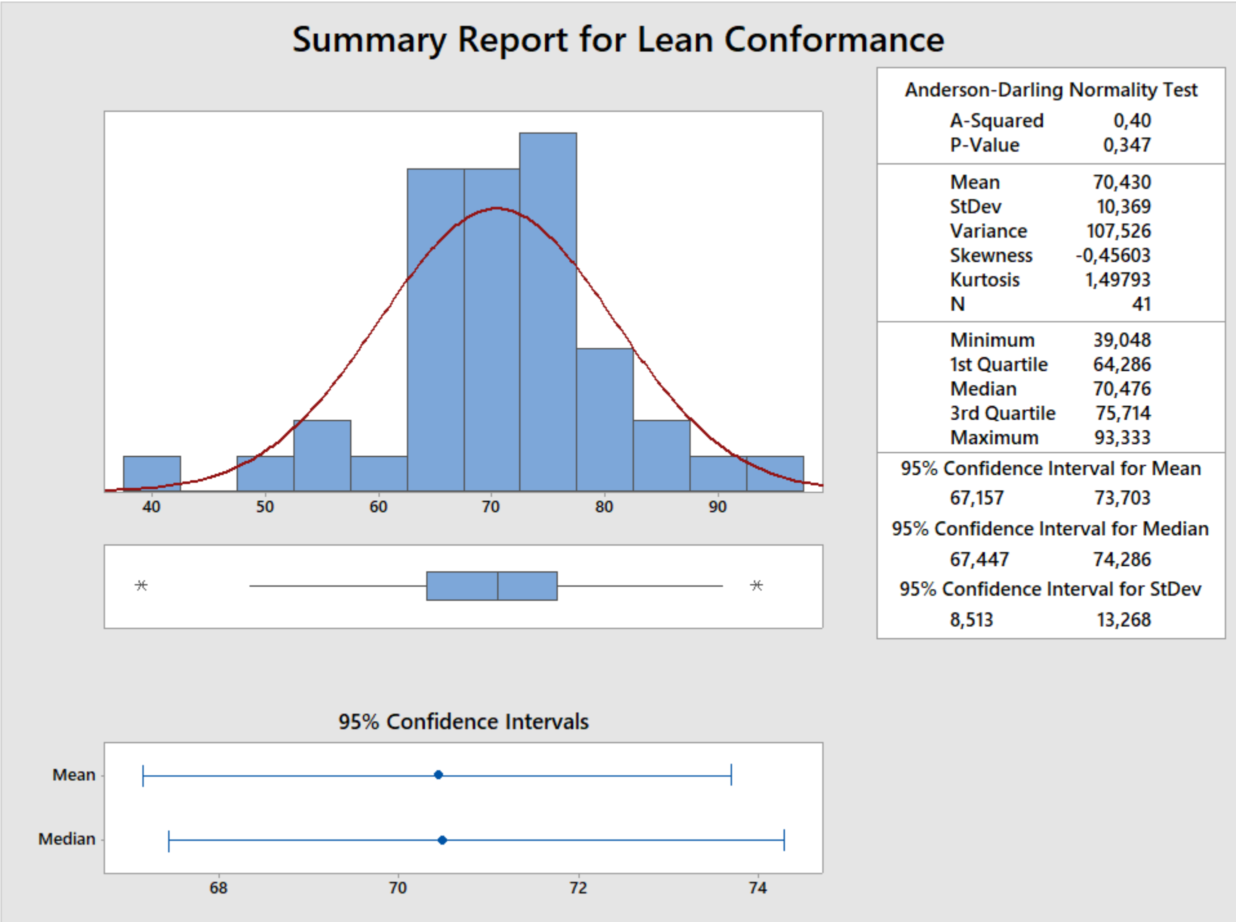
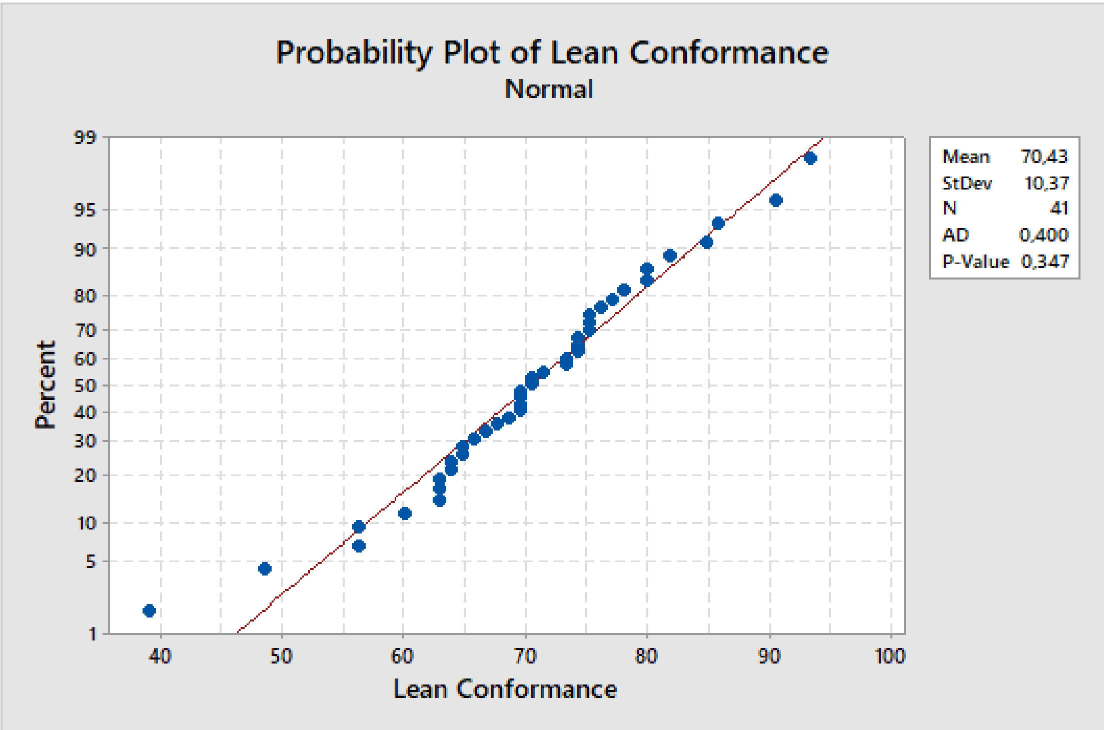
Addendums

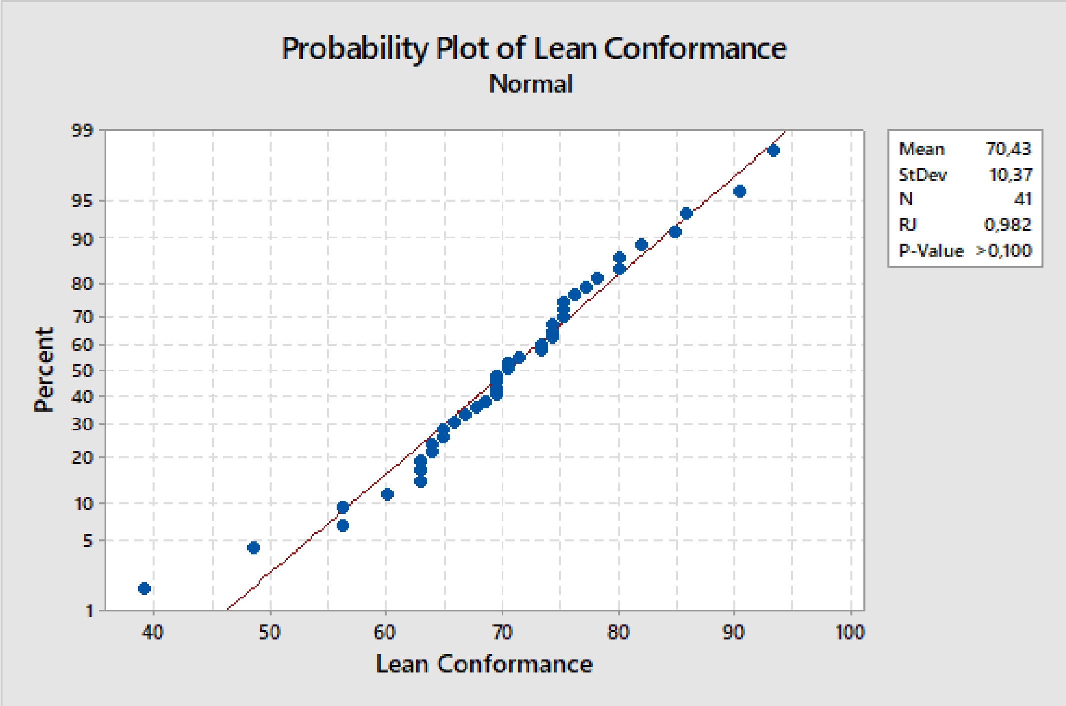
1. Summary report



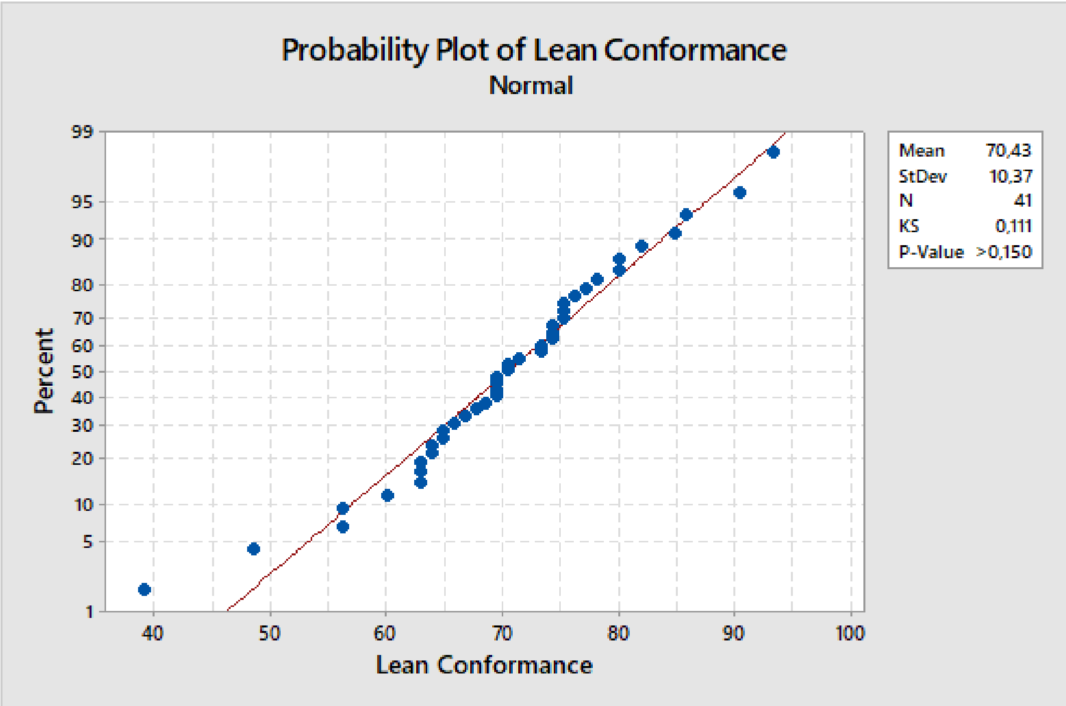
2. Anderson - Darling normality test



3. Ryan – Joiner normality test



4. Kolmogorov – Smirnov normality test



5. ANOVA test result

One-way ANOVA: "10-100; 100-500; 500-1500

Method

Null hypothesis	All means are equal
Alternative hypothesis	Not all means are equal
Significance level	α = 0,05

Equal variances were assumed for the analysis.

Factor Information

Factor	Levels	Values
Factor	3	"10-100; 100-500; 500-1500

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Factor	2	180,9	90,45	0,82	0,447
Error	36	3950,5	109,74		
Total	38	4131,4			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
10,4756	4,38%	0,00%	0,00%

Means

Factor	N	Mean	StDev	95% CI
"10-100	19	51,74	11,08	(46,86; 56,61)
100-500	14	56,29	9,42	(50,61; 61,96)
500-1500	6	52,00	10,83	(43,33; 60,67)

Pooled StDev = 10,4756

DOTAZNÍK

Tento dotazníkový formulář byl připraven ve spolupráci s Katedrou ekonomiky a řízení ve stavebnictví, fakulty Stavební, ČVUT v Praze. Výsledky dotazníkového průzkumu budou sloužit jako podklad pro vypracování diplomové práce.

Během vyplňování dotazníku dbejte na:

1. **Pozorně čtěte instrukce, znění otázek a odpovědí.**
2. **Snažte se být objektivní a odpovídat co nejvíce pravdivě.**
3. **Pokud není uvedeno jinak, každé otázce přiřaďte pouze jednu odpověď.**
4. **Pro označení odpovědi, stačí kliknout do jednoho ze čtverečků ( ), který se následně označí křížkem. Pro odznačení odpovědi, opětovně klikněte na čtvereček a křížek zmizí.**
5. **Pokuste se odpovědět na všechny otázky v dotazníku.**
6. **Před ukončením dotazníku zkontrolujte, zda jsou zodpovězeny všechny otázky.**
7. **Jakmile dokončíte dotazník, uložte jako nový soubor a přejmenujte jej.**
8. **Hotový dotazník odešlete na e-mailovou adresu potuzak.h@gmail.com**
9. **Zaručujeme se, že veškeré firemní a osobní informace jsou považované za důvěrné a budou tedy užity pouze pro akademické účely. Jména respondentů či společností nebudou nikde uváděna.**
10. **Mockrát Vám děkujeme za pomoc a spolupráci s prováděním výzkumu.**

RESPONDENT

1 **Profese**

Architekt	Stavební inženýr	Technik	Jiná

2 **Vzdělání**

Maturita	Dis.	Bc.	Ing. / Mgr.	PhD.

3 **Pozice**

Nižší management	Střední management	Vrcholový management

4 **Zkušenosti v pozici (rok)**

0 - 5	5 - 10	10 - 15	15 - 20	> 20

SPOLEČNOST

5 **Oblast působení (zaškrnout lze více odpovědí)**

Projekční činnost	Vodohospodářské stavby
Pozemní stavby	Trubní vedení
Dopravní stavby	Zakládání staveb
	Technologické celky

6 **Délka působení od založení společnosti (rok)**

0 - 5	5 - 10	10 - 15	15 - 20	> 20

7 **Počet zaměstnanců**

10 - 100	100 - 500	500 - 1500	> 1500

8 **Průměrný roční obrat (mil. Kč)**

1 - 10	10 - 100	100 - 1000	> 1000

9 **Druhy zakázek**

Veřejné

Soukromé

Veřejné i soukromé

10 **Geografické působení**

Pouze zahraničí

Pouze ČR

Zahraničí i ČR

Pozorně čtěte znění všech tvrzení. Odpovídejte objektivně dle toho, jaké tvrzení odpovídá prostředí společnosti, ve které působíte. Pokud odpovídá tvrzení na levé straně, zaškrtněte čtvereček pod číslem 1. Pokud odpovídá tvrzení na pravo, zaškrtněte čtvereček pod číslem 5. Rámečky pod čísly 2 a 4 zaškrtněte v případě, že odpovídá spíše s tvrzení v pravo či vlevo. Rámeček pod číslem 3 zakšrtněte v případě, že odpovídá jak tvrzení vpravo tak s tvrzení vlevo. Pokud nevíte, zaškrtněte rámeček pod znakem N/A. Každé otázce náleží pouze jedna odpověď.

STANDARDIZACE

11	**Informace o zakázkách 1**	
Společnost nemá a tedy neužívá na staveništích zařízení (např. vývěsná tabule), která podávájí zaměstnancům informace o zakázce, týkající se zejména **harmonogramu, produktivity práce, nákladů a bezpečnosti práce.**	1 2 3 4 5 N/A	Společnost má a užívá na staveništích zařízení (např. vývěsná tabule), která podávájí zaměstnancům informace o zakázce, týkající se zejména **harmonogramu, produktivity práce, nákladů a bezpečnosti práce**. Tyto informace jsou volně dostupné zaměstnancům na všech pracovních pozicích.
12	**Informace o zakázkách 2**	
Výše uvedené informace jsou aktualizovány v nepravidelných intervalech.	1 2 3 4 5 N/A	Výše uvedené informace jsou pravidelně aktualizovány a jsou pro všechny srozumitelné.
13	**Organizace na pracovišti**	
Společnost nemá a tedy neužívá standardy, dle kterých je na staveništích organizován **materiál, zdroje, vybavení a nástroje** tak, aby realizace zakázek probíhala efektivně. Chaos a špína se stávají bežnou součásti realizací.	1 2 3 4 5 N/A	Společnost má a užívá standardy, dle kterých je na staveništích organizován **materiál, zdroje, vybavení a nástroje** tak, aby realizace zakázek probíhala efektivně. Chaos a špína, nejsou akceptovány.
14	**Definice pracovních postupů**	
Kritické činnosti a jejich postupy nejsou monitorovány. O jejich průběhu se nevedou důkladné záznamy a je tedy obtížné poučit se z jejich nedostatků.	1 2 3 4 5 N/A	Kritické činnosti a jejich postupy jsou kontinuálně monitorovány. Procesy jsou zobrazovány v grafech, které zobrazují tok materiálu, vybavení a lidských a finančních zdrojů.

LIDÉ A PROSTŘEDÍ

15	**Vzdělání / rekvalifikace**	
Společnost pro zaměstnance ne vyhrazuje finanční prostředky a čas na školení a kvalifikační kurzy, na základě kterých jsou schopni provádět dané činnosti.	1 2 3 4 5 N/A	Společnost pro zaměstnance vyhrazuje finanční prostředky a čas na školení a kvalifikační kurzy, na základě kterých jsou schopni provádět dané činnosti. Každý zaměstnanec má vedenou kvalifikační agendu aby bylo zřejmé, kterou má kvalifikaci případně, které kurzy musí absolvovat.

16	Zapojení lidí	
Zaměstnanci nesdílejí své nápady týkající se zejména redukce ztrát a zlepšování průběhu činností.	1 2 3 4 5 N/A	Zaměstnanci mají snahu podílet se svými nápady na dosahování cílů společnosti jak na podnikové, tak na projektové úrovni. Sdílejí své nápady týkající se zejména redukce ztrát a zlepšování průbehu činností.
17	**Snaha managementu**	
Vedoucí pracovníci nemají snahu zlepšit pracovní prostředí společnosti v zájmu zvýšení efektivity práce.	1 2 3 4 5 N/A	Vedoucí pracovníci mají snahu zlepšit pracovní prostředí společnosti v zájmu zvýšení efektivity práce.

ZAMĚŘĚNÍ NA KLIENTA

18	Optimalizace hodnoty	
Společnost nemá zájem podílet se na tvorbě hodnoty pro klienta. Nechť klient sám stanoví co vlastně chce.	1 2 3 4 5 N/A	Společnost se snaží pochopit klientovu vizi. Na základě toho pak navrhuje, či radí klientovi, za účelem dosažení maximální spokojenosti klienta.
19	**Flexibilita**	
Od podepsání smlouvy o dílo, jde naslouchání klientovi stranou. Na případné klientské změny během všech fází projektu, společnost není připravena.	1 2 3 4 5 N/A	Prioritou společnosti je naslouchání klientovi. Je vždy připravená flexibilně reagovat na jakékoliv klientské změny během všech fází projektu, bez značných časových a finančních ztrát.

ELIMINACE ZTRÁT

20	Zásobování 1	
Materiál je doručován předem. Je tedy nutné ho skladovat na staveništi, či ve skladech mimo staveniště.	1 2 3 4 5 N/A	Materiál na stavbu je obstaráván dle filozofie just-in-time (materiál je doručen podle plánu právě v čas, kdy má být zabudován). Skladování materiálu je téměř nulové.
21	**Zásobování 2**	
Mateirál je ponechán na určitém místě, bez ohledu na to kde bude následně zabudován. Dochází tak ke ztrátám, vzniklých vlivem přesunů materiálu.	1 2 3 4 5 N/A	Mateirál je ponechán na nejbližším možném místě jeho následného zabudování. Nedochází tak ke ztrátám, vzniklých vlivem přesunů materiálu.
22	**Optimalizace pracovní náplně 1**	
Společnost nemá žádné uddělení, které má na starosti plánování a controlling.	1 2 3 4 5 N/A	Ve společnosti je zřízeno oddělení plánování a kontrol. Toto oddělení má jasně vymezené povinnosti a je efektivně využíváno nejen při realizaci zakázek.

23	Optimalizace pracovní náplně 2	
Nasazení jednotlivých pracovních čet není vždy plynulým procesem. Často vznikají prostoje, způsobené nevhodným rozvržením jednotlivých činností.	1 2 3 4 5 N/A	Nasazení jednotlivých pracovních čet je plánováno a prováděno tak, aby nenastal případ, že některá četa bude muset na práci čekat. Veškeré pracovní síly jsou vždy maximálně nasazeny.
24	**Snížení ztrát pracovních cyklů 1**	
Během přípravné fáze zakázek se neklade důraz na detekci ztrátových činností či procesů. Společnost nemá v tomto směru inovativní přístup.	1 2 3 4 5 N/A	Během přípravné fáze zakázek je upřena pozornost na detekci činností či procesů, které by mohly mít za následek ztráty na zdrojích (čas, peníze, materiál, stroje, lidské zdroje). Je snahou tyto procesy změnit již během plánování, za účelem eliminace případných ztrát.
25	**Snížení ztrát pracovních cyklů 2**	
Spolupráce mezi jednotlivými řemesly či subdodavateli není dobrá. Pracovníci či firmy se snaží udělat své a případnou zodpovědnost za chyby přesunout na ostatní.	1 2 3 4 5 N/A	Spolupráce mezi jednotlivými řemesly či subdodavateli je na vysoké úrovni. Pracovníci či firmy si vzájemně vycházejí vstříc a informují se ohledně stavu daných úseků.
26	**Snížení ztrát pracovních cyklů 3**	
Společnost kompletně zanedbává vyhodnocování možných rizik.	1 2 3 4 5 N/A	Společnost hojně využívá technik risk managementu. Možná rizika jsou vždy vyhodnocována ruznými způsoby
27	**Optimalizace výroby**	
Společnost nevyužívá prefabrikované, předmontované či opakovaně použitelné prvky konstrukcí .	1 2 3 4 5 N/A	Prefabrikované, předmontované či opakovaně použitelné prvky konstrukcí jsou upředňostňovány. Firma se má snahu standardizovat jejich užití.

KONTINUÁLNÍ ZLEPŠOVÁNÍ / ZAVEDENÁ KVALITA

28	Prevence závad	
Opatření proti vzniku závad jsou zaváděna až poté co je závada odhalena. Tato opatření jsou reaktivního charakteru.	1 2 3 4 5 N/A	Do výroby jsou předem zaváděna opatření, která mají za úkol zabránit vzinku závad. Tato opatření jsou proaktivního charakteru.
29	**Reakce na vznik závad**	
Závady při výrobě jsou většinou identifikovány náhodně. Neexistují žádné předpisy, které by určovaly jak se v takových situacích chovat. Je tedy jen na vůli projektovém týmu jak bude danou situaci řešit.	1 2 3 4 5 N/A	Společnost užívá kvalitativní plán, který uvádí postupy pro identifikaci závad, dále role a povinnosti pracovníků pokud je závada odhalena. Tyto postupy jsou neustále monitorovány za účelem zvýšením jejich efektivnosti.

30	**Ukazatele**	
Společnost užívá různé ukazatele produktivity. Tyto ukazatele nejsou pravidelně a systematicky meřeny, evidovány a anlyzovány. Nemají tedy vypovídající schopnost.	1 2 3 4 5 N/A	Společnost užívá různé ukazatele produktivity, které pravidelně a systematicky měří, eviduje a analyzuje. Tyto ukazatele jsou srozumitelné pro všechny zaměstnance. Výsledná čísla jsou pak použita pro závěrečné zhodnocení projektu.
31	**Implementace znalostí**	
Společnost neklade důraz na zaznamenávání dat z průběhu projektů. Každý projekt je vyhodnocován jako idndividuální zakázka a znalosti z nich nejsou dále použity k neustálému zlepšování procesů.	1 2 3 4 5 N/A	Společnost má jako prioritu důkladné zaznamenávání dat z průběhu projektů. Tato data jsou dále analyzována a výsledky předány ke zhodnocení. Získané informace jsou užity při zlepšování procesů během realizace příštích projektů a organizace společnosti. Jednoduše řečeno, prioritou je snaha o neustále zlepšování průběhu zakázek.

Nyní prosím dotazník ULOŽTE jako nový soubor s jiným názvem. Dále zašlete na e-mailovou adresu potuzak.h@gmail.com.

DĚKUJI ZA SPOLUPRÁCI