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The presence of Lean Construction principles in Norway's transport infrastructure projects

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<p>Abstract:</p> <p>The construction sector is tainted with cost overruns, time delays, poor quality and repairing work, conflicts between the contracting parties as well as accidents and environmental problems. Thus new ways and methods have been developed in recent years. Especially the term lean construction came up and was implemented first in theory and afterwards in construction and building projects. Processes have been optimized and basic approaches for a new way of thinking has been developed in the construction industry. The body of literature for lean construction with its different facets became overwhelming within a short period of time. Nevertheless its practical application within the construction sector isn't well marked. The thesis intends to broaden the application of lean and its examination to provide knowledge for implementing and existing lean principles in practice. While examining Norwegian infrastructure projects with the help of case studies the researcher aims to prove the application of lean principles. The existence of lean principles is linked to the usage of proper lean tools and methods within the project management approach.</p> <p>The focus of this thesis is to investigate transport infrastructure projects in Norway regarding the practical application of single principles of the Lean Construction approach. First of all, this requires identifying the relevant body of literature to give an overview on this topic with its different aspects. Furthermore this part should serve as an introduction to get familiar with the core ideas of the term Lean Construction and to present the possibilities given by this theoretical described management approach. For the practical part of the thesis current projects carried out by the Norwegian Public Road Authority, as the biggest client for roads, tunnels and bridges, can serve as examination objects. By the usage of proper research methods, relevant data shall be collected considering the mentioned aspects of the theory part. Based on evaluating and validating the collected information the researcher shall describe the current situation about the existence of Lean Construction principles from the client's point of view. Finally the importance of this issue and the role of the client within this approach shall be explained.</p>

Keywords:

1. Lean construction
2. Infrastructure
3. Value, waste, flow
4. Lean project management

(sign.)

Declaration of Authorship

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Preface

This Master of Science thesis was written in the first half of the year 2014 within the master program industrial engineering at TU Berlin. The thesis emerged due to an Erasmus semester at NTNU Trondheim. Afterwards the researcher drafted the thesis in cooperation with TU Berlin (Department for Construction Management), NTNU Trondheim (Department of Civil and Transport Engineering) and the external partner Statens vegvesen. The core idea arose during a couple of meetings and conversations with professors from the NTNU in agreement with the TU Berlin considering the interests of the researcher, the accessibility of data and the need of research.

Acknowledgement

After making this thesis happen I would like to give thanks to the following persons for their great support during the phase editing the master-thesis. First of all Olav Torp who supervised me and was always available to help in word and deed from the creation of the topic until the submission. He made the connection of the researcher with Statens vegvesen possible. At the same I need to mention the openness and the patience of the contacted employees of Statens vegvesen. They provided me with the data I needed for my practical part and made my thesis in this way alive and usable. I also would like to name James Odeck at this point who was especially in preparation of the thesis my contact person and get me with valuable information.

From the TU Berlin the researcher got supervised by Prof. Dr. Kochendörfer. He encouraged the researcher from the first moment to realize the idea of such a cooperation and managed the contact to the home university.

In addition to it I would like to give thanks to my parents who supported and accompanied me during all my years at university, the decisions I made and the different experiences I went through. The times back at home were always a place where I could collect new ideas and new energy to go the next step. During my stay here in Norway I got in touch with so many new people who broadened with their personality my horizon significantly. All of them accompanied me on my ways in Trondheim and at the university in a unique way. Especially my friend Sebastian was from the first moment a faithful companion and a perfect supplement to discover the beauty of the Norwegian landscape.

C.R.

Summary

The construction sector is tainted with a bad image and has a significant impact on the economic situation of a country. Claims for better and optimized processes are existent. The special properties of construction projects, especially their uniqueness, require a holistic understanding and make an adoption of the project team regarding the concerned context essential. A new way of thinking develops to cope with the complex and dynamic features. Lean has its roots in the manufacturing processes of the car industry. The body of literature of the approach called lean construction became overwhelming within a short period of time. The practical application within the construction sector isn't still highly developed. There are still a range of challenges implementing those methods from theory into practice which need to be solved. The thesis intends to make a contribution to broaden the application of lean and to provide knowledge implementing lean principles in practice. While examining Norwegian infrastructure projects with the help of case studies the researcher aims to prove the application of lean principles. The existence of lean principles is linked to the usage of lean tools and methods. There are two important sides introducing a new approach. The application of new processes is one aspect. New processes are depending on the appliers who implement them based on their experience and the way of thinking. LC means a paradigm shift in the way of thinking and requires commitment from all involved people. The approach scrutinizes the integration of the design and construction phase as well as the involvement of the client.

To approach this topic the researcher divided the thesis into six chapters. The **first** part serves to introduce the topic and identifies the customer while presenting the objectives of the thesis. The **second** part presents the researchers approach for the literature part and the project work. The researcher presents the theory in the **third** chapter. This part deals with significant contributions as an excerpt from the huge body of literature. Chapter **four** reflects the case study and the collected data. The researcher is going to present the results of the examination phase by the chosen research method. In chapter **five** the data will be discussed and analysed matching the results with the theory part. With the help of collected data the task is to analyse the project management approach of SVV for the existence of lean principles and to prove the meaningfulness and application of lean ideas within the construction sector in general. The **sixth** part summarizes the results of the thesis and gives an outlook for further research work.

Key words: lean construction, infrastructure, construction management, value, waste, flow

Zusammenfassung

Die Anwendung von Lean Prinzipien ist heutzutage aus industriellen Produktionsprozessen kaum mehr weg zu denken und stellt mehr als nur einen Standard dar. Entwickelt von Managern und Ingenieuren bei Toyota in den 60-iger Jahren hat sich dieser Managementansatz schnell in der ganzen Welt verbreitet und wurde auch auf andere Sektoren übertragen. Ausgehend von den Problemen in der Baubranche und dessem gleichzeitig bedeutenden Einfluss auf die nationale Wirtschaft eines Landes ist der Sektor auf der Suche nach Verbesserungen und Veränderungen. Die steigende Komplexität und Dynamik innerhalb der Projekte sowie das Charakteristikum der Einzigartigkeit fordert Veränderungen. Mittels der Übernahme und Transformation von einzelnen Lean Methoden sollen bessere Projektresultate erzielt werden. Begonnen hat dieser gewissermaßen neue Zeitabschnitt bereits in den 80-iger Jahren ausgehend von Amerika. In Europa ist in den 90-iger Jahren vor allem die britische Bauindustrie durch den Report von Egan, 1998 aktiv zur Anwendung von Lean Prinzipien aufgefordert worden. Mittlerweile wurden viele nationale Institute und Forschungsgemeinschaften gegründet, die sich mit Lean Construction auseinandersetzen und die Entwicklung von Methoden und Prinzipien vor allem theoretisch vorantreiben. Erst seit den letzten Jahren findet eine gezielte praktische Anwendung von Lean in Projekten statt. Über genaue Auswirkungen einzelner Tools und Methoden liegen kaum Forschungsergebnisse vor. Der Ansatz ist eng an Prozesse und Verhalten geknüpft. Weiterhin steht die Integration von Produkt und Prozess sowie die aktive Einbindung des Bauherrn im Mittelpunkt.

Mit dieser Arbeit soll die Anwendung von Lean Ideen in Infrastrukturprojekten in Norwegen nachgewiesen werden. Die zunehmende Komplexität und Anzahl an Projektmitgliedern, das steigende Interesse verschiedener Stakeholder sowie die damit steigende Anzahl an Rahmenbedingungen stellen die Ausgangsbasis für eine verstärkte Implementierung von Lean Prinzipien in Linienbaustellen dar. Mit Hilfe des Theorieteils verschafft sich der Author zunächst einen Überblick über den aktuellen Status von LC. Der Abschnitt dient gleichzeitig als Einführung in die Thematik LC für den Projektpartner Statens Vegvesen, der nationalen Straßenbaubehörde Norwegens. Im praktischen Teil der Arbeit wird mit Hilfe von Fallstudien die Präsenz von Lean Ideen in dem Projektmanagementansatz des Bauherrn nachgewiesen. Mittels Interviews und der Untersuchung von Projektdokumenten wird von den verwendeten Methoden auf die ursprünglichen Lean Ideen zurück geschlossen. Abschließend wird ein Status quo definiert als Ausgangspunkt für die weitere Etablierung einer Lean Denkweise.

Abbreviations

NTP National Transport Plan

LC Lean Construction

LCJ Lean Construction Journal

IGLC International Group for Lean Construction

AEC Architecture, Engineering and Construction

IPD Integrated Project Delivery

TFV Transformation, Flow, Value

OR Organisational structure

OS Operating system

CT Commercial terms

BIM Business Information Modeling

TVD Target Value Design

PS Pull Scheduling

LPS Last Planner System

CIP Continuous Improvement Process

VSM Value Stream Mapping

PTM Primary Team Member

JIT Just-in-time

TQC Total Quality Control

ICT Information and Communication Technology

LCI Lean Construction Institute

PPC Percentage Plan Completed

IFOA Integrated Form of Agreement

KPI Key Performance Indicator

mio Million

NOK Norwegian kroner

KVU Concept evaluation

KS1 Quality assurance

KU Impact assessment

LOV Public law for planning and construction

km Kilometres

n/s Not specified

tba Need to be announced

D/B Design-build team

NMTC Norwegian Ministry of Transport and Communication

e.g. for example

LDPS Lean Production Delivery System

WBS Work Breakdown Structure

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Chapter 1

Introduction

The first chapter of this thesis is an introduction detailing some background information, the problem description and identifying the customer. Simultaneously the researcher defines the scope of the thesis.

1.1 Preface

Lean processes for manufacturing companies are of daily routine nowadays. The term 'lean' is ubiquitous after solving and understanding the secret of success of Toyota's production system. They were pioneering in applying lean principles within their organization in the 1960s. It needs a long time to figure out what it is that made them so successfully. Several opinions about it are existent. (Stone, 2012, 112p)

The construction sector of Great Britain was seriously investigated in the 1990s for example by Latham, 1994 and Egan, 1998. At that time the sector was seen synonymously for cost overruns, time delays, poor quality, low efficiency, removal of defects and conflicts between the involved parties as well as producing a range of safety and negative environmental impacts (Egan, 1998, 6p). All involved parties were forced to think about new strategies to dispose themselves of this negative image against the backdrop of the economic importance of the construction sector. Thus new ways and methods were developed in recent years. This contains especially the fact of the transfer of experience and knowledge from the manufacturing industry unified under the term lean management. With regard to the construction business the term lean construction (LC) was created. Processes were optimized, new methods were introduced and approaches of a new thinking were developed. The aim was to cope with the increased complexity, dynamic and interests of construction projects. The objective was to refresh all the inefficient processes and to break with existing structures. LC is repetitive named in relation to higher efficiency and improved project results. As there are many advocates presenting their ideas and experience. Nevertheless there is still a lack of knowledge referring an exactly definition and distinction in this field. LC is a huge area with many different aspects and facets.

The project 'Integrated Building Process' (SIB-Samspillet i byggeprosessen) carried out by NTNU Trondheim in collaboration with well-known Norwegian construction companies is one of the first steps to implement and transfer the thinking of the manufacturing industry into the building sector in Norway. The aim of this project was to look for new innovative approaches like using increasingly partnership models along the supply chain, focussing on organisational issues and developing simple IT-solutions to ease the exchange of information and data. As an inspiring example in Norway serves the domestic offshore industry which was able to reduce the cost in late 90s for about 50 % by applying a more collaborative model and simplifying the processes. (Haugen, Tore I. and BEAM, 1999, 2p) The project team around Haugen, Tore I. and BEAM, 1999 came up with two main issues which the researcher is taking up for this thesis. The first aim is to shape and configure processes in a way so that they are efficient, simple and robust

whereby. Every process is owned and run by an operator or by a whole team. They are influencing the performance of the process by their own ideas, experience and way of thinking. Besides this, lean it is often seen as a culture and a specific way of thinking. Therefore the behaviour of the involved people needs to be adapted aiming for sustainable effects in the long term. Both

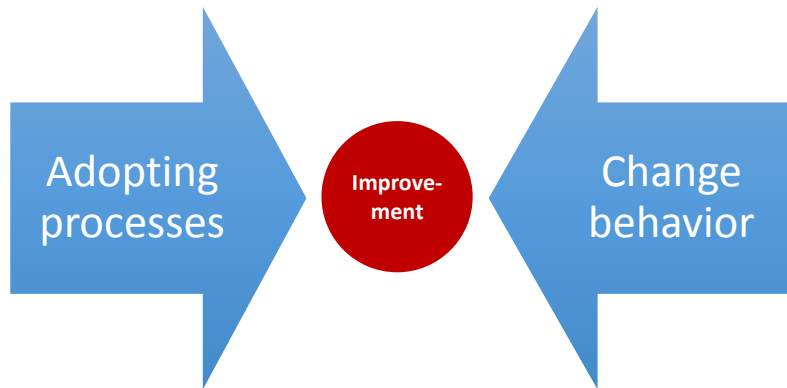


Figure 1: Two sides of improvement

ways are a suitable measures to renew and improve processes. The researcher reflects on both sides within the following pages. The task is to reveal the overall approach of LC considering the construction business. Moreover to some extent are single elements already elements within the management approach of the public road administration in Norway.

1.2 Facts about Norway

- 80% of the population is living in urban areas. The country has five mio. inhabitants and an area of 323.802 square km. The population density amounts up to 1.600 persons per square kilometre. An efficient and effective infrastructure system is essentially linking the different populous areas of Norway. (Norwegian Ministry of Transport and Communication, 2013, 2pp)
- The road network consists of 94.000 km of roads linked by more than 900 tunnels and 1.000 bridges (Norwegian Ministry of Transport and Communication, 2013, 2pp). The geographical conditions in Norway with its variety of mountains, fjords and rivers need to be considered for realizing infrastructure projects.

- The construction business in Norway is dominated by the infrastructure sector and the prosperous construction sector is influencing the national economic situation. (Albrikt-sen, Rolf, 2013, 18).
- The Norwegian government is focussing on developing and constructing road infrastruc-ture, highlighting its importance for the whole country (Brekkhuis, 2014). Considering the current plans of the country many projects are going to be carried out in the near future.
- Representative companies in Norway are aware of the lean topic, try to learn and incorpo-rate aspects of lean management into their organizations. The positive results achieved by applying a lean system are an inspiring example for other industry sectors as well. (Byggeindustrien, 2014)
- Major road projects need on average 10 years for the planning phase (Harvold, Kjell and Tesli, Arne, 2013, 26). The long planning period is a result of many different sub-processes involving multiple sectors, administration levels and authorities. The objective for the government is to halve the planning time. (Rodewohl, 2014)
- Current issues in the world such as urbanisation, climate changes, demographic changes, globalization, resource scarcity and sustainability pose new challenges for construction projects considering the amount of resources needed and the requirements for the project.

The government stated projects with a planning time of five to seven years as a benchmark and proposed the following general considerations coping with the challenges and improving project results. (Norwegian Ministry of Transport and Communication, 2013, 20pp)

- The necessity for a good project management approach.
- A sufficient exchange of information within the project team and the stakeholders.
- The availability of committed objectives and actions to achieve continuously progress.
- The avoidance of conflicts of interests.

Taken into account the individual character of every construction project an approach that al-lows for flexibility and variety in response to the project is necessary.

1.3 Who is the customer?

Before proceeding with further required formal aspects within such a scientific work the re-searcher wants to identify the customer of this thesis. This helps the researcher to address the

right aspects of interest to the recipient after identifying the customer needs. This kind of relation is always alternating and is the first step into the world of lean thinking (Ballard, 2008, 5p).

Identifying the needs of the customer and help them to decide what they
want!

Who would be concerned by this thesis? For whom is the thesis suitable? The thesis is drafted by the researcher to create value for people who are directly affected by this topic in their day-to-day work or at least from time to time. The author is considering people who are involved in launching and operating infrastructure projects in Norway. To determine those parts of the society, the researcher is approaching the topic from two different point of views. First of all every construction project undergoes a life-cycle with different phases and a time period up to 50 years. The different phases give a first hint who could be involved and affected by realizing

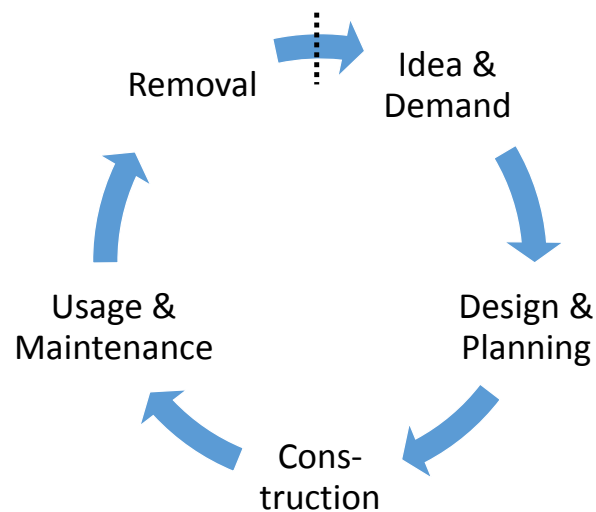


Figure 2: Life-cycle of a construction project
in reference to (Kohler and Lützkendorf, 2002, 340p)

such a project. Secondly the researcher looks at the formal processes, respectively the framework given by legal aspects. By analysing the phases of a construction project and the given framework, generally the following organizations and institutions can be identified (Harvold, Kjell and Tesli, Arne, 2013, 17pp):

- The Parliament of Norway
- The Ministry of Transport and Communications
- The Ministry of Finance

- The Counties
- The Municipalities

Depending on the project, further parties might be involved in such a process. As well as administrative organisations architects, consultants, engineers and construction companies take part at certain stages of the project. Furthermore there is the Norwegian society which is directly or indirectly affected by a construction project. The society also takes part in the consideration of functions of the provided infrastructure.

Finally the paper is mainly addressed to the employees of Statens vegvesen (SVV), the Norwegian Road Administration. It might be also relevant for readers who belong to one of the mentioned organizations above. Naturally all other interested parties who show an interest in this topic are also cordially invited to read this paper.

1.4 Objectives

To describe the intentions of the paper the researcher is reflecting on his field of interests and the needs for research in the chosen area. First of all, from the perspective of the researcher's background as an industrial engineer and the chosen study subjects, it can be said that there is an interest in improving and optimizing procedures in general. The core idea of the thesis is to pick up different demands positioned by different customers. The next step would be to uncover and develop further demands with the customer. The relevant needs launching an examination are summarized in the following table. The origin of all needs is the society with its demand for more mobility. The Government of Norway is naturally interested in the most efficient and effective allocation of limited funding with the aim to fulfil most of the needs at the same time. The overall aim is to create more value with less resources respectively to increase the efficiency ('Doing the things right.') and the effectiveness ('Doing the right things.'). (Crawford and Bryce, 2003, 366p)

All examined processes are related to
the principle of cost-effectiveness!

Starting from this principle and further constraints the task is to find the right methods and tools to act within the given framework. A typical approach for such a problem is to abstract the situation from specific into general, creating simple models and concepts. This is the objective of the scientists. Science means to observe and to experiment (Godfrey-Smith, 2009, 79p). The ability and the tools to research for new ways and possibilities to find proper solutions and answers

Customer	Needs
Society	Transport possibilities
Government	Realization of the targets anchored within the national transport plan
SVV	Responsible for realization as executive institution of the Government
Science	Partly critical reflection on Lean Construction for missing substantiation of a partly biased theory
Author	Scientific contribution in a self chosen topic

Figure 3: The needs of selected customers

on how to deal with such situations. Afterwards the theory can be re-transferred, from general to specific, and applied for the corresponding situation fulfilling the character of the model or closely resemble the specified features. Before using theory, trials are going to be conducted. The theory of launching case studies is then relevant.

The relevant literature of LC is widespread. Scientific critics refers often to difficulties transferring theory into practice. (Stone, 2012, 112pp) Another issue is the weakly considered point of the contextual background (Green, 1999, 27p). Since this is still part of the scientific world the author's intention is to take up this points by investigating it with the help of case studies. The following serves as an orientation about the context of the next chapters:

- Studying, reviewing and summarizing the existing literature referring the LC approach and especially issues related to the infrastructure sector.
- Identifying relevant case studies in Norway to collect data and evaluate them.
- Looking for signs which indicate a coherence with the theory of LC and the management approach of transport infrastructure projects operated by the Norwegian road authorities.
- Introducing the topic LC into the mentioned institutions to show alternatives to the current used approach.
- Finally answering the three research questions combining the findings from the theoretical and practical chapters.

These points are the start for splitting up the thesis into two main parts. The aims of each part will be introduced to the reader in 2.1.1 and 2.2. To combine theory and reality as well as to convey theoretical aspects the author creates furthermore three research questions he wants to focus on. The questions are going to be answered during the course of the thesis. They are serving to keep the focus within this huge field which consists of a variety of sub-areas. The questions serve also to find a comprehensible structure without any interruptions for the reader to follow.

1. Why is it useful and beneficial using the original idea of lean in transport infrastructure projects?
2. How supports the integration of the project team and the project phases lean thinking in transport infrastructure projects?
3. What is the role of the client and how can he influence and support lean thinking while carrying out a project?

The concept of this thesis shall give the customer an awareness about the existence of the lean principles within their own organization. Secondly, it can be established which parts of this topic is already present defining a status quo and to what extent it is worth considering the required efforts to move into the direction of a holistic lean approach. The researcher is giving an introduction of the topic of LC especially for SVV as a starting point reflecting the results and transferring them into its own management approach.

Chapter 2

Methods and proceeding

The researcher is dividing the thesis into a theoretical part and a project part. To answer the formulated research questions both parts need to be integrated at the end. The researcher is using this chapter to describe the further research strategy. This section is divided into the proceeding for the literature research and secondly into the project work. The theoretical knowledge of research methods is presented in connection with contextual issues and used methods of the thesis.

2.1 Literature research: Scope and research strategy

2.1.1 Scope and focus

Lean management is a holistic approach which covers a variety of aspects (Stone, 2012, 112pp). The existent body of literature reflecting the topic LC is therefore enormous widely diversified and can be backdated to a technical report of Koskela, 1992. In Jørgensen, 2006 the interested reader can get easily an overview about the different reflections of this issue. Both, for the researcher and for the customer the main target of this part is to describe the field and to get more familiar with the core ideas of lean. It becomes apparent at an early stage of the research that the majority of the literature is related to the construction of buildings (Jørgensen, 2006, 34). There is a range of papers which are examining the application of the lean approach within infrastructure projects like e.g. Walker and Shen, 2002, Heidemann, 2010 and Dave et al., 2013. By identifying and examining the literature the application of LC especially within transport infrastructure projects can be questioned and scrutinized. That way the reader gets familiar with the theory of LC. The researcher is giving a broad insight presenting the theory of LC based on the attributes of construction projects, the roots of lean management and finally its transfer to the construction business.

To reveal the differences, the researcher is referring to the traditional way of construction management polarizing the situation and contrasting both approaches. The author is aware about the point that this process has been improved already over the last years as response to the increased requirements and complexity of the sector in general.

The thesis restricts its scope to the field of transport construction projects. The task is to expand the available theoretical knowledge, using the results of the thesis. Furthermore, the focus tends to adopt the viewpoint of the clients side within the lean approach, using the viewpoint of SVV. The customer SVV gets an introduction into the lean world by presenting the common international terms and definitions as well as the core ideas. Within such a broad field and its application within a new sector it is necessary to create and define a common basis and to introduce into the language and key points of lean first of all. Those aspects can be linked to the project management landscape of SVV later on. The researcher is assuming that the management approach of SVV contains parts of the lean approach. Another aspect is that it is necessary to use the same terms within the project to guarantee a goal oriented communication. This is important especially since there are several experts and different parties involved. The thesis helps to create a common and wider understanding as well as presenting new aspects.

Because the author has access to projects of the mentioned field, all the project data will be collected from employees of the contracting authority. The investigation of the case studies refers to a specific point; the date of the interview. An investigation about a longer period of time wasn't possible with regard to the general set up of a master-thesis.

The original intention of the researcher was to take the viewpoint of the client and of a contractor who operates physically on the project. This couldn't be realized. Thus there is the chance to narrow the field of the study by focussing on the client. As a consequence of this, the most interesting phase is the design and planning phase as well as the passage to the construction phase. This is based on the fact that the client first works on administrative tasks considering the current procedure. Another point is the decreasing ability to influence the project. The costs of changes are increasing at the same time as the project progresses. The still broad scope

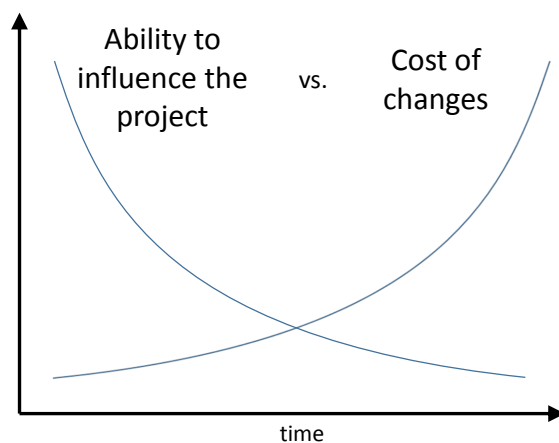


Figure 4: Cost-influence curve
in reference to McGeorge and Palmer, 2002

of the thesis wasn't consciously further narrowed down because of the high uncertainty of the expected results referring the case studies.

2.1.2 Research strategy

The field of LC is multi-disciplinary and has been developed since the beginning of the 90s. The first step was to search for literature which means examining and evaluating a variety of references. This is based on the core idea of the researcher intentions being active in the field of LC connected with infrastructure projects. In this case the dissertations Jørgensen, 2006 and Hei-

demann, 2010 are the starting point for further reflections. Because of the variety of literature a strict proceeding schedule was required to keep track and find answers for the formulated research questions. The researcher identified a process consisting of four phases.

(1) Identifying the basis literature referring to lean management. This step is necessary to get in touch with the origins of lean and the core ideas behind this topic as well as the contextual background. The roots of lean can be discovered within the writings of Ohno, 1988; Womack et al., 1990 and Womack and Jones, 2003.

(2) The next step refers to the existent literature of LC in general. The task within this step was to understand the development and the features of applying LC in the construction business. The following remarks can be made as input for the progress. The theoretical knowledge about LC is continuously growing since Koskela, 1992 started to transfer the ideas of lean from the manufacturing industry to the construction sector. This process is mainly driven by the International Group for Lean Construction (IGLC) which was founded in 1993 (International group of lean construction, 2014). Annually a variety of papers and research is presented. Thus, this group of people has an important impact shaping and developing the future of LC. Considering the local aspect, it can be noticed that especially the USA and Australia triggered the development of LC by actively transferring and applying the lean principles into their projects (Heidemann and Gehbauer, 2011, 19pp). These countries can be seen as pioneers.

(3) With the third step the writer searches for information about the current status of LC in particular. Besides the annual meetings of the IGLC where a variety of papers is presented every year, there are also national lean construction institutes, for example in Germany, Norway and Great Britain who are regularly publishing new papers. Another approach to keep track with current developments especially in Norway is to follow proper on-line journals. As a result it can be noticed that the majority of documents is related to the building industry.

(4) The last step of the literature research is to look especially for LC topics closely connected to the area of infrastructure projects. This step serves as link and preparation for the project work. By referring the identified references the findings of step (2) and (3) can be used. Some of the researchers sources are already mentioned. What are the further information sources and in which way are they managed? The sources used differ from step to step because of the format of the specific search code, the type of reference and the expected reliability of the results for references. Dependant on the research level, the researcher is using the sources mentioned in figure 5. As a consequence three categories of sources can be identified:

- Library systems of NTNU Trondheim and TU Berlin

Research level:	(1)	(2)	(3)	(4)
NTNU library	X	X	X	
Online library system: BIBSYS	X	X	X	
Online library system: Knowledge Portal Primo	X	X	X	
Google scholar	X	X	X	
IGLC database		X	X	X
SVV database				X
Journal websites			X	X
Institute websites			X	X
Company websites				X
Conference websites				X

Figure 5: Overview about the used sources

- Databases
- Websites

The library systems serves mainly to identify the basis literature referring 'Lean Management' and 'Lean Construction' for books, journal articles and theses. Recently published papers give also a first indication of the current status of LC. The on-line system BIBSYS of NTNU offers the possibility for an advanced search request and includes more than 100 Norwegian libraries. Another search tool is the "Knowledge Portal Primo" run by TU Berlin.

For a more detailed view and for the preparation of the project part, the databases of SVV and the IGLC have been chosen. The IGLC provides a variety of papers and conference proceedings within their internal database called 'Lean Construction Journal' (Lean Construction Institute, 2014). This database is run and reviewed by the international group itself. With the help of fixed review instructions a high level of scientific quality shall be ensured. All the papers have the same formal structure and are in English. Other external scientists and authors quest the validity and independence of the papers of the LCJ (Jørgensen, 2006, 72p). Many sources refer to previous published articles of the same journal. The sources allow to gain an overview of the research which has already been undertaken. The database of SVV consists mainly of documents that reflect the standard project management approach and consist of handbooks, guidelines,

standards and provisions (Statens vegvesen, 2012). With the help of the chosen sources the researcher is trying to identify lean principles within the organization itself.

The last category consists of websites which provide closely related information to this topic. They are partly invalid and can't be used as a basis for further scientific studies. The information given by journals, companies and institutes are needed to gain knowledge about the presence of this topic in the construction business in general to be able to prepare the interviews.

The researcher is going to use the process flow illustrated in figure 6 for all research levels referring to the collection of relevant and valid references. Searching by using the mentioned sources



Figure 6: The research process flow

is followed by a reflection of the results in regard with the scope of the paper. The identified literature will be examined for its relevant parts of context. It can be further noticed that the more specific the research field was outlined from step to step, the more informal were the results. The scientific validity is to scrutinize in every single case.

All identified references are going to be collected and archived with the help of the current student version of the reference management tool 'Citavia 4'. The studied literature represent the basis for the project work as well as influences the design and the approach how to investigate the case studies (Yin, 2014, 42p).

2.2 Project work: Method and design

The project work is marked by carrying out a case study. The theoretical knowledge to work with this tool is explained in this section. The decision for or against a research method should be based on the objectives of the research and on the research questions. The quantitative approach is useful to apply when dealing with mechanistic driven issues which are often visualized by "what" questions. Qualitative methods serve to specify the humanistic and psychosocial side as well as to find answers for "how" and "why" questions. A mix of both approaches is also thinkable and in some cases even necessary. Using different research methods help to confirm the

validity of the collected data and to increase the reliability of the research results by examining advantages and disadvantages of both approaches. (Bryman, 2012, 33)

2.2.1 Research method

The researcher decided to apply the qualitative approach. The table describes shortly the main ideas of the qualitative research approach. Accordingly the focus is on improved understand-

Qualitative research	
Philosophical foundation	Indicative
Aim	Complex human issues
Study plan	Iterative proceeding
Position of researcher	Integral part of research process
Assessing quality of outcomes	Indirect quality assurance
Measures of utility of results	Transferability

Figure 7: Qualitative research method
in reference to Marshall, 1996

ing, comprehensiveness and visualization. That means to uncover causal relations, processes and reasons. The generalizability of the research results needs to be proven in every single case. To answer the questions in connection with this method, theory is required. Theory is based on data that needs to be generated first. (Sutton and Staw, 1995, 373pp) Afterwards the data needs to be transferred into the theory which is the task of the researcher. The easier the applied methodologies, the more useful results can be generated. (Mintzberg, 1979, 584p). The next step is to carry out the research by experiments, surveys, archival and historical analysis and the implementation of case studies. Launching a case study means to study current events against the backdrop of its real contexts. There is no active control or intervention necessary. A case study observes a current event more detailed related to a real life problem. (Yin, 2014, 9pp) The contextual background is the part that has not been studied very well. Therefore investigating real cases is the best approach to further investigate at this issue. The decision of using case studies as a research method has several reasons:

- the formulated research questions,
- the topicality of the issue lean,

- the demand for more efficiency and
- the high complexity of construction projects.

This research with its case studies aims to generate empirical evidence to what extent the used project management approach reflects lean principles.

The theoretical knowledge follows the feedback observing and investigating the current used approach within the case studies. This alignment permits to evaluate the present situation by focussing on the field of LC. By uncovering applied methods and tools which belong to the lean approach, the practical utilization can be simultaneously proven and evaluated. The case studies serves for realizing two targets in this case. First, an alignment of theory and practice is undertaken by the researcher and secondly the evaluation of the applied theory. This results in gaining more valid data about the implementation of the theoretical knowledge. The author is conclusively trying to define the status quo of LC of the investigated projects considering the limitations of the research method.

For illustrating the phenomenon of the existence of lean principles within the management approach of SVV the data collection method, case study, is used. The researcher is conducting non-participatory case studies. As a consequence it is possible to collect in-depth data for single aspects within the case study. Furthermore recommended are multiple sources of evidence with a preceding theoretical discourse (Yin, 2014, 15pp). A multiple case study design is used to increase the validity of the research results.

2.2.2 Case study design

The application of a multiple case study design is based on the following reasons:

- Using more than one case study generates a higher validity caused by individual character of every single construction project.
- LC is referring to its definition an interpretable term. Furthermore within the Norwegian language other terms and definitions exist.
- None of the cases seems to be extreme or unique to serve as a single case at this point of research.
- The results aren't going to be dependent on the progress, development and character of one single case. The prospect for transferability is given.

- Projects with different parameters like the impact of different involved parties or local impacts can be considered.

The design consists of disadvantages the researcher should be aware of. It is a time consuming task to investigate several projects at the same time. Furthermore, there is not enough time to uncover more details about some aspects. The overall context is given by the construction of in-

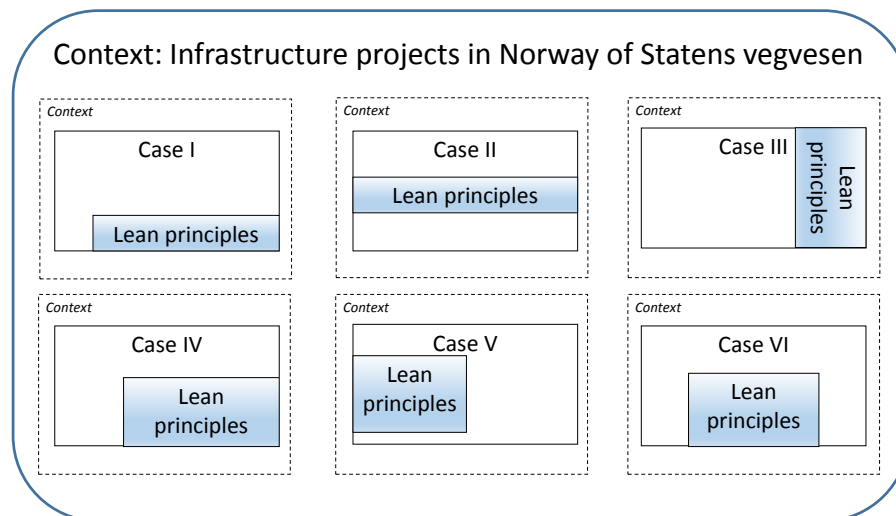


Figure 8: The case study design in reference to Yin, 2014

Infrastructure projects in Norway conducted by SVV. Every case has its own sub-context referring to the involved parties, the local site with its available resources and character, the function of the construction and the aim of the project. Six individual cases are examined within the thesis illustrated by figure 8.

2.2.3 Selection of the cases

Whilst selecting the cases it is important to have a balanced mix within the sample (Yin, 2014, 50). In this case, the case studies were chosen by SVV itself. All project cases except one case have one common feature. The projects exceed the costs of 750 mio. NOK (approx. 93 mio. €).¹ They are important within the project portfolio and an external quality assurance is required (Rodewohl, 2014). The researcher itself have had no impact on the selection except describing the research intention to trigger the selection process. Another important part of the projects

¹The researcher uses consistent the currency Norwegian kroner, shortly NOK. To reflect the given figures with projects in the euro area an exchange course of 1 €= 8 NOK can be used.

is that they are located in different areas of Norway. Similar results can be expected despite different sub-contexts given the fact that the same management approach is installed in every case. Working with six such individual cases the replications will strengthen the research results (Bryman, 2012, 46p).

2.2.4 Data collection

The principles of data collection are to maximize the benefits and foster the validity and reliability of the collected information. There is a wide range of possibilities to collect data from case studies. Methods like non-participant observation, questionnaire, group interview or individual interview, study of project documents, conversation, e-mail correspondence, physical artefacts and collecting quantitative data are thinkable. (Yin, 2014, 102p)

Because the author gets access to projects in the mentioned field, all the data for the project part is going to be collected from employees of the contracting authority. All projects are investigated at a specific single date. The first idea was to look into projects collecting information from the constructor and from the client. This has methodical reasons and the practical effect to bring client and constructor closer together. This is especially for the processes during the execution phase of importance and can help to foster a mutual understanding for the project approach. After considering the boundary conditions for such an investigation and in consultation with the supervisor the researcher is focussing on the client's side only. The validity and reliability of the findings won't be weakened by this aspect. Referring the transferability of the results it is necessary to take this issue into account.

Yin, 2014 recommends to collect data from different sources using different methods. In this case the following reasons cause such a progress:

- The time of investigation is short.
- The term LC is interpretable.
- The range and quality of the data is difficult to forecast.

All case studies are different but are unified by the same project management approach. The approach used by SVV in every project is the same because it is fixed within their standards and handbooks which are also constrained by the public law. The researcher decided to focus on accessible project documents and on interviews with the assigned contact person. Subsequent to the interviews a questionnaire shall be launched to verify the collected data. The following strategy is identified:

1. The researcher studies the relevant handbooks and provisions of SVV. The documents

comply with the Norwegian act for public clients. All relevant documents and information are available on the website of SVV.

2. The information are verified in the interviews and e-mail correspondence with employees of SVV.
3. The next step is to get familiar with each single case studying the accessible information of the project.
4. Based on this information the guideline for the interviews can be prepared.
5. Contacting the project manager and providing them with the relevant information about intention, proceeding and notes about the context of the interview.
6. Conducting the interview using the guideline and collecting the information.
7. Subsequently editing the results of the interview.
8. *With the interviewee's help identifying further persons for launching a survey.
9. *Undertaking the survey.²

2.2.5 Research by questionnaire

The initial thought was to launch a questionnaire subsequently to the interviews as a further method to augment and corroborate the findings. After conducting the first interview the researcher decided to disregard the survey. A survey is an inefficient tool and highly dependent on the type of questions. An indication of the prior knowledge of the potential candidate is needed and the same state of knowledge for all candidates that are going to be interviewed. (Samset, 2003, 120p) In this case a survey is not flexible enough because of the mentioned level of uncertainty above. As a consequence the author considered it as inappropriate in this case. Instead the researcher is going to use data provided by students of the university in Agder who investigated a road project of SVV at the end of 2013. They forwarded the results compiled within the frame of a bachelor-thesis (Hagen et al., 2014) to the researcher via e-mail on 24th of March 2014. Parts of the results are going to be presented in 4.2.2. The survey confirms the assumptions made by the researcher and serves as input to design the interview guideline.

²A * marks the steps of the original idea. In the used research method the researcher renounces for this two steps.

2.2.6 Research by interviews

An interview serves to uncover human affairs and behavioural events. The focus lies on verbal information. Interviews have the distinction of being flexible, focused, goal directed and insightful. It can also cause bias by inappropriate questions and answers, misunderstandings and the possibility that the interviewer hears what he expects. Furthermore there are different types of interviews. There is the in-depth interview which focusses on facts and opinions. The second type is the focused interview which is short and open-ended following a set of questions. (Yin, 2014, 102pp)

The researcher identified the focussed interview as the most appropriate tool to be used. With this knowledge, the theoretical knowledge about LC and the expectations for the results the researcher is preparing an interview guideline. The expectations are based on assumptions deduced from an intensive exchange with the supervisor and the results of the mentioned survey above. The following points are necessary to be aware of when launching the interviews:

- The interviewee should decide about the time for the interview!
- Give an introduction about the intention and the procedure!
- Follow the prepared protocol guidelines!
- Be flexible, react to interviewee and avoid biased questions!
- Avoid 'Why' questions!
- Be focussed on the objectives and the information needed! (Yin, 2014, 102pp)

With regard to the interview guidelines the researcher decided to use a semi-structured approach influenced by the character of the situation. Flexibility and openness to uncover new features and aspects are the success factors in this case. The specific questions are going to be formulated during the interview. As guideline and reminder serves a prepared list of single keywords. This makes the approach robust and tolerant in case of unforeseen events. Previously collected data from other sources can be substantiated. The interviews aren't going to be recorded. The researcher is preparing minutes after the interview to record the information. Figure 9 gives an overview about the sources used.

2.3 Quality in case study work

According to Yin, 2014 quality in case study work can be achieved by proving reliability and validity within the research work. Triangulation supports the thinking of the generation of evidence within research results. A proper collection method, the careful and sensible choice of

Research sources	Case I	Case II	Case III	Case IV	Case V	Case VI
Study of public project documents	X	X	X	X	X	X
Individual interview with project manager			X	X		
Individual interview with project participant		X			X	
Communication via e-mail					X	X
Questionnaire	X					

Figure 9: The used sources within the cases

the sample and the utilization of several information sources serve to provide reliable and valid data. (Samset, 2003, 153p)

Validity is the accomplishment to measure what the researcher intends to measure (Samset, 2003, 157). The concept of validity can be divided into three different perspectives. *Construct validity* is the requirement for the correct usage of measurement within the case to examine the area the case study is used for. This can be achieved by following the appropriate steps while using multiples sources and aiming for an easy comprehensible chain of evidence (Yin, 2014, 26p). *Internal validity* is the result of the construction of logical models or pattern. First of all it is required within explanatory research tasks and can be supported by a discussion and an evaluation agreeing upon the results within a team (Samset, 2003, 157). In this case the researcher is aiming to produce a descriptive study. The third level of validity is the *external validity*. It fosters the transferability of the made conclusions from one case to another (Yin, 2014, 27).

Whether reliable results are existent is depending on whether the measurement used is repeatable by different researchers. Thus the results remain equivalent for the same case under the same circumstances (Samset, 2003, 157). The used research methods need to be described as precisely as possible.

Figure 10 visualizes the researchers efforts to implement elements which trigger the generation of reliable and valid data. Furthermore the researcher searches within the sample for confir-

mation of previously gained information and uses an approach of cross examination. The data collection method of a semi-structured interview provides the required flexibility to react to upcoming topics during the conversation. In preparation for the interviews the researcher studied the corresponding accessible project documents in English and Norwegian to take up interesting issues or project features. The derivation of results is supported by tables and illustrations to make the approach more comprehensible. Besides the results the researcher provides the used documents such as an interview guide and the table about the project data which are annexed. They are useful tools representing the process of the researchers work.

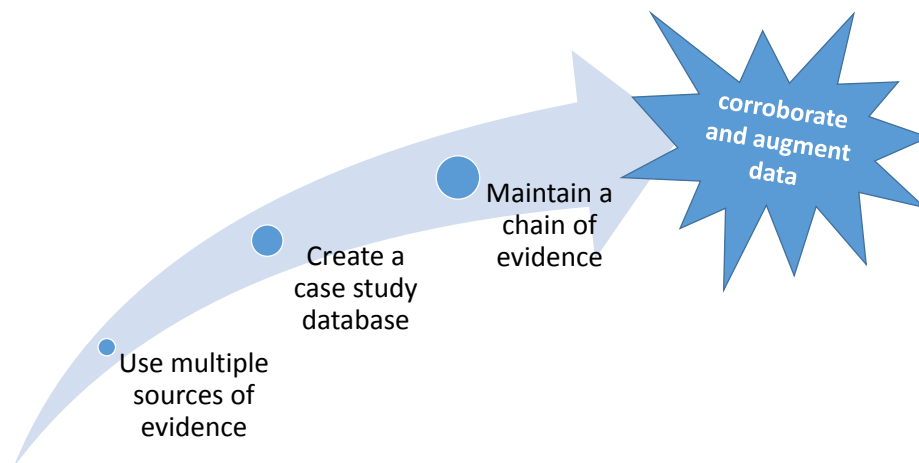


Figure 10: Establishing quality within the results

2.4 Ethical considerations

It is a matter of interest of the researcher to mention the following points related to ethical aspects with regard launching a case study design and documenting the results.

- To avoid any kind of impact from the research to the real project processes or create any kind of discomfort among the project parties, the scope for the observation is focussed on the perspective of SVV.
- The researcher is aware that participants remain anonymous avoiding any unwanted impacts resulting from the research to the individual person.

Chapter 3

Literature research

The following theoretical discourse presents an overview of the core ideas of lean, the development of lean construction (LC), the existing tools and concepts as well as the current trends in the project world. It is just a briefly glimpse compared to the huge field of lean. The researcher presents the main ideas of the identified relevant body of literature with the aim to give an introduction into the topic and to make core elements more comprehensible. Coherences will be pointed out afterwards enabling the reader to understand this approach and implement it.

3.1 Construction Management

Infrastructure projects effect many people and that is the reason why there are in general many stakeholders. They have often a high value and are of strategic of strategic importance. (Dave et al., 2013, 743) Ideas for new approaches and the transfer of successful solutions from other fields serve as means to cope with old and new project challenges to improve the project results. Using special methods and principles for a special field means to analyse and mark out the corresponding area first of all. Only the purposeful use of lean principles can lead to better project values in the end (Heidemann, 2010, 12). Working in projects requires knowledge and skills about the rules and liabilities within the project. Especially in several fields of the construction business where some new attributes bring to bear. The following sections serve the aim to pose those attributes and its meaning for further reflections. Finally a short overview is given considering the current evolution of management approaches coping with the challenges in modern times. In this way the reader should get a feeling for the roots and backgrounds adopting lean.

3.1.1 Project work

The contextual background of this work is given by road, tunnel and bridge constructions. Construction work in this sector is organized as project work in order of its complex and multidisciplinary demands. A project can be seen as a task fulfilling the needs of a requesting party ,the construction owner and finally the delivery of a product which makes the demander satisfied (Oberlender, 1993, 4). In general a project is framed by the scope of work, the limited amount of resources and the time line. (Oberlender, 1993, 4p) They should be defined as clear as possible make the project comprehensible for all involved parties. The source of many problems in the later phases of a project is the one-sided reflection on cost and time without considering the scope of work in a proper manner. That's why the challenge for the operators is to balance these three components which influence each other. (Oberlender, 1993, 4p) Nowadays projects become more and more complex by additional constraints which influence the main components significantly. An enhanced consciences about environmental issues extends the amount of workload (Turner, 2003, 16). A higher public awareness from different sides requires additional work for the whole project team and finally more man power (Oberlender, 1993, 4p). Project teams become bigger and more interdisciplinary. The amount of involved experts and specialists is continuously grown up in the history (Koskela, 2000, 126pp).

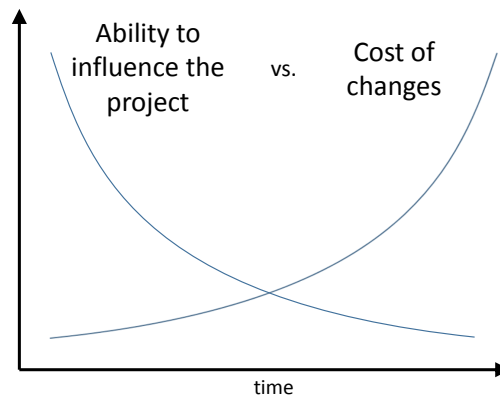


Figure 11: Holistic view on cost, time and scope of work

3.1.2 Construction projects

The project management approach is often dealing with the project like a simple ordered product. To produce such a product a division into contracts referring the supplier, project phases, the progress, activities or work packages for a better coordination is often the first step. Management -as-planning and a strict top-down approach are the consequence. (Bertelsen and Koskela, 2004, 7p) The character of those projects in general can be described with the help of adjectives like complex, unique and dynamic. A system like this results in high uncertain and variable processes which are challenging and difficult to control during all project phases for a project team. The construction environment is influenced by two basic elements. The issue weather inducts uncertainty. The second aspect is the long lead time of construction projects which is a source for unpredictability as well. Moreover the work results are based on craft technology and on human interrelationships. (Applebaum, 1982, 227p)

From the manufacturing world's point of view construction equalises an assembly process. Several material and components are composed to one final product on a specific site using specific processes. (Koskela, 2000, 185p) Looking on the arrangement of the process in total, a range of processes are independent from each other and can be executed in random order without affecting the project results (Bertelsen and Koskela, 2004, 8). Another part of activities is highly related to each other and depending on the results and quality of the upstream activities. A construction task contains of a range of several preconditions. They are influencing the variability of the processes at the site and so the flow. Thus, the whole construction process consists of a range of production tasks with a high amount of input flows. Work stages and flows need to be

sophisticated at the same time. (Koskela, 2000, 185pp)

What are the classic attributes of construction projects? In general the supply chain of the processes is more flexible and therefore less robust towards externalities. The members of the project team come from various disciplines and professions. From unskilled labourer to master craftsman to the project manager. All belong to one professional project team. It is originally "a face-to-face operation" which takes place on the field (Applebaum, 1982, 220). Thus employees with different level of labour costs meet each other within a project. The quality of the end product results from the conformance of the particular used materials and commodities. According to the scope and complexity are defects not of rare occurrence respectively after starting the usage of the product a quick quality loss can occur if the product don't meet with the daily requirements. Within all project phases the project team has to meet with several national regulations referring safety, environmental issues and the conformance by the national and local public authorities. The amount of compulsory constraints increases with the scope of the project. In the majority of the cases one final product is handed over to the client in the end. (Salem, 2006, 168p) Applebaum, 1982 emphasizes next to the uniqueness of time and location the active correlation occurred by a set of the following impacts: unforeseeable events during a long lead time and a certain required combination of craftsman, equipment, material and tradesman (Applebaum, 1982, 220). Koskela, 2000 summarized those attributes as follows:

- On-site production
- One-of-a-kind project
- Temporary organization.

Every project is carried out at its final place. That means the site is simultaneously an important and unique resource with its special attributes and offers local resources. The location with its changing attributes brings a variety of constraints within the project the project teams needs to take care about. All construction projects are unique making it impossible using the same solution and structures again. Every project is marked by a unique composition of attributes and constraints. The time aspect is mainly caused by the other two factors. That means many different and special building materials are possible for the customer. The mix of needed materials, available local materials and further local resources make it a temporary organization. (Koskela, 2000, 181pp)

Another attribute which should be named in this context is complexity. It is the result from the three attributes. The realization of activities is based on interaction and team work of different

skilled operators. The effect of all these aspects can be simply summarized under the term uncertainty. Getting control over the project means to reduce uncertainty by collecting information and data about the current situation. (Salem, 2006, 168p)

3.1.3 The challenges of a traditional management approach

The handling of those projects is in theory named as construction management. This way of management is mainly based on the idea of production as transformations. The traditional view was changing over time due to more complex projects and thus more involved and bigger teams (Applebaum, 1982, 227p). From Koskela, 2000 point of view has the building industry completely changed considering the technology part of the industry in the last century and the branch was globally marked by problems. The reasons for this are poor management and organisational approaches (Koskela, 2000, 131p).

Where do the problems come from? Why are they unsolved so far? How can they be solved? These questions are just one starting point making it worth to search for new ways to cope with the challenges of construction projects.

Scientists speak about construction management considering concepts and theory for the construction business which is developing since the Second World War. The focus is thereby on project planning and economic analysis (Koskela, 2000, 139pp). The co-ordination and balance of objectives, product, organization and the environment is the main task of the project team and can be the root for problem. The creation of a set up making the project team able to perform on daily work packages as efficient as possible is an approach to overcome complexity and variability (Bennett, 1991, 387p). The development of a new management approach should consider the following four attributes intensively:

- The processes are triggered by the client with a requirement capture and a brief formulation plot as the basis for everything in the project. This can be identified as the weakest link in the chain and thus a cascade problem arises.
- There is a varied group of customers. It is a large group of users represented by the client who is carrying out the contracts. The customer group represents a variety of technical, functional, safety and aesthetic requirements and the long life requirements. Every project consists of an own mix of requirements and interest.
- It is a temporary organization which is carrying out the project. Obviously they are less

efficient and in general more steps are necessary. Often contrary objectives dominate the organizational structure.

- Every project is of a prototype nature. There is no prototype construction possible debugging defects and errors. (Koskela, 2000, 200pp)

The management must cope with a dynamic and complex system influenced by a variety of external factors. Thus a non-linear setting is given (Koskela, 2000, 200pp). Moreover there is the fact about the fight for a limited amount of resources within the project (Bertelsen and Koskela, 2004, 7p).

The researcher is going to speak about a delivery system for the purpose of a project which is aiming to create a product for the customer. In this case, the product is a road, bridge or tunnel. The way how such a system can work is described by the following chapters.

3.1.4 The organizational structure around the client

A typical project team consists of the three parties: client, constructor and a team of architects and engineers (Oberlender, 1993, 12pp). The mentioned life-cycle in 1.3 is determining the project procedure roughly. In the literature and the praxis prevail different ideas about the way of realizing an idea. The management team is dealing with the project under ideal conditions by generating drawings, calculations and cost and time tables. (Applebaum, 1982, 227p) The engineers and architects are responsible for the design and planning phase realizing the ideas of the client with the help of drawings and maps. Constructor and subcontractor are responsible for the execution phase. (Koskela, 2000, 126pp) They are confronted with the reality of the field. That means they need to cope with all the daily challenges the construction side can offer such as failures, chaotic processes, environmental influences, human emotions and needs and fighting for scarce resources. (Applebaum, 1982, 227p)

Two separate organizations are existent. Both phases are closely accompanied by the client. Both sides are triggered and motivated by different objectives and experienced by different backgrounds. The craftsman of the different trades are aiming for visible results. The management function is driven by higher level expecting them to square the project with the given framework. In many cases they aren't able to coordinate their work among each other. (Applebaum, 1982, 227p)

For establishing a structure within a system proper contracts strategies are required. A classic and often used type of contract in infrastructure project is the unit-price contract. The contrac-

tor get paid on the basis of the spent resources in combination with a price per unit. This price is negotiated in advance based on an estimation for the amount of units. The unit-price contains all cost elements such as labour, material, overhead and profit. Another option is to use a lump sum contract which contains one total sum of costs in exchange for a certain scope of work. (Gordon, 1994, 208)

These types of contracts have their advantages basically within projects which have a clear scope, are already fully designed and there are enough time resources available (Gordon, 1994, 196pp). A minority of projects is doing so. That means the client needs to think about alternatives to cope with challenges which arose within the projects.

3.2 Lean Management

This chapter gives an introduction to the most important terms of lean stating out their meaning and importance in general. The reader shall get familiar with the main terms and principles.

3.2.1 Towards an understanding of lean

The idea of a lean system was developed in the halls of the young founded car producer, Toyota in Japan between 1950 and 1960. The engineers of Toyota, especially Taiichi Ohno (1912-1990), established a new approach for the production of cars. Since Toyota was the pioneer and innovator it is also called the "Toyota Production System" (TPS). (Stone, 2012, 113p) In the 1990's several authors especially Womack et al., 1990 introduced into the world of production in Toyota and named the application of Toyota's approach as "lean production". The authors are describing first of all different principles used within the production hall which are also defined under the term "lean manufacturing". Besides them the approach includes also activities and methods which are undertaken during the product development, the selling process, the attraction and involvement of new customers, the relation and integration of suppliers as well as the distribution of the final product. The term lean production or lean manufacturing got widespread describing a range of tools which have been developed the preceding decades. (Stone, 2012, 113)

Womack et al., 1990 can be seen as a strong proponent of Toyota's approach predicting that this approach will change the world in the twenty-first century. The author opened the view for other sectors beyond the manufacturing industry giving attention to Ohno's inventions which are supposed to be superior and everywhere applicable. (Womack et al., 1990, 278) Hayes and

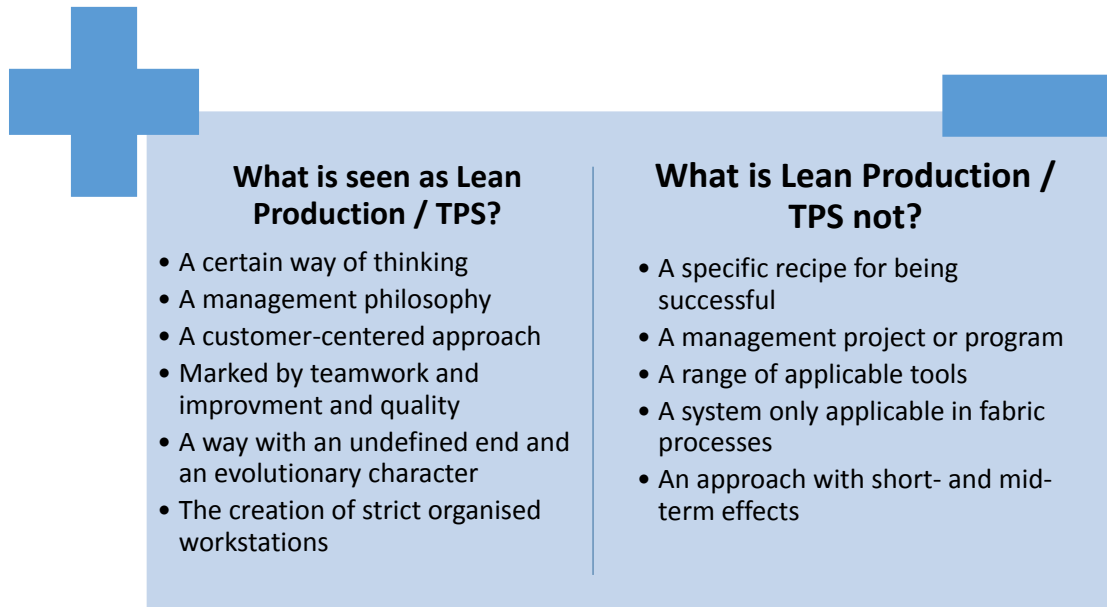


Figure 12: How lean production is seen in reference to Jørgensen, 2006

Pisano, 1994 introduced lean as a direction a company can move to doing changes. With other words, lean production is not a state or the solution for an existent or upcoming problem. With regard to productivity applying lean means to increase the productivity of processes. (Hayes and Pisano, 1994, 79).

“Productivity isn’t everything but in the long run it is almost everything”
- Paul Krugman

Productivity can be quantified by the ratio of input and output. The formula is based on the ultimate economic behaviour to satisfy human needs at the most minimum usage of efforts and resources. (Saari, 2006, 2p) Green and May, 2005 reveal that lean production itself is simply understood as, “a set of techniques, a discourse, a socio-technical paradigm or even a cultural commodity” (Green and May, 2005, 503p). This lack of understanding aims to contrast what is seen as lean production and what it is not. Figure 12 is showing the reader that an overall explicit definition for lean production is missing.

The researchers view on lean production is determined as a specific and common way of thinking within an organization. The thinking is following the core ideas of lean and is framed by the peculiarities and requirements of the construction sector.

3.2.2 Lean thinking and its roots

What are the roots of this way of thinking? What is the contextual background of the story of lean management?

The roots of lean thinking can be found in TPS. Thus the contextual background has been developed within the car industry.

The core idea is to create value for the customer and to abandon waste.

(Womack et al., 1990, 64)

The principles of lean production were developed in the 1960s within the whole system of producing and selling cars (Womack et al., 1990, 64pp). In the first half of the 19th century, Toyota has been suffered big problems such as being forced by the government to produce cars they wanted to have, a small domestic market, a wide range of different requirements using a car for and high energy prices. The company was forced to act and the engineers introduced the Toyota Production System. (Womack et al., 1990, 46pp) The idea of lean production was born.

The engineers of Toyota started to think more in-depth about the terms value and waste. The Japanese term for waste is muda and this term was going to be one of the key terms of the new approach. Waste can be identified as a human activity using resources without creating a benefit for the customer (Koskela, 2000, 57). Inspired by this observations the engineers tested a range of new methods and processes. (Womack et al., 1990, 55pp)

- The production of small batch sizes instead of producing huge amounts with the aim to offer products of high quality and reliability.
- Toyota installed a system to change the tools of the machines to reduce the tool changeover time from one day to three minutes.
- Toyota created interdisciplinary teams with strong leaders and fostered team players by a reward system. Every team is responsible for a range of tasks they had to solve in the most efficient way. The improvement of the current process was the aim. Hence the idea of Kaizen was born which describes the installation of a continuous, incremental improvement process.
- Referring the issue how to handle rework or upcoming errors, Toyota stops the whole process immediately to search together for a solution.

- Instead of just fixing a problem in trust that it will never appear again, Toyota invented the five “Why” approach to identify the original source of the problem.

The results were significant; no breaks during the production, no rework and the occurrence of defect products was rare. High reliable products were produced. (Womack et al., 1990, 55pp) Furthermore Toyota was able to offer many different types of cars because of the low production-engineering costs. The relation between the customer and the producer became more and more important. Toyota figured out that the company needs to align their amount of produced goods with the amount the customer need for. The development of a build-to order system was triggered. The aim was to identify the customer’s preferences and buying behaviour. The idea of the ‘Pull-system’ was born. (Womack et al., 1990, 64pp)

Nowadays the application of lean principles standard within the production industry. Companies need to implement and develop new processes to remain competitive in a globalized market. (Vienazindiene and Ciarniene, 2013, 1pp)

3.2.3 The five lean principles

The two central terms of lean production are value and waste. Several authors try to describe this approach and uncover its secrets. Hence different scientific statements are available. The researcher decided in this case for the approach of Womack and Jones, 2003 who described and defined five lean principles as follows. Another reason is to stay consistent to the preceding words partly based on Womack et al., 1990.

Additionally to the two mentioned terms, further concepts arose. These are ‘value stream’, ‘flow’, ‘pull’ and ‘perfection’ which have the final aim to reduce waste and improve on that way the system as a whole. (Womack and Jones, 2003, 16pp).

This five concepts against waste are summarized by the term lean thinking. The idea is to determine together with the customer the value of a product, organize the required processes in the most efficient sequence to avoid any kind of breaks or disruptions and aspire for improvement all the time. That implies also to reach more with less resources such as human effort, equipment, time and space. The aim is to create a system which produces exactly the demanded products. (Womack and Jones, 2003, 16pp) These ideas reflect the lean philosophy and describe a certain way of thinking within an organization or unit. To achieve this way of thinking a range of tools are needed. (Womack and Jones, 2003, 15)

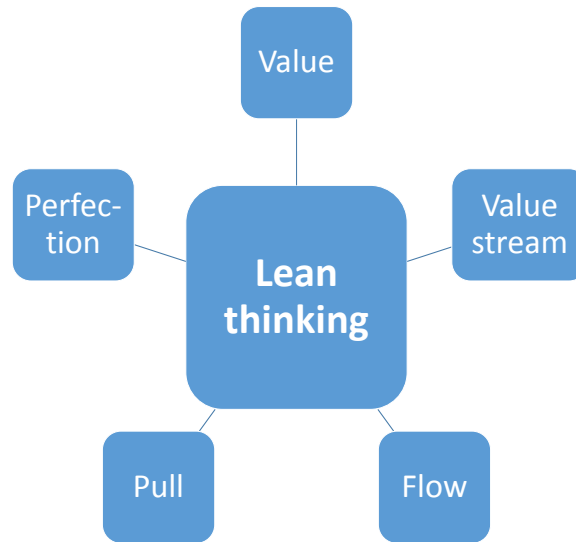


Figure 13: The five lean principles

Value

Lean thinking starts with the step of specifying value. Value is supposed to be expressed with the help of a specific product and its features defined by the customer. From the customer's point of view the producer is responsible to deliver exactly what the "voice of the customer" has ordered regarding specific product attributes as price and time. For the customer something is of value what he can directly use. First of all the end customer (3.5.1) needs to be identified. Afterwards it is the task of the producer to enable the customer to determine those features giving him the knowledge. (Womack and Jones, 2003, 16p) A close relation between producer and customer is required. The concept of the customer is the basis for this specific thinking. (Jørgensen and Emmitt, 2008, 386p)

The counter part of value is waste. The aim of lean is to increase the value while eliminating and reducing waste (Womack and Jones, 2003, 15). Providing a product a customer isn't asking for is an activity of producing waste. It is necessary to examine a system onto whether single processes directly add value to a product or service. Every transformation process from input to output is linked to work and waste. There are two types of waste. The first type of waste can't be avoided and should that's why reduced as far as possible. The second type consists processes which aren't necessary for the value of the end product and should be eliminated. (Womack and Jones, 2003, 16) The thinking of waste is related to the seven categories of overproduction, rework, transport, over-processing, inventory, waiting and motion. Waste can effectively identified to

the extant the customer has defined value. (Ohno, 1988, 19p)

Value stream

Every product underlies three management tasks: a problem-solving task, an information management task and a transformation task. Focussing on a value stream means to create an environment where a product and its required activities can pass the three management areas in the most efficient way. (Womack and Jones, 2003, 19p) Moreover it can be determined which specific actions need to be involved into the whole process from the first idea until delivering the product. The value stream is visualized with the use of a mapping method. Based on the identified process disruptions can be observed and proper actions can be undertaken. On that way waste can be reduced and eliminated. A value stream can be used to depict all internal affairs and can be extended to the whole supply chain. (Womack and Jones, 2003, 37p) The central tool aiming for a value stream is the value stream mapping method. It means to focus and analyse the activities in detail. Drawing the material and information flow with a pencil helps to get into the bird's eye perspective and understand the process in total. (Rother and Shook, 2003, 37p) By illustrating the present process flow with the help of a mapping method supports to optimize the flow. The performance of a value stream can be operationalized determining the attributes lead time, inventory and operational costs. (Jarkko et al., 2013, 49pp)

Flow

The concept flow is one of the core elements of lean thinking. It enables the user to remove waste making the remained processes flow after a value stream analysis. As a consequence the lead time can be reduced and hence the probability for unforeseen events declines. (Womack and Jones, 2003, 21p) To get a flow into the process, the manufacturing industry uses working cells instead of sending a product along the production line. (Suzaki, 1987, 27p). The work of functions and departments are redefined by ignoring the traditional approach and focussed on each product separately. In that way they are questioned whether they perform a positive contribution to the process. Applying special tools, interruptions and breaks can be eliminated and the object can proceed continuously. (Womack and Jones, 2003, 52p) Further methods to create a flow are given by standardization of work (3.2.3) or just-in-time (57). Flow can be realized in any kind of activity besides the production world. The traditional classification thinking is conquered installing an one-piece flow after being able to see the process from another point of view. (Womack and Jones, 2003, 64p)

Pull production

Within pull production the production is triggered with the order of the customer. The order marks the starting point to produce a product. Cascading backwards along the product process every production step starts to demand of getting input from the production step before. (Womack and Jones, 2003, 24p) The output of a production step is the input needed by an activity further downstream (Tommelein, 1998, 280p). A supermarket system within the production process develops. Refreshment of the material or inputs is precipitated by consumption (Liker, 2004, 23). Each step in a production line is treated as a customer. Having internal customers

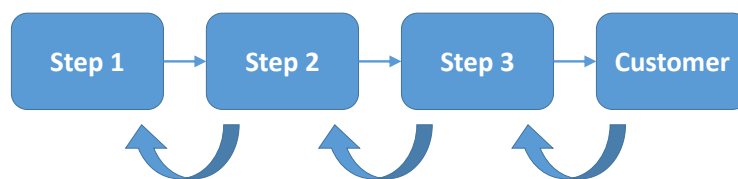


Figure 14: Pull production

raises also the awareness for quality (Deming, 2000, 58p). Further benefits having a pull system are to be flexible regarding the demand of the customer, making the process flow and reducing the waiting time of products between the single steps of the production line as well as reducing inventories. All production steps are connected within an information system giving every step a sign to get active. (Womack and Jones, 2003, 67p) It is a whole set of principles enabling the user to deliver the right products in time to the right place with the right amount. The organization is in this way flexible on changes in demand. (Liker, 2004, 23pp)

Perfection

The management of Toyota was able to establish a culture within the organization that makes the employees to strive for improvement all the time (Womack and Jones, 2003, 25). A culture is a pattern of ideology or an general behaviour showed by members of the same organization who are acting together for a certain period of time (Wit and Meyer, 2010, 171). Based on this culture a mindset developed to aspire for more value, a better flow and less waste. The fifth principle of lean is matching with high transparency. The more open all processes are for all involved parties, the higher are the chances to find better solutions which make the whole system better. (Womack and Jones, 2003, 25p) The term Kaizen describes the aspiration for perfection and is part of the mentality of the Japanese. The way to move further all the time is taken for

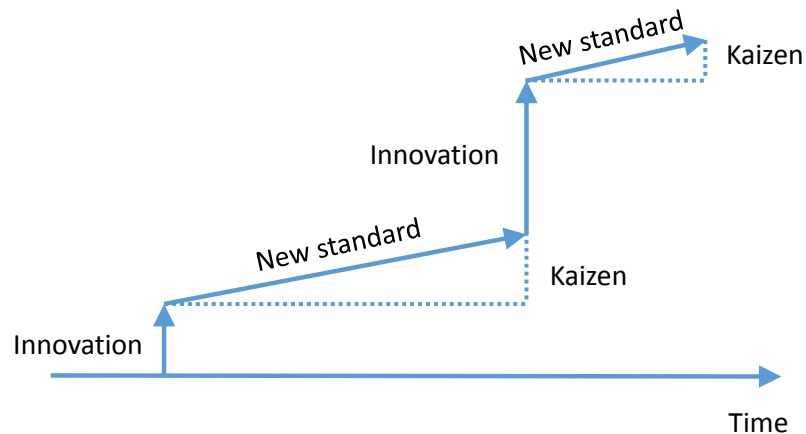


Figure 15: Maintaining improvement
in reference to Wit and Meyer, 2010

granted here in contrast to the Western world which has another attitude to changes. It is necessary to distinguish between gradual and abrupt changes. The Kaizen idea stands for a gradual change and can be described as a continuous improvement process in the background of the day-to-day business. It is an undramatic process where the results are not always seen directly. All employees are involved in it. (Wit and Meyer, 2010, 195pp) It is the source of all further existent concepts originated from Japanese companies especially the awareness about quality and reliability of the products. Standardization helps to settle and maintain an achieved status. (Womack and Jones, 2003, 91pp) Kaizen is an universal concept and can be applied in every kind of activity (Wit and Meyer, 2010, 195pp).

3.2.4 Lean techniques

The lean principles can be realized and implemented by using lean techniques. It is the last element within a system but for the user the most visible and comprehensible one. In recent years a huge range of different tools has evolved. The focus should be on understanding the system and the thinking on causes and their effects. (Seddon and Caulkin, 2007, 14)

3.3 Transferring of principles

The researcher gives with this chapter an overview about the development of LC referring the knowledge transfer from the manufacturing industry to the construction business.

Transferring principles means first of all to consider similarities and differences before connecting two different fields. Such a comparison is done already within a variety of works e.g. by Salem, 2006; Jørgensen, 2006 and Santorella, 2011.

- The client can influence the production process by specifying the term of value which is the foundation of all following processes (Bertelsen, 2004, 54).
- Construction teams can be seen as problem solvers at the site. They are going to operate and perform at the edge of impossibility every day. A construction team needs to know every step of producing a product to have full control about it.
- The construction site can be described as a dynamic place formed by individuals and their interaction with each other.
- There are different interest groups like the customer, the users, the workers or the suppliers. Those stakeholders can be part of the execution phase and they give feedback directly.
- Many construction processes are dependent on subcontractors such as technical experts and master craftsman. These players are naturally not interested being team players and adopt the activities for the purpose of the optimization of the whole project. (Santorella, 2011, 1pp)

The report of Koskela, 1992 was the first one who discussed the topic lean production within the construction sector. Within the dissertation, Koskela, 2000, the author takes up with this topic again and introduces the TFV concept highlighting the construction processes from another perspective than all other scientist did before. The concept is based on the handling of the management of:

- Transformation,
- Flow and
- Value.

The transfer of tools realizing and applying the ideas of lean within the construction fields are visible reviewing the theoretical body of literature about LC. Critique is often related to the topic, to what extent such principles originated from the production industry can be transferred to other sectors. (Green, 1999, 22p). A range of new tools and methods developed considering the character of construction projects as well as consisting the core idea of lean.

By adopting a new approach two requirements can be stressed. The first point is to scrutinize how and why the new tools and processes are driving the change. The next step is necessary to ensure that the new processes work reliable and that they can be monitored and measured. (Poppendieck and Poppendieck, 2003, 15p) To evaluate the implementation process, tools to monitor and assess the process were developed by Salem, 2006 or Heidemann, 2010. The status can be monitored with the help of check-lists and tables. By this means the status of the implementation process can be quantified and changes can be tracked as well as effects with regard to the project results (Salem, 2006, 171pp). Further indicators for single areas can help to measure the process implementing lean (Vienazindiene and Ciarniene, 2013, 368p).

Another interesting point of criticism was given by Jørgensen, 2006 uncovering that the body of literature isn't a conceptual starting point for further theoretical research on LC. This is based on the fact that there is no common definition about LC available. Thus a common comprehension about this field doesn't exist so far. (Jørgensen and Emmitt, 2008, 386pp)

“Emerging techniques have started to change the way constructors manage their own operations.” (Salem, 2006, 169)

3.4 Lean Construction

The following chapter acquaint the reader with the term LC in general and its different definitions. Based on the traditional wide spread approaches described in theory, the following chapter is created to give an overview about the most important tools and methods. There are three starting points to approach and realize lean principles in an organization: the organisational structure, the operating system and the commercial aspects.

3.4.1 Lean Construction as a management fashion

From the overall point of view there are actually two things happening within the construction business. The first concern is happening on the conceptual and theoretical level named as LC.

The second impact is on the level of the transformation of information summarized under the term building information modeling (BIM). Both aspects tend to change the sector and its processes elementary. Scientists observed that both approaches brings synergies for the user if they are applied parallel. (Sacks et al., 2010, 968pp)

Influenced and based on the research of Koskela, 2000 several authors developed discrete instruments for the design and production phase (Jørgensen and Emmitt, 2008, 387p). A representative survey launched by Green and May, 2005 about the interpretation of the term LC three central aspects were coined representing lean: elimination, partnering and structuring the context (Green and May, 2005, 508). Eliminating and reducing waste means to install smooth operation steps and increase the performance of the whole process. The second character is aiming for strategic and close relations between the involved parties of a project made by knowledge sharing and teamwork. Moreover having a culture of learning and supporting each other. The last aspect is scrutinizing the traditional structure of construction projects and is postulating a new delivery system carried out by a new structured organisation. Beside the training of individuals is the involvement of them by an innovative system through bottom-up activities of importance. (Green and May, 2005, 508p)

Jørgensen, 2006 tried to give an overview about the several existent definitions. LC is seen as a management fashion (Green and May, 2005, 501pp). A management fashion is defined as a temporary common belief widespread by management-knowledge entrepreneurs. New introduced management techniques result to a new management approach. (Abrahamson and Fairchild, 1999, 708p) One important character of such a fashion is the interpretative viability. This feature gives a fashion the chance to get adopted by a variety of different organizations. The applicability get increased by the possibility to use and implement the fashion in an own way. Different versions of the same concept can be existent after a certain periods of time. (Benders and van Veen, 2001, 37p) The mentioned survey is showing and confirming that there are multiple interpretations existent which are essential for an effective diffusion. LC is tackling a set of different areas within an organization. It can be further seen as an innovation process of social and technical issues aiming for a certain state of the system. Such a process is going to be steadily implemented against the background of new local contextual issues. (Green and May, 2005, 509p)

An often used implicit statement about LC is the usage of the lean production ideas within the construction business. Production consists in this case of an integrated approach of designing and making activities. Following this argumentation the term lean design has the same at-

tributes as LC. It is the application of lean production ideas within the processes of the designing phase. (Jørgensen, 2006, 110p)

That means LC is focussing on lean methods and tools during the execution phase aiming for a lean site and a lean delivery of the product. Lean design is focussing on all upstream activities necessary to prepare the execution phase. This separation is only touching the level of processes, not the methodology (Jørgensen, 2006, 110). This fact is important looking on projects carried out by public clients with their boundedness to public procurement restrictions (Heidemann and Gehbauer, 2011, 19p). Due to the holistic character of lean and the independence from the type of activity it can be said that a design phase shaped by lean activities has a huge impact on the execution phase. But both phases can be handled and optimized separately as well. The design phase is also part of the suggested lean delivery system by Ballard, 2000 (3.4.6). In common usage lean design is seen as a branch of LC.

Looking on LC as management fashion means that lean principles are also relevant for organizations dealing with infrastructure projects without using the terms around of LC or having a specific knowledge about this field. This fact triggers in turn the demand for the examination of projects about indicators for lean principles and the demand for a step in the direction of one common comprehension to overcome the status of a fashion. One possible method for this concern is the conduction of case studies.

3.4.2 Effects: Challenges and opportunities

The implementation of lean is fragmented. That means a range of scientist figured out that the usage of single tools and methods is already widespread. More important than the tools is the comprehension of the new system in a holistic way (Seddon and Caulkin, 2007, 14). The cases in which tools are used can be seen as an important step spreading and triggering this approach as pioneer projects to learn from. Often several tools are applied which makes it difficult to reveal exactly the effects. It is more about using LC, whether it is dependent to a bunch of methods and a large number of actors involved in the project. (Andersen et al., 2012, 126) The body of literature provides a range of case studies trying to identify and quantify the results applying lean principles within infrastructure projects such as Walker and Shen, 2002, Eastmann et al., 2011 and Dave et al., 2013. All of them report positive aspects for their examined activities. Those non-generalizable effects were mainly reduced lead times, reduced costs, better quality, better cooperation among the project parties and better health and safety performance.

The missing common definition and thus the space for interpretation can be a challenge as well.

There is not one recipe for the 'right' implementation heading towards a state using lean principles. The widespread application based on different comprehension and experiences makes it difficult to develop a guideline implementing lean principles. (Jørgensen and Emmitt, 2008, 386pp) Launching lean is disruptive to the status quo and difficult to undertake (Vienazindiene and Ciarniene, 2013, 367).

3.4.3 Identifying waste in construction

The discussion of value and waste within the construction sector is of central importance and similar to lean production. Value is first of all discussed against the background of the project as a process and of the product (Ballard, 2000, 2). The viewpoint of a whole-life perspective is necessary. As a result the questions about value and waste became more complex and are automatically shifted from the execution phase to the design phase. (Jørgensen and Emmitt, 2008, 388p)

Reducing and eliminating waste is one of the key factors in LC. Waste in construction can be classified using the categories of lean production introduced by Ohno, 1988: correction, over-processing, delay, inventory, conveyance, over-production and motion. An eighth type of waste was introduced by Koskela, 2004. The type "Making-do" is about activities which are started without fulfilling the requirements to complete the process in one go. Processes should be started when required (3.2.3) and when the input parameter are fully available or their availability can be ensured. Otherwise workers are executing their work under suboptimal conditions which leads to lower productivity. Suboptimal conditions are existent due to congestions, out-of-sequence work, multiple stops and starts, inability to do detailed planning in advance, obstructions due to stocks of materials, tries to cope without the most suitable equipment for the task, interruptions due to lack of materials, tools or instructions or over-sizing the crew. Reasons for this upcoming conditions are rework in order to changes or defects. (Koskela, 2000, 190p)

The input parameters are given in figure 16. A rest of uncertainty remains given by external conditions and impacts. Waste occurs if at least one of the input parameter is unconsidered and isn't available in time. (Koskela, 2004, 1pp) Looking at the causes for "Making-do" issues it's necessary to distinguish between the design and the production phase. During the design phase making-do issues are caused by the incompleteness of information. (Koskela, 2004, 4p)

A further type of waste can be seen in unused human resources referring the experience and ideas. A way of lean organizations to reduce this kind of waste is to establish a suggestion sys-

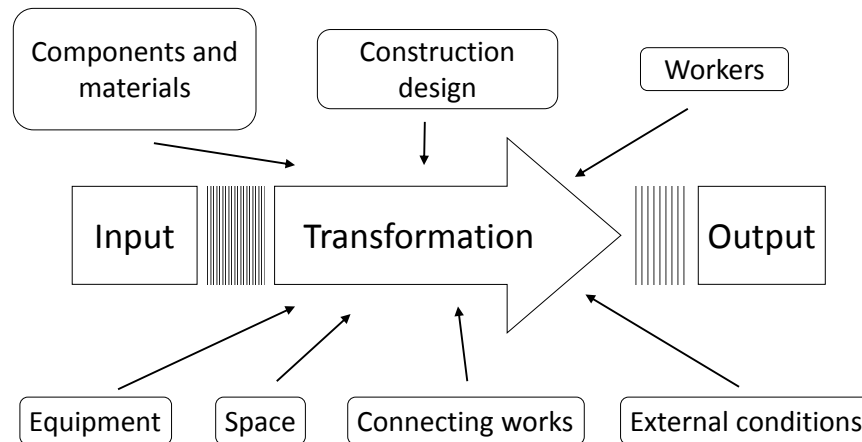


Figure 16: The input parameter for transformation in construction projects in reference to Koskela, 2000

tem. By this means all team members can be involved. A culture of aspiration for perfection can develop and can be the first step for having a 'Kaizen' structure. (Nahmens and Ikuma, Laura H. & Khot, Digvesh, 2012, 92p)

Avoiding waste is the overall objective of lean, the lean principles and the provided methods. Methods which aspire,

- to reduce the lead time,
- to reduce the variability,
- to simplify the progress,
- to increase the flexibility or
- to increase the transparency

can be used to tackle waste in construction projects (Koskela, 2000, 57pp). The applicator of lean methods needs to have the view, experience and later the attitude being able to identify waste and to tackle it in its particular case in favour of the whole project. Handling waste means after the step of identification to examine their causes. The consequences of eliminating waste are better facilities which can be designed and constructed for lower costs (Ballard, 2008, 3p).

3.4.4 Implementing lean thinking

The development of the new approach within the production field proceeded with three steps. First of all it was seen as a collection of tools which serve for realizing something. The next step is the view as a method. That means the focus is on the way how someone is doing something. Finally a special way of thinking is evolving. (Liker, 2004, 13)

While considering construction projects it is important to know about the attributes in contrast

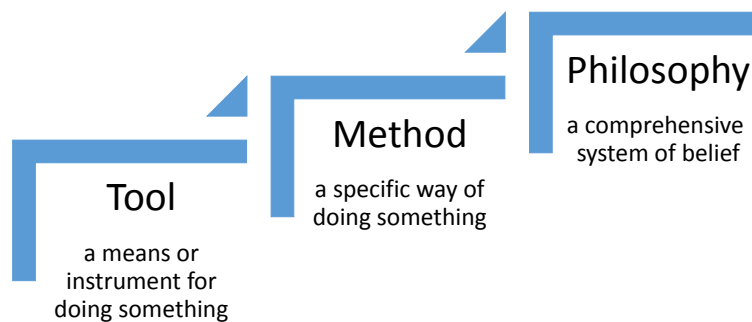


Figure 17: The steps of implementing lean thinking

to the manufacturing industry. Especially referring the physical features of the end product of these industry fields there are differences. Both sectors have in common to aspire with their production processes a state with the highest value for the customer considering a long term period (Salem, 2006, 169).

New processes are needed by implementing various tools and techniques which help to move into the direction of lean. Because lean is a different way of thinking a new environment is required to influence the behaviour of the humans. (Vienazindiene and Ciarniene, 2013, 367pp) To implement a new system into an existing organisation, there are two essential requirements. The first one is to provide the right and efficient tools for the right situation. A purposeful usage of the tools is necessary (Heidemann, 2010, 12). Those should be confidently and function properly. In the case of lean the best solution is a combination of both to force and motivate the employees to take up new ways of progressing and enable them to understand why and what they are doing. The change of behaviour is necessary as well. This can be a change referring either to many aspects or to some specific aspects, either to a whole organization or to parts of the organisation. A change requires the commitment of the concerned people. The success factors are to give the users adoption time, to support them with proper resources and to have a

clear plan. (Amaral et al., 2012, 9p) Monitoring this process with the help of previously defined indicators can be one approach for a successful implementation of lean. (Vienazindiene and Ciarniene, 2013, 367pp)

For applying a new approach in such a broad field means to tackle an existent system from different sides. All mentioned core values of lean can be realized applying certain techniques within a project management system. Compared to a traditional system there are differences in defining the phase, the relation among the different phases and the persons who participate in each phase. (Ballard and Howell, 2003, 121pp) The concept used in this case to analyse the done research is based on the lean triangle. The triangle, illustrated in figure 18, is consisting of the three areas of organizational structure, operating system and commercial terms (Heide-mann and Gehbauer, 2011, 27). On this way lean can be approached holistically (Lichtig, 2005, 106p). That means there are three domains of LC to focus on which contain several ideas and

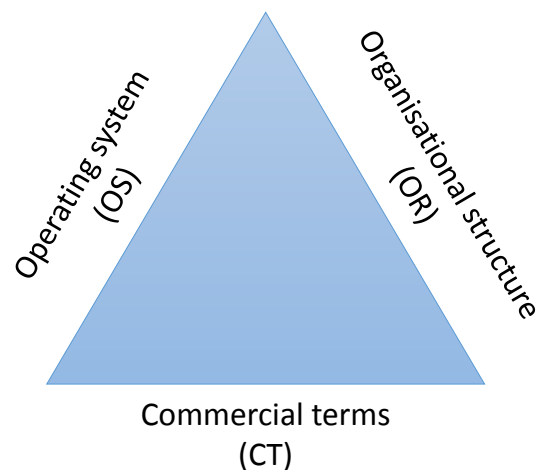


Figure 18: The lean triangle

techniques which help to become a lean system.

3.4.5 Organisational structure

The first side to meet is the organizational structure (OR). How is the project team structured and how is it working? Furthermore this area is tackling which relationships and structures are needed.

Integration within the project

This side is dominated by the Integrated Project Delivery (IPD) approach. To get the needed materials as well as reliable and consistent information from other project parties is one of the biggest challenges (Applebaum, 1982, 232).

The phases design and execution are decoupled from each other in many cases (Koskela, 2000, 128). Projects take up on the mentioned systematic problems caused by the traditional approach. The IPD approach is sounded by the advocates of LC. A more collaborative and integrated approach is seen as one tool to generate better project results and lower costs in response to a high fragmented market (Egan, 1998, 8p). An “over-the-wall” syndrome was pointed for the traditional management approach which need to be overcome. Evbuomwan and Anumba, 1998 speak about a paradigm shift within the construction industry towards the competitive situation. All important players along the different trades need to create one multi-disciplinary team tackling the topics along the life-cycle from the early stage of the project. The level of integration is both project management and design implementation. A framework for operating and collaborating is required to do so. (Evbuomwan and Anumba, 1998, 587p)

To achieve a lean project structure the project parties need to be aware about the following aspects (Matthews and Howell, 2005, 46pp):

- Every member is sharing the whole responsibility for the project.
- Deviations and faults are solved within the team.
- The optimization of the whole project is in the foreground.
- A close collaboration and good relations determine the daily business.
- The team is looking together for improvements and is sharing the benefits.
- All interests are aligned to aim for one common objective.

The team should consist of project members from all important project parties and it is advantageous to share one common place together. The team has to designate together about the personnel of key positions. Those positions are working for the team, report to the team and get paid by the team. A solution given by the advocates of LC is seen within the application of relational contracts (3.4.7). IPD is therefore one specific manifestation of relational contracting. It is the core part of a lean delivery system. (Matthews and Howell, 2005, 46)

The project members need to be selected deliberately ensuring that the lean approach can be

implemented using a proper selection method. The key parties such as architects, engineers, consultants, constructors and important subcontractors are conjuncted from an early stage of the project. As a result the tool of concurrent engineering can be used and teams around specific assignments can be created. (Forbes and Ahmed, 2011, 171pp)

All aspects influence each other and underpin the presence of an integrated approach. The aspects support an integrated approach but do not create an integrated approach itself. (Kim and Dossick, 2011, 62pp) Results of testing software tools like BIM (3.4.6) and VisiLean (3.4.6) require and foster the integration of downstream contractors providing relevant information and feedback as input for visualizing the structures. (Dave et al., 2013, 750) The benefit of an IPD

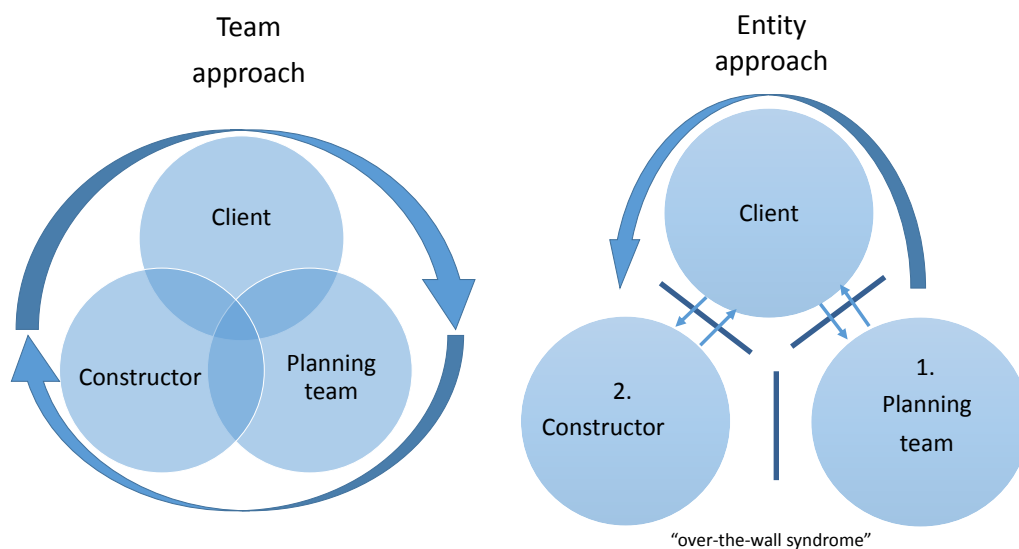


Figure 19: The organizational structure

is the search and creation of value starts with the start of the project. The whole project team works together from the first moment. For a better coordination and a focussed work on certain issues can the team divided into several cluster groups often depending on the type of tasks. (Matthews and Howell, 2005, 50p) An IPD organization has the premisses being able to adopt and implement the principles of a lean production system (Forbes and Ahmed, 2011, 173).

Communication platform

The construction sector is marked by multi-disciplinary teams, high dependence towards time and the existence of a high amount of data of different formats. It is described as one of the most-dependant industries. The provision of information is the basis for all decisions, the physical progress and serves to overcome communication barriers. (Deng et al., 2001, 240p)

The infrastructure of 'Information and Communication Technology' (ICT) supports an integrated team approach by sharing, documenting and producing data during all project phases. Within the construction industry ICT solutions serves first of all to visualize projects in 2-D or 3-D, for data analysis, for the handling of communication and collaboration processes and the distribution of information. The area of information management solutions provides proper infrastructure for capturing, storing, organizing and retrieving data. (Forbes and Ahmed, 2011, 203pp)

Nowadays, there is the possibility to chose among a variety of information systems and to create the own system adopted to the corresponding needs of the project work. Such a platform helps among others to avoid double work, to create high transparency, to shift the official correspondence to a collectively used platform and to reduce the response time right up to a real-time dialogue. The transaction costs can be reduced and the handling of information can be managed in a more speedily, accurate and traceable manner. The usage of internet-based services affects the management of construction projects in many aspects to overcome the barriers of time and distance. (Deng et al., 2001, 240p) ICT supports the idea of integration significantly and triggers the change for the way of thinking by providing a network creating new ideas. (Forbes and Ahmed, 2011, 226)

3.4.6 Operating system

The operating system (OS) is about the used tools and methods within LC. While reviewing the literature, collecting ideas from previous case studies and preparing the interview it gets discernible that the dominant part is represented by OS respectively the methods for a production based planning, control and management system. This side in general is coined by the term LPDS, the lean production delivery system.

Establishing a lean project delivery system

A LPDS represents a variety of tools and methods. Handling construction projects regarding to LC means to determine a certain set of tools chosen from a toolbox which supports the ambitions to establish a lean delivery system. (Salem, 2006, 169p)

The LPDS describes the way of implementing a lean approach. The model, introduced by Ballard, 2000, the co-founder of the IGLC, was developed in 2000 and relaunched in 2008. It can be seen as a philosophy and framework realizing construction projects from a production orientated point of view. The LPDS can be seen as a try to create a simplified model introducing

LC as a holistic system which incorporates lean principles and takes up with the ideas of the TVF-concept of Koskela, 2000. The aim is to align people, system and business practises in such a manner to take advantage of the available resources and the knowledge of the involved people in an optimal way. The user gets with this model a guide how to make a system lean. (Ballard, 2000, 1pp) The current distinction between planning, execution and control causes of

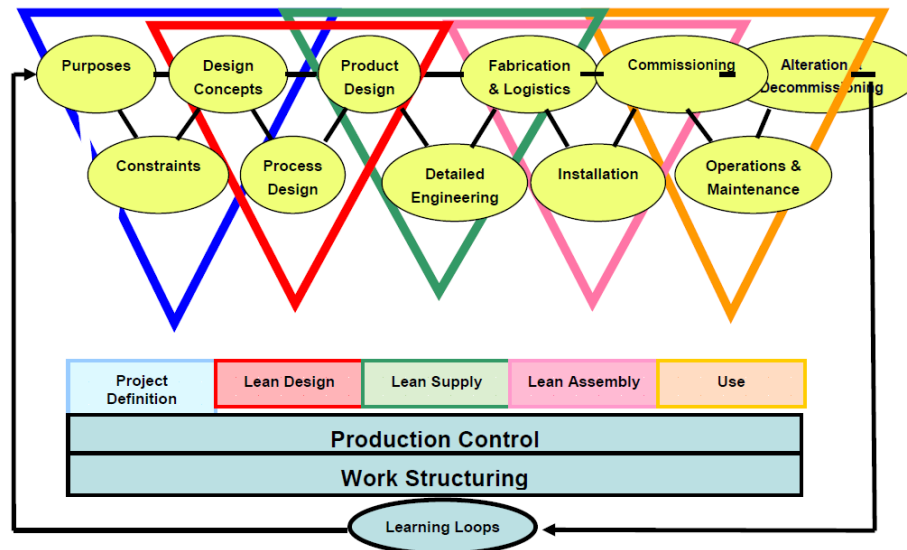


Figure 20: Lean Project Delivery System
in reference to Ballard, 2008

poor project performance and hampers of what is possible (Lichtig, 2005, 107). The model contains of five phases with several modules. The modules next to each other overlap and influence each other. The first three phases can be summarized as preparation phase. The phase 'lean assembly' is the execution phase starting with the delivery of tools to the site until the handover of the product to the customer. The single phases with its modules are accompanied by the overall proceeding modules 'work structuring' and 'production control'. That means project parts are disassembled into chunks identifying a reliable work flow of value adding processes. Furthermore production control is realized by using the Last Planner System (3.4.6). (Ballard, 2008, 2pp) A LPDS can be illustrated in the following way:

$$LDPS = IPD + LPS + TVD + BIM + JIT + CIP + PS + VSM$$

It can be therefore spoken about the interaction of a variety of tools and techniques. Additionally to this summands there is the aspect about the relation of the team members. Based on the IPD approach, the organizational structure needs to be defined by the commercial term (3.4.7). The single items of the equation are shortly named and described within the following paragraphs.

Scheduling with Last Planners

Who is creating the schedule? The engineers who have little information about the time used for single processes or the craftsman and trades who have little information about the logical sequence of the project through the different phases?

The scheduling process is dynamic and highly interrelated to the daily contact of human beings, the confidence in human commitments, the tolerance for honest mistakes and the handling of suddenly upcoming events. (Applebaum, 1982, 230).

Considering the features of construction projects 3.1.2, scheduling is a challenge for every project team. Special tools are required supporting the idea realizing a lean delivery system. Tools of the manufacturing industry doesn't help to tackle the scheduling process due to their linear planning character (Dave et al., 2013, 742). The required activities are deduced by the functions of the building. A sequence is existing. Each sequence is operated by one trade in general. (Koskela, 2000, 136)

The Last Planner System (LPS) is a popular tool within the lean approach for the construction site considering the construction peculiarities and taking up the flow concept of Koskela, 2000. The tool has been designed by Ballard and Howell, 1998 since 1992 and is licensed by the LCI. An integrated team consists of the concerned contractors and project managers who are planning the processes step by step. (Jørgensen, 2006, 83pp)

There are three different level of planning depending on the considered period of time. The initial planning schedule contains all important milestones of the project as well as the total budget. It has overall coordinating character. The look-ahead schedule includes the activities for the next six weeks with the aim to make single processes ready for take-off and activate the required resources. It can be seen as a check-list for every single process proving that all requirements are fulfilled in time and the process can be started like scheduled. Based on this plan the weekly plans can be deduced with more details about the time and duration. The planning at the last step actuate immediately the execution of the work based on the commitment of all participating project teams. (Ballard and Howell, 1998, 11p) By dividing the number of activities which are fully completed with the number of total activities, an indicator with a message for the performance of the project can be calculated. The ratio 'Percentage Plan Completed' (PPC) indicates the performance of the schedule. By reviewing the causes of incomplete activities the schedule can be improved tackling exactly the source of the causes. The goal is to aim continuously for a PPC value up to 100%. Productivity, reliability and the flow of processes are triggered. (Salem, 2005, 4p)

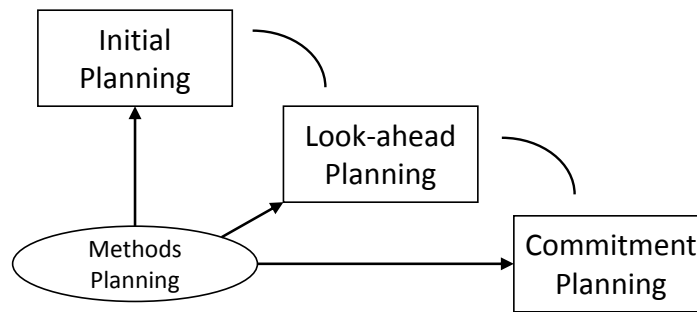


Figure 21: Last Planner System
in reference to Ballard and Howell, 1998

Preconditions for applying this tool are a work breakdown structure and a pull character of the processes. The LPS is often used in connection with a “Big room” as central office at the field making decisions based on the visualized process. As a result a detailed and backward generated process flow exists which helps to identify the preconditions for each task. (Salem, 2006, 171pp)

The variability of workload can be reduced at the same time. Another effect of this kind of planning is to identify proper buffers make processes towards unforeseen impacts more robust. (Jørgensen, 2006, 83pp) The aim is to increase the reliableness and robustness of the processes significantly. Moreover the typical start and stop progress can be eliminated and the activities which consist of waste can be reduced. (Bertelsen, 2004, 58pp)

A proper software tool is 'VisiLean' to generate a Last Planner-work flow and to integrate the planning steps of the product and the required processes. (Dave et al., 2013, 741)

Designing and planning by target costs

Target value design (TVD) is aiming for a state that the project team and especially the architects and designers compile a design matching with the available funds. TVD is deduced by the target costing concept of the manufacturing industry where the customer value drives the design phase. (Zimina et al., 2012, 384pp) The budget and the practicability are drawing the design instead of being an outcome of the design. An integrated team with knowledge about different aspects is necessary. Ballard, 2008 presented the following formula:

$$\textit{Allowable Cost} \geq \textit{Expected Cost} \geq \textit{Target Cost}$$

TVD serves to realize the determined target cost (TC). The TC should be defined together with the client. By defining the value, the target costs are determined. (Zimina et al., 2012, 384) Design decisions can be reflected from different sides and are based on more available information. The client has a central role within this method. He is responsible to communicate their needs and he takes the final decisions. (Ballard, 2008, 8p) The value orientates to best practise solutions and the costs shall be even lower than those performances. It serves to create incentives among the project team. The team including the client aim to come below the TC value triggering at the same time the system for perfection and close collaboration. It can be used either for the whole project or for parts of the project to cope with attributes of construction projects. (Ballard, 2008, 8pp) The current costs need to be aligned continuously with the target costs (Heidemann, 2010, 64p).

Visualization with BIM

BIM is defined as a verb or adjective phrase to describe tools, processes, and technologies that are facilitated by digital machine-readable documentation about a building, its performance, its planning, its construction and later its operation. (Eastmann et al., 2011, 586p). It is an activity using a software to create a building model. Building and construction structures can be constructed virtually in advance. The whole life-cycle can be reproduced on the screen as a 3-D model (Dave et al., 2013, 742). Furthermore it provides new potentials for new ways of designing and constructing facilities. Mutations considering the distribution of roles within the project team are thinkable as well. (Eastmann et al., 2011, 1p)

The tool is marked by the feature of steadily and simultaneously provision of information for design, schedule and costs. The input parameter are fully integrated and coordinated. Benefits for all phases of a construction project can be reached. (Forbes and Ahmed, 2011, 214pp) The simultaneous planning of the product and the required processes can be strongly supported by having a visual image (Dave et al., 2013, 748). Initiated by the client the team has the whole project in its viewpoint instead of single parts. The effects of changes can be seen immediately. Moreover further stakeholder or people which are affected or interested into the project can be informed with the help of the visualized project. The orientation within a 3-D environment is significantly eased compared to deal with 2-D drawings. (Eastmann et al., 2011, 70p)

Infrastructure projects are marked by uniqueness and non-standardized members. Moreover especially road projects have the attribute of long horizontal and linear expansions. More resources are needed applying BIM and producing 3-D data. (Yabuki, 2010, 1pp) Details about the

impact of BIM are rare. The application of BIM within projects with linear job sites increases. (Dave et al., 2013, 742)

Looking at the effects overlaps with the benefits of LC can be recognized. That means that the application of BIM produces to some extent the same benefits LC is supposed to generate (Eastmann et al., 2011, 297pp). Both areas can work independent from each other as well. This implies that LC can be practised and applied without using BIM and BIM can be used without considering LC. Sacks et al., 2010 examined the hypothesis whether the combined utilization enable the user to realize the full potential. The author uncovered 56 interactions of both approaches revealing significant synergy effects. Consequently projects which apply BIM deliver lean results. (Sacks et al., 2010, 968p) The main points taken into account are a better understanding of the project, the aspiration for a high level of visualization, the generation of data for the construction phase and data about cost and time. Using it from the very beginning of the project an integrated team and the integration of product and process are the consequences. (Eastmann et al., 2011, 494pp)

Just-it-time processes

Koskela, 1992 emphasized that a just-in-time (JIT) approach is one of the roots of the new way of thinking. JIT is mainly based on the fact that inventories and buffers are seen as waste. The core idea of JIT activities and resources should be available when they are needed. (Salem, 2006, 169) The method is often named in relation to the precast concrete sector and includes first of all processes at the logistics management level. The philosophy has its origins based on the fact that the capacity of place is limited and expensive. JIT is consequently the reduction of waste and inventories to keep the work progressing. (Pheng and Chuan, 2001, 495p) Small batches of resources which are easier to handle and to coordinate are the key factor. The concept is triggering the prefabrication of construction parts and is shorting the lead time on the construction site. A close collaboration between the client, constructor and the suppliers is essential. (Forbes and Ahmed, 2011, 50pp)

Aspiration for continuous improvement

Construction projects are unique. Due to this fact the project team need to be aware about learning processes during the project. Learning means to extend the knowledge about the project itself, its objectives, the client needs and the project parties. (Bertelsen, 2004, 61p) The aspiration for perfection 3.2.3 is realized within the concepts Kaizen or continuous improve-

ment processes (CIP). A constant stream of changes over a longer period of time is termed 'evolution'. Single aspects are modified through extension and adoption. Such a slow process is similar to a learning process. Know-how must be acquired on the job in case that it is not direct obtainable. This is the case if humans and groups of humans try to become familiar with new processes. A new way of thinking can be established like in case of LC. Changes are made step-by-step without any dramatic jumps. (Wit and Meyer, 2010, 171pp) To keep up with such a steady process there are the three success factors commitment, motivation and adoption. (Wit and Meyer, 2010, 171pp)

It is rather an attitude and culture than a method. Such processes happen subconsciously and should be present all the time. The approach for realization can be diverse from concrete problem solving up to the usage of certain creative techniques. Huddle-meetings help to share information directly at daily meetings on the site. The aim is allocate work and organize hand-overs. (Salem, 2006, 170p) Another point is to learn from the project afterwards reflecting single situations as well as store the gained knowledge and experience. It is necessary to find a management approach to support and trigger cooperation and learning. In general there are two ways. Either a tight control of all processes which requires many resources or the establishment of a self-organized learning system. (Bertelsen, 2004, 61p)

Pulling the processes

The pull scheduling (PS) approach is specific attribute of the manufacturing industry (3.2.3). The core idea is that the processes get activated by downstream activities. That means to do only work when it is demanded (Ballard and Howell, 2003, 127p). A customer thinking is necessary. The start time of the activities is therefore flexible. It is the counterpart of the push philosophy where all activities are fixed scheduled and often without any relation to each other. A range of mentioned tools incorporate this approach such as LPS or JIT. (Forbes and Ahmed, 2011, 95p) The effects reported from a pipe case study were smaller inventories, a reduced lead time and higher productivity within all processes of the project. Informations about the current status of single activities and about the availability of resources are necessary in real-time while using LPS. (Tommelein, 1998, 280p)

Transparency using mapping methods

The application of a value stream mapping (VSM) tool aims for high transparency and for making the processes flow. It enables the process owners to improve the processes with the view for

the whole project. By illustrating the process with an iterative approach the present state can be uncovered (Jarkko et al., 2013, 49pp). By illustrating the flow of material and information, single activities can be categorized as value adding or non-value adding activity. Afterwards a future state can be determined which needs to be accomplished working with the generated drawings (Forbes and Ahmed, 2011, 116).

Within construction projects the whole conglomerate of processes is unique because the product is unique and the processes are marked by high variability. Single parts of the management approach are standardized like the claim management, the bill run, the accounting control or audits. Those identified processes are suitable for simplifying and eliminating unnecessary steps considering the level of quality. (Forbes and Ahmed, 2011, 116) The performance can be operationalized by the factors lead time, inventory and operational costs (Jarkko et al., 2013, 49pp). The aspects around VSM is also strongly related to the topic of waste (3.4.3).

Acting under the Five Big Ideas

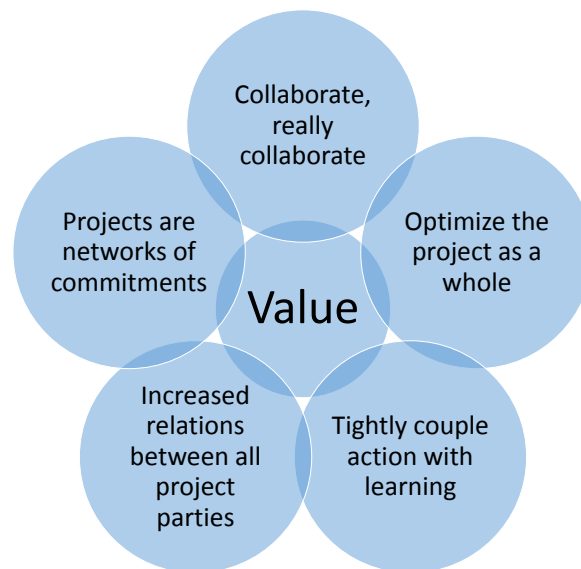


Figure 22: The Five Big Ideas in reference to Lichtig, 2005

Another more overall approach which reflects and incorporates the mentioned ideas in another way is the concept of the “Five Big Ideas”. It was introduced by a public hospital company in America in the course of the application of LC in its construction projects. As a pioneer they used a lean approach in their building projects and developed together with their constructor the approach further. This five behaviour patterns are forming the basis for a lean system and

can be seen as a guideline how to act. (Lichtig, 2005, 106pp) It is a frame for the LPDS illustrating the key facts of a lean delivery system by simple and short slogans. Furthermore they define the language, behaviour and the relation among the constructors in general. It can be transferred to every other project. (Heidemann, 2010, 58p) The five slogans can be reduced to the five key words optimization, relatedness, innovation, trust and commitment (Lichtig, 2005, 106pp).

Structuring the work

The work is structured based on the single crafts and the contracts in many cases. Such a structure, also well-known under the term work breakdown structure (WBS) aims for an optimal performance within the single parts of the project. This fact leads often at the expenses of the overall project performance. The new way of structuring under the impact of lean is to develop a process design while considering the following aspects at the same time: the attributes of the final product, the relation and dependencies to the supplier, the distribution of the resources and the efforts about easing the assembly process. (Tsao, Cynthia C. Y. et al., 2004, 780pp) The process of work structuring is dynamic and needs to be adopted in the course of the project after having created an overall structure based on the design. The last product structuring the work is the time schedule. (Ballard and Howell, 2003, 127) The objective is to establish a more reliable and accelerated work-flow. Finally an integrated product-process can be achieved (Tsao, Cynthia C. Y. et al., 2004, 780p).

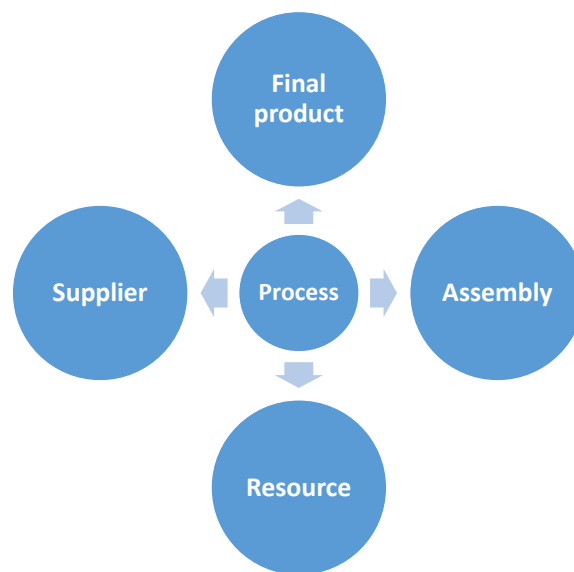


Figure 23: Items to structure the work

3.4.7 Commercial terms

The third side deals with problems how contracts need to be structured respectively which contracts strategies are generally appropriate in such a case. A contract regulates important parameter of the organisational structure and has a significant impact on the productivity of a project (Gordon, 1994, 203). Contracts have significant influence on how the members of a system behave and which culture is dominant (Lichtig, 2005, 106pp). A lean project delivery system needs to be supported by a proper contract and procurement strategy (Heidemann and Gehbauer, 2011, 25pp). The client is responsible to determine the scope of the contract, the type of organization of the contracting partner, the type of the contract itself as well as the method to award the contract and select the project team. (Gordon, 1994, 196pp) A construction project is often carried out in a linear fashion (Koskela, 2000, 136). The delivery process for buildings is still fragmented. (Eastmann et al., 2011, 3pp) Within a lean approach new contract strategies are needed.

Partnering

A term which gains more importance in this context is partnering. Such an approach is present since the 1980s and not directly connected to a certain type of contract or a contract strategy. Rather it is a certain state organizations want to accomplish which is represented by the attributes such as regard, confidence, collaboration and excellence for the involved stakeholders. Such attributes represent an IPD approach as well. The motivation lies in the reduction of disputes and transaction costs (Matthews and Howell, 2005) Partnering can be established on a strategic level and a project level. The two main attributes for setting up such an approach is the question for the kind of involvement of the project parties and its arrangement in general. (McGeorge and Palmer, 2002, 229p)

Contracting in construction projects

The most mentionable contract methods are the design-bid-build approach and the design-build approach. Considering public clients, the proceeding of a project within the *design-bid-build* arrangement is quite common and in many cases mandatory bounded to the national framework of public laws. The design phase is followed by a bidding process for to execute the project in the field. A design-bid-build approach is the result where the design and construction phase are executed by two different contractors. (Gordon, 1994, 198p) The method has two

significant advantages. The process of bidding stimulates the market competition and gives the owner the possibility to choose among the lowest bidders. This aspect leads further to the second point since choosing with the help of economically driven criteria reduces the risk to select a contractor due to political dependencies. Furthermore the fairness and equal treatment of all interested and qualified contractors can be guaranteed. (Eastmann et al., 2011, 4) The disadvantages are that the issue about the constructibility arises and documents lack of information due to low budgets and low comprehension of the project. (Forbes and Ahmed, 2011, 167) The LC approach is limited by the character of the design-bid-build contract (Heidemann and Gehbauer, 2011, 106p).

The *design-bid* strategy unifies the owner for designing and executing the project. It represents a reaction considering the problems and challenges mainly evoked by the separation of planning and executing. (Eastmann et al., 2011, 3pp) The client has just one contractual relationship with one entity which is able to provide most of the demanded services the client is asking for. (Eastmann et al., 2011, 4) The responsibility of the design is transferred from the owner to the D/B contractor (Chan and Chan, 2004, 630p). The owner's input possibilities into the design phase are reduced (Forbes and Ahmed, 2011, 167)

Both contract strategies display a variety of disadvantages coping with complex and dynamic projects due to their adversarial nature. Mainly there are no incentives which trigger collaboration and cooperation and for each contract the focus is on the fulfilment of a single piece instead of looking on the project as a whole (Forbes and Ahmed, 2011, 168). Matthews and Howell, 2005 pointed out four major problem areas. Information, ideas and improvement suggestions are kept back, the space for innovation is rare, the coordination of the project parties is of poor quality and incentives for a local optimization is high (Matthews and Howell, 2005, 47pp). Especially the public client is framed by a range of restrictions regulating the tendering process. New contract strategies need to be aligned with the frame given by the terms and provisions for the public authorities. (Gordon, 1994, 206) The award method defines the selection process of the contractors. Due to the unique character of every project it gets an important role. The client aims to get a service or product at the most appropriate price by using the market forces as well as information about the product and experience from previous contract procedures. Gordon, 1994 is revealing the two extrema of a competitive bidding and a single-source negotiation with many opportunities between them. This means either to focus on the most efficient price or for a better relationship. It is a trade-off decision between cost and relation. (Gordon, 1994, 204)

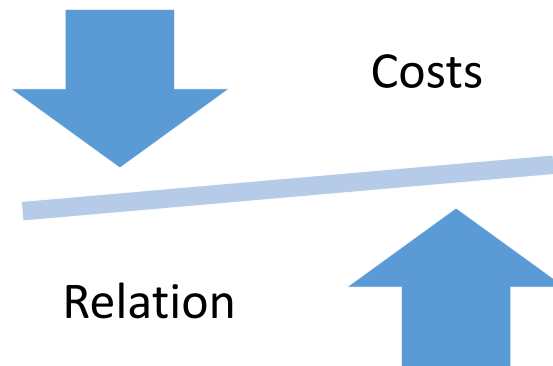


Figure 24: A trade-off decision while contracting

Transactional and relational contracts

For the implementation of an integrated team a relational contract system is required. A relational contract is the counterpart of a transactional contract and focuses on the organisational arrangement of the contractual members. Figure 25 is illustrating a traditional client-producer relation. The definition of the exchange object itself fades into the background. Provisions installing a mini-society with its unique features and interaction rules are highlighted. (Williamson, 1979, 238p) This type of contract emerges as less discrete. Looking on the high amount of disagreements between the project members in general, a contract which covers all upcoming uncertainties, risks and cases progressing the project is almost impossible. By using a relational contract form, parties are automatically forced to collaborate for the purpose of the project.

The IPD approach makes use of both contract forms illustrated in figure 26. On the face of it a transactional contract between the client and one member party of the project team is existent. He is providing provisions for the scope of work, the price and about the attributes for the demanded product or service. The prime contract has a traditional character like in a design-build or design-bid-built contract strategy. All selected team members, called primary team members (PTM), are bounded by a relational contract. The contract is regulating all issues within the project team (Forbes and Ahmed, 2011, 174). The provisions are created by the team itself to generate high acceptance. They are also called the team member agreements which bind the PTM's together for the fulfilment of the prime contract and for a certain period of time. The PTM's are united by the price and the project scope. These two factors let the individual entities melt into one team guided by one contract and aiming for one objective. These are the con-

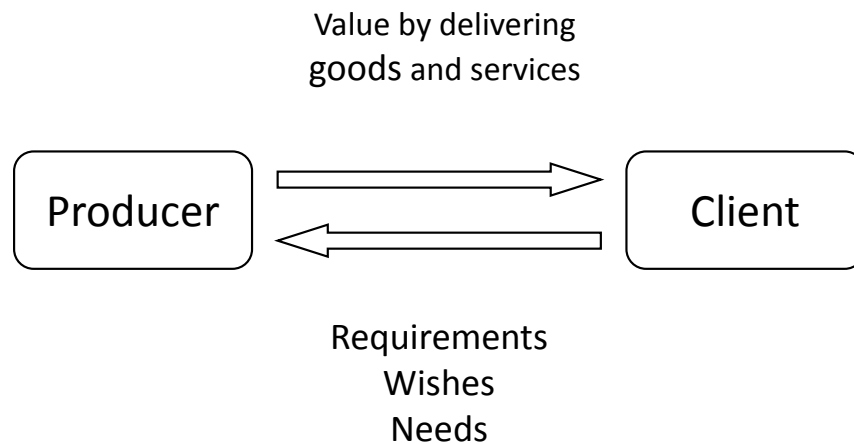


Figure 25: Producer - client relation

ditions which move a project to a lean project striving for innovation, collaboration and global optimization of the project. (Matthews and Howell, 2005, 47pp)

Further lean adopted contract forms

In the USA and Australia are relational contract forms used since the beginning of the 20th century. They enable the project team to be more flexible providing the configuration of a project delivery system with lean features. 'Alliance' agreements are used in Australia and in the USA the contract method of the 'Integrated Form of Agreement' (IFOA) has been developed. (Heidemann and Gehbauer, 2011, 19pp) The utilization of relational contracts such as IFOA and alliances support the LC approach.

Integrated form of agreement The IFOA fosters a delivery of the product by an integrated team consisting minimum of the the client, architect, consultant and the constructor. They are performing on the project together from the outset. All project members are on the same hierarchical level. The contract is negotiated within the team. With the help of team-building methods a team spirit is generated focussing on the settled objectives. This kind of contract consists basically of a commercial strategy and a behavioural strategy. The commercial part provides provisions about costs, profit, risk and incentives for savings. The application of lean tools is directly named and part of the contract (Heidemann and Gehbauer, 2011, 23). The behavioural part is based on the 'Five Big Ideas' (3.4.6). The foundation for a culture of innovative

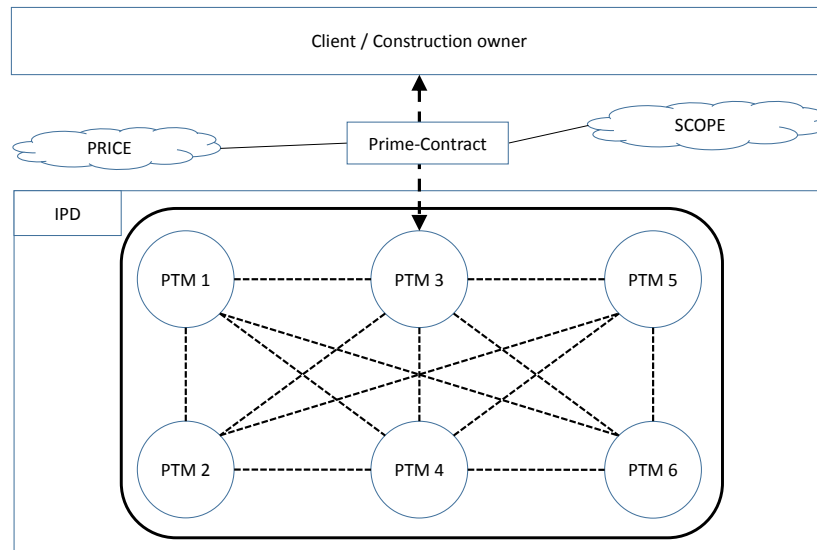


Figure 26: A relational project arrangement in reference to Forbes and Ahmed, 2011

thinking and problem solving is triggered by them. (Heidemann, 2010, 73pp)

Alliance agreements The conditions of 'Alliances' are used in infrastructure projects in Australia. This kind of contract has the same attributes like an IFOA. An alliance constitutes a collaborative team including the client. The multi-party agreement consists of a client, an architect and a general contractor. Subcontractors are not part of alliances. The selection of partners is based on qualitative criteria. The selection process itself is precisely fixed. The agreement consist of a commercial part and a behavioural part. The latter is based on the value defined by the client, the attributes of the specific project and the information collected during the selection process. (Heidemann and Gehbauer, 2011, 22p)

3.5 The role of the client

Based on the statement, "*value can only be defined by the ultimate customer*" (Womack and Jones, 2003, 16), it is worth to have a more detailed look on the client. The following aspects serves highlight the client's position, liabilities and tasks within the holistic approach of lean.

3.5.1 The customer in construction projects

The constructor is the producer of value. How value is identified depends on the customer (3.2.3). Thus two central questions arise. Who is the customer? What is of value for him. It is highlighted as the core problem identifying the ultimate customer within a construction project (Jørgensen, 2006, 195). The client represents often a group of users or owners. Client, user and owner can be different persons or organizations.¹ The following attributes try to frame the client and their behaviour after (Heidemann and Gehbauer, 2011, 22p) and (Bertelsen, 2004, 51pp):

- The client is an intangible and undefined identity.
- The client is seen as a short term complex system.
- A client is asking for something and has special wishes.
- A client is marked by interfering and supporting decisions.
- The client is often acting in a chaotic process.
- The client's organization is a complex social system.
- The client represents different interests.
- The client determines the constraints.

Furthermore the client can be considered as a mediator linking all different parties together (Jørgensen, 2006, 196). Koskela, 2000 suggested to see the broad society as a customer. Especially in construction projects are client and users different. A third group is represented by the external stakeholders such as authorities, neighbours, public organizations or further affected parties which strongly influence the character of the product and the production processes. Construction projects incorporate mainly elements with social importance respectively serve to fulfil the needs of a whole society. In comparison to buildings the original intention and purpose of an infrastructure project is not going to change during the long life-cycle. (Jørgensen, 2006, 195p)

3.5.2 The corresponding value

The starting point of lean thinking is to determine and define value based on the customer. When it is not possible to identify the customer, thus it is not possible identifying the customer value. The definition of value is limited. Furthermore the value perspective is limited to a specific point in time. (Womack and Jones, 2003, 16)

Traditionally the customer is addressing its needs within two steps. One is about what shall be acquired and the second one is about what to acquire. These constraints are expressed by draw-

¹The word customer and client are used synonymous by the author.

ings, list of quantities and finally the contract itself. Often many iterations loops are needed before finding the right product. Another point is that every organization defines in his own way what of value for the customer is while satisfying at the same time their own needs. (Ballard, 2008, 4p)

Communication with the customer is mandatory while looking at the whole product from the viewpoint of the customer. Also the channel of communication is crucial. Client and team need to work closely together scrutinizing and redefining the product from different sides during the idea phase (Ballard, 2008, 4pp). Due to the long lifetime of construction projects, value for the client need be identified considering the whole life cycle (Jørgensen, 2006, 196). Finally, the three aspects of figure 27 need to be balanced. After looking on value one needs to consider the

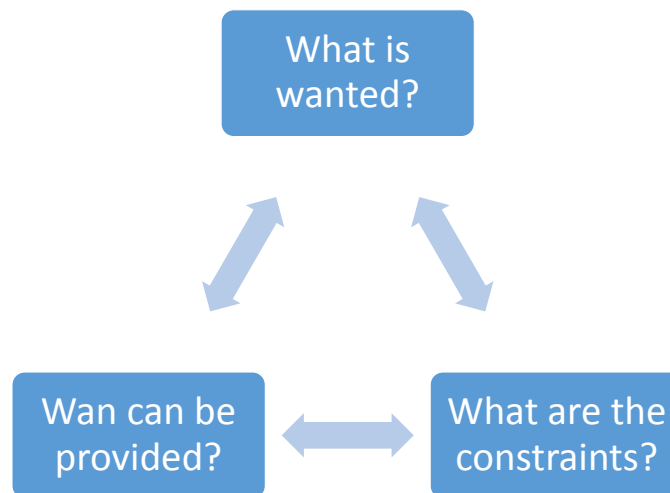


Figure 27: Finding the customer value
in reference to Ballard, 2008

counterpart waste as well. Identifying waste is depending on the level to which extant value is understood and acquainted. Tackling waste is therefore limited applying the lean approach and defining value is once again highlighted. (Jørgensen, 2006, 202p)

3.5.3 The new role of the client

Looking on new types of contracts which are more appropriate for a lean approach, the customer occupies a new role. The position of the client moves from the role of a mediator between the different project parties to an active role within the project team. The customer keeps its traditional tasks but is a team member on the same hierarchical level. So, he gets more directly involved in single processes and decisions. (Heidemann and Gehbauer, 2011, 22p) That's

why the client needs to be prepared and trained. (Heidemann, 2010, 168)

The client is responsible for the initiation of an IPD team by a proper selection process and for the determination of lean tools (Eastmann et al., 2011, 153pp). The 'rules of the game' are committed within the team considering the objectives and constraints of the client. The lean approach is also providing proper tools to monitor and track the processes during planning and executing the project. The client is responsible to create the foundation for a lean delivery approach and to create the following success factors realizing a lean system: (Heidemann and Gehbauer, 2011, 25pp)

- An appropriate procurement strategy to identify resources and project parties.
- An integrated multi-skilled team right from idea phase of the product.
- The involvement of the client itself into the team as an active member.
- The usage of proper lean methods.
- The establishment of a culture of collaboration and innovation.

3.6 Cultural and structural barriers

Liker, 2004 recognized that most of the power shifting a system into the direction of lean lies in the commitment of the management level investing in the employees and providing an environment encouraging and enabling the members to aspire for improvements. (Liker, 2004, 13) These examinations are based on studying the TPS of Toyota.

While implementing new processes barriers and resistance need to be overcome. A study in the UK construction industry investigated such barriers in retrospect to the demand of a change referring culture, style and management by the report of Egan, 1998. A successful implementation of lean is hampered by cultural and structural barriers. In the UK could be identified ten different types of barriers illustrated in figure 28. With the help of a qualitative research approach the most three significant barriers were identified. One of the biggest problems is the lack of understanding of the fundamental concepts and ideas of lean. Other issues in this context are the lack of support of the management as well as the specific way of thinking. To overcome those aspects proper measures are necessary to trigger a successful implementation of lean. (Sarhan and Fox, 2013, 4pp)

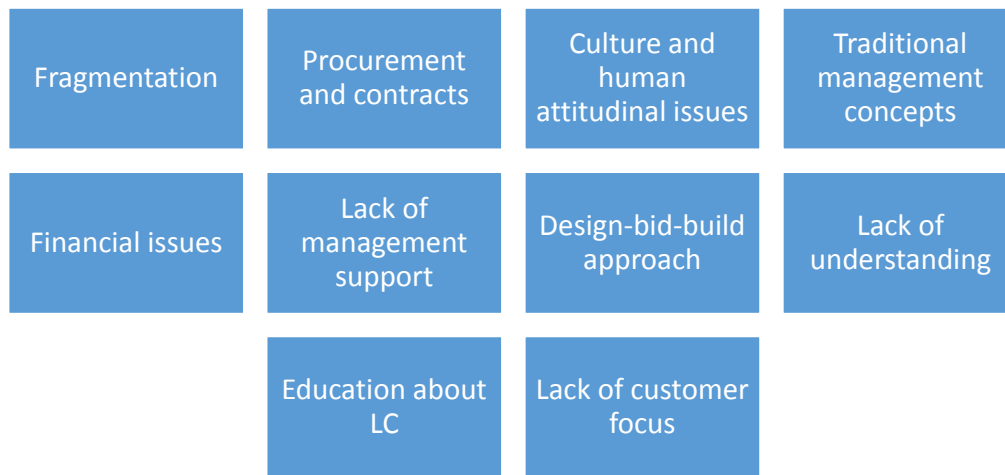


Figure 28: Cultural and structural barriers in reference to Sarhan and Fox, 2013

3.7 Establishing lean construction

The movement into the direction of lean is a paradigm shift for all potential team members and need to be handled with caution. Using alone tools and methods isn't sufficient enough establishing a lean delivery system. The time aspect is important to develop and apply a lean system based on a long term strategy. (Liker, 2004, 10pp)

Liker, 2004 is using the "4P" model examining the status of the implementation of lean. The status can be considered within four bricks. Many organizations remain stuck to the *process* level which is described by using single tools for having a flow within the activities and a pull system. The *problem solving* level is about implementing learning processes and having a culture of continuous improvement. Take intensively care about the employees and suppliers coins the level of *people and partners*. The *philosophy* level is described by an integrated long term view guiding the decisions. (Liker, 2004, 10pp)

Another model was introduced by Heidemann and Gehbauer, 2011. The core element of a LPDS is an integrated team determining the character about handling planning, consulting and executing services. The lean project system developed by Heidemann, 2010 highlights the fully integration of a public client. The system is the foundation for a holistic implementation of lean considering the project organization, the client's internal organization and the procurement strategy. It was developed within the German context based on case studies in the public sector in America and Australia and highlights the following points:

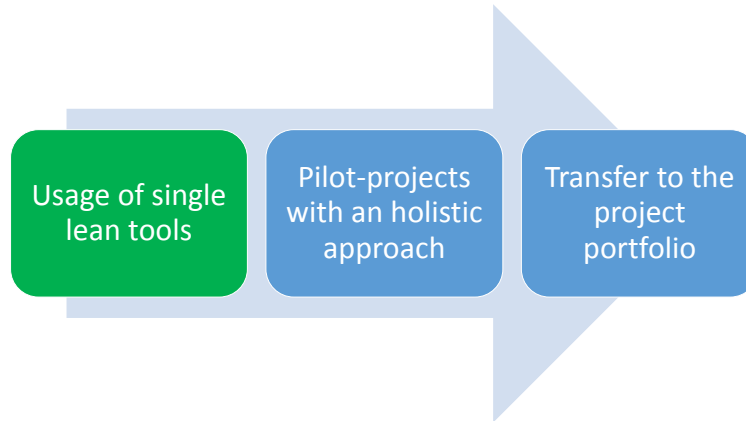


Figure 29: Implementing a lean system
in reference to Heidemann and Gehbauer, 2011

- Establishing an integrated team using the knowledge and experience of several parties at the early stage of the project when the impact on the product and its processes is the highest and most beneficial.
- Establishing an environment of trust and collaboration which needs time and resources.
- An integrated team causes higher costs in the beginning and contractors need to be attracted being ready to give input from the outset.
- The integration of lean tools and their impact is depending on the customers framework.
- Qualitative factors like lean methods, innovation and collaboration should be part of the selective process instead of focussing on the price.
- The potential project members need to be informed based on their knowledge introducing one common language and presenting the suggestions of the client.
- Implementing lean needs the support of the management level since a change of behaviour and thinking is necessary. An recommendation is to start with the implementation of single tools. This is the stage, the author is assuming to find.

Chapter 4

Project work

This chapter aims to present the collected data of the case studies. The projects shall act as examples to study the lean approach phenomena in a real life context to substantiate the presented theory and to answer the research questions. With the help of the cases the existence of lean principles shall be verified. Within the following remarks the researcher introduces the observed projects and the findings by using the same structure presented in the theory chapter. All projects are introduced by their general facts and their features to introduce the reader to the challenges of the projects.

4.1 The public road authority of Norway

4.1.1 Introduction

The transport infrastructure projects in Norway are conducted by the Norwegian public roads administration, Statens vegvesen (SVV). The organization is one of eight subordinate agencies which directly reports to the Ministry of Transport and Communication. SVV is in charge of building, maintaining, planning and administering the national transport system. They are also responsible for rest areas, road safety, noise control, traffic engineering and thematics. SVV is the biggest contracting client for road projects in Norway with more than 7,000 employees. The annual budget of national funds for 2013 was about 21,000 mio. NOK with the tendency to be increased. A share of approximately 9,000 mio. NOK was invested into national road projects. Figure 30 is illustrating the organizational structure of SVV. (Statens vegvesen, 2013a, 4pp)

The law where the organization tasks and activities are statutorily regulated is called “Instruks for Statens vegvesen” and is from 2011 (Samferdselsdepartementet, 2011). The “Lov om planlegging og byggesaksbehandling” from 2008 is regulating the process for the planning and construction phase (Davidsen, Knut, 2008). Five regional divisions are in charge for carrying out the

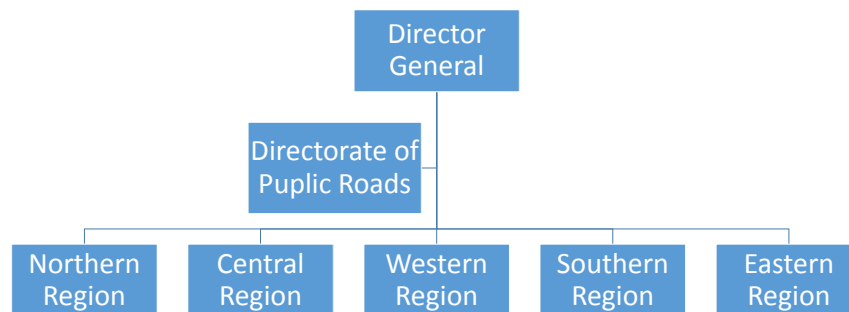


Figure 30: The organizational structure of SVV in reference to Statens vegvesen, 2013a

projects. The Directorate is responsible for the overall administration and organization of the road network. Moreover they develop the management tools and communicate with the political institutions in Oslo.

The client’s function is a formal role rooted in regulations and legislation. Furthermore SVV is

seen as adviser, facilitator and executor developing requirements and standards for constructing, operating and maintaining the road network. SVV is the construction owner with an internal organizational model that encompasses far more than only the contract phase. As an administration builder they have full responsibility for the development, design and construction as well as planning and executing the operation and maintenance of the entire road network. Preparatory planning, land acquisition and further facilitation belong to the tasks of SVV that is carrying out the project work as efficient as possible. (Rodewohl, 2014)

SVV is fulfilling tasks arising from decisions of the government which is informed by SVV itself about the status of the road network. Based on this input the government is creating the National Transport Plan (NTP) which encompasses a ten-year plan period. The plan is updated every four years and represents the framework of the activities. (Statens vegvesen, 2013a) Three main topics exist considering the general objectives of infrastructure projects in Norway: safety issues coupled with a zero vision policy, environmental issues by avoiding negative impacts and the road network itself providing a good maintained and accessible net of roads. (Statens vegvesen, 2006, 2pp)

4.1.2 The project management approach

The planning and assessment of road projects is going to happen on various levels, from conceptual studies at a general level till a municipal and environmental impact assessment for the development of different route plans. SVV's task is to anticipate developments and respond to orders by the needs of the society. The whole process can be described with the keywords problem analysis, looking for alternatives, analysis of consequences and giving recommendations. SVV isn't involved into all planning processes. Their task is to support the project parties with the proper tools, templates and work flows administrating the processes around the designing and engineering work. The aim of SVV is to have an open and inclusive process to collect local knowledge, edit the data and share the information with local actors. The formal requirements of the planning process are precisely regulated by law. (Statens vegvesen, 2013a)

The handbook 151 is about the management of road projects and depicts SVV's guidelines for executing. It is for the planning of projects, the accomplishment of projects and the proceeding within operating and maintaining projects. It is the "project bible". (Rodewohl, 2014)

All required processes from the decision to the maintenance of the project are regulated. Furthermore all necessary documents and process iterations are given. The manual 151 is edited

for planning and implementing of development projects. It has the character of a guideline and provides the standard project management approach. Often it has a check-list character to ensure a proper project execution and a certain level of quality. (Statens vegvesen, 2012)

The single phases of the management approach can be described as follows:

- **Stage 0: Project order** - Identify the objectives and results of the project
- **Stage 1: Clarification** - Clarify the order and comprehension of the project itself
- **Stage 2: Planning** - Establish an organization and trigger the planning activities
- **Stage 3: Execution** - Implement and monitor effectively the execution processes
- **Stage 4: Learning and handover** - Terminate the project and transfer the gained experience

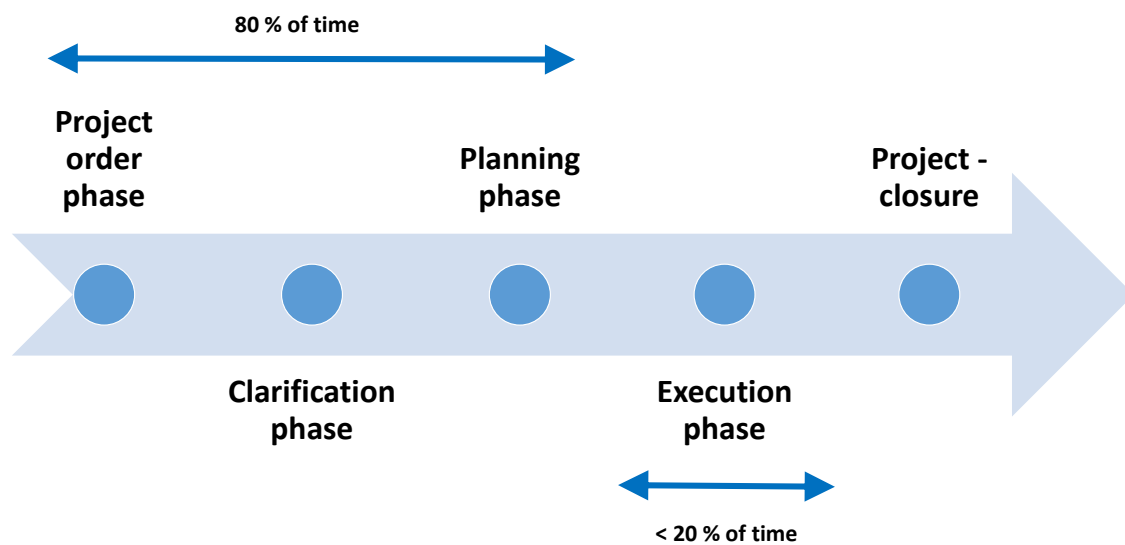


Figure 31: The project phases of SVV in reference to Statens vegvesen, 2012

The handbook highlights the common understanding of the project processes and the awareness of the different steps within a project. Moreover it highlights the importance of the first steps within the project process and claims to focus on the interfaces. (Statens vegvesen, 2012, 5pp) A first hint for lean traces is visible.

4.1.3 Objectives

Major road projects need on average about ten years from the start of planning until the commencement of construction. The planning phase can cover up to 80% of the lead time. One of the objectives is to halve the planning time. (Rodewohl, 2014)

An effective planning phase is one reason achieving the objectives of the NTP in time. The need for faster and more effective planning processes arose. Due to the unique character of every project there must be changes in the management approach. Therefore the measures revealed in Norwegian Ministry of Transport and Communication, 2013 are to establish a good project management, to have a good exchange of information between the involved people, to commit the objectives and actions and to avoid conflicts of interest.

To reduce the planning time the following measures are suggested in Heldal and Rasmussen, 2012.

- A clear and early involvement of the authorities in planning matters should be strived for. The public law for planning and construction from 2009 emphasizes obligatory involvement and cooperation between the relevant authorities early in the planning phase.
- Precisely formulated deadlines shall help to realize required activities and processes in time.
- The concept evaluation (KVU) and the quality assurance (KS1) should be used to clarify the main lines in the selection of the road to align and develop standards - using those instruments in the right way and coordinate them more in agreement with the planning processes.¹
- The regulations settled by the government are supposed to be used more actively.

Looking at the objectives and suggestions, overlaps with the effects of LC in theory can be recognized (3.4.2). Effects in reducing the planning time would be significantly.

From the governmental side a new organization structure is planned which takes care of the high priority projects. Moreover a new approach for funding and organizing the identified corresponding projects is planned. The aim is to provide predictable funding and to create efficient processes. For the development of roads the government wants to create more competition and better coordination adapting the contract strategy by developing roads on longer contiguous sections and handling larger tenders. (Norwegian Ministry of Transport and Communication,

¹The author is using the Norwegian abbreviations to avoid translation misunderstandings.

2013, 20pp)

By analysing those aims in connection with the current approach it can be recognized that there are no tools available which help to realize the plans. A reduction of the planning time from ten to five years is notably and can't be realized without significant changes of the existing approach. To have the knowledge and understanding about the right tools and methods which enable the project managers and operators to handle a new approach is necessary. Developing and adopting new tools alone though isn't sufficient enough. While using a new approach, a new way of thinking is required moving away from the traditional approach. One approach is given by LC. The following cases serve to identify to what extent lean principles are already existent.

4.2 Case study work

The researcher's case study portfolio consists of six infrastructure projects allocated in the whole country and carried out by four regional offices. These six cases represent the sample of the researcher. The case descriptions are based on information given by the public project database of SVV and are added by information from the interviews.

4.2.1 Project descriptions

The project **case I** is a pure road project that consists of the expansion of about 30 km road in the western region of Norway. The aim is to expand the road onto four lines and to increase the safety conditions. The project is in its planning phase. The start of construction is scheduled for 2018. Information about the cost aren't available.

The second case, **case II**, consists of a 10 km long road and a tunnel. The project is included in a row of other previous finished projects. The road is to expanded to four lines. Big parts of the project are already realized and other parts are going to be finished soon. The project costs are about 3.5 mio. NOK. The current road system shall be linked in a better generating a more efficient traffic flow and unburden the bordering local places. The time line of the project is from 2006 - 2015. The project is divided into a range of different contracts and contracted to several companies. Different types of contracts are used.

Case III is in the southern part of Norway. The planning phase has finished in the beginning of 2014 and the construction has already started. The project is contracted to two main construc-

tors which are in charge of a seven km long road including a bridge. The used type of contract is a unit-price contract. The total costs have a scope of 3.2 mio. NOK. The project is going to be finished in 2017 after a total planning time from 2006 until 2013.

The next case is about the expansion of a 70 km long road in the south-eastern part of Norway. The project, **case IV**, is divided into nine sections depending on the different affected municipalities and to splitt the expenses into smaller pieces. The total costs for this road are about 11.25 mio. NOK. The project is aiming for upgrading the road considering higher safety conditions and a better traffic flow to serve properly as a main link to the border of Sweden. Each section is represented by an extra planning and execution phase. At the time of the interview, six of nine sections were finished.

Case V is an inner-city project which contains the new construction of a eight km road section as well as the appropriate infrastructure considering a cycling zone, public transport lanes and stops as well as pedestrian ways. Another part was an immersed tunnel which has already opened. The project is divided into four big contracts. The end of the project is scheduled for 2015. After a planning time of five years the construction phase started in 2005. The costs were estimated with 7.13 mio. NOK.

The last **case VI** includes a city tunnel, a sub-sea road tunnel and a sub-sea city-tunnel. Additionally, another part is the appropriate connection into the existing road system. The total costs amount up to 8.7 mio. NOK. The project is in its execution phase and consists of eight contracts. The project includes three tunnels with a length of four till fourteen km which run partly under the sea. All tunnels have two individual tubes with two lanes. The project is going to be finished in 2019.

4.2.2 Findings

The researcher was conducting the interviews with the help of an interview guideline. The researcher launched the interviews from March until May 2014. The collected data is the result from six interviews with one representative of each case study.

Lean management in general Before presenting detailed data categorized by the different sides of the LC triangle, the researcher is presenting some data about LC in general. For case

I quantitative data is obtained by the mentioned questionnaire. The students provided the pure results to the researcher who is going to use relevant results for its own analysis, as preliminary considerations and as input for his own qualitative research. The students investigated the project within the framework of a bachelor-thesis for the following three main issues: the overall project management plan, the used contract strategy and the knowledge management. Not all collected data is relevant and worth to investigate further. The evaluation of the data was made by the researcher itself and with regard to his own specific research field. The participants of the survey have either the job as project manager or as construction supervisor. The last two questions of the survey were considering directly the term LC. For the question about the degree of familiarity with the term LC, 61% of the participants answered that it is an unknown field for them. 77 participants answered this question in total. Only 4 % categorized their knowledge about LC as good referring the given scale of good, moderate as well as the choice 'unknown'. In the case of 30 persons there is to a certain extant knowledge about the term available. (Hagen et al., 2014, 9p) As a result, the knowledge about LC is significant low. The question whether LC is part of the project management approach of SVV, 50 person chose the possibility 'unknown'. The evaluation of a term which is unknown isn't possible. 27 persons responded that LC is used. Nevertheless one third think that it is important for SVV. (Hagen et al., 2014, 10) Based on this results further investigations for the topic lean are relevant.

It can be assumed that the term LC isn't widespread in the daily project language of SVV. This can be proven by examining the handbooks of SVV which are the basis for the daily project work. In the examined handbooks the term wasn't used. This matter of fact triggers even more the need for a deeper insight for the project management work about the presence of lean principles. The results of the interviews also prove that point. Most of the interviewees reported that they have heard about this term. Some linked this term directly to the flow principle or connected it with the JIT approach.

It is a useful tool which makes the processes working more smoothly. (Rodewohl, 2014)

LC is more than only a tool. The knowledge about lean is fragmentary which was confirmed by another interviewee.

The term LC is known but not what is behind it. (Rodewohl, 2014)

Moreover the majority of the interviewees were convinced that it is important for SVV and that there are already a lot of aspects available within the used project delivery system even when the term itself isn't used so far. All participants showed interest in this topic. In addition to this data about LC there is another interesting aspect with regard the mentioned project management

approach and the operational objectives in the short term.

There are two main fields, SVV is currently focussing on. First of all, SVV implemented BIM into the project management approach and secondly, the lead time of the planning phase shall be reduced significantly. (Rodewohl, 2014)

With regard to the close relation of BIM and LC given by Sacks et al., 2010 considering their effects, using BIM means to have signs for a lean behaviour within the system.

Organizational structure of SVV

The organizational structure is revealing how the project team is structured and how it is working. Furthermore this area tackles the relationships and the set-up in general needed realizing a lean delivery system. The organizational structure of a project team is mainly defined and influenced by the choice of the contract strategy.

Communication Related to the issue communication it could be examined that the project management approach is using a responsible-matrix and a decision-matrix. Project members can quickly get an overview of the deployment of the project team and their corresponding individual tasks. It needs to be created in the beginning of the project, maintained with the expansion of the project team and provided at a central place that every project member has access to. (Rodewohl, 2014)

Another point is SVV's own web-based communication platform used since 2009. The platform can be adopted to the particular project attributes and is available online. In many cases the constructor is still using its own system at the same time.

The platform supports the handling and exchange of documents and files especially for change orders, approvals, drawings, meeting minutes, technical solutions and performs on special parts of the project. (Rodewohl, 2014)

Besides operating such an internal platform the communication between not directly involved parties is also highly relevant for optimizing the outcome of the project. A variety of external stakeholders is often involved due to the large geographical expansion of the projects. Referring to the external communication, informations by SVV are mainly provided using the homepage and social media. The website of SVV contains a database with all projects. Extensive information and current events are presented while working on the project. Data is curtly also available on 'facebook' project sides. Especially information about current and short term events are presented by pictures and short statements. (Rodewohl, 2014)

Samhandlingsfasen The method “Samhandlingsfasen”² was introduced to the project management phase of SVV in 2010. The concept behind this aspect is to foster common accepted procedures among the project members, collaboration, trust, inspiration and to trigger processes of steady development and improvement. These provisions can be part of the contract for the construction of new facilities, for expansion projects as well as for maintenance projects. If so, the provisions must be part of the tendering procedure. SVV suggests four weeks for this phase depending on the scope of the project, its complexity and the available capabilities. The client prepares a written report to document the agreements. All parties and later selected sub-contractors need to sign this as a requirement for their involvement. The document needs to be updated as required after the work has commenced. (Statens vegvesen, 2013b, 6p)

In the examined cases (except case I) Samhandlingsfasen is part of the contracts (Rodewohl, 2014). It describes the passage phase from planning to construction and describes the time between signing the contract and starting with the activities at the field. The provisions for it can be found within the specific contract terms under point eight, C2-7 (Statens vegvesen, 2013b). A kick-off meeting, workshops and informal events mark this phase. Participants in this meetings were representatives of the client, constructor, consultants as well as persons from the local authorities and the municipality. (Rodewohl, 2014)

The feedback about this tool contained mixed opinions (Rodewohl, 2014). An analysis of the impacts on the project results by SVV four years after its introduction is in progress. That’s why it is categorized by the researcher with an implementation status.

Quality gates SVV is using quality gates (Rodewohl, 2014). Quality assurance one (KS1) and two (KS2) are executed by external consultants to ensure the target quality level considering mainly time, safety, environment and costs aspects (Statens vegvesen, 2012).

Operating system of SVV

The operating system (OS) is representing applied tools and methods within the LC approach. Such tools are helpers on the operational level moving a system in the direction of a LPDS. They influence the existent process and require simultaneously another way of thinking. Because the term LC wasn’t known itself the researcher avoided to ask directly for special tools as the interview guideline shows but rather tried to paraphrase those. Except in the case of BIM where the researcher had knowledge that this tool is used in some of the projects of SVV.

²The researcher is using the Norwegian term further since its proper character given by SVV.

BIM SVV has identified pilot projects testing the application of BIM and its effects on the project results.

SVV implemented BIM into its project management approach to reduce the costs, to visualize the projects, to inform the concerned stakeholders about the project and the project objectives. Actually, there are pilot projects using BIM before rolling out this concept onto all projects. (Rodewohl, 2014)

The activity BIM is used in two of the six examined cases. In those cases everything was planned from the outset with a proper software. The focus using BIM is rather on the handling of interfaces between different contractors and on technical aspects.

Compared to building constructions more space is available in road projects. (Rodewohl, 2014)

An evaluation of the impact of BIM on the project results wasn't available so far.

Project closure The phase of the project closure is part of the project management approach of SVV anchored in the handbook 151 (Statens vegvesen, 2012, 6pp). All experiences within all types of projects carried out by SVV are expressed by a project report and shall be collected in an internal data base. The purpose of all types of reports is to spread knowledge and experiences easily within the organization. In practice it isn't used like it is supposed to.

For the phase of the project closure is often not enough time scheduled. The project members are moving directly to the next project. The templates for a project report and a database are available on the internal project management system. But the system isn't well-known within the organization at this moment. (Rodewohl, 2014)

Case II reports that project members are often going directly from one project to another one. There is only few time between the end of a project and the start of a new project. There is less time for a project follow-up. Project reports are therefore under represented. Currently there is only one project report available in the category construction projects within the database. The knowledge management system is under construction.

A good approach could be to write regularly about special features and problems while progressing on the project. At the end of the project the notes can be summarized for the final report. (Rodewohl, 2014)

Standardization Based on the handbook an on-line quality system is visualizing the standard processes of SVV and the related tasks. It enables the user to browse the connected single phases, their sub-phases and the corresponding check-lists. Single activities can be executed

more consequently and goal-orientated. The system is currently under construction and not well-known within SVV. (Rodewohl, 2014)

Preparation phase Another important topic examined by the researcher is the focus on the preparation of the construction phase. The aim is to collect as much information as possible about the project before the constructor is starting with the field work. In case III it was mentioned to collect information about the ground, to assess the environmental impact of the project and to prove all technical issues in detail to make sure establishing a state-of-the-art product. (Rodewohl, 2014)

Providing tools, methods and proper infrastructure is important to make all following processes smooth and operable. (Rodewohl, 2014)

By the detection of all kind of risk stopping processes waste can be reduced. It supports the flow of the processes on the construction site and also during the planning phase. By eliminating unnecessary iteration loops and making processes flow the lead time can be reduced.

Continuous improvement A knowledge management is part of the current management approach of SVV mentioned under the point project closure (Statens vegvesen, 2012, 58p). Employees need to experience the benefit of such a system combined with exchange possibilities of knowledge beyond the regional office borders. In case IV the researcher was able to identify a situation where one team of approximately 25 people, consisting of employees of SVV and external consultants, moved from section to section carrying out the project together. Through this proceeding one team is working nine times on the same kind of project so that a learning effect can be considered. The interviewee confirmed this aspect reporting of a culture where the team members take care of each other and aspire for better efficiency from contract to contract. Another case revealed the contrary. (Rodewohl, 2014)

The planning results are often of poor quality and several attempts are needed to realize the agreed level of quality respectively to meet the requirements and objectives of SVV. (Rodewohl, 2014)

The disadvantages of a design-bid-build strategy are touched in this case (3.4.7). In another case the responsibility as driver for innovation was delegated to the constructor.

The constructor has to be the driving force of innovation in the field considering how to work and operate within this phase of the project. (Rodewohl, 2014)

Innovation is only possible within the framework given by the client's objectives and constraints. In another case the researcher examined the same situation. The interviewee highlighted the

situation that the objectives and constraints given by SVV needed to be kept.

New methods are generally possible but they need to be approved by SVV first of all. A new approach should be verifiable cheaper and should be within the constraints defined by the client. (Rodewohl, 2014)

There is no reason for the contractors striving for innovation looking on the side of the contracts.

Commercial terms of SVV

Within the commercial term chapter the researcher is presenting the used contract strategies of SVV. The contract relation is regulating important parameters of the project in total.

Contract strategy A design-bid-build strategy is used in the examined cases. The design and construction phase are separated by the chosen contract strategy and the constructor isn't involved into the planning phase. External consultants evaluate the constructibility of the planned design.

Everything is related to the contract due to the matter of fact that everything is individually regulated by their provisions as precisely as possible. (Rodewohl, 2014)

Several prime contracts exist with various constructors, consultants and engineers using their special services and skills. The handling of small contracts have the advantage to distribute the risk. In one case the differences between one big contract and towards splitting the contract into several smaller contracts was tested. From the clients point of view and confirmed in case IV, bigger contracts are preferred. Types of contracts which support a lean approach are already available. But in the sample of the researcher, they were not used. (Rodewohl, 2014)

Transactional contracts In the examined cases unit-price contracts are used. Another observed type of contract is the lump sum contract. The focus of those contracts is the exchange relation of commodities and services for a bargained price. The contracts are therefore as precisely as possible and have often more than 1000 pages. The consequence is that a lot of time and experts are necessary to draft the contracts and control the execution of each term afterwards. Right from the beginning everything is regulated by the terms of the contracts to make sure that every unforeseen situation is covered. Simultaneously the contractor is looking for missing information within the contracts using it for supplements and their own benefit. To achieve the highest value possible with a project is the basic need of SVV. The usage of incentives within the contract is of no importance in the examined cases. The contracts are the basis

for carrying out field work as described. After the handover of the product it serves as a check list to control and evaluate the performance of the contractors work. The researcher has no information about the character of the contracts for the design phase. (Rodewohl, 2014)

Tendering procedure The contractor is awarded based on the cost after a competitive bidding process. Other tendering procedures which are in line with the law are available but not used. The tendering procedure is aiming for a fair treatment of all potential pre-qualified contractors and for competition among the interested contractors. Another examination was the described unwillingness of the contractors using new approaches within the project. (Rodewohl, 2014)

Implementing new methods fails caused by lack of knowledge of the other project parties. There is little interest in using new methods. There is automatically the requirement for training and instruction which causes the need for more resources. (Rodewohl, 2014)

The existence of qualitative criteria is important. In all the cases quantitative economic criteria are dominant for choosing the contractor. In one case also qualifications, experience and environmental issues had an impact on the selection procedure. (Rodewohl, 2014)

The tender procedure has the potential to reward the contractor for the usage and application of LC methods related to their offers. (Rodewohl, 2014)

This would mean that the share of the costs for the decision process will be reduced and their importance decreases. In other cases it was seen as helpful and necessary not to limit the choice of the contractor only by the price (Rodewohl, 2014).

4.2.3 Role of the client

Looking at the lean approach with its different facets to create a new delivery system the client needs to accept simultaneously a new role (3.5.3). One can recognize that the role of the client is changing while implementing lean principles. Referring to the question in which role the interviewees see SVV within the project, the following statements could be collected.

We control and track the work of the contractors to make sure that they fulfil the conditions of the contract. We make the companies keep on working. We make sure that the project gets money. We prepare the construction site for the constructors, deal with all administrative aspects and uncover all possible aspects in advance. (Rodewohl, 2014)

SVV is the initiator of the processes around the project from the very beginning until the end of the project. SVV is handling the formal processes in advance of the project involving all concerned public authorities.

Chapter 5

Analysing and discussion

Considering the description of each project, the research questions and the theory part it is now possible to identify existing lean elements within the examined cases. Moreover their meaning and importance for the existence for a lean delivery system can be discussed and analysed. The capabilities of the system applied are visible afterwards and give the project owner the chance to rethink the processes for the purpose of a lean approach. The discussion part provides no concrete instructions for implementing a special lean technique or method. It rather serves than as the starting point for the discussion about creating a proper delivery system for the specific character of a project.

5.1 Identifying Lean elements

Within the discussion part the researcher is going to link the main ideas given by the theory with the key results of the launched case studies. The contextual background are transport infrastructure projects. The discussion is focussing on the phase before starting to work on the construction site. There is the highest potential to influence the parameters of a project and implement cultural aspects for a holistic project approach. The single aspects are going to be presented from the view of the client and its role acting on the three sides of the presented LC triangle. Figure 32 is illustrating the procedure for this chapter. First of all the researcher needs

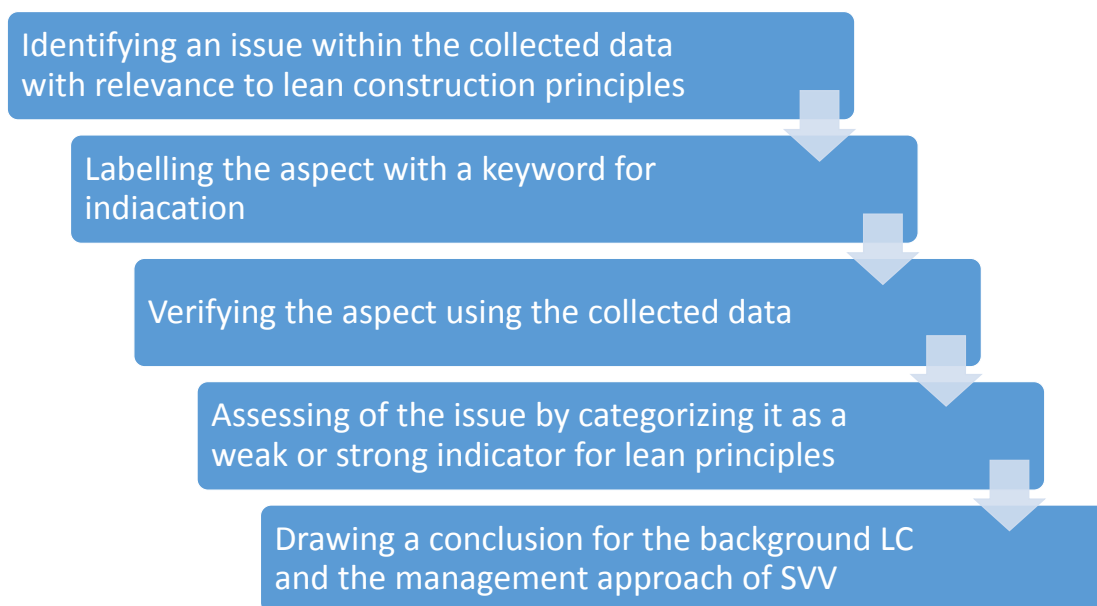


Figure 32: The researchers strategy analysing the data

to identify the relevant issues from the collected data with relevance to the identified lean principles. The researcher is using the original lean principles connecting them with the collected data. Either they are directly related to the aspects of the lean approach and deliver indications that the system contains traces which are indicating a lean delivery system or they directly hinder the system moving towards a lean approach. The aspects are labelled with a keyword picked out from the theory which serve as unique identifier for a bunch of collected data. As a consequence, a classification with regard to the three sides (3.4.4) is automatically given. By using indirect speech (indented parts) or references (Rodewohl, 2014) single aspects are verified with the help of the cases based on chapter four. An assessment is made by categorizing the indicators as a strong or weak indicator for one of the five lean principles. Hence a rela-

tion between indicator and lean principle is constructed. Due to the depending and integrated character of the principles often more than one of the principles is affected. Chapter three, four and five are closely connected using the same approach three times given by the lean triangle. First the theoretical description is followed by the findings. Finally the discussion is following integrating the remarks from three and four. To ease the procedure the researcher decides on the most relevant in each case being aware that other impacts are given at the same time. Methods which are not entirely used because they aren't well-known or are in the implementation phase are marked by a star . An impact is given though. The results are given in a table and can be taken out of the appendix. For the presence of lean principles the following scale is used by the researcher categorizing the collected data of the interviews and illustrating the results. The following two-point scale is used:

- **Strong indicator:** The aspect is directly related to LC. At least one of the five lean principles is immediately touched respectively a goal-orientated application can be assumed. Aspects which touch more than one principle by the perception of the researcher are categorized as a strong indicator as well.
- **Weak indicator:** In this case the relevance impact of the indicator is weak till moderate. There is an indirect relation to other aspects which shift a system into the direction of a LPDS. A relation to the five principles can't be directly deduced from the recognized matter.

Aspects which directly block the availability of lean principles fall into the category of no relevance. From the researchers point of view it is important to list them as well. In this way a connection is established between single used, aspects of the management approach of SVV and the five lean principles .

5.1.1 Organizational structure

Communication A *responsible-matrix* and a *decision-matrix* clarifies the allocation of power and responsibilities for the project team (Rodewohl, 2014). Project members get an overview of the deployment of the project team. By using such a simple tool the flow of information is ensured. It can be seen as weak indicator improving the communication among the project team. Improving the flow of information by finding the right person for single positions within the single parties. Related to the lean approach the team need to find together the best person outside company borders. Positions are staffed through the commitment of the whole team

(Matthews and Howell, 2005, 5). Norwegian companies have a flat hierarchy and are more flexible. (Rodewohl, 2014) The need to balance the fact of being structured and flexible at the same time requires to adapt to new situations properly.

SVV is providing *communication platform* for the handling of the flow of information (3.3). The platform is adoptable considering the requirements due to the uniqueness of each project and the different human relations depending on the changing contractor from project to project. Nevertheless the constructor is often using its own system at the same time which creates redundancies within the project. A full integration and transparency isn't given because of this fact. Real-time communication can be supported. Borders between the project members are abolished (Deng et al., 2001, 240p). The communication can start to flow and the transparency of activities and decisions can be enhanced. A consequent usage by all team members triggers a close collaboration of the project parties and eases the whole communication process (3.4.5). Referring to the communication with the stakeholders, information by SVV is provided both using the homepage and social media. A part of the stakeholders with access to this platforms is therefore closer to the project and knows more about the current processes. Referring to the social media the project becomes even part of the daily life of the people and a communication between stakeholder and SVV is possible using the functionalities of the used medium. The stakeholder can follow the progress of the project and can develop a deeper interest and comprehension for the project. The transparency of the project can be enhanced with the result that the people feel more involved. Specifying the product of the project the voice of the user needs to be involved. Doing it from the early stage a higher value out of the project can be created. The effect for lean principles is rather low given the fact that the interest of the user should be the point of focus for determining the value of a product. (Womack and Jones, 2003, 16) The challenge within construction projects is the variety of different interests given by different customers within the supply chain of such a project. Their impact possibilities into the product and the process are caused by the statues of the public law. (Davidsen, Knut, 2008)

Samhandlingsfasen The method '*Samhandlingsfasen*' aims for a better project understanding, a closer collaboration and a committed interaction among the project parties. The effects of such a phase are challenged by the current used contract strategy (4.2.2). In case of using many different contracts and having so a project team consisting of different companies, the focus is on handling the interfaces. (Rodewohl, 2014) The introduction of such a phase can be seen as the aspiration for increasing the value of the project. Therefore it is classified by the re-

searcher as a strong indicator. The constructor and SVV move closer together and get a better comprehension of each other. Without looking at the planning phase, the project parties and their members are conjoined from the first moment. The “over-the-wall” syndrome can be blocked creating a framework for more collaboration (Egbuomwan and Anumba, 1998, 587p). Further more the chance is given to shift the system from a strict transactional thinking to a more relational thinking and behaviour. This is the basis for further steps into the direction of lean. (Matthews and Howell, 2005, 47pp)

Similarities to an IPD (3.4.5) can be examined as well. The client can develop a better understanding for the way of thinking and acting by the constructor. The project members of the constructor have a better comprehension about the objectives and constraints given by the client. At the same time the share of waste activities can be reduced given the fact that processes of coordination can be reduced and the processes on the construction field can start based on previous made agreements. It's also the prevention of potential upcoming problems instead of looking for solutions afterwards. Especially waste of the type making-do (3.4.3) can be reduced making the involved parties aware about the requirements of the process activities. A development of guidelines based on the 'Five Big Ideas' can foster such a cooperation.

Quality gates Quality gates along the linear progress of the project are used by SVV ensuring the target level of quality. The traditional way of executing a project is directly blocking the usage of an integrated team (3.1.3). By using this approach only single parts of the project are optimised instead of the whole project. The product itself is handed over from one party to another one to evaluate whether the product has the defined attributes at a certain point of time. The thinking of value progressing in a project is interrupted. Therefore the researcher identifies no relevance of this aspect for a lean delivery system.

5.1.2 Operating system

BIM The activity BIM is only used in selected projects of SVV. Looking at the sector in general BIM is a current fashion and used in many projects aspiring for improvements. SVV also introduced this tool to their project management approach recently. The utilization of BIM within SVV is related to the handling of interfaces between different constructors and the avoidance of clashes with the existent infrastructure.

BIM is seen as a strong indicator in theory for LC. Both elements and their effects are highly interrelated to each other (Sacks et al., 2010). In these cases BIM is classified enhancing the

value of the projects. BIM is used mainly within the building sector. The effects of BIM for road projects aren't entirely covered with the help of case studies. First effects are validated with the help of case studies in Eastmann et al., 2011 and Dave et al., 2013. Given by the geographical extension of roads a lot of resources are necessary generating data (Yabuki, 2010, 1pp). Considering bridges and tunnels the extensions are not so huge (Eastmann et al., 2011, 494pp). In general the usage of BIM triggers the need for an integrated team and the integrated planning of the product and the correlated processes (Eastmann et al., 2011, 297pp). The software isn't used in the observed cases to such extent (3.4.6). The researcher is classifying this aspect therefore as 'weak'. The capabilities of this tool aren't fully exploited in the cases.

Project closure Stage four of the project management approach of SVV incorporates the transfer of knowledge (4.1.2). The main output of a project closure, the project report, is under represented. A knowledge management system is under construction and needs to be filled with knowledge and information first before everyone can participate and benefit from the system. The effect of a project closure isn't given looking at the results of the interviews. The impact of a filled data base can be significant despite the unique character of each project. The exchange of information isn't therefore well-marked. Sharing information is done on an informal basis directly from person to person and thus quite limited. For less experienced employees it is difficult to participate from the existent knowledge beyond the project borders. The danger of unused employee knowledge is high. Thus a type of waste is uncovered referring to 3.4.3. Due to the provision of experience doubled up work can be avoided and so another type of waste is eliminated. A company and its following projects thrive from the experience and knowledge of the staff. In companies with many employees a database is the solution to overcome borders due to time and place referring the exchange of knowledge. The benefits of best-practises and lessons learned methods are low in the cases. The project managers should motivate or use incentives that every team is providing a report to overcome the described stadium soon and to establish a self-maintaining database. The incentive in writing a report can be seen as having an own knowledge management system with a variety of information. A report can emerge already while progressing on the project. By giving the phase of a project closure more importance can be the starting point for a learning culture. This indicator has an implementation status and has a weak impact.

Standardization An on-line quality system is visualizing SVV's standard management approach. The system is still in the implementation phase. Processes can be based on practical experience

standardized, fixed and adopted in view of the optimization of the whole project. Every process has a process owner who is in charge of maintaining the quality and being a contact person. Such kind of standardization helps first of all to conserve and maintain a certain reached level of quality (Wit and Meyer, 2010, 195pp). It is the foundation for further improvements and is also an indicator which makes processes flow. Moreover the transparency can be enhanced significantly. The effects within the approach of SVV are moderate because of its implementation status. Moreover a culture of learning consisting of feedback loops couldn't be observed by the researcher (3.4.6). Signs for the aspiration for perfection are given. The flow of processes can be enhanced. The researcher is categorizing it as a weak indicator in its implementation status.

Preparation phase Another examined topic is the focus at the preparation of the constructors field work. Such a phase isn't obviously part looking on the standard approach of SVV. The term was marked in some of the interviews and the researcher is using it to determine its relevance for a LC approach. Bundle different measure to such a phase helps to reduce the probability for delays and unforeseen events. This has an impact on reducing waste within the project. The

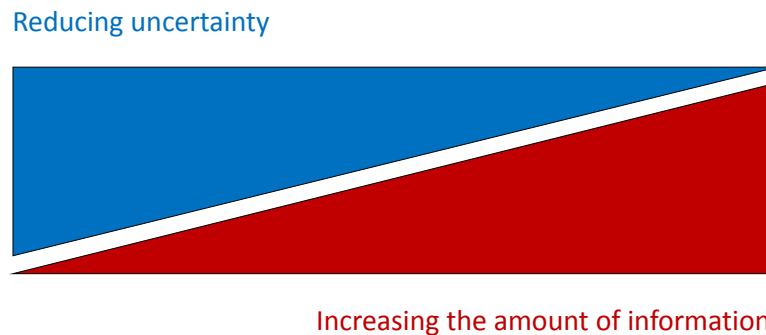


Figure 33: Aims within the preparation of the site

management of transformation and flow is touched by such operations (3.3). The buyer tries to establish a safe and predictable environment. In doing so a longer lead time for the planning phase is the result. The benefits of a state with low uncertainty and a high level of information content to the expenses of a long planning phase need to exceed the costs of having a high amount of waste during the construction phase. The lean approach is supporting a process flow on the one side as much as an efficient planning and preparation time on the other side. The collection of information can proceed parallel to the field work which requires close collaboration and other contract strategies. Focussing on lean during the planning phase can lead to a

reduced planning time with the focus to reduce the share of waste activities and avoid replications of planning steps. All downstream activities of the project are influenced. It serves further to avoid start and stops of the activities and supports a making-do state starting activities as scheduled and with the resources used (3.4.3). The preparation phase is highlighting therefore the tools which can be used to achieve a predictable state. A LC approach is aiming for close collaboration and open communication having a high level of information within the project. Having only such a separate phase executed by the client itself isn't sufficient enough for a lean delivery system. The relevance of the indicator 'preparation phase' is therefore weak.

Continuous improvement The internal culture of continuous improvement is driven by the project members itself. The overall goal is the aspiration for improvement from day to day by connecting knowledge and experience of the whole project team to cope faster and more efficient with challenges and daily tasks (3.4.6).

One case reflects the disadvantages of a design-bid-build strategy due to cost pressure and little comprehension of the project on the side of the design team. The result lacks of information within the supply chain. Hence reiterations of planning activities are necessary. The absence of communication is the overall root for this problem. Looking on the fact to build a road from point A to point B it can be considered that such a project can be handled in the same way all the time. The attributes of a construction project in general counter this view (3.1.2). The team in one examined case is familiar with the processes because they are working together since a while. The level of the human relationship is in a predictable state and everyone knows about their tasks. A level of automatism is reached. This can be connected to a learning effect and a self-organized system (Bertelsen, 2004, 61p). Through the changing contractor the effect observed is only one-sided. But CIT isn't reducible to one project party. Improvement occurs from different sources and skills. Referring to a lean approach the whole project team needs to have and live such a culture.

Construction projects are often coined by less collaboration and integration. The change of contracting parties caused by the one-of-a-kind character, the used terms and conditions and the high competitive market make the aspiration for such a culture more advanced. (Bertelsen and Koskela, 2004, 7) Another point is that within the contracts is little space and no incentives for the contractors to work on solutions which make the final product better and the work more efficiently. The used contracts in the case studies are not using any kind of incentives or terms to implement benefits for the involved project parties (Rodewohl, 2014). A culture of learn-

ing, improvement and innovation is prevented by the transactional character (4.2.2). Incentives and the type of contract can have a significant impact on the productivity of the project (Gordon, 1994, 204p). Improvements within the whole team aren't existent. The classification of this factor is weak due to the fact of the presence of separated single teams and their individual aspiration for improvement.

5.1.3 Commercial terms

Within this chapter the researcher is discussing the used contract strategies of SVV against the backdrop whether they support the lean approach or not.

Contract strategy The planning and construction phase are separated within a design-bid-build strategy. The construction projects of SVV are carried out in a linear fashion. The design phase is followed by a bidding process selecting the constructor for the field work. The involvement of the constructor happens at a point of time where the project has progressed quite far. Changes are connected with high costs. A full application of LC is limited by the character of such a contract strategy (Heidemann and Gehbauer, 2011, 106p). In a LPDS the constructor is supposed to be part of an integrated team which is operating and collaborating from the outset of the project (3.4.6). An integration of constructor and planning team isn't used. The idea of an IPD isn't existent due to the linear way of executing the project. The usage of BIM can be the driver for using the knowledge of the constructor at an earlier point of time in the project. Another contract strategy is necessary considering lean. (Rodewohl, 2014)

The side of the commercial terms which serves as the foundation for the team culture and the interaction among the project parties isn't sufficient for a lean delivery system in the examined cases. The phenomena that a buyer is using the type of contract he is used to is often recognized (Gordon, 1994, 196p). Several project strategies are often fitting to the current project. The basis for the decision for a contract strategy is to have a proper comprehension about the project. To get an understanding of a project the client needs the help of experts (Gordon, 1994, 202). An early integration and establishment of an IPD can be a solution.

The public client is limited in the application of special types of contracts by the public law. In the interviews it could be examined that more appropriate contract strategies are applicable considering the restrictions (Rodewohl, 2014). New contract strategies like IFOA or alliances need to be proved. The contract strategy is also influencing the management structure of a project (Chan and Chan, 2004, 632). In this case a design-bid-build strategy is hampering a

LPDS. The indicator has therefore no relevance for the existence of lean principles.

Transactional contracts The next step to decide about is the type of the contract itself. Often a unit-price contract or a lump sum contract are used. Moreover the contracts are revealing the criteria for the contractors work and have therefore a transactional character (3.4.7). Relational aspects are of no importance within the contract except the part of Samhandlingsfasen. A strong transactional characters leads to a state where only the delivery of the product with its defined attributes is important. There is little scope and no incentive seeking for innovation or for a higher value for the project parties. The idea is to establish one project unit aspiring for one common goal. In the examined cases a lean approach is hindered by a variety of isolated transactional contracts. The used types of contracts by SVV with its transactional character aren't sufficient for the integration of project parties and processes. The aspect has therefore no relevance for a lean system.

Tendering procedure The award method is to select the contractor and is often price orientated. The transactional exchange of products and services is of first priority within the unit-price contract. Therefore the first choice has the bidder with the lowest offer. Within the unit-price contract it can be the objective to look for solutions where as less resources as possible are spent to cap the costs to a minimum. With regard to the lean approach other criteria can be important as well as finding the right project parties.

The ability of the contractor for a new way of carrying out a project can be part of the tendering procedure. The application of new tools and the search for innovative solutions shouldn't be hampered by the fact that the contractors prefer to stick to their old approach of proceeding within the project or because of lack of knowledge. To avoid such a case, qualitative criteria with regard to a LPDS are required during the tendering procedure. Considering more criteria it is possible to figure out the right contractor on the level of closer collaboration, the way of interacting and to improve the project procedure within a holistic approach (3.4.5). The selection process of alliances can be used as a model shifting the focus to a collaborative team (Heidemann and Gehbauer, 2011, 22p).

Choosing a contractor based on their price is to the expense of the relation among the project parties (Gordon, 1994, 204). The current used tendering procedure isn't supporting a lean delivery system. It has the potential to involve more criteria. Therefore no indications for the presence of lean are visible.

5.2 Overview about the results

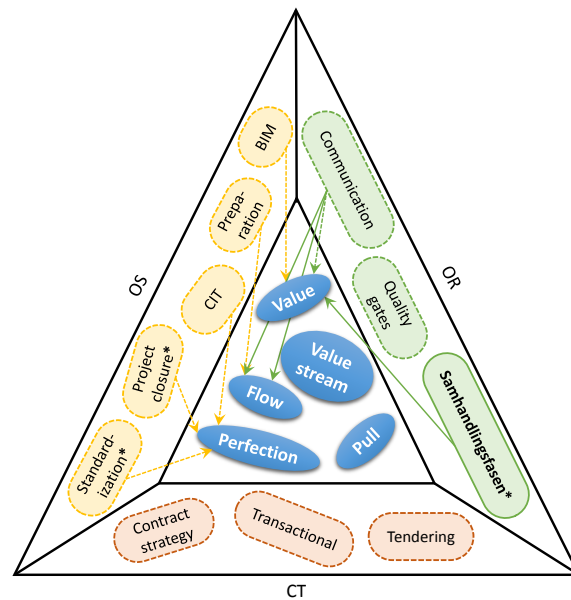


Figure 34: Case study results

The graphic 34 is summarizing the mentioned indicators and the results of the discussion. This is simultaneously the input for answering the research question within chapter six.

In total the researcher could identify 11 topics within the case studies which are directly related to LC. The issue communication is divided into three parts. Therefore 13 topics are available. Nine of those elements can be directly matched with one of the lean principles based on the theory and the assessment of the researcher. These nine elements are further categorized whether they are representing a strong or a weak indicator. The majority of the elements indicates lean principles in a weak way. The methods 'Samhandlingsfasen' and the project platform are indicators with a strong impact for a lean delivery system. The tool BIM isn't used to full capability but it is also a sign for the existence of lean principles. In figure 34 the researcher illustrated the match between method and lean principle as well as their relation to each other. As a result three of the five lean principles are reflected by the identified methods which are part of the standard management approach of SVV. Value, flow and perfection are represented by elements of the organisational structure and the operating system. For the principles value stream and pull were no signs uncovered by the researcher. This relation is illustrated by figure 35 referring to the mentioned procedure described in 5.1.

The elements named for the commercial terms have no relevance. Moreover they hamper the

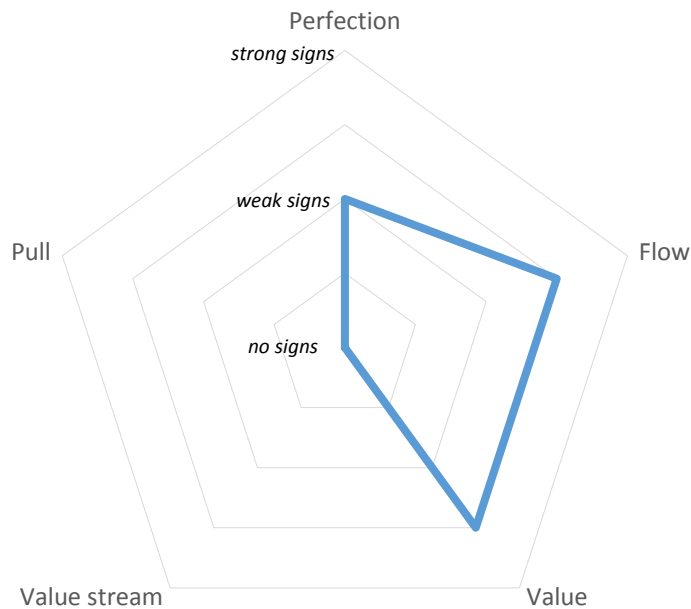


Figure 35: The presence of lean principles

system with their present character to establish a lean delivery system. They were identified by the researcher because of their importance establishing a lean system. They are the foundation to create a lean system and set the starting point for a way of culture and thinking (Lichtig, 2005, 106pp). To sum up, the examined cases display signs for a lean delivery system of moderate significance. Hence the made assumptions from the beginning of this report can be confirmed (2.1.1). Lean results are existent within the management approach of SVV without finding them directly in the given guidelines and the daily project language.

Single results could be partly confirmed within the sample by other case studies. The existence of more indicators can't be enclosed. The presented results are the output of the researchers sample. Six specific cases were examined which are representing six projects operated by SVV. The total number of construction projects amounts up to 500. 50 projects of them have also a contract sum above 750 mio. kroner (Statens vegvesen, 2013b). The sample of the researcher is comparatively small. The transferability of the results to other projects of SVV is partly given. An argument for the transferability is the usage of the handbooks which are representing the standard management approach. The same proceeding and application of standard tools and methods can lead to the same results for projects with similar attributes in comparison to the sample of the researcher.

Chapter 6

Conclusion and outlook

The research was set out to find answers for the following research questions. (1) Why is it useful and beneficial using the original idea of lean in transport infrastructure projects? (2) How supports the integration of the project team and the project phases lean thinking in transport infrastructure projects? (3) What is the role of the client and how can he influence and support lean thinking while carrying out a project? The researcher summarises the results integrating the theory and the project part. There is a statement about the outreach of the research method and its results. A verification of the undertaken research promotes the application of the conclusions in the future and shall encourage for further research.

6.1 Research questions

Lean management within infrastructure projects To answer the first research question the researcher needs to have in mind that the generalization of the results isn't given in this case with regard to the limits of the research method. Moreover can the question "why" not conclusively answered with the results of the thesis since the focus was only on identifying lean principles instead of evaluating their effects.

The traditional approach is limited to increased complexity, dynamics and interests. The project team of construction projects needs to cope with a type of processes which are executed by a multi-skilled and temporary organization, result in one-of-a-kind products and are realized at a specific place. Construction is a type of production managing transformation processes, the flow of work and the creation of value.

Lean supports to get a view for the whole project and improves the results in a holistic way considering the whole life-cycle of the product. Value needs to be defined by the customer first of all. To cope with complex systems means to use their capability to establish a self-organized environment for improvement, order and flow. Instead of having a management-as-planning, the new approach is to go for a management-as-cooperation and learn within an integrated team. To overcome and handle such a paradigm shift, lean provides tools and methods to support this step. The final step needs to be done by a structured and equipped system itself.

By applying a lean approach the awareness about waste is stressed identifying and reducing the share of non-adding value activities. The focus is on simplifying and easing the processes to make them flow. Defining value and making processes flow are the fundamental principles. These principles were discovered in the researcher's sample. More and more projects apply BIM activities. Often the users trigger in that way unconsciously but directly the system to move into the direction of lean because of the close relation between LC and BIM.

An integrated approach A kind of integration wasn't discovered in the case studies. The management approach is characterized as a linear approach carrying out the project. The approach and its single tools like the contract strategy and the quality gates hamper directly the integration of a team and of the project phases. Within the results three points can be mentioned considering lean: BIM, Samhandlingsfasen and the communication platform. These concepts can be seen as steps into the direction of lean provided by the client. They reflect single components of a LPDS. BIM delivers data about the required processes while designing and planning the product. Whereas Samhandlingsfasen and the communication platform bring the project par-

ties closer together. An “over-the-wall” syndrome and an isolated optimization of single parts of the project at the expenses of the whole project can be avoided. All aspects are in a close relation. They create value for the customer based on a better comprehension and can be seen as a starting point for a learning culture. A state of partnering is required making the team able to aspire for a higher value and establishing a culture of continuous improvement.

The new role of SVV within a LPDS Lean is a holistic approach which requires prior knowledge, comprehension about what to do and a specific way of thinking and behaviour. To support a lean delivery system the client needs to be aware about its new role and the change of behaviour. This is mainly triggered by the application of new processes and activities. The single aspects should complement and support each other properly. Given the fact that there is no common definition high variability is given. The client needs to define its own approach to adopt the interpretable LC approach to its own philosophy and policy. The single aspects of the lean triangle are linked and highly interactive to each other. This means the construction owner needs to initialize the search for higher value using more appropriate contract forms, creating a culture of learning and establishing a team with one common objective. The customer itself is an active member and driver of the processes during the design and construction phase. The client determines and settles the structure of the system as well as the operative tools based on the commercial terms. The conduction of trainings and social events are the first step into the direction of lean having the same level of knowledge and the commitment of all involved people.

6.2 Conclusions

With the help of the case studies lean principles can be uncovered within the management approach of SVV for transport infrastructure projects in Norway. Referring to the presented models the status of lean can be categorized on the process level using single tools. Three of the five lean principles are present within the researchers sample. After making lean visible, a rethinking of the system and single processes is possible for the purpose of a lean approach. First indicators are visible which have the capability for extension. They serve as a starting point to develop a deeper understanding for this approach.

- The preceding paragraphs haven't mentioned all existing tools and methods referring to a lean approach. Using tools is the last step in such an approach which is first of all based on understanding, commitment and the availability of a common culture.

- In theory a variety of methods were developed giving organizations tools to make them able realizing lean. Organisations make use of a range of tools adopting and transferring them to their own culture. Therefore tools and methods can emerge under another name. The ideas and the principles remain the same. Those need to be understood by using the same language and having the same level of knowledge within an organization and beyond companies borders.
- Using techniques alone isn't sufficient enough. Most of the power shifting a system into the direction of lean lies in the commitment of the management. Using the 'Five Big Ideas' can help to create a comprehension in general what lean is going to do within the project.
- A purposeful usage of lean tools is required being able to aim for better project results and a higher value for the customer. A long term strategy is necessary.
- The processes of lean need to meet with the framework given by the law referring especially the relational character.
- The tendering procedure has a significant impact deciding about the culture and the way of interacting among the different contractors. A new tendering procedure is necessary considering the fact to use other criteria beside economical ones.
- Construction processes can be seen as a type of production processes being aware about the peculiarities in contrast to the manufacturing industry.

There are limitations implementing a new approach. LC can't be seen as a universal remedy solving all problems. Lean needs to be adopted to every single project. It is the way itself moving into the direction of a LPDS.

"The journey is the reward."

The used processes and the behaviour of the people are determining this way to overcome resistors and barriers while changing the system.

6.3 Limitations of the research work and outlook

This research was conducted through a qualitative approach of six case studies uncovering lean principles within the projects. The term lean itself wasn't represented in the management ap-

proach. The case studies were chosen by the construction owner itself based on their importance within the project portfolio measured by the project costs. The research is limited because of the following reasons:

- The sample of the researcher is small.
- Despite the common project management approach there are different personal approaches focussing on different aspects while executing projects.
- The amount of information sources is limited in this case.
- The conduction of the interviews wasn't in the mother tongue of the interviewees.
- There is an one-sided perspective from the viewpoint of the client.

An active transfer from theoretical knowledge into practice isn't provided.

For implementing lean a long term strategy by the organization is needed. Moreover with the help of further case studies the effects and opportunities given by the implementation of single tools need to be examined. Research designs over a longer period of time need to be established. All data for the project part were collected from the employees of the contracting authority. An investigation about a longer period of time was with regard to the general set up of such a paper not possible. Another issue is the examination of the relationship and collaboration among the key project parties. The sounded identification of waste can be a topic for further research enhancing the awareness for such an approach. An noticed issue within the case is that provided tools given by the organization guidelines are not used or only partly used. The reasons for this phenomena need to be examined for each case itself.

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List of attachments

1. Project attributes
2. Question guide
3. Organisational structure
4. Operating system
5. Commercial terms
6. Selection of lean tools
7. Thesis overview

Case study	I	II	III	IV	V	VI
Project description	road project about 32 km expansion to 4 lines	road project about 10 km tunnel project 2 km Expansion to 4 lines	7 km of road system and a bridge	70 km of road Expansion to 4 lines 9 segments 6 section already finished	8 km city streets including road lane, cycle lane, pedestrian lane and public transport lanes, an tunnel is already opened	3 tunnel and their connection into the existing road system, 2 tubes and 4 - 14 km
Type of contract	tba	Different types of contracts	Unit price contract	Unit price contract	Unit price contract	n/s
Costs	tba	3,5 mio. NOK	3,2 mio. NOK	11,25 mio. NOK	7,13 mio. NOK	8,7 mio. NOK
Planning	tba	n/s	2006 - 2013	1990 - 1998	2000 - 2005	n/s
Construction	2018 -	2006 - 2015	2014 - 2017	1998 - 2022	2005 - 2015	2012 - 2019
Status	Planning phase	Execution phase	Execution phase	Execution phase	Execution phase	Execution phase
Funding	not clarified	Toll (80%) and government (20%)	Toll and government	Toll and government	Toll, governememt, municipality	Toll, government, municipality

Question guide

(interview time approx. 45 min)

Date and time

Introduction / role of the person / involved in the project since / working for Statens since / working in construction industry since

- ✓ features and challenges of infrastructure projects in general and of this project

Operating system (OS)

- ✓ current used tools and methods either to optimize or to control the project
- ✓ personal opinions about new approaches or thinkable methods
- ✓ culture doing something new, taking risk and trying new approaches
- ✓ meaning about the tools/objectives:
 - a. Last Planner System (LPS)
 - b. Building Information Modeling (BIM)
 - c. Kaizen – continuous improvement
 - d. Target Value Design (TVD)
 - e. Integrated Planning Design (IPD)
 - f. Lessons learned / best practise

Organisation (OR)

- ✓ structure client – constructor – planning team
- ✓ define the role of the client within the project
- ✓ involvement of the constructor

Commercial terms (CT)

- ✓ “Samhandlingsfasen” in this project
- ✓ Type of contract and selection process

Lean thinking (LT)

- ✓ meaning of Lean Construction in general
- ✓ critical reflection to this topic in general

Further comments / critical reflection to the questions

Introduction into the prepared survey / documents / observation


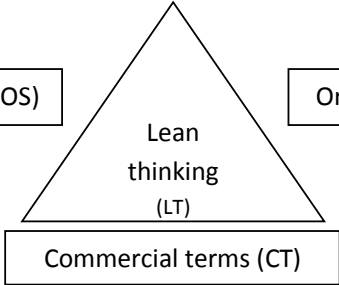
Thanks for the support and time

No.	Keyword theory = indicator	Results of the case studies	Lean principle	Conclusion	Relevance
Organizational structure					
1	Communication	Responsible-matrix and decision-matrix for the project team.	Flow	Improving the flow of information finding the right person for single positions within the single parties.	weak
		SVV has an own central plattform which serves for i.e.: the exchange of information, data and drawings, for decisions processes and results and for the communication beyond company borders.	Flow	Improving the flow of information and bring the project members closer together sharing information in real-time and easliy.	strong
		Involvement and enlightenment of effected stakeholders is executed by the usage of the website and social media. Inforation are shared about the project in preparation of local meetings during the planning phase.	Value	A part of the effected people with access to the used media by SVV can develop a deeper understanding of the project. Based on this fact more input by the local people can be generated and a higher transparency is given.	weak
6	Samhandlingsfasen	The part "Samhandlingsfasen" is part of the contracts. It's an interphase and is installed generating a better understanding about the project, let the project parties work closer together and create interaction agreements.	Value	A better comprehension of the project is the basis for generating a higher value for the customer. Processes which add no value can be reduced.	strong*
11	Quality gates	SVV is using quality gates along the linear progress of the project. Quality assurance 1 and 2 executed by external consultants are supposed to ensure the the target quality level considering mainly time, safety, environment and costs aspects.		The traditional way of executing the project is directly blocking the usage of an integrated team. Using this approach only single parts of the project are optimised instead of the whole project.	no relevance

No.	Keyword theory = indicator	Results of the case studies	Lean principle	Conclusion	Relevance
Operating system					
3	Continuous improvement	One team is moving from contract to contract within one project. Within a constant environment they can developed among their members a culture of improvement and innovation.	Perfection	Processes are well-known and the team members work together since a certain time. A learning effect is partly given but not beyond company borders.	weak
2	BIM	BIM is seen as a useful tool, but not in every project used of SVV. The focus of using BIM is to handle interfaces between different contractors and providing information for the public.	Value	The full capability of BIM isn't used in the cases. BIM and LC are highly interrelated to each other. BIM triggers the integration of teams and the planning of product and process.	weak
5	Project closure	The phase of the project closure is part of the standard approach. In practical it is under represented and not used like it is supposed to be. Project reports are under represented. The required templates and tools are available but not used.	Perfection	The effect by a project closure isn't given looking on the results of the interviews. The impact of a filled data base can be significant despite the unique character of each project.	weak*
4	Standardization	Based on the handbook a online quality system is under progress visualizing the standard processes and enable the user to browse the phases and their checklists.	Perfection	Processes can be standardized, fixed and adopted in view of the whole project and in agreement with the determined process owner. The quality and the flow of activities can be increased.	weak*
7	Preparation phase	During the interviews was in some cases spoken about the preparation of the field work. The aim is to achieve a predictable environment.	Flow	The measures serve to reduce the share of waste avoiding interruptions and having a making-do state.	weak

No.	Keyword theory = indicator	Results of the case studies	Lean principle	Conclusion	Relevance
Commercial terms					
8	Contract strategy	A design-bid-build strategy is used. External consultants evaluate the constructibility. Several prime contracts are existent with various constructors, consultants and engineers using their services and skills.		An integration of constructor and planning team isn't used. The idea of IPD isn't existent due to the linear way executing the projects. The usage of BIM can be the driver for a more integrated approach.	no relevance
9	Transactional contracts	The focus of the used types of contracts is on the exchange relation of commodities and services for a bargained price. A unit-price or lump sum contract are used in the cases.		A strong transactional character of the contracts leads to an isolated state of the project parties. A lean approach is hindered by a variety of transactional contracts.	no relevance
10	Tendering procedure	The contractor is awarded based on the cost in the majority of the cases after a competitive bidding process. Other tendering procedures which are in line with the law are available but not used.		With the tendering procedure the right project partner can be fined reducing the share of economic criteria. Within a LPDS the focus is on the relation and collaboration besides the cost factor.	no relevance

No.	Side	Name	Abbrevitation	Short description
1	CT	Partnering	-	Get to know each other and align all project parties with the project aims
2	OR	Integrated project delivery team	IPD	Organizational form consisting of key project members applying Lean principles
3	OR	Quality at the source	-	Producing products with a certain level of quality avoiding to transfer bad quality within the project
4	OR	Quality assurance	QA	Using consultants or experts evaluating the project
5	OS	Big room	-	Visualization of management tools and KPI's by a team of experts
6	OS	Value stream mapping	VSM	Overview about all steps needed to deliver a final product as a flow chart
7	OS	Pull scheduling	PS	Processes are triggered and needed by the following process which is seen as a customer
8	OS	Continuous improvement process	CIP	The aspiration to improve continuously all resources and activities within a project little by little using Kaizen and PDCA.
9	OS	Standardization	-	Using processes regularly and match certain problems with previous determined processes
10	OS	5S	-	Method to organize and maintain order at the work place
11	OS	Work breakdown structure	WBS	Planning the single work packages with focus on disciplines and interfaces
12	OS	Start operations like planned	-	Usage of a meeting structure which investigates and triggers regularly the operations
13	OS	A3	-	Visualization of the main aspects with a A3 paper informing others
14	OS	Choosing by advantages	CBA	Decisions based on the importance of advantages compared to each other
15	OS	Concurrent engineering	-	Planning of the product and process at the same time
16	OS	Just-in-time/sequence	JIT / JIS	Appropriate products when they are needed for further proceeding
17	OS	Prefabrication	-	Transferring processes away from the site
18	OS	Poke Yoke	-	Preventing any kind of errors or defects by engineering
19	OS	5 Why analysis	5W	Investigating the root of problems by using this question word
20	OS	Six sigma	6σ	Statistical approach reducing variability and errors by define-measure-analyse-improve-control

<p>LEAN MANAGE- MENT</p>	
<p>LEAN CONSTRUC- TION</p>	<p>LPDS = IPD + LPS + TVD + BIM + JIT + CIP + PS + VSM + further tools which are sounding, addressing and creating a lean thinking system</p>
<p>Master- thesis</p>	<p>“The presence of Lean Construction principles in Norway’s transport infrastructure projects”</p>
<p>RESEARCH QUESTIONS</p>	<ol style="list-style-type: none"> 1. Why is it useful and beneficial using the original idea of lean in transport infrastructure projects? 2. How far can an integrated approach referring the project team and the project phases support lean thinking in infrastructure projects? 3. What is the role of the client and how can he influence and support lean thinking while carrying out a project?
<p>PROPOSI- TIONS</p>	<ul style="list-style-type: none"> ❖ Lean principles are applied in the phases: pre-design, design, planning and the passage from planning to execution. ❖ Lean principles play an important role carrying out construction projects in modern times. ❖ Lean principles affect the project results significantly. ❖ The role of the client has changed applying production orientated tools.
<p>CASE STUDY</p>	<div style="display: flex; align-items: center; justify-content: space-around;"> <div style="border: 1px solid black; padding: 5px;">Operating system (OS)</div> <div style="text-align: center;">  <p>Lean thinking (LT)</p> </div> <div style="border: 1px solid black; padding: 5px;">Organisation (OR)</div> </div> <div style="margin-top: 20px;"> <ul style="list-style-type: none"> ✓ Identifying used methods and tools ✓ Identifying traces of Lean ✓ Identifying personal opinions and experiences towards Lean ✓ Identifying starting points for implementation of Lean ✓ Identifying effects towards cost, time and culture </div>