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Lean Construction in Norwegian Transport Infrastructure

The Client's Perspective

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Abstract:

This study seeks to answer the problem: "Map the current situation and review the possibilities of further implementing the lean methodology to Norwegian public infrastructure agencies operating in road and railroad. The scope lies in the client's perspective, and the study is approached with a qualitative research method where four public agencies in Norway are interviewed.

Findings show that the lean methodology somewhat exists in Norwegian transport infrastructure, however that projects mainly are organized under traditional project management. The possibilities and constraints in implementing a project delivery system that correspond with the lean methodology is discussed, and proposition for further research is recommended.

Keywords:

1. Lean construction
2. Lean methodology
3. Client's perspective
4. Transport infrastructure

Preface

This thesis marks the end of a 5-year integrated masters study program in Civil and Environmental Engineering at NTNU. The study is about lean construction, more specifically to map the current state and review the possibilities of further implementing the lean methodology to Norwegian public infrastructure agencies operating in road and railroad. The topic was chosen based on an interest to both lean and infrastructure.

Some people deserve some special thanks for their contribution to the study. Each interviewee, who set aside time from their daily work to comply to this thesis. Hans Thomas Holm, Thomas Edlund, Ole Holte Sandvik and Geir Saxebøl. At last, I would like to thank my supervisor, Frode Drevland, for his help with defining the problem of the study, identify interviewees and for his help on the finishing touch before hand-in.

Summary

The construction industry lags in efficiency compared to other industries, thus it needs higher performance. Lean construction (LC) has been adapted over many years as a competitor to traditional project management. Studies indicate the same problems to performance in transport infrastructure as to the building sector, however there are significantly less research that refer to LC in transport infrastructure. This study reviews LC in Norwegian transport infrastructure from the client's perspective. The problem of the study is:

"Map the current situation and review the possibilities of further implementing the lean methodology to Norwegian public infrastructure agencies operating in road and railroad."

The study is approached with a qualitative research method, thus interviews and existing literature has been the source of information. The cases of study are Bane NOR, Nye Veier, Statens Vegvesen (SVV) and Statsbygg. One representative of each organization is interviewed, and Statsbygg only for comparison purposes. The interviewees are key members of their organizations, thus the findings are precise. Findings show that lean has been implemented by Bane NOR and Nye Veier, however that SVV does not work with the lean methodology. Bane NOR has implemented a lean transformation that corresponds perfectly with Womack and Jones (2010) principles of lean to their operations and maintenance division. Nye Veier works with standardizing procedures and reducing waste in the organization, and approaches projects with a high-end focus on early involvement of contractors and suppliers.

This study finds that there are no specific challenges related to transport infrastructure, seen from the client's perspective. Implementing the lean methodology to the client's organizational framework equates to that of organizations operating in other industries. The differences between transport infrastructure and building projects, being the location and that transport infrastructure is more sequential, surely cannot reject the Lean Project Delivery System. However, some challenges in implementing Set-based strategies and alignment of stakeholder interests occur due to public tender rules in Norway and the status of to which lean is being currently used. This study has discussed the project model of Nye Veier to SVV, being respectively a design-build model that involves contractors early versus design-bid-build with practically lowest price as award criteria. Issues that occur with design-bid-build and lowest price as award criteria are a high number of change-orders and cost-overruns. These issues correlate to lack of alignment of stakeholder interest.

No prior studies have been done mapping the current situation and reviewing the possibilities of further implementing the lean methodology to Norwegian transport infrastructure, thus this is the first of its kind. The value of this study is that it opens for further research on the topic. This study suggests, however cannot conclude as performance indicators are not available, that more use of design-build or other co-operative models, and Target Value Design (TVD) with share in risk and responsibility can lead to increased performance in transport infrastructure. Further research should include case studies that compares the performance of Nye Veier's approach to SVV, and evaluates the effect of TVD with share in risk and responsibility.

Sammendrag

Byggebransjen lider av lav effektivitet sammenlignet med andre bransjer, og krever dermed forbedring. Lean construction (LC) har over flere år blitt utviklet som en konkurrent til tradisjonell prosjektstyring. Studier indikerer at de samme effektivitetsproblemene forekommer i infrastruktur, men det er betydelig mindre forskning som referer til LC innen infrastruktur enn den resterende byggebransjen. Dette studiet omhandler LC i norsk infrastruktur fra byggherres perspektiv. Studiets problemstilling er:

«Kartlegg dagens situasjon og se på muligheter for å videre implementere lean metodikken til de offentlige byggherrene som opererer innen Norsk veg- og jernbanesektor.»

Oppgavens tilnærming er en kvalitativ forskningsmetode, der intervju og eksisterende litteratur har vært kilden til informasjon. Organisasjonene som studeres i oppgaven er Bane NOR, Nye Veier, Statens Vegvesen (SVV) og Statsbygg. En representant fra hver organisasjon er intervjuet, der Statsbygg bare er med for sammenligningsgrunnlag. Intervjuobjektene er nøkkelmedlemmer av hver deres organisasjon, slik at funnene anses som reelle. Funnene viser at lean er implementert av Bane NOR og Nye Veier, men at SVV ikke jobber med metodikken. Bane NOR har implementert en lean transformasjon i drift- og vedlikeholdsseksjonen som korresponderer tett opp til Womack og Jones (2010) lean prinsipper. Nye Veier jobber med å standardisere prosedyrer og redusere ikke-verdiskapende aktiviteter i organisasjonen, og har et stort fokus på tidlig involvering av entreprenør og leverandører i prosjektmodellen.

Dette studiet finner at det, sett fra byggherres perspektiv, ikke er spesielle utfordringer tilknyttet infrastruktur og implementering av LC. I det organisatoriske rammeverket er mulighetene ved å implementere lean metodikken tilsvarende som for organisasjoner i andre industrier. Det som i hovedsak skiller infrastruktur og byggeprosjekter er prosjektets lokasjon og at infrastruktur er mer sekvensielt, og disse ulikhetene kan umulig avvise bruken av Lean Project Delivery System. Likevel forekommer det noen utfordringer i å implementere «Set-based»-strategier og tilrettelegging av aktørers interesser grunnet norske anbudsregler og den grad LC idag er tatt i bruk i Norge. Studiet har diskutert Nye Veier's og SVV's prosjektmodeller, som er henholdsvis Totalentreprise med tidlig involvering kontra byggherrestyrte entrepriser med tildelingskriterie som i praksis tilsvarer lavest pris. Et høyt antall endringsordrer og kostnadsoverskridelse er konsekvenser som følger av byggherrestyrte

entrepriser med lavest pris som tildelingskriterie. Disse konsekvensene korrelerer med interresekonflikt mellom aktørene.

Det er ikke tidligere gjennomført studier som kartlegger dagens bruk og ser på mulighetene for å videre implementere bruken av lean metodikk i norsk infrastruktur, dermed er dette det første. Verdien i dette studiet er at det åpner for videre forskning på temaet. Dette studiet foreslår at mer bruk av totalentrepriser eller andre samarbeidsmodeller, samt Target Value Design (TVD) med deling av risiko og ansvar kan føre til økt ytelse i infrastruktur. Grunnet mangel på ytelsesindikatorer kan det likevel ikke konkluderes. Videre forskning bør inkludere case studier som sammenligner ytelsen til Nye Veier's prosjekter med SVV's, og evaluere påvirkningen av TVD med deling av risiko og ansvar.

Abbrevations

Transport infrastructure	–	Refers to road and railroad
LC	–	Lean construction
LPDS	–	Lean project delivery system
LPS	–	Last planner system
SBD	–	Set-based design
TVD	–	Target value design
SVV	–	Statens Vegvesen

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1. Introduction

1.1 Background

The construction industry plays an important role in an industrial country. Construction influence the daily life of everyone, through work for some, and for others through the houses we live in, roads we drive on and so forth. As such, there is a need for the industry to operate at a high performance (Jonsson, 1996). Even so, the construction industry seems to lag in efficiency compared to other industries. Several studies show the low efficiency compared to other industries and the need to improve in construction (Allmon et al., 2000, Force and Britain, 1998, Miller et al., 2009). In Norway, we are essentially good at project management in construction and the industry is by no means in a state of despair. However, the opportunities in adapting "Best practice" are significant. A study on 122 apartment block projects in Norway finds that the efficiency on the "Best practice" projects are over twice as high as the least effective. Simply put, some projects use twice the amount of resources as others, producing the exact same thing (Ingvaldsen and Edvardsen, 2007). Studies show that infrastructure is no better (Flyvbjerg et al., 2003). The Office of the Auditor General in Norway criticize Statens Vegvesen for significant cost- and time-escalations on large infrastructure projects (General, 2013). A problem with traditional project management is that it lacks development. Some new tools and technologies have emerged, but essentially it hasn't changed in 60-70 years (O.H. Sandvik, Discipline supervisor Lean/quality Nye Veier, 23.05.2017, interview). Hence, new ways and methods in project management are being adapted and developed from other industries. Lean construction (LC) is an adaptation of the Toyota Production System, Lean Production (Howell, 1999). The Toyota Production System became a case for study as their production system differed from the traditional craft and mass production, yet delivered products with high quality and better performance. Lean production came to be a global phenomenon with the book "The Machine that changed the world" by Womack et al. (1990), which led to several industries attempting to adapt the concepts of waste reduction, pull production and flow. Koskela (1992) introduced lean production to the construction industry with his technical report "Application of the new production philosophy to construction", and his Dr. thesis "An exploration towards a production theory and its application to construction". His Transformation-Flow-Value (TFV)-theory of production is considered the starting point of LC.

The theoretical framework surrounding LC is comprehensive. The fact that it is based on a better theory then traditional project management makes it more effective (Koskela et al., 2002). The practical application of LC is relatively small compared to its massive body of literature. However, several organizations has seen significant results in implementing it (Alarcón et al., 2008, Thomassen et al., 2003), and tendencies show an increasing interest in the construction sector. However, apart from Lean Support to Highways England, there has been less initiative in embracing LC in the infrastructure industry compared to the building sector. Cost overruns and time escalations are common in infrastructure projects, and the UK Highways Authority has had success in reducing costs from implementing lean principles (Chloe Chen BA, 2012).

1.2 Problem definition

The construction industry lags in efficiency compared to other industries, thus it needs higher performance. LC has been adapted over many years as a competitor to traditional project management. Its theoretical framework is massive, and its practical application has seen good results. However, there are few publications referring to LC in transport infrastructure, both from a theoretical and practical point of view. Hence, it opens the question as to why transport infrastructure, which uses a substantial amount of a country's BNP and like the building sector lags in efficiency, have not adapted the lean philosophy to the same extent. The fact that few publications refer to it, does not necessarily imply that the transport infrastructure industry rejects the methodology, however it does mean that it requires further research.

This study reviews LC in Norwegian transport infrastructure from the client's perspective. The problem of this study is:

"Map the current situation and review the possibilities of further implementing the lean methodology to Norwegian public infrastructure agencies operating in road and railroad."

There are three research questions to answer the problem.

(1) Do the Norwegian public infrastructure agencies operating in road and railroad, work with the lean methodology?

(2) Are there specific challenges related to transport infrastructure, which makes an implementation of LC less opportunistic than that of the remaining construction sector, seen from the client's perspective?

(3) What are the possibilities and constraints of implementing LC to the Norwegian public transport infrastructure agencies?

1.3 Cases of study

The amount of research surrounding LC in the Norwegian transport infrastructure industry is limited. As such, the best way to acquire information is to appeal directly to the sources. Four organizations are being interviewed and analyzed in this study. (1) Bane NOR, a state-owned company responsible for the Norwegian national railroad infrastructure. (2) Statens Vegvesen, the Norwegian public Roads Administration. (3) Nye Veier, a wholly state-owned corporation with the mission to plan, build, operate and maintain important highways in Norway. (4) Statsbygg, a public-sector administration company whom is the Norwegian government's key advisor in construction. Statsbygg is being reviewed for comparison purposes, as the organization has some experience with lean in projects.

1.4 Limitations

The study has a wide scope, while being limited to one semester and one student. Hence, the author cannot acquire all in-depth information he would want. The organizations reviewed in this study are large, however the study is limited to one interview per organization. Interviewing several key informants would've given more precise results as interviews within the same organization could be crosslinked and compared. This thesis extends only to find results from one key member of each organization, analyze it and discuss it with existing literature. Hence, the findings might not be directly comparable to each other and the means to answer the problem is weakened.

1.5 Structure of the thesis

The following part of the thesis is structured in five chapters.

- *Methodology, chapter 2.* The verifiability of this study is presented through a description of the methodical process. The chosen approach, literature review and interviews, are presented in this chapter.
- *Theoretical framework, chapter 3.* Existing literature on the topic is introduced to the reader. The chapter is structured to first present the general theory on the topic, before the theory necessary to answer the study's problem.
- *Cases of study's approach to lean, chapter 4.* In this chapter, the findings from the interviews are presented. The structure on the sub-sections of this chapter differ, as the findings were not directly comparable to each other. Therefore, the chapter also includes a reflection to theory, to allow for the discussion in the next chapter to flow better.
- *Discussion, chapter 5.* Results are discussed to answer the research questions.
- *Conclusion, chapter 6.* Conclusions from the study are summarized and proposition for further research is presented.

2. Methodology

This chapter explains the methodical process of the master thesis. As the introduction showed what the author wanted to research and why it is important, this chapter explains how.

2.1 Qualitative research

The choice between qualitative and quantitative research depends on what the researcher seeks to understand. Simplifying the differences between quantitative and qualitative research, one could say that qualitative research seeks an explanation based on large selections and numbers, whereas qualitative research involves around processes and experiences that not necessarily can be quantified or measured (Thagaard, 2003). The author of this thesis recognized the qualitative approach as the most suitable to answer its research questions.

According to Yin (1996), different strategies in doing social science research depend on three conditions: "(a) the type of research question, (b) the control an investigator has over actual behavioural events, and (c) the focus on contemporary as opposed to historical phenomena." (Yin, 1994).

This master thesis is a qualitative study with a comprehensive literature review and interviews as the research methodology. The author considered the said approach to be the most efficient in answering the research questions. Case studies would be an interesting approach, however deemed impossible due to no relevant cases being available for study.

2.2 Literature review

Literature review is the main source of data gathering for the theoretical framework. It includes finding the right literature and evaluate it properly. Lean management and lean construction consists of quite the massive body of literature, hence it is important with a systematic approach to reject what is not relevant. The data gathering was divided mainly into three steps.

1. *The basis literature of lean management.* The author searched the origins of lean to get an understanding of its core ideas and history. The origins of lean can be backtraced to Ohno (1988) and Womack et al. (1990).

2. *The literature referring to LC, both from a theoretical standpoint and its practical application.* The author sought to identify how the complexity and uniqueness of construction processes differentiate LC from lean in manufacturing. Backtracing LC to Koskela (1992) and (2000), followed by several publications by Koskela, Ballard and Howard gave the necessary understanding to the ideas and theoretical foundation of LC. Key aspects are the TFV concept of production and the LPDS. A strong theory does not transform itself into successful practical application. The practical application of LC has spread wide in the later years. To understand LC, especially to the extent of what makes LC better than traditional project management, the author reviewed its practical application. The goal being to understand how the strong theoretical framework of LC can be implemented in a way to ensure less waste, more value and thus more successful projects.

3. *The literature referring to LC in transport infrastructure.* The objective of this thesis lies in the transport infrastructure industry. As such, reviewing the literature surrounding LC in transport infrastructure is highly relevant and important. Compared to the remaining construction sector, there is a small amount of literature about LC in transport infrastructure. When reviewing sources related to it, the author searched to understand why the transport infrastructure industry has seen less of LC, while at the same time seeking the answers to how it can work successfully in transport infrastructure. One known example is the "Lean support to Highways England".

2.2.1 Evaluation of literature

To ensure quality to the master thesis, evaluating the literature and their origin is important. The masses of information, and the open publication principle of the internet makes the evaluation process necessary. Several publications recognize the importance of evaluating information sources and give guidelines for how to do it (Brand-Gruwel and Stadtler, 2011, Metzger, 2007). Following a course last semester, the author did a report on literature review for this study. The frequently used databases for finding literature and the sources were evaluated. Sources were evaluated on the criteria of credibility, objectivity, preciseness and suitability, as proposed by the NTNU guidelines. For more details on the evaluation of databases, search history corresponding with the literature review and evaluation of sources, see appendix A.

2.3 Interviews

Interviews are an exchange of views between two people talking over a common theme. The purpose of an interview is to gain deep and descriptive information about others experience, thoughts and feelings. Knowledge is created through the interaction between interviewer and interviewee (Dalen, 2011, Kvale et al., 2009). There are mainly three different kinds of interviews. *(1) Structured interviews, (2) semi-structured interviews and (3) unstructured interviews.* Qu and Dumay (2011) argues that *(1) structured interviews* are suitable when studying facts, *(2) semi-structured* when focusing on meaning and *(3) unstructured* when the social construction of situated accounts are of interest (Qu and Dumay, 2011).

For this study, the author found the *(2) semi-structured* approach as the most suitable. Semi-structured interviews are the most used in qualitative research because of its flexibility. It allows the skilful interviewer to steer the conversation towards unlocking response with impact and suitability for the research purpose (Kvale et al., 2009, Qu and Dumay, 2011). There are little, to no literature that show the lean experience for some of the organizations interviewed in this study, hence it is difficult for the interviewer to know all relevant background going into the interview. The semi-structured approach allowed the interviewee to bring up topics the interviewer did not think of in advance.

2.3.1 The interview guide

In advance of the interviews, an interview guide was made by the interviewer. As the method followed the semi-structured approach, the interview guide mainly consists of topics and subjects for the interview, but not clear "questions/answers" as a survey or structured interview would have. An interview guide should be shaped by starting off with more neutral questions to make the interviewee feel relaxed and comfortable, and advance into the more complex and hard questions with a smooth flow (Dalen, 2011). The author kept this in mind when structuring the interview guide, starting with an introduction to the interviewees, followed by easy topics before the "why do you think?" questions, which are usually harder to answer. Learning through the experience of the interview situation, the author recognized that sending the interview guide to the interviewees in advance would be beneficial. As a result, it was sent to the interviewees in the latter performed interviews. The interview with Statens Vegvesen did not follow the interview guide, as the author soon realized that the organization does not work with the lean methodology. As such, the author made up questions during the interview, to get relevant data for the study. See appendix B for the interview guide.

2.3.2 The interview situation

Three of the interviewees were recommended by the author's supervisor as suitable for the study, and the fourth found by the author through an internet search. The author contacted the interviewees over mail and introduced the purpose of the interviews. The interviewees who accepted the invitation got the opportunity to set the time and place of the interview.

Two of the interviews were done in person and two over Skype. It was found best to do the interviews in person to get the personal relation which is harder to establish over Skype, however due to geographical issues two of them could not be done in person. During the interviews, a tape recorder was used to ensure precise data. Each interview lasted between an hour and an hour and a half.

The interview situation was new to the author of this study, having never performed interviews before. As such, mainly two challenges were encountered. (1) Getting the interview back on track if the interviewee started talking about things with no relevance, as it felt unpolite to interrupt them. (2) Reformulate the question if the interviewee misinterprets or misunderstood it.

2.4 Ethical considerations

Qualitative research with interviews as the research method require some ethical considerations. *"The general ethical principle with regard to the interviewee is to impose no harm."*(Qu and Dumay, 2011). Considerations were made by the author regarding:

- *The use of tape-recorder.* The recordings will only be used for transcription of the interviews and not published in any way.
- *The anonymity of the interviewees.* The interviewees are given the opportunity to remain anonymous.
- *Protection of confidential information.* Some information gathered in the interviews are confidential and cannot be published. This information will not be used, and the interviewees are given the opportunity to look over the information gathered in the interviews before the study is handed in.

3. Theoretical framework

This chapter is meant for the reader to get an introduction to the theory relevant for understanding this study. It is divided into four parts. First, it gives an insight into the need to improve in the construction industry. Second, it describes the theory and history surrounding lean production and lean thinking. Third, it describes the background and explains the essentials in lean construction, and compares it to the traditional approach. At last, it refers to some important tools and the practical application of LC in the construction sector.

3.1 Construction industry – the need to improve

Several studies on the performance in the construction sector show that it lacks efficiency compared to other industries, and that it needs to improve. To mention but a few, Force and Britain (1998) outlines the need for improvement in the UK construction sector. Flyvbjerg et al. (2003) show that nine of ten infrastructure projects fall victim to cost escalation with an average of 28%. Further, there seem to be no evidence for learning, as these escalations have not decreased over the last 70 years. Teicholz et al. (2001) show that the labor productivity in the US construction industry has declined at a compound rate of -0.48% per year in between 1970-1998, compared to all non-farm industries which in the same period increased by 1.71% per year. Miller et al. (2009) find that over 50% of the costs in U.S. construction attributes to waste.

3.2 Lean production

Lean production consists of quite the massive body of literature. This part-chapter introduces the origins of lean and describes the main principles of lean.

3.2.1 The origins of lean production

Lean production arrived from the Japanese car manufacturers Toyota. Their attention to the production system differed from the traditional focus of craft and mass production. Chief of production-engineer Ohno recognized the traditional production system as full of waste. As such, he began to experiment on a production system with a high-end focus on waste reduction and customer satisfaction. This led to what Toyota came to call the Toyota Production System, which is now known as lean production (Womack et al., 1990).

3.2.2 What is lean thinking

Lean is a methodology, a way of thinking to optimize performance in a production system and meet unique customer requirements. To shortly summarize it, lean is about creating the maximum amount of value whilst minimizing waste. Waste in lean thinking is defined as any activity that consumes resources, but does not add value, and should thus be eliminated. Seven types of waste were originally identified, with the recognition of an eight category in the later years (Koskela, 2004, Ohno, 1988). Womack and Jones (2010) propose a guide to becoming lean. Through their long-time study, they identified five main principles of lean thinking.

(1) Specify value

Value is an ambiguous concept, with no clear commonly agreed upon definition. According to Womack and Jones (2010), value can only be defined by the ultimate customer. An important aspect in defining value for Japanese firms is where value is created. Drevland and Lohne (2015) presents nine tenets related to the concept of value, by reviewing selected definitions found relevant to the term value in construction projects. Understanding and specifying value is the critical first step in lean thinking.

(2) Identify the Value Stream

The next step in becoming lean, after understanding value, is according to Womack and Jones (2010) to identify the value stream. The whole value stream includes every action running from *"concept through detailed design to actual availability, from the initial sale through order entry and production scheduling to delivery, and from raw materials produced far away and out of sight right into the hands of the customer."*(Womack and Jones, 2010).

Understanding actions of other parties involved in the value stream is essential in identifying and thus removing waste. Waste can be divided in two types. Type I is the pure waste, which should be eliminated immediately. Type II is necessary waste. Activities that do not create value, but are necessary for other operations to do so. Necessary waste should be reduced when possible and eliminated when they no longer are necessary. They call the organizational mechanism for mapping the value stream, lean enterprise[1]. Value Stream

[1] Lean enterprise refers to a continuing conference of all the concerned parties to create a channel for the entire value stream WOMACK, J. P. & JONES, D. T. 2010. *Lean thinking: banish waste and create wealth in your corporation*, Simon and Schuster.

Mapping is an essential part in becoming lean. It is a visual representation of every process in the material and information flow (Rother and Shook, 2003).

(3) Flow

Lean flow is about making items or people in a process flow as smoothly as possible from the first step to the last. The Parade Game[2] is a tool to illustrate how work flow variability impacts the performance of a trade, or rather a process. Standardizing work is key to reducing the variability, thereby creating flexibility. The third step in becoming lean is thus to convert from departments and batches to making value flow (Womack and Jones, 2010).

(4) Pull

Pull production as described in the book, is to produce based on customer demand rather than pushing production to always have products available. This step is described as the fourth principle of lean thinking, and will dramatically reduce waste in over-production and inventory if implemented properly (Womack and Jones, 2010).

(5) Perfection

The last principle is to continuously strive for improvement. As value is specified, value streams identified, wasted steps removed, and flow and pull are introduced, the idea is to start the process over again as each principle interact with each other and show new possible improvements. To constantly seek improvement, hence perfection, is a well-established mind-set of the Toyota employees. Kaizen, the practice of continuous improvement, comes from the Japanese, and refers to involving every member of an organization to gradually make small changes seeking long-term improvement (Womack and Jones, 2010).

Some simple, but effective techniques have emerged for implementing the five lean principles to organizations.

5S

5S is a lean system of process improvement to reduce waste, clean the workplace and improve labor productivity. The process utilizes visual control for continuous improvement, and is

[2] For a comprehensive explanation of The Parade Game, see TOMMELEIN, I. D., RILEY, D. R. & HOWELL, G. A. 1999. Parade game: Impact of work flow variability on trade performance. *Journal of construction engineering and management,* 125**,** 304-310.

often implemented early in organizations that adapts the lean methodology, as it facilitates other techniques. The 5S comes from Japanese words and refer to: Sort (Seiri), Set in Order (Seiton), Shine (Seiso), Standardize (Seiketsu), and Sustain (Shitsuke). The implementation of 5S leads to eliminating waste and a more transparent process flow (Al-Aomar, 2011, Hirano, 2016).

Visual management

Several visual control tools have emerged to facilitate the communication process of lean factories. The different practical approaches will not be explained, as it can be anything from visual control boards to managers walking the facility in daily follow-ups. A key driver shared by the different approaches, is that for necessary adjustments to be recognized, every person involved must see and understand the process and its status at any time. Visual management is an important aspect for success in lean production, as it facilitates Value Stream Mapping and protects the principles of continuous improvement (Parry and Turner, 2006).

3.3 Lean construction

Just as lean production consists of a massive body of literature, so does lean construction (LC). This part-chapter introduces the lean methodology specified for the construction industry.

3.3.1 Background

LC is an adaptation of the lean production philosophy. Although the construction industry rejects many ideas from manufacturing as they are fundamentally different, the production system design criteria as a standard of perfection is accepted into LC (Howell, 1999). Koskela (1992) was the first to refer lean production in context to construction. He criticizes the traditional conceptual basis of construction and highly recommends that the construction industry adapt the lean production philosophy. As such, the report can be considered the birthplace of LC, with Koskela being the first theoretician.

Koskela came to research further on the field and published his Dr. Thesis in 2000. Historically, theories of production have been viewed as either transformation, flow or value. Koskela propose that all concepts are necessary, which results in a transformation-flow-value (TFV) theory of production. Traditional project management in construction focus simply on

the transformation view of activities, whereas LC is based on the TFV concept of production.

"TFV adds conceptions of production as consisting of flows of materials and information through networks of specialists, and the conception of production in terms of the generation of customer value." (Ballard et al., 2001). Optimization principles for respectively the concept of transformation, flow and value follow by Table 1:

Table 1: Optimization principles for the TFV-concept (Koskela, 2000).

Transformation	Flow	Value
• Correct decomposition • Minimize cost of value-adding activities • Insulate production through buffering	• Reduce the lead time • Reduce variability • Simplify • Increase flexibility • Increase transparency	• Capture customer requirements • Ensure requirement flow-down • Ensure comprehensive requirements • Ensure the capability of the production system • Measure value

There are two slightly different interpretations of LC. The first is the idea of implementing methods from lean production to construction. The second views lean production as only a theoretical inspiration for a new production theory for construction. The latter regards the TFV-theory of production from Koskela (2000) as the starting point and is the most dominant view (Ballard et al., 2001, Koskela et al., 2002).

The core idea of lean production, minimizing waste while maximizing value, is accepted into LC. There are several studies referring to waste in construction. To mention some, Ballard (2000) presents how waste can be reduced through elimination of negative iteration. Josephson and Björkman (2011) propose 31 recommendations to reduce waste and thus increase profitability. Vrijhoef and Koskela (2000) finds based on case studies, that there are high amounts of waste in the construction supply chain. Root causes of the waste and problems usually have ground in previous activities by a prior actor. Further, the waste is largely caused by myopic control of the construction supply chain.

3.3.2 Lean project delivery system (LPDS)

The LPDS is a structured and controlled system pursuing the TFV goals. One of the key elements of the LPDS is how it relates the relationship between phases and the participants in each phase, and thus differentiates it from traditional project delivery (Koskela et al., 2002).

As such, it is relevant at some aspects to compare it to the traditional approach when explaining it.

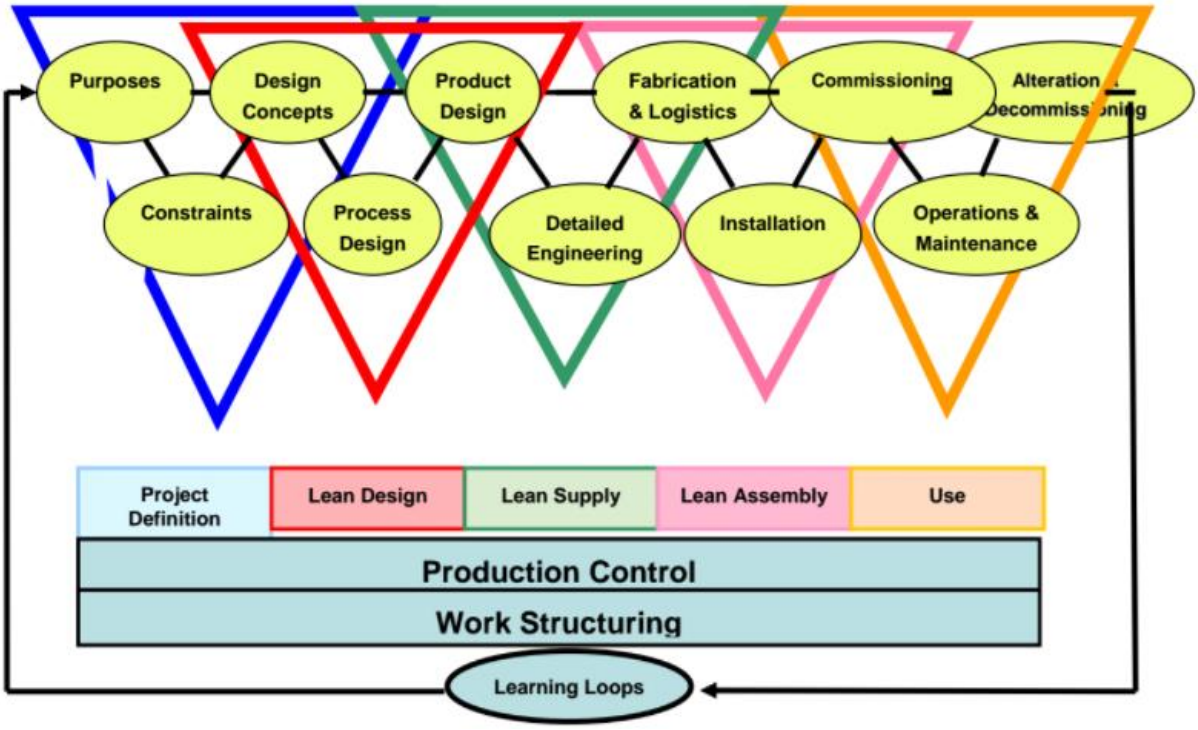

Figure 1: Lean Project Delivery System (Ballard, 2008).

The first phase in the LPDS is project definition. In this phase, every stakeholder involved should come together to align purposes and values, design concepts and design criteria. As each element influence the other, a conversation is necessary to achieve the best and most reasonable project definition. An interesting note is that the project delivery team is assumed to not only provide what the customer want, but to also help them decide what they want.[3]

Followed by project definition is lean design. Lean design is the phase where product and process design are aligned and developed. If opportunities consistent with customer and stakeholder constraints in the search for value is revealed during this phase, it may revert to project definition. In light of that comes a striking difference from the traditional approach in which design tasks are selected and executed as quickly as possible. Lean design uses a "set-based" strategy where interdependent specialists are allowed to move forward to some limit, as the selection and execution of design tasks are done at the last responsible moment[4].

[3] For further detail, see BALLARD, G. 2008. The lean project delivery system: An update. *Lean Construction Journal,* 2008**,** 1-19.

[4] The last responsible moment means deferring decisions as long as possible to get more time for exploring alternatives and developing them.

Selecting and executing design tasks based on the last responsible moment reduces the amount of rework and disruption necessary when decisions from different specialists are in conflict. Lean supply is the transition into detailed engineering, fabrication and logistics. The first key step in detailed engineering is to identify the uses of design. The phase includes reducing lead times of materials and information. Lean assembly follows by lean supply, with fabrication and logistics at the hinge between them, as it occurs repetitively. Lean assembly completes when the client has beneficial use of the facility (Ballard, 2008, Ballard and Howell, 2003, Koskela et al., 2002).

3.4 Traditional project management in construction

Traditional project management is criticized for lacking a unified theoretical framework. It has merely been developed by advances achieved by practitioners, rather than scientists. In the 20th century there has been three concepts of production. *"The transformation concept on the value-adding transformation; the flow concept on the non-value-adding activities; and the value generation concept on the control of production from the customer point of view."* (Koskela, 2000). The traditional approach is dominated by the transformation view of production. The process involves around converting an input to an output. In the process, subprocesses are made under the same principle, essentially dividing them into tasks. The goal is to acquire the inputs to these tasks with minimal costs and carry each individual task as efficiently as possible. Several disadvantages follow from this model (Koskela, 1992, Koskela, 2000, Koskela et al., 2002). To mention some:

(1) *Neglects the flow in the production system.* There are seldom any iterations in the design process and constraints of subsequent phases are not regarded in the design phase. Activities are rarely linked together in sequential chains, rather made up of a series of activities in a CPM network. Control involves around tracking the completion and cost of these activities, rather than focusing on a reliable work flow. Hence, the root cause of variances from upstream activities are not dealt with thus leading to a large number of change orders and suboptimal solutions. The changes that occur during a project are tougher to manage when decisions are made early and the focus lies in local optimization.

(2) *Lack of early involvement and cooperation between all actors.* Mainly due to the contractual templates being used, each stakeholder is only involved in the phase of

their work. Each stakeholder has different interests, thus there is a shift of interest in every phase, and the project is often not the focus. Different contractual models, such as design-build has been embraced as a contradictive measure, however it also fails to involve and align the interest of every stakeholder during every phase of the project. Contractual terms will be described further in chapter 3.5.2.

(3) Segmented control. In the transformation view of production, control is focused in a hierarchical organization, keeping cost control over single tasks and units. Resulting from this is maximization of utilization rates and large batches. Disadvantages follow that of space and attention required for materials and work-in-progress, slow error correction and multiple handling.

3.5 Comparison of the traditional approach to LC

Koskela et al. (2002) argues that LC is based on a better theory than conventional construction and that it is more effective. The main difference in traditional project management in construction and lean construction is that while the traditional approach only focuses on the transformation of inputs to outputs, LC acknowledge the goals of the TFV view of production. Table 2 compares the traditional approach to lean project delivery systems.

Table 2: Comparison of traditional and lean project delivery systems (Koskela et al., 2002).

Lean	Traditional
Focus is on the production system	Focus is on transactions and contracts
TFV goal	T goal
Downstream players are involved in upstream decisions	Decisions are made sequentially by specialists and "thrown over the wall"
Product and process are designed together	Product design is completed, the process design begins
All product life cycle stages are considered in design	Not all product life cycle stages are considered in design
Activities are performed at the last responsible moment	Activities are performed as soon as possible
Systematic efforts are made to reduce supply chain lead times	Separate organizations link together through the market, and take what the market offers
Learning is incorporated into projects, firm and supply chain management	Learning occurs sporadically
Stakeholder interests are aligned	Stakeholder interests are not aligned
Buffers are sized and located to perform their function of absorbing system variability	Participants build up large inventories to protect their own interests

As shown by Table 2, project management with the lean approach contradicts the disadvantages that follow from the traditional approach.

3.5.1 Contractual terms

One of the key elements of LC and the LPDS is the alignment of stakeholder interests and early involvement. The principle is governed by contractual terms.

Traditional contracts

Traditionally, the most used procurement form has been execution contracts. There are several forms of execution contracts, however they are all based on the same principle. Dividing design and execution through design-bid-build. The project owner keeps the risk and responsibility of design, which is usually traded off to consultants, and draws one or several

contracts with contractors for the execution. This procurement form does not invite suppliers to participate in early stages of design and does not allow for alignment of stakeholder's interest throughout the phases. Builders are not responsible for errors in design, and designers are not responsible for methods, cost or schedule. Each party is responsible only for their own outcome and failure caused by other party's results in redress for the affected party and change orders. As a response, the design-build model has become more used recently (Koskela, 2000, Ashcraft, 2014b). In the design-build model, the contractor is responsible for both design and execution. Studies show that design-build is superior to design-bid-build in terms of time and cost on building projects, and time on large highway projects (Hale et al., 2009, Shrestha et al., 2011). The advantage follows from that of the design-builder being given the authority to use their flexibility to improve cost and schedule efficiency. The flaw of the design-build model is that the owner not only gives away risk and responsibility, but also the means to influence design. Hence, good and measurable function descriptions are necessary to secure the owners interests to quality. The design-build model does indeed involve the contractor early, however the model does not fully invite to cooperation and partnering with the different stakeholders as it trades of the design phase from owner to contractor. Ashcraft (2014b) propose that for design-build to really be collaborative, the suppliers must share in risk and reward, and should not be able to assert claims against each other.

Lean contracts

Lean contracts are focused on early involvement of the construction supply chain and cooperation between stakeholders, in correspondence to the LPDS. Traditional contracting allows and incentivizes individual firms to profit by transferring risk and blame to other parties rather than spending resources to avoid or solve the problem. In lean thinking, root causes should be identified and eliminated immediately. Integrated project delivery (IPD) is a lean contracting model. IPD combines transactional and relational contracts. The client and the suppliers enter a transactional contract in addition to signing an internal relational contract they are bound by. The relational contract that defines the relationship between client and its suppliers are governed by two main principles. *"With IPD, all PTMs are responsible for all provisions of the prime contract with the Client. Primary Team Members share the risk and profit for total project performance.* (Matthews and Howell, 2005). Common goals are agreed upon and profit is tied to project performance, thus individual firms does not profit by

trying to escape from or forward the problem, nor hold back ideas in fear of having to pay for other solutions. Project cost is the most common performance metric. Target cost is set and the potential profit is at-risk, whereas if the project is delivered to target cost or for less, their profit is respectively the agreed upon or higher profit. Aligning the party's interests and involving every stakeholder throughout the project incentivizes the team members to work for a common goal, namely optimizing project performance. Five factors of IPD are especially important in influencing project outcome: Early involvement of key participants, shared risk/reward based on project outcome, joint project control, reduced liability and jointly developed/validated targets (Ashcraft, 2014a, Ashcraft, 2014b, Matthews and Howell, 2005).

3.6 Implementing LC and the LPDS

"Various tools and techniques have been developed to implement the Lean Project Delivery System (LPDS). No list will be accurate for long, as innovation is very much underway and new tools and techniques emerge all the time."(Ballard et al., 2002).

3.6.1 Target Value Design (TVD)

TVD is a method to plan and design based on target costing. One definition of target cost is seen in relation to allowable cost and expected cost. Allowable cost would be how much the customer is willing and able to spend to accomplish their means on a project. Expected cost is the estimated cost of the project at current best practice, and target cost is what the team commits to deliver and is usually below expected cost as an inspiration for better performance (Ballard, 2008). *"The main idea of TVD is to make a client's value (specific design criteria, cost, schedule and constructability) a driver of design, thereby reducing waste and satisfying or even exceeding the client's expectations."* (Zimina et al., 2012). TVD joins target costing principles with factors like project organization, commercial terms and the lean methodology. In contractual terms, one often used tool in TVD is pain/gain-share mechanism, where the customer and contractor share responsibility in the case of cost overruns and share profitability when delivering a project below budget (Zimina et al., 2012).

3.6.2 Set-based design (SBD)

SBD is one of the core ideas in implementing the LPDS. As shortly described in 3.3.2, Set-based strategy makes decisions at the last responsible moment whilst letting interdependent specialists move forward with their solution to some limit. *"The basic idea is to apply*

all relevant criteria in producing, evaluating and choosing from design alternatives from the outset of design, rather than introducing new criteria as new players come onto the team." (Ballard, 2008). Resulting from the above statement is that every involving actor in the project, such as architects, engineers, consultants, contractor and suppliers should be part of the design team. There are three principles in SBD: (1) Map the design space, which means identifying the set of alternatives to carry forward. (2) Integrate by intersection, to look for solutions within the intersections of sets and intervals. (3) Establish feasibility before commitment, which means that a design contributor is responsible to maintain consistency with the agreed upon design when making a change (Ballard, 2000a).

3.6.3 Tools for on-site management

One of the core ideas in LC is the Last Planner System (LPS) of production control. It is a philosophy, rules and procedures, and a set of tools to link the flow of work together. It has two components: work flow control/lookahead planning and production unit control. Other tools that work in alignment with the LPS is takt-time planning and flow line visualization (Ballard, 2000b, Yassine et al., 2014). These tools will not be elaborated further, as they are not relevant for the scope of this study.

3.7 Practical application of LC

Several firms have implemented LC, some with a high investment in their organization, and some at the level of project-based testing. MT Højgaard, a large contracting firm in Denmark has invested seriously in implementing it. Thomassen et al. (2003) show the experience and results from implementing lean on 30 construction projects. Findings follow as a comparison between LC projects and projects without LC. Results show that customer satisfaction, profit and internal subcontractors profit is slightly higher on LC projects. Another interesting finding is that absence due to illness and accident rates are reduced in the projects with LC. Alarcòn et al. (2011) reviews the implementation of LC in over one hundred projects. The main findings show the effectiveness in implementing the LPS to increase PPC. Performance improvements are observed in almost every project, although measurements of performance could not be done. The introduction of lean into the UK Highways Agency's supply chain (Lean support to Highways England), is a well-known use of the lean methodology in infrastructure projects. The implementation includes an assessment of each main supplier's

approach to lean and continuous improvement. Examples of methods being used on different projects are; group of lean specialists to look for improvement on continuous supply, collaborative planning and Lean visual management. Results show savings of £51 million, shared between the agency and its supply chain (Chloe Chen BA, 2012).

4. Cases of study's approach to lean

This chapter shows the empirical data gathered from the interviews. The structural template on the sub-chapters differ, because the organizations don't have a comparable approach to lean. As the findings are not directly comparable and not necessarily in alignment with the lean methodology, each sub-chapter has a section where the relevance of the findings is reflected over. Hence, the template of this section differs from the traditional way of dividing findings from discussion, as it was found necessary to reflect over the findings before entering a discussion to the study's problem.

4.1 Statsbygg

The empirical data gathered on Statsbygg is based on an interview with Hans Thomas Holm, a project manager whom is a driving force for implementing lean in the organization. The interviewee has good knowledge and experience in lean, thus the empirical data on the organizations approach to it is precise. The empirical data on Statsbygg is focused in two segments. The KHiB[5] (Kunst- og designhøgskolen i Bergen) project, where the interviewee is project manager, and lean implementation in general. Statsbygg was interviewed with two purposes. First, for comparison purposes as being a public owner in construction. Second, to get an insight in the challenges and success criteria for Norwegian public owners implementing LC.

4.1.1 Approach to lean

The organization has not implemented lean from a top-down perspective. At current state, project managers that are interested and willing can use the lean methodology on projects. Hence, there is no top-down lean initiative in Statsbygg, however it has been used on some projects. A reference project in Statsbygg managed under lean principles is KHiB. The project is characterized for lean process planning and lean design to lean construction and lean logistics. Some key lean initiatives in the project is, according to the interviewee:

[5] For further details on the KHiB project, see the master theses researching the topic: BERGESEN, O. E., TORP, O. & NORGES TEKNISK-NATURVITENSKAPELIGE UNIVERSITET, F. F. I. O. T. I. F. B. A. O. T. 2014. Fokus på kundeverdi som en integrert del av lean prosjektgjennomføring ; Focus on customer value as an integrated part of lean project delivery. Institutt for bygg, anlegg og transport, MUNTHE - KAAS, T. S., LÆDRE, O., HJELMBREKKE, H. & LOHNE, J. 2015. Lean Design versus tradisjonell prosjekteringstilnærming. NTNU.

- *Process planning.* The project implemented flow efficiency in contrast to the traditional resource efficiency. The purpose of implementing flow efficiency is to eliminate the "silo" thinking and make different teams see the holistic view, which has several interdisciplinary dependencies. The interviewee claims this initiative leads to more proactive thinking.

- *Lean design.* Large, unmanageable pieces are divided into smaller more manageable. The design phase is based on visual planning and to see the holistic view and achieve transparency. Some themes are necessary to solve early, whereas others are needed later in the process. Hence, the design is structured in the right sequence, so that information is available at the right time. Each theme has someone responsible to it, to eliminate the risk of the typical "Someone should have solved this." problem.

- *Systematic completion.* The delivery, thus the value of a construction project, is the functions of the product. Problems related to the functions of a building in the completion phase is not uncommon. The project included this as a main process to ensure the functionality of the product. To shortly describe the process, it includes early testing of technical systems and early involvement of operating organizations for input.

The project used design-bid-build tendering. They experienced some problems related to change orders, which in fact is normal, because the contractor was not involved in design. A typical argument surfaced when descriptions did not arrive in time, whereas the contractor would demand allowance for either having built something incorrect and having to rebuild it, or wasting time for having to wait for information. From the client's perspective, the delay was caused from lack of input from suppliers, whom is the contractor's responsibility to contract. In the interviewee's experience, these problems can be reduced from involving suppliers to the contractor early. Statsbygg attempted to involve key stakeholders early in the project. They had a two-day seminar on startup with designer, architect and some contractors. The interviewee describes it as a way to get early input from contractors, however that contractors often say no to these invitations as they might not see their interest in it.

4.1.2 Success criteria and challenges

The interviewee discusses some success criteria and challenges for both implementation of LC and projects in general.

- *Early involvement of contractor and suppliers.* In the interviewees experience, this leads to less conflict between contractor and owner. Traditionally, in design-bid-build contracts, the contractor is late involved. Especially in the public sector, where they are involved only after design is complete. Contractors has the advantage of better understanding economy related to execution, which is better utilized in design-build contracts. The counterargument of giving design away to contractors is that they often think about their own finance, rather than the client's quality. However, involving contractors early is a benefit. The interviewee is positive to other procurement forms that aligns better with lean principles. He is fond of IPD and hopes to try it out in his next project. He explains design-build with solution proposal, which Statsbygg have some experience with, as a positive way to get contractors competence to design. Design-build with solution proposal first enter a prequalification after which a few contractors are left. These contractors enter a dialogue with the client to find an optimal solution, after which the best is chosen based on the award criteria.

- *Award criteria.* In selecting the right contractor, award criteria are important. The interviewee has in some projects used lean experience and competence as 20% of the award criteria. In general, if the only handled criteria is price, the client will have to struggle with a contractor that might have priced themselves so low that plenty of change-orders are inevitable. Price is an important criterion indeed, however other criteria that protect the client's quality is also important.

- *Cultural change.* Understanding that implementing LC is not only about the tools and measurements, but rather more importantly changing the culture of the project organization. This is of course a challenge, especially as every team member is new and the organization is temporary.

- *Continuous improvement.* The interviewee is per date the driving force of lean implementation in Statsbygg. As much as he would like the organization to embrace the principles of lean, the current state is that project managers willing can implement it in their project. However small, lean initiatives will lead to continuous improvement as positive aspects are taken forward and the not so positive is changed in a positive direction. Hence, doing something is better than doing nothing.

- *Patience.* LC is a new way to think and work, at least compared to traditional project management. It is very structured and can be considered quite comprehensive because of the detailed planning that is required early. Hence, results may vary on the first few implementations, but experience is gathered and it leads the way for other projects to be more successful.

4.1.4 Reflection to theory

The author finds the KHiB project interesting as it separates itself from the current situation to project management in construction in which new initiatives are rare. An interesting aspect of the project is that it shows that a project manager can successfully manage a project with the lean methodology without the organization following it up. When one person, as competent as he might be, can successfully do it, it opens the questions as to how much more could be done with a top-down initiative in the organization.

Success criteria and challenges

The success criteria and challenges of Statsbygg's experience with lean can be directly or somewhat linked to transport infrastructure. Transport infrastructure and the remaining construction industry undergoes the same challenges when it comes to contractual terms with early involvement of stakeholders and alignment of their interests. As described in the theoretical framework, studies show that the design-bid-build model is inefficient and does not correspond well with the lean methodology (Ashcraft, 2014b, Hale et al., 2009, Koskela, 2000, Shrestha et al., 2011). KHiB is a design-bid-build project that has implemented lean principles well. Without having the absolute details on the project's performance, it opens the question: Does the project reject other studies to that of the design-bid-build procurement form's performance, or would the project have allowed for higher performance with a more co-operative contract model more aligned with the lean methodology? The question can't be answered thoroughly with the available information, however based on the empirical data gathered, crosslinked with theory, the author believes the project could have deemed higher performance with a more co-operative contract model.

Early involvement of contractors is described as important by the interviewee. It is confirmed by the theoretical framework, and the author cannot see any situation whereas involving the contractors early would cause any special problems for infrastructure. Collaborative

relationships are one of the key enablers in one of the best reference projects to successful lean implementation in transport infrastructure, Lean Support to Highways England.

The interviewee describes award criteria as important to protect the client's interests. Force and Britain (1998) notes the same, as they wish to see criteria to which partners are not chosen on lowest price, but ultimately on the grounds of teamwork, ability to innovate and to offer efficient solutions. Indeed, the principle of protecting client interest through other award criteria than lowest price is potential. Some challenges occur, especially due to public tender rules in Norway. Qualitative criteria are harder to compare and fairly evaluate, thus demanding a clear and objective point-system in choosing best offer. About lean as award criterion, it can be argued that having competence and experience on lean not necessarily give any advantage to the project, hence scoring points on lean experience might lead to the not best offer being chosen. In the future however, if a substantial number of contractors gets experience with lean, the client can simply have lean as a pre-requirement, thus not needing it as award criterion.

The interviewee draws out cultural change, continuous improvement and patience as key enablers in implementing lean construction. These factors correlate with each other, as cultural change demand a long-term commitment of continuous improvement, which surely require patience. Perfection, as the last principle in achieving a lean organization, correspond with these ideas (Womack and Jones, 2010). Studies does show that for improvement tools to work, they need to be applied over a long term with a foundation of culture of teamwork and continuous improvement. Several companies have failed in the attempt to apply lean tools for instant profit (Moore, 2011).

4.2 Bane NOR

The empirical data gathered on Bane NOR is based on an interview with Thomas Edlund, their chief of production in the infrastructure division. The interviewee has high experience in lean and is the organization's specialist on the field, thus the empirical data on the organizations approach to lean is precise.

4.2.1 Approach to lean

The organization's approach to lean is per the time of interview limited to operation and maintenance work. They have a team of lean-navigators that works daily in establishing lean

in the infrastructure division. The lean navigators work successively on transformations of the seventeen railway lines of Bane NOR. Each transformation takes about 13-16 weeks and includes 5-6 weeks in analyzing the current situation, and the remaining 8-10 weeks in testing the implementation and follow-up on results.

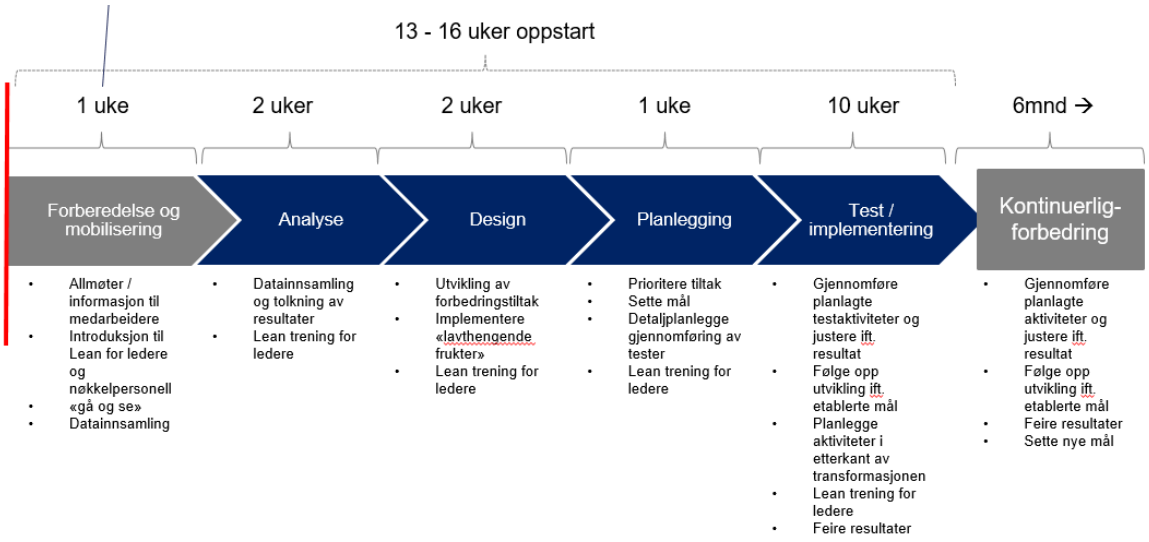

Figure 2: Structure of the transformation (T. Edlund, chief of production Bane NOR, 10.05.2017, sent by email).

Their lean transformation includes stabilizing operations through standardizing work, visual control and reducing variation in three dimensions:

(1) *Production setup.* How tasks are solved, in which methods, tools and equipment is used.

(2) *Management structure.* What prerequisites does the managers have? To what extent they are capable of leading in line with lean principles, such as visual control, follow-up on standards and structured problem solving.

(3) *Culture.* Behavior and attitude of the unit. Do the people performing the work, want to do it?

"Each dimension is equally important. They have a mutual influence on each other, thus if you take out one, the other two will fall." (T. Edlund, chief of production Bane NOR, 10.05.2017, interview).

The fundament in stabilizing operations is standardizing work. This does not necessarily mean to invent new standards, but also to make sure the standards that already exists are followed. Standardizing work in Bane NOR is to simplify, and making sure the same procedures are

followed in the instance of work that correspond with previous work. Visual control is their second stabilizing factor. They see the importance of showing managers and co-workers the results of their work. Visual control includes a system where managers easily can extract the data of the work performed and the work to be performed. Mainly, their agenda is that for employees to continuously improve, they need to know the performance of their work. The last factor is reducing variation. Their approach to reduce variation is proper planning. It collaborates with standardized work because proper planning entails that whomever plans from day to day, the outcome should be the same.

Example of a transformation

Response time on signal failure. The window from an alarm runs until the operators are out and ready to fix the problem is analyzed. First, several events are reviewed to see what the response time is. Second, they do a value stream mapping to identify waste in the process. Each waste is attacked, and lean tools such as 5S is implemented. If the response time improved, standards are made. Standards can i.e. be pictures of how the workplace should look or rules and procedures. The managers of each facility are challenged to follow up on the standards, i.e. by making improvement rounds minimum once a week.

4.2.2 Success criteria

The interviewee outlines some key issues for a successful implementation of lean principles in their organization:

- *Daily follow-up.* Rather than sending managers on weekly courses, there are navigators in the field helping and following up every day for a longer period. This is essential for a long-term commitment and change of mindset.
- *The managers under training makes their own decisions.* It is key for the lean principles to last, that the navigators only facilitate and help the managers, rather than making decisions for them.
- *Top anchor and commitment.* In Bane NOR, the infrastructure director and EVP is interested and positive to the implementation of lean principles, which is key for a long-term commitment. The organization embraces the lean implementation for what it is. The interviewee has experience from organizations where lean establishment has become a victim for streamlining through downsizing. In Bane NOR, the idea is to get

more done for the money funded, in opposition to the same amount of work for less money.

- *Lean-navigators are employees of the organization.* When the interviewee and his team of lean-navigators are out talking to managers and co-workers, they are associates. They have a genuine interest in the organization's success. A few challenges can occur when hiring an outside consultant. First, they usually have a pressure on short-term profit and solutions. Second, the culture of continuous improvement is tough to establish if the facilitators are only there for a short period.

4.2.3 Challenges

Several challenges are avoided because of the top anchor and commitment. There will always, however, be encountered some challenges when implementing a new way of thinking in managers and co-workers that have worked the same way for a long time. Criticizing the efficiency of others work, can lead to some unpleasantness. Some subjects feel attacked when their work is analyzed to show waste and bad exploitation of their time. This challenge is however, significantly reduced because of the organizations mentality to work to improve managers rather than downsizing, as the managers in most cases are positive to the idea of improvement.

4.2.4 Results

The author was not allowed to print specific details surrounding the results from lean work. However, some improvements from the implementation of lean can be summarized:

- Higher completion rate of maintenance control.
- Reduced response time.
- Reduction of necessary corrective maintenance.

4.2.5 Future lookahead

The reason they started their lean implementation in operation and maintenance is because that is where the work is conducted, thus the value crated. *"I don't create value. You either create value, do work necessary for others to create value, or your work is waste. At best, I'm necessary to create value."* (T. Edlund, chief of production Bane NOR, 10.05.2017, Interview). Bane NOR is flirting with the idea of creating a lean program in the whole

organization. There are no concrete plans, however ideas of using the current initiative in operation and maintenance as a fundament for establishing lean in other divisions. The EVP wants the same effects of lean in the remaining organization.

4.2.6 Reflection to theory

Bane NOR understands the fundamental principles of continuous improvement and that a change is demanding in both use of resources and time. Based on the available data, results seem to outweigh the disadvantages of lean implementation, however much can still be done, which the organization recognizes. At the current state, Bane NOR undergoes the implementation of lean thinking to one division. The full effects will not show in a short-term perspective, thus their results cannot be properly evaluated yet.

The organization's implementation of lean principles is not too complicated, yet effective. Basic tools like 5S, value stream mapping, visual control and standardizing is applied to reduce waste in their operations and maintenance section. The tools are simple, and in themselves not revolutionizing nor a guarantee for increased productivity. However, Bane NOR has experienced great results from it, which must come from their comprehensive follow-up and understanding of lean thinking. They do embrace the principles of Womack and Jones (2010) in becoming lean. Every success criteria described by the interviewee does really entail around long-term commitment, thus corresponding with the last principle, perfection.

In difference to Statsbygg's implementation of lean on single projects, Bane NOR has implemented lean principles in the organizational approach, currently to one division. The approaches are not directly comparable, however what can be seen is that both interviewees understand cultural change in the organization as a criterion for success. Whether that be a temporary or permanent organization. As Bane NOR has an organizational approach to the lean methodology, there are no different challenges to them operating in transport infrastructure rather than the building sector.

4.3 Nye Veier

The empirical data gathered on Nye Veier is based on an interview with Ole Holte Sandvik, discipline supervisor of lean and quality. The interviewee has both a good understanding to the concept of lean, and works with it daily, thus the empirical data on the organization's

approach to lean is precise. Due to the interview being time-dependent, the insight into the organization's work with lean is slightly less comprehensive than that of Bane NOR.

4.3.1 Approach to lean

Nye Veier approaches lean both in the organizational frame and project-based. In the organizational frame, they embrace the principle of continuous improvement through process quality. The organization works with making procedures and standards, i.e. standards for technical procurement. They have a high-end focus on their control system, using table based management with action control. More specifically they are working to replace meeting reports with action lists, thus eliminating meetings with no clear action to ensure constant progress.

Nye Veier approaches projects with the lean methodology mainly around early involvement of contractors and suppliers, with a high-end focus on startup. Their contractual template is design-build, where they invite contractors and suppliers to participate in discussions on challenges, and challenge them on improvements. Principally, they try to avoid change orders after the contractor has been chosen and the project started, although from time to time some changes are necessary. The organization's principal is to build more road for less money. They communicate with municipalities and landowners to open their eyes to possibilities of other route selections to save money.

4.3.2 Success criteria and challenges

According to the interviewee, there are three main success criteria to Nye Veier's approach to lean. The first, and to which their model is built upon, is early involvement of contractors and suppliers. The contractor has a competence on constructing infrastructure that the client doesn't, and involving them early reduces the significant amounts of uncertainty factors that exist in early project phase. An important aspect when operating with design-build contracting is measurable and good function descriptions to ensure the quality the client wants. The second success criterion is standardizing processes and procedures. Projects might be unique and different, but there will always be something similar in every project. Hence, standardizing the processes that are repetitive is one of their key lean initiatives. The last, is a comprehensive understanding of the lean methodology. Understanding that lean management entails around involvement and co-operation, and rather than implementing a set of tools, the foundation of culture-change with focus on continuous improvement is necessary.

The author did not acquire any information on challenges with the organization's approach to lean. However, the interviewee did not see any specific challenges in managing infrastructure projects with the lean methodology, rather the same challenges on project management occurs as in the remaining construction sector.

4.3.3 Future lookahead

The organization has developed a lean tutorial package and several of its members has knowledge on the field. Lean is part of the organizations strategy. They lack now, however are working on an implementation plan for lean in the company. The interviewee states that the organization will take bigger responsibility in development of contractors, whereas lean will be a natural part of it.

4.3.4 Reflection to theory

Nye Veier is a new company that has only been in operations for about one year. As with Statens Vegvesen, they work under the ministry of transport and communications, as an owner to road projects. The organizations differ in many aspects, i.e. where Nye Veier has a bigger focus on industrialization and standardization.

Nye Veier can be said to be an organization operating with the lean methodology. In the organizational approach, they are comparable to that of Bane NOR in many aspects. Both organizations standardize procedures to reduce the number of time-wasting activities, and both operate under the principle that cultural change and continuous improvement is necessary and more important than implementing a set of tools.

"Something that differs us from Statens Vegvesen, is that they work uniquely with every project. We work on industrializing aspects of it. Rather than building down competence, which is the consequence of their approach, we have systems in place to ensure continuity through control systems." (O.H. Sandvik, Discipline supervisor Lean/quality Nye Veier, 23.05.2017, interview).

Standardizing repetitive activities in different projects is one of their key lean initiatives. Theory corroborates the efficiency of standardization and if implemented properly it could give promising results. However, as the organization is new, there are no results to verify it by. Their other key lean initiative is early involvement of contractors and suppliers. They use the design-build model, which theory confirms to be more efficient than design-bid-build. The

interviewee explained that contractors are invited to pre-design, which makes the model even slightly more collaborative then regular design-build, as from the author's understanding, it must mean that contractors can influence the client's wishes even before tender. Hence, their model corresponds with the LPDS to some degree, because the contractors can help the client decide what they want, and how to get it. However, complete correspondence would require every stakeholder to be involved in every phase, total alignment of interests and a share in risk and responsibility. The model fails to achieve this, but is still more co-operative than traditional transport infrastructure contracts in Norway.

4.4 Statens Vegvesen

The empirical data gathered on Statens Vegvesen (SVV) is based on an interview with chief-engineer Geir Saxebøl in Vegdirektoratet. His role in the organization makes the data gathered on their approach to projects precise, however the interviewee might not have all insight on whether some sections have implemented lean in their administration.

Findings from the interview showed that SVV does not work with the lean methodology, however comparisons will be made by the author. As a result, the structure of this section differs from the format in other sections. The following paragraphs elaborates findings from the interview.

4.4.1 Ongoing efficiency measures in SVV

According to the interviewee, SVV acknowledge the need for improvement in the industry, and as with most organizations they have taken measures to improve efficiency. Some key measures they are working with is:

- *An efficiency project on identifying factors to time escalation.*
- *Increased use of state plan, change of legislations and possibilities in object and appeal.* At current state, the municipalities have decision-making authority on municipal plan and zoning plan. SVV's objective is to govern transport-related business, such as transport routes and navigability. The local community is more interested in nature diversity, cultural landscape and function relative to the local traffic environment. Hence, there is a conflict of interest, which often leads to reversal

and appeal. There are projects with several years delay because the plan had to change every time the municipal board changed.

- *A program on smart internal interaction.*
- *Building longer road sections coherent.* Rather than having a project divided into several sub-projects with shorter road sections, they try to divide the project into larger sections. The interviewee says that building 25-30 km coherent takes the same time as building 7-8 km, as it simply involves around the number of attack points times the number of machines. Hence, this measure will lead to higher productivity.

An example of delay relating to object and appeal is Oslofjordtunnelen. It was constructed as a single tunnel at first, and the zoning plan, which was decided by the parliament at the time, regulated that another tunnel would be built when the traffic increased. However, as the planning was well underway, forces wanted to evaluate it in a bigger picture, thus including other municipalities. The other alternative was building a bridge. To shortly summarize, the tunnel was ready to be tendered in 2014, which did not happen, and it has now been spent 3 years on reviewing the alternatives. The current recommendation is to build the bridge, which costs 16-17 billion, rather than the tunnel which costs 5-6 billion.

4.4.2 Contractual model

Traditionally, SVV has used design-bid-build procurements. They are currently reviewing the use of design-build procurements in hope to increase the productivity. They have tested a collaborative development-contract at E6 Helgeland[6], in which the contractor was involved in a dialogue during pre-planning after which they overtook the project in a design-build procurement. However, according to the interviewee, SVV believe that design-bid-build will still be their main procurement form as they find it difficult to describe the risk in a design-build project. Further, they find making measurable function descriptions that protects the client's demand to quality, to be more challenging than designing the project themselves.

4.4.3 Risk and responsibility

In general, SVV keeps the risk and responsibility in design-bid-build projects. In tunnel projects, there is often a combination of fixed and variable prices. The risk is somewhat

[6] To learn more about the experiences from the project, see http://www.bygg.no/article/1262049.

shared between client and contractor as some work has fixed price and some work is priced on quantity. In sharing risk and reward, open book projects have shown that the contractor in some cases has hired equipment that is not being used.

4.4.4 Award criteria

SVV tenders the economically most beneficial offer. Practically, this usually ends up with lowest price, as price is the dominating award criterion. All criteria are measured in money terms, meaning that i.e. the execution model can give deduction to the price. The interviewee states that awarding based on points is in danger of being subjective rather than objective. The average cost escalation due to change orders are 20%, however variates based on the design.

4.4.5 Reflection to theory

The interviewee seems to understand lean as cost-cutting. His understanding implies that lean principles resort to reducing quality when streamlining projects. Even so, the organization undergoes several improvement measures on performance. They work on identifying time thieves in their projects and a smarter, more efficient internal interaction, which is somewhat comparable to value stream mapping and elimination of waste.

The author understands change of planning to be one of the organization's biggest challenges to performance. All large infrastructure projects must go through the State project model and the Planning and Building act. The State project model includes preliminary phase, KS1, government decision, planning phase, KS2 and parliament treatment. The Planning and Building act includes planning phase, municipal plan, local political treatment of the municipal plan, zoning plan, local political treatment of the zoning plan, injections and documentation. It becomes clear from the interviewee's perspective that the comprehensive framework projects must go through leads to large number of changes, thus cost- and time-escalations. Oslofjordtunnelen as described by the interviewee, is an example. These changes are highly affected by political views, socioeconomic benefits, rational views in people's perception and costs. The Office of the Auditor General in Norway confirm these challenges in a report where they conclude that SVV's projects have cost-escalations of over 20%, and that 25% of the reviewed contracts had time-escalations of over 6 months (General, 2013).

The agency's most used contractual model is design-bid-build. Several challenges and disadvantages follows from this procurement form. To mention some, they include no alignment of stakeholder interests and high amounts of re-work and change orders. As

described in section 3.5.1, studies show that design-bid-build is outperformed by design-build. A study on SVV's contract strategies recommend that they use more design-build procurement (Høy and Storhaug, 2010). The advantages of using design-build seem to outweigh the disadvantages, as it aligns better with co-operation and increasing performance than design-bid-build. However, a consideration must be made. One of SVV's strategies is to evolve small and middle-sized contractors. These contractors might not be able to take the risk in design-build contracts as SVV find it hard to describe it precisely in early phase. Even so, as the advantages are many, and the disadvantages, to be honest, are not. The organization could benefit from following the example of the remaining construction sector and the studies that indicate higher performance in design-build contracts.

High number of change orders are common in transport infrastructure projects in Norway. These arise both from the contractual model and the award criteria. In the current tough market, contractors must often underprice themselves to win contracts where lowest price generally wins the tender. Doing so, incentivizes contractors to look for flaws in the description, hence resulting in change-orders. The combination of design-bid-build with lowest price as award criterion leads to conflict, as the interests of the client and contractor do not align. These issues contradict the LPDS, where alignment of stakeholder interest, early involvement and share in risk and responsibility are key.

5. Discussion

Some discussion on the organization's approach to lean has been done in the previous chapter. The discussion in this chapter elaborates to draw the lines between the organizations, whilst comparing to theory. As a result, the research questions of this study will be answered.

There are three research questions in this study.

(1) Do the Norwegian public infrastructure agencies operating in road and railroad, work with the lean methodology?

(2) Are there specific challenges related to transport infrastructure, which makes an implementation of LC less opportunistic than that of the remaining construction sector, seen from the client's perspective?

(3) What are the possibilities and constraints of implementing LC to the Norwegian public transport infrastructure agencies?

5.1 Research question one - Norwegian public transport infrastructure agencies approach to lean

Bane NOR

Bane NOR has implemented lean in the infrastructure division, more specifically they apply transformations to streamline operations and maintenance. Their transformation includes stabilizing operations through standardizing work, visual control and reducing variation in three dimensions: production setup, management structure and cultural change. The transformations align closely to Womack and Jones (2010) principles of lean, apart from pull, as it can't be considered relevant in an operation where the maintenance team needs to be on alert all the time.

- Operations and maintenance is identified as the place where value is created. *(Specify value)*
- The first part of the transformation is a value stream mapping. In the example of response time on system failure, every action from when the alarm runs until the operators are out and ready to fix the problem is mapped. *(Identify the value stream)*

- 5S measures are implemented to clean the workplace and attack each waste. If the efficiency of the process improved, standards are made. *(Flow)*
- Visual control systems where managers easily can extract the data of the work that has been done and the work to be performed, are made. The information is used for employees to know the performance of their work, which is necessary for improvement. Managers are also challenged on routinely follow-up of the transformation. *(Perfection)*

Bane NOR embraces the principles of lean in their transformation, however it is currently limited to one division.

Nye Veier

The organization works with lean in two aspects. In the organizational frame, the flow principle of lean is accepted, through standardizing processes and elimination of waste in meetings with action control. Their project model corresponds to some degree with the LPDS, as it is built upon early involvement of contractors and suppliers. To fully corresponds, the project model would require an alignment of interest through share in risk and reward as proposed by Ashcraft (2014b).

Statens Vegvesen

SVV does not operate with the lean methodology, however are working on some performance measures that align somewhat to lean thinking. These measures are: Identifying factors to time escalation, increased use of state plan to reduce time in design and a program on smart internal interaction. Even so, their most used contractual model, award criteria and approach to projects in general contradict the principles of LC and the LPDS. SVV is the Norwegian public transport infrastructure agency that operates the least in alignment with the lean methodology.

5.2 Research question two - Specific challenges to transport infrastructure and lean implementation

The second research question can only be answered based on the interviewees opinion and in reflection over theory. From the client's perspective, neither of the interviewees see any specific challenges relating to transport infrastructure and LC. Studies are yet to be made in

the comparative basis of implementing lean to transport infrastructure and the remaining construction sector, thus this is the first of its kind.

In the organizational framework, thus implementing the lean methodology to streamline the organization, the author cannot see any specific challenges to being a public owner in transport infrastructure to that of being a public owner in the building sector. There are no studies to contradict the statement, however several studies do confirm the benefits of implementing lean in companies, as shown in the theoretical framework.

Transport infrastructure projects differ from building projects in often being more sequential and spread across larger geographic areas. Hence, whereas in building projects the construction happens at one location, the location is being moved in a sequential chain in infrastructure. In general, building projects have a larger number of teams involved at the same time, thus requiring more transparency in interdisciplinary dependencies. As such, tools for on-site management, such as the LPS, flowline scheduling and takt-time planning might deem more appropriate for building projects than transport infrastructure. However, these tools are not that relevant when discussing the implementation of the lean methodology to the client, especially with the design-build contractual model, as the client tenders away the responsibility of the design and execution phase. Their main criterion for a successful project becomes to ensure that their values are protected. The author cannot see how these values are more difficult to protect under the lean methodology in transport infrastructure than the building sector. There are no studies that conclude with there being specific challenges for aligning lean with transport infrastructure. Combining the above discussion with the interviewee's opinions of not seeing any specific challenges to transport infrastructure, and the success story of Lean support to Highways England, aligns the author's conclusion. There are no specific challenges to implementing LC in transport infrastructure, seen from a client's perspective.

5.3 Research question three - Possibilities of implementing LC to Norwegian public transport infrastructure agencies

The third research question is more complex to answer, thus in need of a proper discussion. Toward the understanding of the potential of implementing LC to the Norwegian public transport infrastructure agencies, the author finds it natural to compare and discuss Nye Veier

and Statens Vegvesen. These organization's works with the same agenda, under the same ministry, however operates under different principles. Nye Veier is a new organization that works with the lean methodology, whilst SVV do not. SVV is criticized by The Office of the Auditor General for high cost- and time-escalations, whereas results on the performance of Nye Veier is not available. Nye Veier works to standardize procedures that are repetitive in projects, and SVV works project to project. Data is not available for direct comparisons of their performance, however reflection over theory and the empirical findings can suggest some conclusions. In general, when reflecting over the appropriateness of LC from a client's perspective, the author finds the LPDS to be the obvious starting point. The fundamental idea of LC is to create the maximum amount of value, whilst minimizing waste, which must correspond with the interest of the client. The question to be asked is: Does the principles of the LPDS align with transport infrastructure?

The key aspects of the LPDS are:

- Early involvement of stakeholders
- Alignment of stakeholder's interests
- Set-based strategies

This study is not about reviewing the performance of LC in general, as that has been confirmed in other studies, but whether the same opportunities exist in transport infrastructure. The differences to transport infrastructure and the building sector has been described to be the location of the project and that transport infrastructure is more sequential. Surely, these differences cannot reject the LPDS, and the key aspects of the delivery system is just as relevant to transport infrastructure. However, as this study is limited to the possibilities and constraints to Norwegian public transport infrastructure agencies, some reflections must be made. At current state, to the author's knowledge, lean contractual models such as IPD has not been applied in Norway. Thus, it is far fetching to suggest that a large organization like SVV should go from traditional project management to implementing a lean contractual model in correspondence with the LPDS. However, as noted from the interview with Hans Thomas Holm at Statsbygg, doing something is better than doing nothing.

SVV has piloted a cooperative contractual model as described in the previous chapter, however mostly uses design-bid-build as they find it hard to describe the risk in early project phase and more convenient to design the project rather than making measurable function

descriptions that protect the client's demand to quality. Their award criteria are in practice lowest price. The combination leads to a high number of change-orders, thus cost- and time-escalations. Nye Veier on the other hand, uses only design-build procurement as they find it important to involve the contractor's competence to design. Neither of these models fully correspond with the LPDS, however the design-build model does involve the contractor early.

Public tender rules in Norway makes it more difficult to form a cooperative project team as a public client than that of being private. To ensure a fair competition, all public agencies in Norway are regulated by public tender rules. A contractor cannot be chosen for the project outside this process, hence involving a contractor early, or merely forming a project team of different stakeholders requires some measurable criteria to which they are chosen. This is a challenge that must be considered when talking about implementing lean contractual models like IPD. The challenge also relates to implementing set-based strategies, as the public tendering rules not only affects the client's relationship with the contractor, but with every stakeholder involved. Hence, involving every stakeholder in the project in design phase, does require a comprehensive description of the project at to which firms can be evaluated accordingly when contracted. The author by no means reject IPD and set-based strategies, merely accepts that there is a long way ahead from current state to implementing the delivery system.

Aligning the interest of stakeholders is a key part of the LPDS. With traditional contractual models, especially design-bid-build, the different stakeholders do not profit from fixing the error of other parties, but rather from change-orders resulting from it. Design-build eliminates some of that conflict, as the contractor is responsible for both design and execution. However, in the case of flawed function descriptions from the client, the contractor will still benefit from either constructing a cheaper solution or demanding more for producing the quality the client wants. To conclude on one of the biggest flaws in traditional contracting, the contractors can profit when the project is unsuccessful to the client. The author proposes that the best way of aligning the interest of stakeholders, is to use TVD with pain/gain-share mechanism. It is a fact that SVV is taunted by cost-overruns, and the author can only assume, as they still have a highly competitive marked in contractors, that the contractors in general profit from their involvement in the projects. Yet, neither SVV or Nye Veier uses strategies to share in responsibility and profit with their contractors. The interviewee of SVV explained some challenges shown by open-book projects, where the contractor would hire equipment

from their own organization that is not being used. Hence, in the case of the project going below budget, the contractor still would profit from it. Even so, the author must suggest that pain/gain-share mechanism should lead to more aligned interest, and thus reduce the cost-overruns of the client.

Some considerations have been discussed regarding the LPDS. SVV does not operate in correspondence to the delivery system, however Nye Veier can be said to operate closely to it in some respects. To conclude upon the third research question of this study:

What are the possibilities and constraints of implementing LC to the Norwegian public transport infrastructure agencies?

The possibilities are many. In the organizational framework, there are no specific constraints for these organizations, thus meaning that the possibilities equate to that of other organizations. Implementing LC to projects is more complex. Nye Veier operates more aligned with lean principles than SVV, however their performance cannot be compared in this study. Some considerations have been discussed regarding the implementation of lean contractual models that correspond with the LPDS. The author cannot see how these considerations rejects the model, but cannot confirm its appropriateness to Norwegian transport infrastructure either, as no specific data on project performance is available. The author suggests that the way forward should include contractual relations that corresponds more with the LPDS. Hence, more use of design-build contracting or other co-operative models and TVD with share in risk and responsibility. The research question is only vaguely answered, and the author propose that for an exact conclusion on the possibilities, case studies are required. These case studies can include a comparison between Nye Veier's and SVV's project performance, or a study of a IPD project in the instance of either organization piloting it.

6. Conclusions

This study has mapped the current situation and reviewed the possibilities of further implementing the lean methodology to Norwegian public infrastructure agencies operating in road and railroad. The focus of the study lies in the client's perspective, hence representatives from Bane NOR, Nye Veier and SVV has been interviewed. The interviewees of Bane NOR and Nye Veier are lean supervisors, and the interviewee of SVV is a chief engineer whom works with their approach to projects, thus the findings must correlate with the organization's actual approach. LC has been adapted over several years as a competitor to traditional project management as construction lags in efficiency compared to other industries. There is significantly less research referring to LC in transport infrastructure, than that of the building sector. No prior studies have been done mapping the current situation and reviewing the possibilities of further implementing the lean methodology to Norwegian transport infrastructure, thus this is the first of its kind. The problem of this study is answered with three research questions.

(1) *Do the Norwegian public infrastructure agencies operating in road and railroad, work with the lean methodology?*

The lean methodology has been implemented to Norwegian transport infrastructure to some extent. Bane NOR has implemented a lean transformation that align perfectly with the principles of lean thinking, however it is at current state limited to operations and maintenance. Nye Veier works with standardizing procedures and reducing waste in their organization, thus their work corresponds with the flow principle of lean. Nye Veier's approach to projects focuses on early involvement of the contractor and suppliers, hence their project model accepts one of the main ideas in the LPDS. SVV does not work with the lean methodology.

(2) *Are there specific challenges related to transport infrastructure, which makes an implementation of LC less opportunistic than that of the remaining construction sector, seen from the client's perspective?*

This study has found that there are no specific challenges related to transport infrastructure, seen from the client's perspective. The possible challenges relate to on-site-management as the location of transport infrastructure projects differ from building projects, however on-site-management is beyond the scope of this study.

(3) What are the possibilities and constraints of implementing LC to the Norwegian public transport infrastructure agencies?

The possibilities of implementing the lean methodology to the client's organizational framework equates to that of organizations operating in other industries. Due to public tender rules in Norway and the status of to which lean is being used, there are challenges to implementing a project model that corresponds with the LPDS. The research question is not answered fully, as the author finds that case studies are required to conclude. However, the author suggests that more design-build procurement forms or other co-operative models and TVD with share in risk and responsibility can lead to higher performance.

The value of this study is that it is, to the author's knowledge, the first of its kind. As such, it opens for further research on the topic. The author believes that clients in the Norwegian transport infrastructure industry will benefit from following the initiative that has been raised in other industries, thus implement LC. However, there are some clear weaknesses to this study. There were no relevant cases for study as it was written, thus the third research question could not be given a clear conclusion. As the study lacks input data in form of statistical performance indicators, the possibilities and constraints to further implementing the lean methodology are only suggested based on the author's understanding of existing literature and the interviewee's opinions.

6.1 Recommendation for further research

Further research should include case studies of Nye Veier's projects. Results that indicate the performance of their projects can be used to compare the performance of Nye Veier's approach to that of SVV. Further, the author recommends that research be done on TVD with share in risk and responsibility on transport infrastructure project, to evaluate its impact on performance.

Research on LC and on-site-management in transport infrastructure can also be interesting and benefit the industry. The LPS and takt-time planning has shown results in the building sector, and the infrastructure industry could benefit from researching the appropriateness of these tools to infrastructure.

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Appendix A – Evaluation of literature

A1. Evaluation of databases

A1.1 Google Scholar

Google Scholar cover a massive amount of free literature on the internet. With an exact search, such as the name of title, Google Scholar is a great database to use. However, with a lack of specificity it can be hard to find the wanted literature. There are two significant weaknesses with Google Scholar compared to other databases. Firstly, space is considered an "AND"-operator, thus a lot of noise will come in a search of i.e. "Lean construction in infrastructure". Secondly, it logs the search history, thus every search influence future searches and the same literature might come from different search approaches.

A1.2 Oria

Oria is the University Library database. It contains all the available resources of every university and college in Norway. The database is easy to use and to narrow searches into specifics. Its main search areas are E-books and articles.

A1.3 Academic databases

Academic databases contain a big number of scientific journals and research papers. VIKO suggests Scopus and Compendex as the most comprehensive ones for literature referring to construction. As such, these academic databases have been used as a supplementary to Oria and Google Scholar.

A1.4 Other sources of literature gathering

The reference list of sources considered high quality has been used to find additional sources. A good source quite often refers to other good sources, hence the reference list is a good way of finding interesting literature. Some sources were taken from the course literature of TBA4157 Lean Construction at NTNU, as both the university and the course are considered of quality.

A2. Search history

The literature has mainly been searched for in the above databases with a broad approach, gradually narrowed into specifics. Table A1 shows the search history, with number of hits for the corresponding database.

Table A1: Search history for different keywords, divided into the number of hits in the corresponding database.

Keywords	**Number of hits**			
	Oria	Google Scholar	Compendex	Scopus
Lean	141 818	2 200 000	31 214	75 173
Lean Construction	6 829	665 000	2 877	1 941
Lean Construction Infrastructure	203	72 200	85	48
(Lean construction) AND ((LPDS) OR (Lean Project Delivery System))	90	109 000	154	99
(Lean construction) AND ((LPS) OR (Last Planner))	88	31 100	245	148
(construction sector) AND (inefficiency) AND (problem*)	94	153 000	35	19

As table A shows, operators work well in Oria, Compendex and Scopus, whereas in Google Scholar they have minimal effect. The search history in table A was the starting point in finding relevant literature. Tools to further limit the search were used in the databases, such as choosing specific authors, themes, publishers etc. A significant amount of literature was found through analyzing reference lists of other sources.

A3. Evaluation of sources

The author's source criticism follows the TONE[7] method from VIKO, whereas sources are evaluated in four perspectives: credibility, objectivity, preciseness and suitability. Table A2 shows the evaluation criteria for each perspective.

[7] Refers to a Norwegian abbreviation of credibility, objectivity, preciseness and suitability.

Table A2: Evaluation criteria of literature

Perspective	Evaluation criteria
Credibility	1. The authors' qualifications and knowledge. 2. Recognition of the publisher. 3. How many times cited.
Objectivity	1. How objective and/or balanced the source is. 2. Whether the information is conflicting with other quality sources. 3. Whether the information seems exaggerated. 4. Whether the purpose is to inform or persuade/convince/sell something. 5. Conflict of interest.
Preciseness	1. Whether the information is up to date – date of publish and/or last revised. 2. Whether the information is comprehensive, detailed and exact. 3. How well referenced the source is and whether self-occurred information is backed up by data.
Suitability	1. How suitable the source is for this thesis. 2. Which parts are suitable?

Appendix B – Interview guide

1. Introduction to the interviewee
    a) Role in the organization
    b) Experience with lean
2. Organization's approach to lean
    a) Which part of the organization works with lean? Is there a top-down initiative?
    b) LC on projects?
3. Outlook
    a) Will the organization have a bigger focus on lean going forward? How?
4. Challenges
    a) What has been the organization's biggest challenges with the lean methodology?
    b) Why do you think lean has been implemented more and earlier in the building sector than in road and railroad?
    c) Which special challenges is there for a client operating in road and railroad, to implement lean?
5. Early involvement and alignment of interests
    a) Challenges with public tender rules
    b) Contractual model
    c) Award criteria
    d) Share in risk and responsibility
6. Is there something you would like to add?