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A MANDATED LEAN CONSTRUCTION DELIVERY SYSTEM IN A REHAB PROJECT – A CASE STUDY

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ABSTRACT

By implementing Lean Construction in projects, a client may improve their project delivery in terms of cost, quality and time. Guidelines regarding public procurement in Norway prevent a large public client of freely choosing contractors. In the project studied in this paper the Norwegian government property developer – Statsbygg – is implementing Lean Construction by mandating, in the tender competition, that the prime contractor and the designers use Lean Construction principles and a handful of selected methods – a mandated Lean Construction delivery system.

This paper address the following question: What are the experiences of using this mandated Lean Construction delivery system in the construction phase with a prime contract in a rehab project? The research presented in the paper is based on a case study of the construction phase of a 470 Million NOK (57 million USD) rehab project of a listed university building with (a) in-depth semi-structured interviews of eight professional key figures from the client, designer group and prime contractor and (b) a document study of project documents and experience reports from the project.

The findings show that the project failed Lean project delivery because of (I) the actors absent understanding of Lean Construction principles and ideal, (II) the lack of real collaboration, (III) the production system was not aligned properly between client and contractor and (IV) the building’s amount of unforeseen risks.

The research highlights the importance of project actors’ understanding the mechanism behind Lean Construction and the foundation of a real collaboration to reap the benefits. Whether or not Lean Construction is suitable for a rehab project is difficult to conclude based on this research. Further research is needed, where the project’s actors are more familiar with Lean Construction.

KEYWORDS

Lean Construction, Contract Strategy, Public Client, Lean Project Delivery, Production System Management

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INTRODUCTION

Lean Construction (LC) is a theory-based methodology for construction (Koskela et al. 2002), which has theoretical inspiration from Lean Production and the Toyota Production System (Howell 1999). Projects are temporary production systems (Ballard and Howell 2003) and Lean is a way of designing systems to minimize waste and generate maximum value (Ballard and Howell 2003; Koskela et al. 2002). By implementing LC in projects, clients may improve their project delivery in terms of cost, quality and time.

In the past years, LC has entered the Norwegian construction industry. The Norwegian government property developer – Statsbygg – has started to implement LC in its projects. One of Statsbygg's strategic goals is to form the industry of tomorrow by being an innovator of Norwegian construction industry.

Guidelines regarding public procurement in Norway prevent Statsbygg of freely choosing contractors or designers. It is mandated in public procurement to use tender competition in construction projects over a certain budget threshold. The public client is obligated to choose the contractor or designer who satisfy the requirements and wins according to the award criteria. The idea of public procurement is to utilize public funds and ensure fair competition, while the industry's competitive power is developed.

In the rehab project studied in this paper, Statsbygg implemented LC by mandating, in the tender competition, that the prime contractor and the designers used LC principles and a handful of selected methods – a mandated Lean Construction delivery system.

Rehab projects are characterized by a high degree of risks where the sources of risks are diverse and often impact as clusters (Reyers and Mansfield 2001). A previous study of a rehab project indicated that it is more difficult to apply all aspects of LC, due to the amount of unforeseen challenges and the fact that design is based on a relatively ambiguous production information (Bryde and Schulmeister 2012).

A previous research on this rehab project, concerning use of LC and BIM in the detailed engineering, concluded that the Lean methodology and the ideal was more or less absent in the design phase. This due to insufficient Lean implementation and lack of ownership to the collaboration phase (Bråthen and Moland 2015).

This paper looks at the experiences of using this mandated Lean Construction delivery system in the construction phase with a prime contract in a rehab project. This is done by answering the following research questions:

What does this mandatory Lean Construction delivery system imply?

To what extent has the rehab project achieved Lean project delivery?

Why has the rehab project succeeded or failed to achieve Lean project delivery?

Firstly, we present a theoretical framework of production systems and Lean project delivery. Secondly, we describe the research methodology. Finally, we introduce the case study with findings and discussion of what the delivery system implies, the extent of Lean project delivery and causes of why the delivery system failed.

THEORETICAL FRAMWORK

LEAN PROJECT DELIVERY

The term "project delivery system" is traditionally used for a project's contractual structure, e.g prime contract. The Lean community understand "delivery" in terms of the work process from a building's concept to commissioning (Ballard and Zabelle 2000).

Koskela (2000) introduced the TFV-theory of production, which complements the three views of production: Transformation [T], flow [F] and value [V]. Lean project delivery (LPD) systems are structured, controlled and improved in the pursuit of the TFV-theory (Koskela et al. 2002), illustrated in Figure 1. Traditional project delivery focuses primarily on transforming resources to products, and neglects or forgets flow and value.

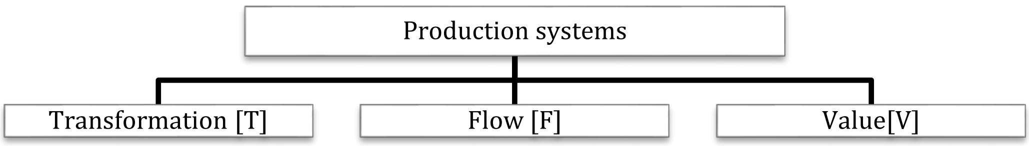

Figure 1: Production systems and TFV-theory.

PRODUCTION SYSTEMS MANAGEMENT

Projects are understood as temporary production systems, which are supplied with materials, information and resources (Ballard and Howell 2003). Production system management – or in other words: Project management – may be divided into three terms: Designing, operating and improving (Koskela 2001), illustrated in Figure 2.

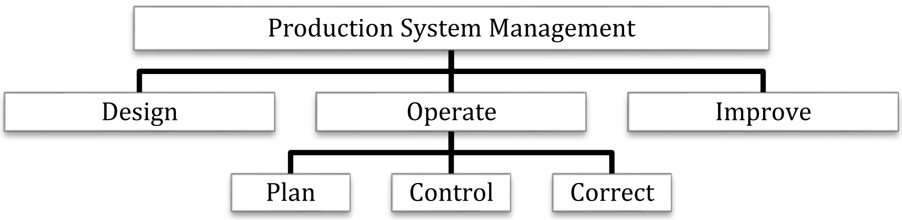

Figure 2: Production system management (Ballard and Howell 2003).

The purpose of production system **design**, also called Work Structuring, is to design the production system that extend from organization to the design of operations (Ballard et al. 2001). Organizational structuring has traditionally been the primary focus, while the design of the production system itself has been ignored, although this is an essential part of the design. Work Structuring serves the production system's three fundamental goals: Deliver the product [T], maximize value [V] and, minimize waste [F] (Koskela 2000). Work Structuring is designed to achieve both the customers' and the producers' purpose. Aligning interests is an important element of the design (Ballard et al. 2001).

Operating is divided into plan (set specific goals for the system), control (advance towards the plan) and correct (change the means used or the goals persued) (Ballard and Howell 2003). **Improvement** is implementing learning, continuous improvement and standardisation in the production system.

All production systems that pursue the TFV goals is a LPD-system (Koskela et al. 2002). However, some will be more Lean than others. **Lean Project Delivery System, LPDS**, (Ballard 2000) is a prescriptive model for project management. The domain in which LPDS is applicable is project-based production systems. LPDS utilizes, among other things, Last Planner System as the control system, Work Structuring to provide reliable workflow, and early contracting and involvement of downstream actors in upstream decisions (Ballard 2000).

PROJECT DELIVERY AS A SYSTEMATIC APPROACH

Project delivery, both traditional and Lean, can be treated as systematic approaches that consist of three elements: Project organization, operating system, and commercial terms and risk management (Thomsen et al. 2009). Table 1 illustrates the different focus for traditional and LPD as a systematic approach.

Table 1: Comparison of traditional and Lean project delivery (Howell et al. 2013)

	Organization	**Operating system**	**Commercial terms**
Traditional	Command & Control	Activity centred	Transactions
Lean	Collaborative	Flow centred	Relational

The element **project organization** consists of contract strategy and management of the inter-organizational relationships before and during the project execution (Zimina et al. 2012). An essential part of LPD is to select the right people to set the proper basis for cooperation and include them in the early stages of the project (Howell et al. 2013).

The **operating system** element is to make the project's actors work as one team on a daily basis – The real collaboration. LC tools and methods may be used, but in the end it requires creating a Lean culture through leadership (Zimina et al. 2012).

The element **commercial terms & risk management** concerns contracts, risk and remuneration. LPD contracts are based on collaboration, e.g. IPD (Matthews and Howell 2005), while traditional contracts use transactional contracts. Traditionally the risk is distributed and transferred among the actors – The risk is hidden in the commercial terms. A contractor will not hesitate to shift the risk further down in the supply chain. This risk shifting is an illusion, in the end the client will always suffer the consequences (Zimina et al. 2012). LPD understands the risk and shares it. First, the risk is reduced by the operating system that measures and improves the workflow. Second, the risk is reduced due to the project organization where the actors collaborate to reduce it (Zimina et al. 2012).

RESEARCH METHODOLOGY

The research presented in this paper is based on a single explanatory case study involving the collection of qualitative data by (a) in-depth semi-structured interviews of eight professional key figures from the client, design group and prime contractor and (b) a document study of project documents and experience reports from the project. All the interviews were conducted at the end of the construction phase. The research has primarily focused on the construction phase of the project, due to previous researches on the project's detailed engineering phase (Bråthen and Moland 2015; Kristensen 2016).

FINDINGS AND DISSCUSSION

BACKGROUND FOR THE CASE STUDY

The study looked at a rehab project of a listed 115 years old university building. The building is a part of the Norwegian University of Life Sciences and is located at Campus Ås, 30 km south of Oslo, Norway. The building has three stories with an additional basement and attic. The total gross area is about 8190 m^2. The building's interior, exterior and surrounding outdoor areas are all listed and the Directorate of Cultural Heritage must approve every change in the project. The scope of the rehab project was to preserve the unique building and adjust it to satisfy current general education standards.

The project's revised cost frame was 470 Million NOK, approximately 57 million USD. The detailed engineering was completed in the second quarter of 2014, while the construction work started in the third quarter of 2014 with a planned commissioning in the second quarter of 2015. This was later revised to the second quarter of 2016.

The project was organized as a lump sum prime contract, while the design group had a unit price contract. The prime contractor was contracted after the completion of the detailed engineering. LC culture, principles and methods were new for almost all actors in the project.

THE MANDATED DELIVERY SYSTEM

An overview of Statsbygg's mandated delivery system is presented in Table 2. Statsbygg's purpose of the system was to pursue the TFV goals – A Lean Construction delivery system.

Table 2: An overview of the public client's mandated delivery system.

Initiatives/tools/Methods	Phase(s)
Requirement for Yellow belt in Lean Six Sigma (IASSC u.d)	Announcement of tender
A separate inspection-and-partially-uncover contract	Concurrent with detailed engineering
Collaboration phase with a duration of three month	Three month before construction start
BIM, Building Information Modelling	Construction
Pull planning and production control based on Last Planner System's plan hierarchy (Ballard 2000)	Construction
Takt Time Planning (Porsche Takt)	Construction
ICE, Integrated concurrent engineering (Kunz and Fischer 2009)	Construction

By clearly stating the required LC delivery system in the tender announcement, Statsbygg removed unmotivated candidates that did not desire to use LC. The **requirement** of the **certification of Yellow belt in Lean Six Sigma** for the project managers and foremen was supposed to supported this requirement.

A separate inspection-and-partially-uncover contract was executed concurrent with the detailed engineering phase. The purpose of this contract was to improve the prime contract's design specification and prepare for better workflow in the construction phase. The building's interior design was 3D-scanned to be able to make a more accurate BIM-model. A majority of the informants pointed out that this enabled the designers to produce better specifications for the prime contract. Some also stated that the inspection work ought to have had a bigger scope to identify and reveal even more risks that could have contributed to reduce the amount of unforeseen challenges. The effect of this initiative would have been optimized if the same contractor executed both the contracts. This would have made the prime contractor more familiar with the building and potential challenges.

The intention of **the collaboration phase** was to align the project's actors to establish a real collaboration, a mutual understanding of the risks and uncertainties regarding the building, the prime contract's specifications, work drawings, BIM-model, projects goal, limitations and constraints. Each and all of the informants agreed that such a collaboration phase would have great potential. However, the actual execution of this phase was not in accordance with the plan. All the informants pointed out a lack of clear goals, i.e. what documents was supposed to be produced, and diffuse distribution of responsibility, i.e. who was supposed to manage the phase, were the main reasons for the phase failing.

During the collaboration phase, Statsbygg arranged a three-day LC workshop at Porsche Consulting in Germany to educate the actors in LC. The purpose was to learn and understand the principles of pull planning and Takt Time Planning.

All of the informants agreed on the **BIM-model** being useful for both designers, management and construction workers. In each of the four stories a BIM-kiosk was placed. Both the BIM-model and drawings were available at the BIM-kiosks. To support the BIM-kiosks, project leaders and foremen had access to the BIM-model on their tablet computers. However, according to a few informants, the construction workers did not have full confidence in the BIM-model. This, because the contract stated that the BIM-model was subordinate to both the specifications and the drawings – The specifications was prevailing over the drawings and the drawings over the BIM-model.

The **pull planning and production control based on Last Planner System's plan hierarchy** did not work as intended. The pull planning was executed at the start of the construction phase. The meeting sequence of the production control was *14-10-8-4-1-* weeks before each takt zone. The meetings' agenda were as following: 14 week: Designers prepare and coordinate for the next takt zone, 10 week: Designers conduct interdisciplinary control and complete work drawings, 8 week: Lookahead planning, 4 week: Weekly plans, and 1 week: Final preparation for the takt zone – Ready to start.

A majority of the informants pointed out the main reason for failing the project control was the lack of previous experiences with the lookahead process. The actors did not do the needed preparation before meetings, and this made it hard to maintain a sufficient workable backlog. Another important factor was the amount of unforeseen challenges due to not knowing the actual state of the old building – It was difficult to make the required preparations.

The Takt Time Planning, as the pull planning, did not work properly. Again, the lack of previous experiences made it difficult to carry out. To compensate for this lack of experience a consultant was hired to establish the Takt Time plans. Despite this effort, the Takt Time Planning was discarded after a few months. The majority of the informants pointed out that the design of the Takt zones and sequences were not suited for the building's design. The building had vertical shafts, which were to be used for risers for electrical and mechanical installations, while the sequences was in horizontal order. A few informants also stated that there were not enough buffers in the plan to compensate for all the uncertainties present as a result of the insufficient workable backlog. When the Takt-train got off track the train was restarted with driving an empty train through the building, however it derailed soon again.

Integrated Concurrent Engineering (ICE) was a useful and suitable method for the project. It made it easier for the actors to communicate, coordinate and ask for assistance. At the start of the design and engineering phase, all of the designers were present at the construction site four days a week, followed by two days a week in the construction phase and once a week towards the end.

THE EXTENT OF LEAN PROJECT DELIVERY

Each and all of the informants stated that the project's construction phase was more or less carried out in accordance with traditional project management. The project started with the mandated LC delivery system, however after a while, the system was discarded and adjusted for the benefit of more well-known traditional project management.

Some blamed the mandated delivery system for making the project execution more complexed than necessary, while others stated that it contributed to reduce the negative result.

As for the project delivery in terms of cost, quality and time, the project performance was not satisfactory compared to the original cost and time goals, while the quality of the work done did satisfy the client.

CAUSES OF FAILURE TO ACHIEVE LEAN PROJECT DELIVERY

Project organization

The prime contractor was included in the project after the detailed engineering and the separate inspection-and-uncover contract was completed. A significant difference between Lean and traditional project management is the relationship between phases and the participants in each phase (Koskela et al. 2002). A Lean approach is to include downstream actors in upstream decisions. I.e. to include the contractor in the design – not after the design is completed. Furthermore, the initiative to extract the inspection-and-uncover from the prime contract is contradictory to a Lean approach, as it results in a more fragmented organization.

The prime contract's award criteria were distributed 65% on cost and 35% on expertise. In a Lean approach, the expertise criteria ought to be more valued. There was a discussion of adding "experience with LC" as an award criterion, however this was discarded due to concern that the field of competitors would become too narrow.

The delivery system was designed before the prime contractor was contracted. There ought to have been a redesign of the production system to align the interests of the client and the contractor, and to adjust it to the mandated delivery system. After all, it is the producer who must design, control and improve the production system (Ballard et al. 2001)

Throughout the project, the replacement rate of key project management personal was high. This made the project suffer from discontinuity that induced waste. Some of the informants stated that LC ideas almost disappeared with the change of Statsbygg's project manager, who was responsible for developing the mandated delivery system, after the completion of the detailed engineering. The project did not have any Lean process leader that could facilitate and help the actors when needed after that moment.

Operating system

Questions regarding LC revealed a lack of fundamental understanding of what LC is. As mentioned before, LC was new for many of the actors in the project. The similarity between Six Sigma and LC is debateable (Clegg et al. 2010). Whether the requirement for Yellow belt in Lean Six Sigma has contributed to a better understanding of LC is therefore questionable. A majority of the informants mentioned that they had focus on the mandated Lean methods, with only a vague focus on the underlying principles and ideal. When the focus is primarily on the methods and not the paramount goals, it will generate restriction and not flexibility, as it should (Modig and Åhlström 2012). The Fundamental concepts such as minimizing waste and maximizing value (Koskela 2000) as well as Koskela's eleven LC principles (Koskela 1992) were either forgotten or unknown. There was a lack of aligning LC with the actors.

Another factor that may have affected the LPD was the amount of new LC elements. There were many methods to learn and comprehend at once. A more gradual approach would perhaps be more effective. It is common to start with Last Planner System as a pilot implementation to assure reliable workflow. When this is working the actors realize the power of the Lean idea (Koskela et al. 2002).

The majority of the informants experienced the building itself to be a challenge. There were many unforeseen challenges, e.g. missing a foundation wall, problems with reusing the old vertical shafts and rot in the roof, and the extra work was substantial. To plan and maintain a predictive workflow was difficult for the novice LC project team.

Commercial terms and risk management

A majority of the informants mentioned the project's contract form not to be ideal. The contract form was a prime contract without any contractual incentives, except day penalties for too late completion. The mechanics of a prime contract may cause sub-optimization due to the contractor earning extra money for alteration work. When problems occur, the contractor needs to prove the need for a change and get an acceptance in order to be paid. Such a process generate waste and contribute to less collaboration.

As for the design group, they had a unit price contract. There was a high hour consumption. The BIM-model did not have any requirements or limitations to what detail level to satisfy. A consequence of this was an extraordinary detail level on the BIM-model. Some of the informants pointed out this to be non-value adding. There were similar cases of waste with the production of detail drawings. The design group did as told – If the contractor asked for a detail drawing that they did not need, they produced it anyway.

The main argument for a using prime contract was the need for control due to the building being a cultural monument. However, the majority of the informants stated that a partnering contract would have adjusted this factor and improved the collaboration.

There was a lot of time and cost pressure in the project. This lead to sick-leaves and a stressful workday for the actors. The reason for this, according to informants, was an unrealistic cost and time limit. In the collaboration phase the actors noticed the need for a bigger timeframe, even so the project continued without any changes in the timeframe.

CONCLUSION

The mandated LC delivery system is presented in the previous chapter. However, this delivery system's level of "leanness" is debatable. The project's construction phase was more or less carried out in accordance with traditional project management. From a systematic approach the project organization was based on command and control, due to the lacking of a well-done collaborative phase. The operative system did have some elements of Lean tools, of which BIM and ICE worked out, but the important LC culture and the fundamental understanding of the LC principles and ideal were absent. The commercial terms were based on transactions that transferred risk to the contractor.

The main reasons for the rehab project failing Lean project delivery were:

- Project management, both at the client and contractor side, failed to implement a Lean culture based on Lean Construction principles and ideal.
- Lack of real collaboration. The contract strategy may have affected this, as well as a poorly implemented collaboration phase.
- The production system was not aligned properly between client and contractor.
- The building's amount of unforeseen risks – The level of variability was high.

This indicates the importance of project actors' understanding the mechanism behind LC and the foundation of a real collaboration to reap the benefits. Despite the project's LPD failure the empirical data indicates that the project actors support a further use of mandatory LC in the public sector in Norway as a mean to reduced waste and costs. Whether or not LC is suitable for a rehab project is difficult to conclude based on this research. Further research is needed, where the project's actors are more familiar with LC. Additional future research proposed is (I) whether Takt Time Planning is suited for rehab projects – Does the need for a high degree of capacity buffers make it an ineffective method, and (II) does the use of the award criteria "LC experience" in Norway unduly limit the competition?

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REFERENCES

Ballard, G. (2000). "Lean Project Delivery System." *Lean Construction Institute. White Paper-8 (Revision 1)*

Ballard, G., and Howell, G. (2003). "Lean project management." *Building Research & Information*, 31(2), 119-133.

Ballard, G., Koskela, L., Howell, G., and Zabelle, T. (2001). "Production system design in construction." *Proc. 9th Ann. Conf. of the Int'l. Group for Lean Constructio*, Singapore.

Ballard, G., and Zabelle, T. (2000). "Project definition." *White paper*, 9.

Ballard, H. G. (2000). "The Last Planner System of Production Control." Doctoral Thesis, The University of Birmingham.

Bryde, D. J., and Schulmeister, R. (2012). "Applying Lean principles to a building refurbishment project: experiences of key stakeholders." *Construction Management and Economics*, 30(9), 777-794.

Bråthen, K., and Moland, L. E. (2015). "Samhandling med BIM og Lean i detaljeringsfasen på Urbygningen ved NMBU." *SamBIM-rapport*Oslo.

Clegg, B., Pepper, M., and Spedding, T. (2010). "The evolution of lean Six Sigma." *International Journal of Quality & Reliability Management*, 27(2), 138-155.

Howell, G., Mesa, H., and Alarcon, L. "Characterization of Lean Project Delivery." *Proc., Proc. 21st Ann. Conf. of the Int'l Group for Lean Construction*.

Howell, G. A. "What is Lean Construction." *Proc., Proc. 7th Ann. Conf. of the Int'l Group for Lean Construction*, 1-10.

IASSC (u.d). "Certified Lean Six Sigma Yellow Belts." (11.02, 2016).

Koskela, L. (1992). *Application of the New Production Philosophy to Construction*, Stanford university Stanford, CA.

Koskela, L. (2000). "An Exploration Towards a Production Theory and its Application to Construction." Doctoral Thesis, Helsinki University of Technology, Espoo.

Koskela, L. (2001). "On new footnotes to Shingo." *Proc. 9th Ann. Conf. of the Int'l. Group for Lean Construction*Singapore, Singapore.

Koskela, L., Howell, G., Ballard, G., and Tommelein, I. (2002). "The Foundations of Lean Construction." *Design and Construction: Building in Value. Oxford, UK: Butterworth-Heinemann*.

Kristensen, K. H. (2016). "Case-rapport: Lean i Urbygningen." *BA2015-initiativet for Statsbygg*, Faveo AS, Statsbygg.

Kunz, J., and Fischer, M. (2009). "Virtual Design and Construction: Themes, Case Studies and Implementation Suggestions." *Center for Integrated Facility Engineering (CIFE), Stanford University*.

Matthews, O., and Howell, G. A. (2005). "Integrated Project Delivery an Example of Relational Contracting." *Lean Construction Journal*, 2(1), 46-61.

Modig, N., and Åhlström, P. (2012). "This is lean." *Halmstad, Sweden: Rheologica*.

Reyers, J., and Mansfield, J. (2001). "The Assessment of Risk in Conservation Refurbishment Projects." *Structural Survey*, 19(5), 238-244.

Thomsen, C., Darrington, J., Dunne, D., and Lichtig, W. (2009). "Managing Integrated Project Delivery." *Construction Management Association of America (CMAA), McLean*.

Zimina, D., Ballard, G., and Pasquire, C. (2012). "Target Value Design: Using Collaboration and a Lean Approach to Reduce Construction Cost." *Construction Management and Economics*, 30(5), 383-398.