



HÁSKÓLINN Í REYKJAVÍK  
REYKJAVÍK UNIVERSITY

Lean production construction –  
Prospects for the  
Icelandic construction industry  
(Lean production construction – Horfur fyrir íslenskan byggingaiðnað)

Christoph Merschbrock

A thesis submitted in partial fulfillment of the requirements for the  
Degree of  
Master of Science in Civil Engineering

Supervisor: Professor Brian L. Atkin

Co-Supervisor: Kolbeinn Kolbeinsson M.Sc.

School of Science and  
Engineering  
Autumn 2009



## Abstract

The emerging concept of lean construction is concerned with the application of the lean paradigm to the construction industry.

**Purpose** – This research paper seeks to identify the prospects and applicability of lean construction techniques at site level construction processes in the Icelandic construction industry.

**Design/methodology/approach** – Firstly, the basis of current project management and tools to control construction in the Icelandic construction industry was identified through field observation at Iceland's biggest contractor Ístak. Secondly, a project controls template aligned to the 'Lean paradigm' that could be used by the Icelandic construction industry was identified. This template was based on lean construction practice examples used by contractors outside of Iceland. Lastly, the likely acceptance amongst Icelandic construction companies of the project controls' template and the appreciation of lean construction within the Icelandic construction industry were assessed. To get acquaintance of the aforementioned points, structured interviews featuring questionnaires as means for structured data collection were undertaken. These interviews were directed at a select number of senior project managers within the Icelandic construction industry.

**Findings** – What became clear after having assessed what lean construction has to offer at site level is that construction controls aligned to the Lean paradigm seek to enhance production efficiency in the sense of a faster, more productive execution of single production tasks. It became also evident that these techniques require a significantly higher amount of planning work to prepare and ready the tasks. It became obvious that lean construction is not applicable to every construction setting and that JIT efficiency considerations can, especially in construction projects with significant variations and disruptive influences, cause difficulties with regards to project delivery. It became evident that some of the presently used project management practices are logically and useful, even though they were identified as 'wasteful' or 'unnecessary' in terms of lean production construction. The results, therefore, show that both construction management philosophies need to be integrated to achieve real effective project management. Furthermore, it is concluded that a more customized approach to the integration of lean construction ideas has to be taken to fit each construction sites specific management situation. The author expects, assumed a more integrated and customized approach to implementation of Lean construction techniques is taken, that a faster production process and improved profitability in delivery of a construction project can be achieved.

**Key words** – Project management/ Lean construction/ Icelandic construction industry/ Controls

## Úrdráttur

Nýtt hugtak, “Lean Construction”, snýst um að beita hugmyndafræði hugmynda um sparneytni í byggingaiðnaði.

**Tilgangur**—Í þessari rannsóknarskýrslu er leitast við að bera kennsl á möguleika og notagildi aðferða sem tengjast “Lean Construction”, við framkvæmdaferla á byggingastað í íslenskum byggingaiðnaði.

**Hönnun/aðferðafræði/nálgun** – Í fyrsta lagi voru borin kennsl á grunn núverandi verkefnastjórnunar og stjórnækja í íslenskum byggingaiðnaði með athugunum á verkstað hjá stærsta verktakafyrirtæki á Íslandi, Ístaki. Í öðru lagi var gerð grein fyrir líkani að stýringu verkefna í samræmi við sparneytnihugsun í íslenskum byggingaiðnaði. Þetta líkan byggðist á verklagi sparneytinnar framkvæmdar eins og er notað af verktökum utan Íslands. Í síðasta lagi var lagt mat á hversu líklegt væri að þessu líkani að verkefnastjórnækjum yrði vel tekið, og hvernig hugsuninni um sparneytni í framkvæmdum yrði tekið meðal íslenskra verktaka. Til þess að kynnast framantöldum atriðum voru tekin skipuleg viðtöl sem fólu í sér þar til gerða spurningalista sem aðferð við að ná fram skipulegri söfnun upplýsinga. Í þessum viðtölum var rætt við valinn hóp herra settra stjórnenda í íslenskum byggingaiðnaði.

**Niðurstöður** – Það sem varð ljóst eftir að hafa lagt mat á hvað “Lean Construction” hefur upp á að bjóða á verkstað er að stjórnækki framkvæmdar sem aðlöguð eru sparneytnihugsunarhætti eru líkleg til að bæta skilvirkni framleiðslu í þeim skilningi að hraði og framleiðni eykst í einstökum verkum. Það varð einnig ljóst að beiting þessara aðferða krefst umtalsvert meiri skipulagningarvinnu við að undirbúa og klára verkin. Það varð einnig augljóst að “Lean Construction” er ekki unnt að beita í öllum byggingaframkvæmdum og að JIT nýtnisjónarmið geta, einkum í verkum þar sem verulegs breytileika og truflandi áhrifa gætir, valdið vandkvæðum í því að skila verkinu af sér. Það varð ljóst að sumar núverandi stjórnunarvenja eru rökréttar og gagnlegar, jafnvel þær sem taldar eru eyðsluvaldandi eða ónauðsynlegar í skilningi “Lean Construction”. Niðurstöðurnar sýna samt sem áður að sameina þarf hvora hugmyndafræðina hinni til að ná fram raunverulega skilvirkri verkefnisstjórnun. Enn fremur er ályktað að sérhönnuð nálgun við þennan samruna verður að koma til til þess að henta stjórnunarumhverfi hvers einstaks verkstaðar. Höfundur væntir þess, að því gefnu að heildstæðari og sérhönnuð nálgun við beitingu “Lean Construction” verði valin, að hraðara framleiðsluferli og bættir hagnaðarmöguleikar geti náðst fram.

**Lykilorð** – Verkefnastjórnun/ “Lean Construction”, /Íslenskur byggingaiðnaður/ Stjórnækki



## Table of contents

---

<b>1</b>	<b>Introduction .....</b>	<b>11</b>
1.1	Background .....	11
1.2	Construction vs. Manufacturing .....	11
1.2.1	The characteristics of Construction .....	12
1.2.2	The characteristics of Manufacturing .....	14
1.2.3	Comparison .....	15
1.3	Appreciation of Lean construction .....	17
1.4	Aim and objectives of the research .....	19
1.4.1	Thesis outline .....	20
<b>2</b>	<b>Research methods .....</b>	<b>21</b>
2.1	Introduction .....	21
2.2	Classification of the research project .....	21
2.2.1	Reliability and validity of data collected .....	22
2.2.2	General research plan .....	22
2.3	Practical Research Methods .....	23
2.3.1	Frame of reference .....	23
2.3.2	Empiricism .....	23
2.3.3	Analysis .....	26
<b>3</b>	<b>Theoretical framework in construction projects and control .....</b>	<b>29</b>
3.1	Introduction .....	29
3.2	Transformation theory in construction projects .....	29
3.2.1	Definition .....	29
3.2.2	Production functions -Mathematical Concept .....	30
3.2.3	Hierarchically decomposition - Concept .....	30
3.2.4	Production involving time - Concept .....	32
3.2.5	Development of the Transformation theory .....	32
3.2.6	Transformation theory in construction .....	33
3.3	Value generation theory in construction projects .....	34
3.3.1	Definition .....	34
3.3.2	Value score functions - Mathematical Concept .....	34
3.3.3	Development of Value generation theory .....	36
3.3.4	Value generation theory in construction .....	37
3.4	Flow View theory in construction projects .....	39
3.4.1	Definition .....	39
3.4.2	Eliminating waste - Concept .....	39
3.4.3	Reducing lead time – Concept .....	40
3.4.4	Reducing variability in lead time - Concept .....	42
3.4.5	Simplicity - Concept .....	43
3.4.6	Technical Efficiency or X-efficiency - Concept .....	43
3.4.7	Transparency – Concept .....	43
3.4.8	Development of the Flow View theory .....	44
3.4.9	Flow View theory in construction .....	45
3.5	Theoretical framework in controls .....	46
3.5.1	Reactive controls .....	46
3.5.2	Proactive controls .....	47
3.6	Conclusion .....	48

<b>4</b>	<b>Case study: Ístak.....</b>	<b>49</b>
4.1	Case description.....	49
4.2	Observations .....	50
4.2.1	Construction Input controls .....	50
4.2.2	Construction Output controls .....	59
4.3	Findings of the case study .....	67
<b>5</b>	<b>Lean project controls template/ Practice examples.....</b>	<b>69</b>
5.1	Introduction .....	69
5.2	Practice Examples .....	70
5.2.1	Lean Construction Input controls .....	70
5.2.2	Lean construction output controls .....	77
5.3	Findings lean construction template.....	86
<b>6</b>	<b>Interviews / acceptance of Lean project controls template .....</b>	<b>89</b>
6.1	Introduction .....	89
6.2	Interview write up.....	92
6.3	Discussion of the results .....	99
6.4	Conclusions .....	101
<b>7</b>	<b>Conclusions .....</b>	<b>103</b>
7.1	Summary of the research work.....	103
7.2	Concluding discussion.....	103
7.3	Final Conclusions .....	104
7.4	Prognosis for future practice .....	105
7.5	Proposal for further research .....	105
	<b>References .....</b>	<b>107</b>
	<b>Online Sources .....</b>	<b>110</b>
	<b>Appendix A .....</b>	<b>111</b>

# List of Figures

---

Figure 1-1 Construction phases .....	12
Figure 1-2 Thesis outline.....	20
Figure 2-1 Validity and Reliability.....	22
Figure 2-2 General plan of the thesis .....	22
Figure 2-3 Construction output of the Nordic countries in 2008 in € bn .....	24
Figure 2-4 Verbal data dimension of this thesis Source.....	25
Figure 3-1 Production as a transformation from inputs to outputs.....	29
Figure 3-2 Production Graph.....	31
Figure 3-3 Bill of materials .....	31
Figure 3-4 Product structure tree .....	32
Figure 3-5 Gantt chart .....	32
Figure 3-6 Production as value generation.....	34
Figure 3-7 Value function .....	35
Figure 3-8 Benefit corresponding to price in VM .....	36
Figure 3-9 Functional breakdown of a bridge .....	36
Figure 3-10 Production as a flow process .....	39
Figure 3-11 Reduction of non value adding activities.....	41
Figure 3-12 Two densities of flow time with unequal variance.....	42
Figure 3-13 Technology set and production function .....	43
Figure 3-14 Feedback control.....	47
Figure 3-15 Feed forward control.....	47
Figure 4-1 Material input .....	50
Figure 4-2 Material logistics system .....	51
Figure 4-3 Project purchase plan.....	52
Figure 4-4 On site material storage .....	54
Figure 4-5 manpower input .....	54
Figure 4-6 manpower logistics system.....	55
Figure 4-7 manpower responsibilities .....	55
Figure 4-8 manpower information database.....	56
Figure 4-9 plant and equipment input .....	56
Figure 4-10 Plant and equipment logistics system.....	57
Figure 4-11 Plant and equipment information database.....	57
Figure 4-12 Information Input.....	57
Figure 4-13 Project board.....	58
Figure 4-14 Information monitor.....	59
Figure 4-15 Time output.....	59
Figure 4-16 Time management tools.....	60
Figure 4-17 Time PC .....	60
Figure 4-18 Updated baseline schedule.....	61
Figure 4-19 Quality output .....	61
Figure 4-20 Quality control plan .....	62
Figure 4-21 Quality feedback control.....	62
Figure 4-22 Database for quality control checklists.....	63
Figure 4-23 HSE output .....	63
Figure 4-24 HSE feed forward control.....	63
Figure 4-25 Cost output.....	64
Figure 4-26 Feedback control.....	65
Figure 4-27 Cost status report .....	66

Figure 5-1 Work cycle production .....	70
Figure 5-2 Material input in flow theory .....	71
Figure 5-3 Lean construction supply chain .....	71
Figure 5-4 Lean feed forward material input control .....	73
Figure 5-5 Manpower input in flow theory .....	74
Figure 5-6 Lean manpower input control .....	74
Figure 5-7 Lean manpower input tools .....	75
Figure 5-8 Lean plant and equipment input .....	75
Figure 5-9 Lean information input .....	76
Figure 5-10 Lean time output .....	77
Figure 5-11 Lean scheduling system Last Planner .....	79
Figure 5-12 Lean feed forward construction time control .....	82
Figure 5-13 Lean construction quality control .....	82
Figure 5-14 Lean construction feed forward quality control .....	84
Figure 5-15 Lean construction quality considerations .....	84
Figure 6-1 Interview structure .....	91

## List of Tables

---

Table 1-1: What is Lean construction? .....	13
Table 1-2: What is Lean manufacturing? .....	15
Table 1-3: Differences between construction and manufacturing .....	16
Table 3-1: Methods in Flow view theory of construction .....	46
Table 4-1: CSC operations .....	53
Table 4-2: Case study findings .....	67
Table 5-1: lean construction template findings .....	86
Table 6-1: comparison of the management systems .....	90
Table 6-2: interview participant .....	92
Table 6-3: answers question 2 .....	93
Table 6-4: answers question 10 a) .....	96
Table 6-5: answers question 10 b) .....	96
Table 6-6: additional comments .....	98

## List of Abbreviations

---

AEC	=	Architecture Engineering and Construction
BAC	=	Budget at Completion
BIM	=	Building Information Modeling
BOM	=	Bill of Materials
CAD	=	Computer Aided Design
CAPEX	=	Capital Expenses
CPM	=	Critical Path Method
CSC	=	Construction Supply Chain
DIN	=	Deutsche Industrie Norm
EPOS	=	Electronically Purchase Order System
EV	=	Earned Value technique
HRM	=	Human Resource Management
HSE	=	Health, Safety and Environment
ID	=	Identity
ISK	=	Icelandic Krona (currency)
JIT	=	Just In Time
LBS	=	Location Based Scheduling
LCC	=	Life Cycle Costing
LCI	=	Lean Construction Institute
LIRU	=	Reykjavik University database
LPS	=	Last Planner System
OBS	=	Organization Breakdown Structure
OGC	=	Office of Government Commerce
OPEX	=	Operational Expenses
PC	=	Project Control
PERT	=	Program Evaluation and Review Technique
PO	=	Purchase Order
PPC	=	Percent Plan Complete
RU	=	Reykjavik University
TFV	=	Transformation Flow Value Theory
TPM	=	Total Preventive Maintenance
TPS	=	Toyota Production System
TQM	=	Total Quality Management
VDI	=	Verein Deutscher Ingenieure (Association of German Engineers)
VfM	=	Value for Money
VM	=	Value Management
WBS	=	Work Breakdown Structure
WWP	=	Weekly Work Plan

## Acknowledgements

---

I would like to start by thanking the Ístak staff for their support throughout this thesis and for their patience in answering all my unending questions.

I thank Kolbeinn Kolbeinsson my supervisor at Ístak, for his support and his good ideas contributing to the purpose of this thesis. Furthermore, I would like to express my gratitude to the construction managers Brynjar Brjánsson, Gísli Pálsson, Gísli H. Guðmundsson and Þröstur Sívertsen for their time and the patience to answer my questions, Thank you!

Thanks are due to Hermann Kreutzjans (Lean Construction and Risk management department, Hochtief Construction, Germany) for his assistance and support with the lean practice examples in Section 5. I thank Christine Pasquire (Director, LCI UK) for the friendly permission to reprint some illustrations property to the Lean Construction Institute UK (Section 5).

I would like to aim my gratitude to RU and more specifically to my supervisor professor Brian L. Atkin. This Master thesis would not have become half as good without your constant support and confidence in me.

Last, but definitely not least, I would like to thank my girlfriend Svala for supplying me with countless cups of coffee.

Takk fyrir,

Christoph Merschbrock

Reykjavik, 9 December 2009

# 1 Introduction

*In this chapter the guidelines for the thesis will be presented. The background to the subject of the research will be briefly described followed by a problem description and the main purpose and objective of the thesis. Finally a reading outline about the main chapters will be given.*

---

## 1.1 Background

The recent recession that hit Iceland at the end of 2008 (Icelandic: Kreppa) left the Icelandic construction industry ‘paralyzed’ as many projects got postponed or canceled due to the fact that access to lending became increasingly difficult and expensive, with mortgage lending rates skyrocketing to as much as 18%. Both private and public clients adopted a ‘wait and see’ approach and froze investments. The outlook for the Icelandic construction market seems to be particularly bad since the Icelandic government does not seem to have the resources at hand to launch recovery plans for the industry.

In the light of these recent developments, Icelandic contractors have to face a radically reduced market, increasing competition, rising material prices and a need for high performance. To survive this situation and to stay in business it could be of critical importance for the Icelandic contractors to adapt new ways of thinking and to look for strategies improving productivity, competitiveness and foremost to cut costs in their operations.

This research is an attempt to look for possible improvements in construction management at the project level. Traditional construction Project Management Tools are criticized by some scientists and practitioners for failing to provide in production process flows. These scientists argue that a different philosophy to control the execution of construction projects known as Lean production construction could offer benefits through enhanced focus on process flows. In Lean Production Construction, when applied to the execution phase, different management tools, like Last Planner, are used as complementary to those tools used at higher level, in traditional construction project management, to create a less wasteful process.

“This new technique originated as response to the low and stagnant productivity typical in the execution of construction projects, especially when compared to the remarkable improvements achieved in the manufacturing industry” (Senior, (2007)).

However, even though there could be potential to enhance construction performance by using Lean techniques no documented evidence has been found that shows that concepts of lean construction have been implemented by any Icelandic construction company thus far. Additionally, there has not been found any evidence that lean construction has been subject to research within the Icelandic research community.

## 1.2 Construction vs. Manufacturing

Lean construction is an attempt to apply the Lean manufacturing paradigm to construction. When applying management controls from one kind of industry to a different kind of industry, it is critical to understand the main characteristics of each industry and their specific management problems. Therefore, it is useful to make some comparisons. This chapter begins with a comparison between construction and manufacturing.

### 1.2.1 The characteristics of Construction

#### Definition

For the purpose of this thesis the term construction is understood as the work of building or making something, especially buildings and bridges etc. In this chapter, the main characteristics of a typical construction process are defined.

#### Type of Production

Construction is the process concerned with the building and assembly of structures, construction is usually executed as project based work. A Construction Project can be described as a temporary endeavor undertaken to create unique structures or buildings. Buildings are typically one-off products made specifically to a customer's order, although some construction products, like modular prefabricated housing, could possibly be classified as serial production.

Construction projects have usually a contractual predefined content or scope with a clearly defined start and end point. Construction when compared to other industries has a low level of automation and requires a high amount of manual labor. Most tools used in construction are multipurpose tools.

The Lifespan of a construction product is commonly very long when compared to most products Life spans in other industries. Therefore, construction products have to fulfill their purpose over a long time range and it is very difficult to foresee what quality demands will arise over such a long period. The typical phases of a construction process are shown in Figure 1-1.

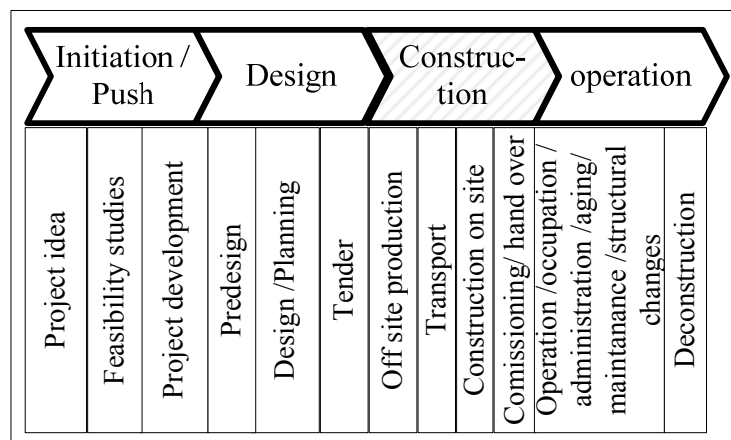


Figure 1-1 Construction phases

#### Types of management in construction

##### Project management

Construction projects are typically managed based on the tools and templates of Project management. The main focus in construction project management is to deliver the project according to scope in the required quality at cost and in time.

The central tools in project management are the Critical Path Method (CPM), the Program Evaluation and Review Technique (PERT) and the Earned Value technique (EV). All of these techniques are based on a long term project execution plan from preconstruction to closeout.

Typically, a Work breakdown structure is employed to generate an activity list and, based on this list, an activity network is defined. The planning process in traditional Project



management is typically done in a top down approach. The sequence of activities in the project is defined straight at the project outset. Performance is monitored and controlled by construction project controls. Traditional construction controls are mainly focused on after the fact control.

### Lean production construction

Lean construction management is a new movement in construction management. Lean construction is focused on a further industrialization of construction. Lean thinking in construction concentrates in general on the design and construction phases of the project.

The elemental ideas of Lean construction stem from the lean manufacturing paradigm e.g. Toyota's production system created by Ohno (1988) and a scholar's manifesto created by Koskela (2000) (Senior (2007)). The theoretical foundation for lean construction is the Transformation-Flow-Value (TFV) understanding of construction.

Lean construction is the application of lean thinking to the construction industry: it is about improved delivery of the finished construction project to meet client needs.

#### 1. Design

Increased modularity/ Reduction of assembly steps/ increase possibilities for off site assembly/ buildability

#### 2. Planning

Last planner system (LPS)/ systematically making ready of tasks/ Shifting planning responsibility towards foremen and other field personal /several levels of planning/ high level of detail/ establishing 'Pull'- driven supply chain (JIT)

#### 3. Working

Reduction of waste/ faster assembly/ higher degree of industrialisation/ cleaner working space/ improved quality with TQM/ reduction of material handling

**Table 1-1: What is Lean construction? [Source: based on LCI UK (2009)]**

Due to the distinct nature of construction and manufacturing, Lean construction techniques differ considerably from those applied in manufacturing. The most important techniques in lean construction management are listed in Table 1-1.

The design phase yields the biggest potential for an implementation of the Lean paradigm since the design of a construction project influences significantly how 'industrial' it can be produced. One important hindrance in implementation of lean manufacturing techniques in construction is that construction product design and production is typically executed by different organizations or firms. This constraint forced implementation of Lean construction techniques to be largely focused on the execution and construction phase.

The main tool of Lean construction planning is the Last Planner System (LPS). The intention of the LPS is to establish a better coordinated and earlier process design similar to manufacturing, where process design is usually finalized before the manufacturing process starts. The LPS is a tool used to shift planning responsibility towards foremen and field personal. Last planner is a tool seeking to systematically reduce waste in construction, by readying all the designs, permits and other resources before execution. Several manufacturing techniques have been tried out to speed up on site construction work up like: 5S, Kanban, Kaizen events, quick setup/changeover, Poka Yoke, Visual Control and Five Whys, and TQM.



## **Resources in construction**

A wide range of different resources are employed in a construction project as it is usually made up of several hundred or even thousands of significantly different assembly steps. Construction materials are daily delivered to the construction site; many of the materials are custom-made for the project.

## **Demand in construction**

Characteristically for the construction industry clients establish project proposals and therefore the initiative for production occurs at the clients' side. So construction demand is typically push demand. Usually, the customer or client is known to the contractor and it is very likely that the client has an impact and requests changes throughout execution. The client's impact can disturb the project's flow.

## **Participants in a construction project**

Parties actively involved in a construction production process are usually the client, the designer, the contractor and the party operating or using the finalized product.

## **Key stages in a construction project**

The key stages in a construction process are: Initiation, design, construction and operation.

## **Production design interface**

In construction, the process and product design are relatively independent tasks. Most of the time, product and process designers are not working for the same firm. Typically, in construction, the process design is happening throughout the construction phase.

### **1.2.2 The characteristics of Manufacturing**

The term manufacturing is understood for the purpose of this thesis as the business of producing goods in large numbers, like car manufacturing or, the manufacturing of military equipment. In this chapter, the characteristics of a typical manufacturing process are defined.

## **Type of production**

Manufacturing is usually the industrial production of goods for sale on a large scale. Manufacturing is a highly automated mass production industry. Manufacturing takes place in a well controlled environment with repetitive and predictable activities. The end product is usually clearly defined and there are hardly any in-process changes. It is possible to improve the product gradually learning from experience. A manufacturing process has no planned end. A production process is usually stopped when the demand for a product decreases. The customer is usually unknown and therefore it is necessary to identify his needs by a Markey survey.

## **Resources**

In manufacturing, the resources needed for production of each unit are similar. Therefore, managers can optimize the tradeoff of used resources by using operations research methods. The availability of materials is typically known in advance.

## **Type of management**

Management of manufacturing is called production management and there are various methods and techniques applied in this field. These techniques include, for example, Manufacturing Process Management, or MPM, which focuses on exploring diverse

production line scenarios and making assembly lines more efficient. Also, Enterprise Resource Planning, ERP, is largely used to optimize supply chains in manufacturing<sup>1</sup>.

### The lean paradigm in manufacturing

A literature review from Shah and Ward (2003) identified the Key practices in Lean manufacturing which were: Just In Time (JIT), Total Quality Management (TQM), Human Resource Management (HRM) and Total Preventive Maintenance (TPM). The lean paradigm in manufacturing is applied throughout both design and manufacturing, it guides product and process design. An overview of lean manufacturing tools can be found in Table 1-2.

JIT	TPM	TQM	HRM
Lot size reduction Continuous flow Cellular manufacturing Bottleneck removal reengineering	Preventive maintenance Maintenance optimisation Safety improvement Scheduling strategies New equipment/technology	Benchmarking Quality programs Quality management Process measurement Continuous improvement	Self-directed teams Flexible workforce

**Table 1-2: What is Lean manufacturing? [Source: based on Björnfot and Sten (2004)]**

### Demand

In manufacturing, the product is usually ‘pushed’ to the customer by distribution and promotion. Typically the customer is unknown, making it critical in manufacturing to execute market research in order to identify the customer needs.

### Production design interface

In manufacturing, product design and process design are executed at the same time by the same firm. This constellation offers great possibilities in optimizing the fabrication before it is launched. The processes are usually planned in great detail (micro view) where every single production step is reviewed and optimized before production.

### 1.2.3 Comparison

Significant differences in the nature of construction and manufacturing could be identified.

Manufacturing is a well automated process taking place in a controlled environment, while construction is a labor intensive process often taking place in the open, exposed to weather and other external influences.

Manufacturing is serial production and construction is often a one-off production. In manufacturing, products are fabricated in high numbers (sometimes millions of similar pieces) and in construction usually only one product is created.

In manufacturing management, micro process controls are applied focused on single working steps or even single worker movements, while construction is typically managed more loosely with macro controls. In construction, several thousand assembly steps are needed to finish the product, while in manufacturing usually few assembly steps lead to the finished product.

<sup>1</sup> <http://en.wikipedia.org> 19:24 16.09.2009

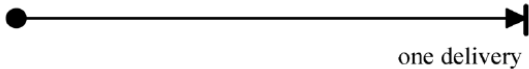
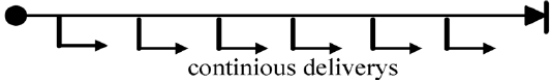
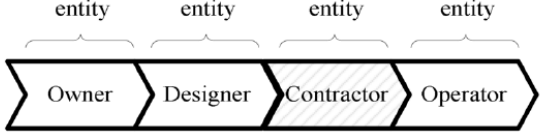
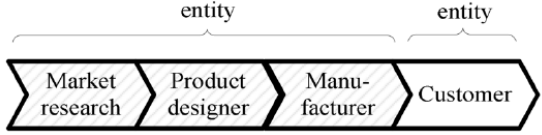



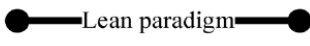
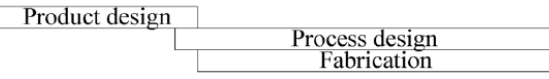
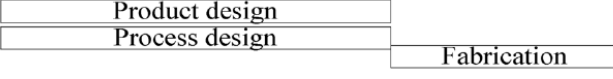


In manufacturing processes are planned before the fabrication starts. In construction process planning usually takes place during fabrication.

In manufacturing, product and process design is usually done within the same company/entity, while in construction the design and production are typically preformed by different entities e.g. Architects office and engineering offices vs. the contracting company.

The main findings of the comparison between construction and manufacturing are presented in the resulting Table 1-3.

**Table 1-3: Differences between construction and manufacturing**

<b>construction</b>	<b>manufacturing</b>
<p>1. Type of production</p> <p>projects</p> <p>One-off-serial production</p> <p>labour intensive industry/ low automation</p> <p>worker is moving to the work/ changing workplaces</p> <p>Predetermined total content</p> 	<p>1. Type of production</p> <p>continious/ steady state production</p> <p>mass production /off line- production</p> <p>less labour intensive /high level of automation</p> <p>work is moved to the worker/ fixed workplaces</p> <p>No planned end</p> 
2. Resources	2. Resources
variable resources	fixed resources
3. Type of Management	3. Type of Management
Project management	Production management
Project controls	Production controls
Lean production construction	Lean paradigm
4. Understanding	4. Understanding
is sometimes seen as manufacturing industry	manufacturing industry
5. Type of demand	5. Type of demand
Push- /demand	Pull- /demand
6. Key participants:	6. Key participants:
	
7. Key stages:	7. Key stages:
	
8. Lean construction implementation:	8. Lean implementation:
	
9. Long product Lifespan	9. Short product Lifespan
10. Design fabrication Interface	10. Design fabrication Interface
	

### ***1.3 Appreciation of Lean construction***

Lean construction is a very controversially discussed topic among scientists and practitioners.

The different camps:

1. Firstly, there is the camp of Lean construction supporters, like the 'Lean Construction Institute', a non-profit research organization founded in 1997. The founders were Ballard and Howell who are considered to be pioneers in this philosophy, supported by scientists like Koskela and others. This camp argues that conventional project management techniques are inappropriate tools to manage construction projects. They argue that despite the difference between construction and manufacturing Lean techniques can be successfully applied to construction.
2. Secondly, there is a camp of scientists and practitioners arguing that Lean is an inapplicable concept for construction management due to the very nature of the construction process and the significant differences between manufacturing and construction.
3. Lastly, there is a camp of scientists arguing that the criticism of CPM/MS Project is misplaced and problems in current construction management have nothing to do with inappropriate concepts and theories but rather with a failure of many practitioners to use CPM or PERT. They argue that >90% of users of tools such as Microsoft Project (CPM-based) do not know how to use it correctly and have no understanding of CPM and the rules that govern it (Birrell, 1980).

The different arguments:

#### **1. Some of the lean construction supporter camp arguments are compiled and listed here:**

Lean construction can significantly improve construction results: a better utilization of resources, improvement of productivity, efficiency and radically enhancement of value to the customer (Ott (2005)).

According to Koskela (1992), a senior researcher and leading theorist in lean construction management, the underlying theory in project management is flawed and project management techniques are not the best available approach to manage projects. Furthermore, he states that project management techniques can be counterproductive and create self-inflicted problems when used in complex and speedy projects. The main reason for this criticism is that the underlying theory does not deal with the production process itself, but is solely focused on inputs and outputs. Koskela recommends to improve theory and to implement concepts used in the manufacturing industry like the flow view of construction and the value generation view that are explained in the following chapters.

According to Koskela, the major drawback in current project management practice based on input and output transformations is that it might work in rational and ordered systems (like a minor construction project), but in complex and dynamic systems where it is hardly possible to create reliable plans, it does not seem to be working properly.

According to Bertelsen, (2004) military Management principles could be a source for inspiration in improving project management since war is probably the ultimate complex system in a management point of view and fighting cannot be managed in a detailed top-down approach. Freedman (2000) states, in his book about managing principles in the US



Marine Corps that one of the applied principles is: “Manage by end state and intent. Tell people what needs to be accomplished and why, and leave the details to them”.

## **2. Some of the lean construction opponent’s camps arguments are listed below:**

“Much energy has been expended over the last ten years in hypothesizing that a construction site should be viewed as a manufacturing facility. On this basis, industrial engineering methods have been applied to the analysis of construction operations. Indeed, manufacturing principles are the basis for concepts of production control and lean construction. These principles are valid in construction only to the extent that construction is like manufacturing. If important differences exist, then their application is like fitting a round peg in a square hole” (Thomas and Sinha (2002)).

Other concerns about lean construction in the camp of lean critics is that lean production is a movement driven by large construction clients seeking to extend their influence on the construction supply chain and that this fact has to be critically discussed.

“It is understandable that the large clients who support the Egan Report should wish to increase their control over the UK construction supply chain. That this control is in wider public interest has to date been taken entirely for granted. With very few exceptions, construction researchers have to date taken it for granted that lean production is a ‘good thing’... There have been few attempts to relate concepts such as lean construction to the broader social, moral and political context ... The articulation of a critical perspective on lean construction provides a small step towards correcting the current imbalance”

(Green (1999)).

## **3. Some of the ‘criticism of CPM/MS Project is misplaced’ camp’s arguments are listed below:**

CPM is the right tool often in the wrong hands or applied in the wrong situation.

Since the early days project management techniques have experienced consistent problems in their implementation and, it is repeatedly argued that the reasons for these difficulties are external to the method and imply that there is a lack of understanding and education. A recent research paper on the awareness of the EV method in Reykjavik states that it is evident that local construction managers are still unaware of major concepts in project management theory (Þorvaldsson (2008)).

In summary, many researchers are very optimistic about the potential of lean construction ideas to enhance construction performance while several scientists and practitioners have a more cautious opinion on this subject. It can be concluded that the optimistic view on the potential of this technique is predominant and very little that is negative is said about lean production construction.

### ***1.4 Aim and objectives of the research***

The goal of the thesis is to identify the potential value of lean production construction ideas for Icelandic contractors when examined at the project level. This thesis is an attempt to identify whether there is a basis for lean construction thinking within the Icelandic construction industry. The objective is to present the findings in a way that is valid and applicable for both companies and researchers.

The objectives of the thesis:

1. Determine the current appreciation of lean construction within the Icelandic construction industry.
2. Identify the basis of project management and tools used to control construction in the Icelandic construction industry.
3. Define a project controls' template aligned to the lean construction paradigm that could be used by Icelandic construction companies.
4. Assess the likely acceptance amongst Icelandic construction companies of the project controls' template.

Scope and Limitations of the research:

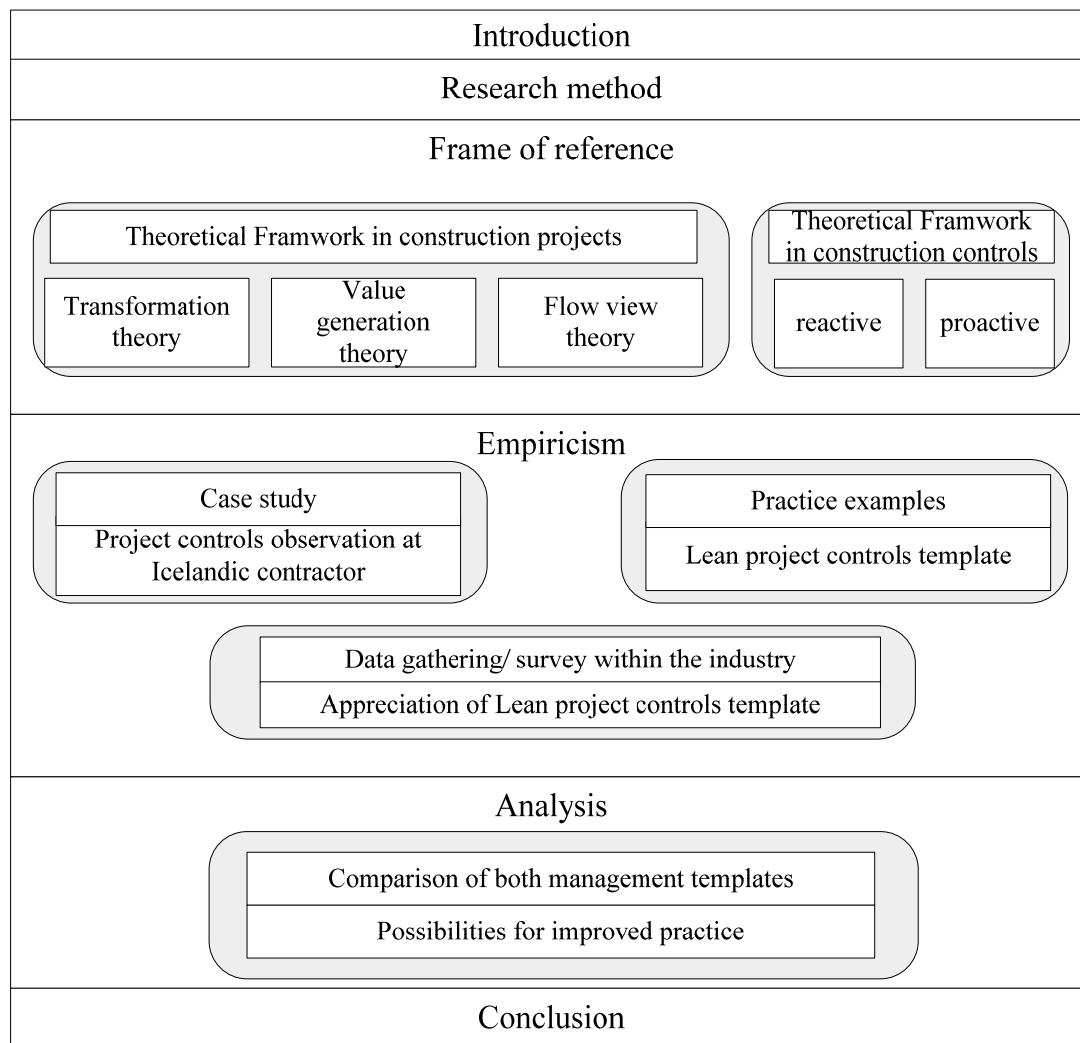
The author decided to restrict the research solely to project level implementation of lean production construction. The reason for this limitation is that Icelandic construction projects are typically procured in Design-bid-build contracts where the owner contracts separate entities for each design and construction of a project. In design-bid-build contracts the construction design has come a long way before the construction company is appointed. Ergo the people that have actually to execute the construction job are typically not or, only to a minor extent, involved in the product design.

This form of contracting reduces the possibility for an increased industrialization of construction processes since designs are typically driven by functional and aesthetical considerations rather than considerations about the construction process. To exploit the full potential of lean production construction the design has to be focused on increased modularization and facilitate possibilities for preassembly and outsourcing of construction activities away from construction sites into production facilities and so forth. To sum up, design has to be both product and process design to increase industrialization in construction. Nevertheless, lean production construction could yield potential for improvement at the project level. Therefore, this thesis is focused on an examination of the value of lean production construction at the project level.

A second limitation to this research work is that it is only conducted at a single Icelandic construction company, but this sample represents 9.33% of all construction activity in Iceland (excluding residential) see further explanations in chapter two. The reason for this limitation is the time constraint for the research work and, that the author regarded an in-depth investigation at the project level necessary to facilitate an understanding of the topic.

### 1.4.1 Thesis outline

This thesis follows the outline of an academic report with stating the frame of reference first, followed by executing the empirical work and, concluding with an analysis of the findings.



**Figure 1-2 Thesis outline**

Figure 1-2 shows the arrangement of the chapters in the thesis; the starting point is the research method statement. Then the frame of reference is given to define the theoretical background in construction projects, followed by a definition of the theories in control. In the following chapters, empirical information is compiled and arranged. The thesis concludes in analyzing the findings and giving a prognosis for future practice.



## 2 Research methods

*This chapter describes the research methods underlying this thesis. This chapter starts with classifying the research methodologies on which the research project is based and concludes with a description of how the practical research work is executed and which methods are used in the field.*

---

### 2.1 Introduction

It is very important for good research to clearly state how it is executed to help the reader understand what methodologies were used to construct the findings. Appropriately chosen research methods are important to guarantee knowledge creation and effective research. It is also vital to use research methods that are defensible and produce reliable and valid results.

### 2.2 Classification of the research project

According to Arbnor and Bjerke (1997) there are three different methodological approaches to gain knowledge:

- the analytical approach,
- the systems approach,
- and the actor's approach.

The methodological approach of this research thesis can be classified as Systems thinking approach. In system thinking the reality is represented by explanatory models. When conducting research on project controls, it is critical to understand that a construction project is a complex system of interacting cultural, economic, political, social and physical factors (Hughes (1991)). A way to make this complex system visible and understandable is to model the reality using explanatory models.

In research work based on systems thinking the consequences of using each approach in various practical and theoretical situations is examined. This thesis starts with a frame of reference presenting the underlying explanatory models in construction projects and controls. This thesis is based on three different explanatory models in construction projects (Transformation, Value and Flow) and two models for control (proactive and reactive).

These models are used to classify the current used project controls systems at an Icelandic contractor and Lean managed construction projects. The systems approach therefore helps to create a foundation to understand the underlying mindset in the different cases. The systems approach is a well suitable approach for this research because it facilitates a deep understanding of the theories in question rather than being just explanatory. This approach suits the study well since the focus of the thesis is to broaden and improve understanding of project controls.

In the systems approach a goal-means orientated study can be used to create knowledge. In a goal-means orientated study a goal or problem is identified at the outset and it is tried to eliminate the gaps between reality and goals. This thesis has a well defined goal, the methods of achieving which are also well defined. Thus, this thesis will be a goal-means orientated research work.

This research can most likely be regarded as hermeneutic research since the focus is merely to understand the reality than to be totally objective. The main purpose of hermeneutic research is to interpret and understand reality. Since this research uses Explanatory models it does not claim to be perfectly objective. The study has a focus on project controls theory, and the understanding is of more importance than the explanation.

### Conclusion/ type of study

The thesis has been defined thus far as hermeneutic study with a base in systems research.

#### 2.2.1 Reliability and validity of data collected

There exists two ways to collect data, there are primary sources, meaning new data is collected, and secondary sources of data, meaning the data has been previously collected by others. When collecting the data required for the research it is essential to consider the threats to research work. The data and information needs to be carefully selected so that it can be regarded as reliable and valid. The data collected needs to be reliable to make sure that the research, when repeated by others, leads to the same results. In this thesis the sources are carefully chosen to guarantee reliable work. Additionally, the data and information collected needs to be valid, meaning there needs to be an inner consistency in the thesis; the data collected has to be relevant to answer the research question.

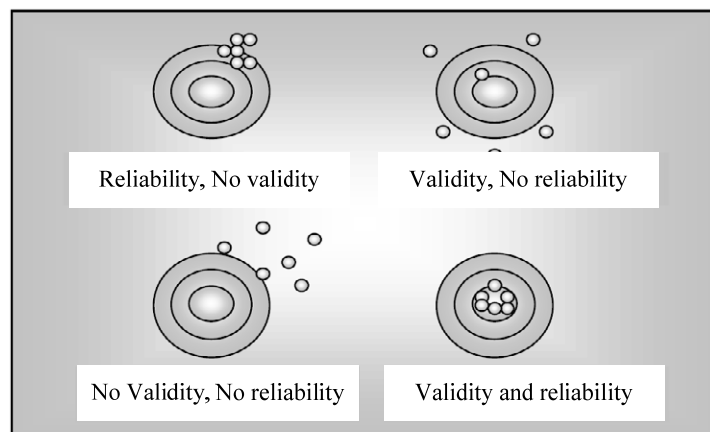


Figure 2-1 Validity and Reliability [Source: Varkevisser et al. (2003)]

#### 2.2.2 General research plan

This thesis will be executed using a general plan which is shown in Figure 2-2. This research starts with a real problem, which is current problems and difficulties in project management, and seeks to identify possibilities for improvement, which could be found in the mindset of Lean construction.

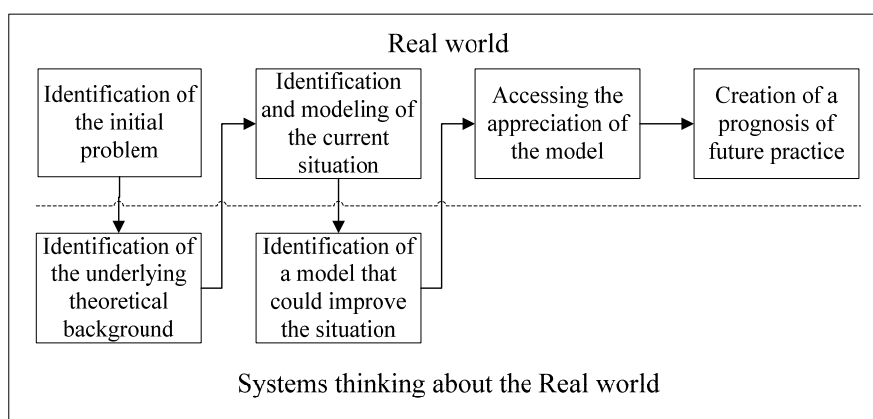


Figure 2-2 General plan of the thesis

## 2.3 *Practical Research Methods*

After having defined the Type of study it needs to be examined which practical research techniques are best suited to perform the actual research work. Since there are many factors and threads for the quality of a research it is of critical importance to think about how the work shall be performed at each stage of the research. The following chapter can be understood as a method statement for the research at its main stages: the frame of reference; the empirical work and the analysis.

### 2.3.1 **Frame of reference**

This Thesis is based on three main theories, the Transformation, Value and Flow view theory in construction (TFV), and on two theories of project control. The practical research work is to gather credible and sufficient information on these subjects. Literature research is executed by using Reykjavik Universities databases LIRU, other search engines and the RU Library. The main reference in the TFV Theory definition is Professor Koskela's work.

### 2.3.2 **Empiricism**

Here the research tools used to gather data at the empirical stages of the research are described.

#### **Case study Icelandic contractor Ístak:**

The research objective at this stage is to identify the basis of project management and tools used to control construction in the Icelandic construction industry.

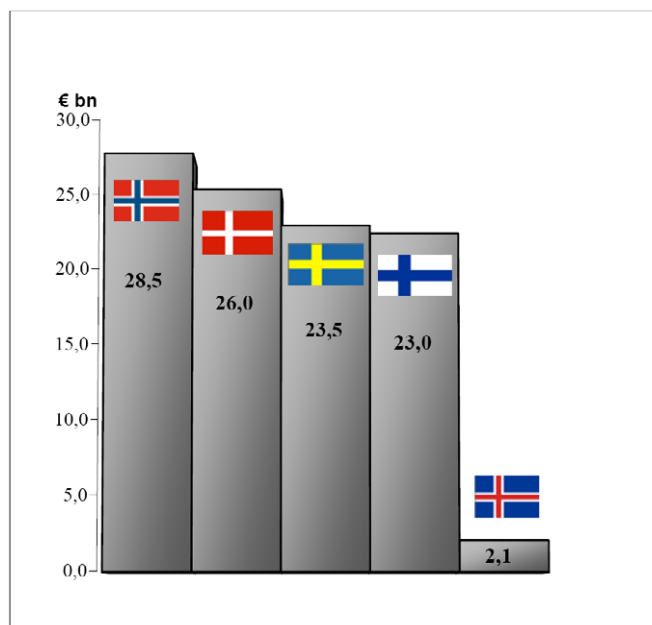
Case studies would be a suitable way to execute this inquiry. Case studies support the in-depth investigation of a certain complex phenomenon like a construction project controls system (Fellows & Liu 2003). The advantage of a case study approach is the opportunity to study the full complexity of a problem without simplification and additional assumptions. Case studies can be used for description, discovery and theory testing.

This research uses a case study approach to gather data. The case studied is the project controls system within the biggest Icelandic contractor. For the purpose of this thesis, it is of value to collect the data on the project controls system at the Icelandic contractor from an 'inside point' of view, to create an accurate portrayal of the phenomenon and to fully understand the working methodology of the project controls in use.

Therefore, this work will be produced by exclusively using primary sources. The data collected in this research are project controls templates and management tools used throughout the construction projects. When choosing the underlying case for a case study it is very important to consider whether the case can be regarded as a representative sample for the population. In the particular field subject to this research, the project controls at Icelandic contractors, it is very difficult if not impossible to find a valid sample to represent the entire population. The applied construction project controls can differ significantly between contractors depending on their knowledge, company size, strategies and field of activity.

But fortunately for this study the Icelandic construction market is considerable small. Its size when compared to the Nordic neighbour countries is shown in Figure 2-3. The value of the Icelandic construction sector for 2008 amounts according Statistics Iceland to a total of ISK 250 bn ~ € 2.1 bn (exchange rate: ISK 120 to € 1). This figure includes: civil engineering renovation, new civil engineering, non residential renovation, new non residential, residential renovation and new residential construction activity. Therefore, when

sampling the project controls practice at the largest Icelandic contractor it is possible to make a valid statement for 9.33%<sup>2</sup> of all construction projects in Iceland (excluding residential). Hence, the sample or case is regarded to be a sufficient indicator for wider project controls practice in Iceland.



**Figure 2-3 Construction output of the Nordic countries in 2008 in € bn**  
Source [Euroconstruct, Statistic Iceland (2009)]

### Practice examples / Lean project controls template:

The research objective at this stage is to define a project controls' template aligned to the lean construction paradigm that could be used by Icelandic construction companies.

A sufficient way to define this template would be to collect information on practical implementations of lean construction in the Industry outside of Iceland. For the purpose of this thesis, practitioners using Lean production construction techniques within their organizations will be contacted and asked to provide information on the techniques they are using. Additionally, to gather information on this topic, a foreign Lean construction institute will be contacted and asked to provide information about tools that could be used at project level. This work will be supported by a literature research, seeking to identify wider practice in Lean construction.

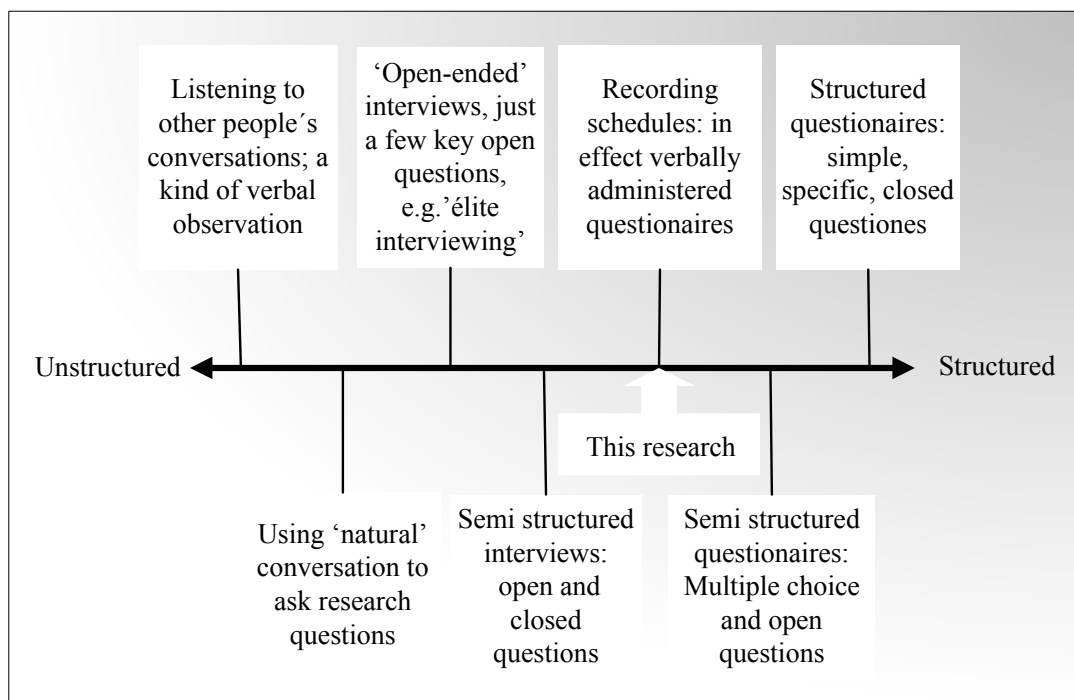
The sources are merely secondary information's collected from others. One problem with secondary sources is that they might not be trustworthy therefore the sources have to be carefully selected. The 'data' collected are project controls templates and management tools. The range of lean project control tools in construction is still considerable narrow since these ideas are rather new, therefore it should be possible to produce a state of the art template.

<sup>2</sup>The author assumes that typically one third of the entire building activities take place in residential construction. Based on this assumption the building activity in Iceland without residential construction amounts to c.a. € 1.4 bn. The contractor's turnover for 2008 was ISK 18 bn ~ € 0.15 bn (exchange rate: ISK 120 to € 1). So, Contractors market share in non residential construction in Iceland is 9.33%.

The research objective that needs to be covered here is to assess the likely acceptance amongst Icelandic construction companies of the project controls template. The data that needs to be collected for the purpose of the thesis has to be suitable to get acquainted with how practitioners appreciate the Lean construction techniques and ideas.

The author is fully aware of basic statistical concepts, and that the limited number of respondents could be source for criticism in the sense of statistical relevance. Nevertheless, limited numbers of respondents is regarded as sufficient for the purpose of this thesis since the main goal at this stage is to acquire acquaintance of the ‘likely’ acceptance within the industry and to examine an idea rather than deliver a statistically representative study.

The interviews are executed in a structured manner, meaning that all interviewees have to answer the same questions. Also, all interviewees will be introduced to the subject and key terms before they fill out a questionnaire designed to support the interview. Figure 2-4 highlights how the interview technique used in this thesis could be classified.



**Figure 2-4 Verbal data dimension of this thesis [Source: Gillham (2000)]**

**Questionnaire design:**

*“A crucial part of good research design concerns making sure that the questionnaire design addresses the needs of the research. To put this another way; somehow we need to ensure that the questions asked are the right ones. To move from the research aims to deciding what are the right questions to put on a questionnaire is a key aspect that needs to be addressed by the researcher” (Leeds (2009)).*

The questions asked to the interviewees have to reflect the line of inquiry underlying this research. Therefore, the questions are designed to identify the (1) Appreciation of Lean construction management tools within the Icelandic construction industry and, (2) to assess the likely acceptance amongst Icelandic construction companies of the project controls template.

The design of the questionnaire is typically done in three steps, firstly it is determined which questions to ask; secondly, the question type is identified and the wording is reviewed. Finally, the question sequence and overall questionnaire layout is finalized. The questionnaire in this research is designed using factual, knowledge and opinion (attitudes, beliefs...) based questions. The layout of the questionnaire paper is designed with special focus on creating a clear structure. The wording of the questions is carefully chosen to prevent the use of offensive questions. All questions are designed in a non threatening way to receive positive reactions and cooperation from the respondents. The questions are merely closed end questions and worded to receive straightforward and clear answers.

Different types of closed end questions are used throughout this questionnaire:

- Seven questions offering two choices, dichotomous yes/no questions were used in the questionnaire. All seven questions offered space for comments to enable the respondents to deal with qualification responses e.g. Yes, but... or it depends.
- Two questions offering three choices, e.g. multiple questions were used in the questionnaire. Also these questions offered space for comments to enable the respondents to deal with qualification responses e.g. Yes, but... or it depends.
- Two questions are offering the respondent to show his degree of agreement/disagreement with a statement. These questions use the Likert scale for assessment.

The sequential arrangement of the questions takes the logical course of inquiry into account; the respondent is asked basic questions about waste on the construction site and the questionnaire continues with more complex themed questions on Lean construction techniques.

To prevent the use of biased or leading questions and to insure the questions will be understood by the interviewees the questionnaire is piloted before used in practice. The full questionnaire used in this research can be found under Appendix A.

**Analysis:**

The research goal of this thesis is to identify whether there is a basis for lean construction thinking within the Icelandic construction industry. Therefore, the main goal of this analysis is to generate understanding of how the ‘phenomenon’ lean construction is appreciated within a relevant context, the Icelandic construction industry.

From a theoretical point of view, analysis in this research is a result of human interpretation of a phenomenon within a certain social context. The human interpretations of the lean construction ideas are collected and assessed by conducting interviews with Icelandic

construction site managers. Only after the interviews with the practitioners are conducted, will it be possible to analyze the findings and to draw conclusions.

Since the analysis has to lead to a valid conclusion the data, first and foremost, needs to be systemized and arranged to create clearness. After having made the data comparable it is possible to analyze and to draw conclusions. The analysis in this thesis is focused on identifying techniques which could possibly be used to improve project controls practice. Therefore it will be essential to present the main differences between the techniques using explanatory models to illustrate how they work, and to identify what could possibly be improved in current practice. Then a prognosis for future project control practice is given and recommendations for future research are made.





### 3 Theoretical framework in construction projects and control

*In this chapter, the three main underlying theoretical concepts in construction projects, their definition, origin and development are presented. Additionally, the two main concepts in control are presented. The basic ideas will be addressed. Key Theories discussed: Transformation theory - Value Generation theory - The Flow View theory - in projects Feedback theory and Feed forward theory in control*

---

#### 3.1 Introduction

The research objective at this stage is to identify the theoretical background of projects and control. The theories described here seek to establish the foundation for the research to come in this thesis e.g. project management and Lean production construction. There is much discussion these days about the theory of project management. This includes participation from many quarters, ranging from traditional approaches based on PMBOK to new approaches based on Lean construction concepts. A vast amount of research on the theory in projects and controls has been produced. The definitions and explanations presented in this thesis are largely based on professor Koskela's work. The theories in Project management identified for the purpose of this thesis are Transformation, Flow Management, and Value Generation theory. The Mechanisms for control presented at this point consist of Feedback and Feed-forward control.

#### 3.2 Transformation theory in construction projects<sup>3</sup>

*"As Gregor Samsa awoke one morning from uneasy dreams he found himself transformed in his bed into a gigantic vermin."*

(Die Verwandlung by Franz Kafka, first published in 1915 by K. Wolff, Leipzig)

##### 3.2.1 Definition

Production as understood in the Transformation theory is the transformation of one set of inputs into a second set of outputs. The inputs are labor, capital, machinery, material and business services and the output is a certain desired product. Regardless of its very basic form the 'box' in Figure 3-1 describes the essence of a Transformation process. The Transformation itself (in the 'box') has been subject to various research and arguments so it is rather difficult to give a single valid definition of this term.



Figure 3-1 Production as a transformation from inputs to outputs [Source: Grubbström, 1995]

---

<sup>3</sup> A project is a complex, non routine, one-time effort limited by time, budget and resources - ergo in the wider sense it is production.

An elemental principle in Transformation theory is the hierarchically decomposition of the process in sub processes until the lowest manageable level or work package is defined. These sub processes are regarded as transformation processes with inputs and outputs.

### 3.2.2 Production functions<sup>4</sup> -Mathematical Concept

The Production functions provide the main mathematical framework in Transformation thinking. This chapter presents the mathematical formulation and a short description of the most important concepts.

#### Wicksteed's production function

The relationship between inputs and outputs can be expressed by Wicksteed's Production equation. Wicksteed states a linear relationship between inputs and outputs, meaning when doubling the inputs the outputs are as well doubled. The assumption of linear relationship implies that an input substitution is impossible (Mishra (2007)):

$$Q_{output} = f(x_1, x_2, x_3, \dots, x_n) \quad (1)$$

where:  $Q$  = quantity of output

and  $x_1, x_2, x_3, \dots, x_n$  = factor inputs

#### The Cobb-Douglas function

The Cobb-Douglas function is based on Wicksteed's function. The main difference is that Cobb-Douglas includes constants in their equation that create the possibility for input factor substitution (Grubbström (1995)):

$$Q_{output} = a + x_1^{a_1} + x_2^{a_2} + x_3^{a_3}, \dots, + x_n^{a_n} \quad (2)$$

where:  $Q$  = quantity of output

and  $x_1, x_2, x_3, \dots, x_n$  = factor inputs

and  $a, a_1, a_2, a_3, \dots, a_n$  = constants

### 3.2.3 Hierarchically decomposition - Concept

One of the main underlying concepts in Transformation theory is to decompose a product or project into assemblies and subassemblies of various categories in a logical way. The required input resources are identified and assigned to each assembly stage. This chapter describes different approaches to doing so. The models introduced in this chapter are rather practical templates than well-established theories.

---

<sup>4</sup> In economics, a production function is a function that specifies the output of a firm, an industry, or an entire economy for all combinations of inputs.

### Product Graph (P-Graph)

Derived from the production models is the Product graph (P-graph) a sample is shown in Fig.2-2. The principle idea in this P graphs is to breakdown the transformation process into sub-processes, which are also regarded as transformation processes. The P-Graph represents the structure of a process system. In this graph, the assembly steps are indicated by horizontal bars and their input and output materials by solid circles. This form of presentation makes it possible to split a process into sub-processes and show which inputs are required at what stage. This form of presentation makes it also possible to indicate the sequences in a process.

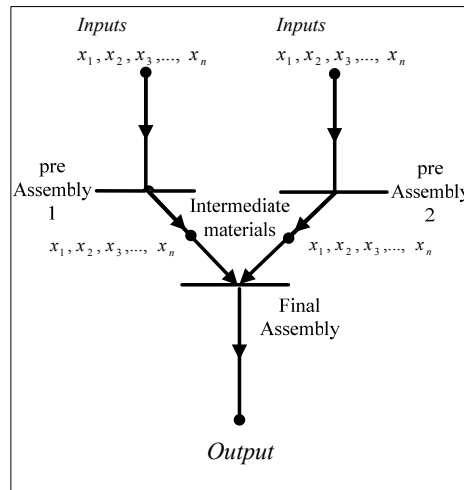


Figure 3-2 Production Graph

### Bill of materials (BOM)

The Bill of Materials (BOM) is a list explaining how a product is made up, it lists components and sub-components required to complete the product. BOM's describe the logical relationship between components in a process, but they do not give information about the process sequence.

<b>Intended BOM</b>	
<b>Product 1</b>	
Component 1.1	
Component 1.1.1 – resource 4pcs	
Component 1.1.1.1 – resource 2 pcs	
Component 1.1.2 – resource 3pcs	
Component 1.1.3 – resource 3pcs	
Component 1.2	
Component 1.2.1 – resource 3pcs	
Component 1.2.2 – resource 3pcs	
Component 1.2.2.1 – resource 2 pcs	
Component 1.2.3 – resource 3pcs	

Figure 3-3 Bill of materials

A sample intended BOM is presented in Figure 3-3. Each level in an intended BOM requires a certain process to be completed. The Item with the highest intent represents the final product. The BOM indicates which resources like e.g. labor, material, plant and equipment are required at what level in the process.

### Product structure tree or Work breakdown structure (WBS)

The probably best instrument for a visual description of a production process is the Product structure tree also known as Work Breakdown Structure (WBS). These structures explain how many and which assemblies are required to complete the next higher-level tasks in the production chain.

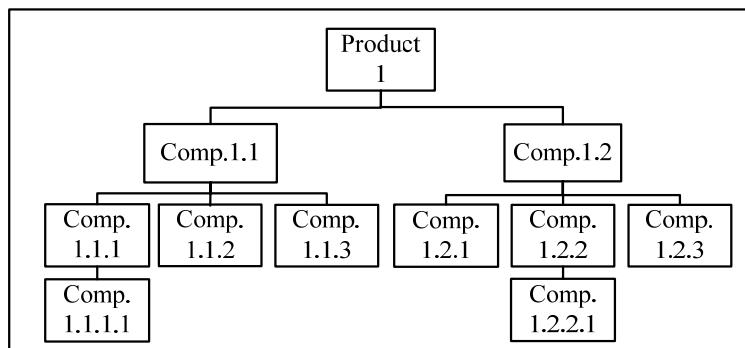


Figure 3-4 Product structure tree

### 3.2.4 Production involving time - Concept

It is widely recognized that each production task consumes time from initiation to completion. The following model is theoretically supported by the Cobb-Douglas production function when including an input factor for time.

#### Gantt chart

The most common template to model the interdependencies of production tasks and time is the Gantt chart. These charts contain the time factor on the x-axis and indicate the production tasks on the y-axis. Gantt charts usually include information about single tasks like task name, task ID, start and finishing times based on the Work Breakdown Structure of the project. Gantt charts can be used to show the dependency and relationships between activities, as well as, to visually communicate information's about the current schedule status of a process. Additionally, they are often used to visualize the most critical tasks on the way to process completion; these charts are a powerful tool for critical path management (CPM).

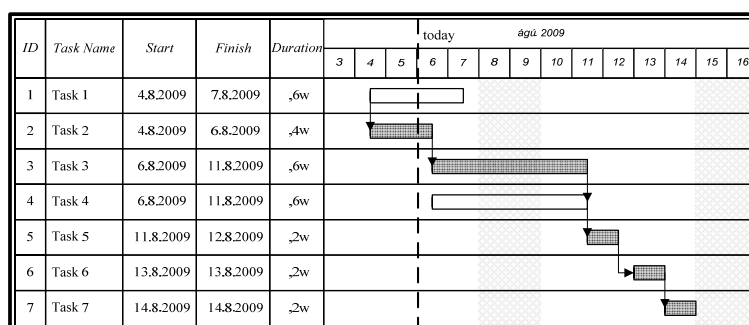


Figure 3-5 Gantt chart

### 3.2.5 Development of the Transformation theory

The transformation theory of production originates in the 18th and 19th centuries within the field of classical economics. In the agricultural society of the late eighteenth century, questions about production factors like land use, labor and capital and their interrelationship arose. These questions triggered the development of production theories. The point of departure for the Transformation theory was agricultural production (Grubbström (1995)).

The way of thinking, in those times, focused on gaining skills and knowledge to maximize the output of agricultural operations.

Smith (1776) gave a very early reasoning about the relationship between input and outputs and decomposition of processes. Smith wrote about a Pin maker manufactory that could generate production advantages when splitting processes into sub-tasks. The evolution of the Transformation theory started with the ideas of Smith (1776) and concluded in the 1930s with the development of production functions for manufacturing. Classical economists like Walras (1874), Wicksteed (1894) and Leontief (1928) developed the production functions at the turn of the twentieth century.

Menger (1871) was one of the first scientists to identify a logical scheme for classifying products into various categories depending on their position in the production chain. Menger classified the finalized products as “goods of first order” and factors entering the production as “goods of second order” and so on (Grubbenström (1995)).

Shortly after Menger’s (1871) discoveries, the concepts were put into action and models dealing with the practical engineering context emerged. These models are, for example the P-Graphs, R-graphs, WBS, BOM and the Gantt charts, all these models have in common that they describe the logical relationship of components in a process and all of them are used to define processes inputs at each stage.

Both the production functions and the hierarchically decomposition of processes and their interrelationship can be seen as the management basis in the Transformation theory. In the terms and wording of modern Project management, which is largely based on the ideas of Transformation theory, the activity of identifying assembly steps on the way to a finalized product is called Scope definition. According to Turner (1993) “without scope there is no project...scope management is the principal project objective”. According to Kerzner (1988), scope equals the work to be done and therefore the outputs of a project.

### **3.2.6 Transformation theory in construction**

According to Koskela and Howell (2002), the underlying theory of today’s construction project management is based on the traditional Transformation theory of production, which has dominated production thinking throughout the 20th century. Transformation theory in construction is focused on defining the scope of a project and delivering according to it, taking care to do the necessary things (Ballard, (2000)).

Today, many practitioners in the construction field use models established in the mindset of the Transformation theory. These models are typically highly deterministic and based on techniques like CPM, the Gantt chart and WBS. The models are used to construct cost estimates, and to forecast and evaluate economic performance. Cost management in the context of the Transformation theory is understood as minimizing the cost of each decomposed part of the construction project.

Transformation models are very successful in construction because they provide planners with the possibility to sufficiently model reality and they enable users to analyze and control projects in an easy way (Koskela, (2000)).

The concepts are communicated through institutions like the PMI and IPMA offering training to professionals based on Project Management guidelines like the Body of Knowledge (PMBOK). Moreover, governmental standards e.g. PRINCE2 in the UK are widely accepted and provide knowledge on Project management.

## Transformation management procedure

The actual techniques focus on delivering project objectives by defining activities, setting up activity sequences, estimating the inputs like durations and required resources. There is equal focus placed on setting-up project network, monitoring and comparing set goals against actual performance (Gray and Larson (2008)).

Most important methods and practices used throughout the project stages are:

i. Defining the project scope	Tool: Product structure tree / WBS / BOM
ii. Assigning responsibilities	Tool: Organization breakdown structure (OBS)
iii. Assigning/ Estimating cost	Tool: WBS / BOM
iv. Planning the durations	Tool: Gantt chart / Network
v. Assigning resources	Tool: Resource profile /plan based on Project Network/ Gantt chart with resources
vi. Managing time/ risk	Tool: Gantt chart / Critical Path Method / PERT
vii. Monitoring performance	Tool: thermostat model
viii. Reporting performance	Tool: Earned Value analysis (EV)

### 3.3 Value generation theory in construction projects

*“The Value Methodology is a systematic process used by a multidisciplinary team to improve the value of a project through the analysis of its functions. Value is defined as a fair return or equivalent in goods, services, or money for something exchanged”* (Save, 2007).

#### 3.3.1 Definition

Production as understood in the Value Management theory is an effort undertaken to create and deliver a product of maximum value for the customer. The aim of Value Management is to find the best balance between satisfying the needs of a customer and the resources required to achieve them. In Value Management, methods and tools are applied to turn subjective customer expectations into measurable and manageable value objectives.

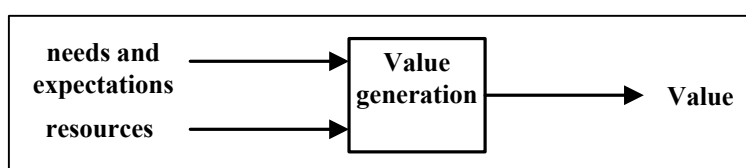


Figure 3-6 Production as value generation

#### 3.3.2 Value score functions - Mathematical Concept

The Value score functions provide the main mathematical framework in Value thinking. Customer's value judgment can be assessed using the Value score functions. This chapter presents the mathematical formulation and a description of the most important concepts.

### Value score function

The Value score model is the key instrument in systematically value assessment. This model helps evaluating the client's opinion of a certain product characteristic. The idea is to assign a Value score  $V_i(x)$  to a given attribute  $x$ . The results of this assessment can be presented in a value score function. A sample Value score function is shown in Figure 3-7 here value scores ranging from 0-1 are assigned, where 1 indicates a very high value for the customer and 0 indicates no value contribution.

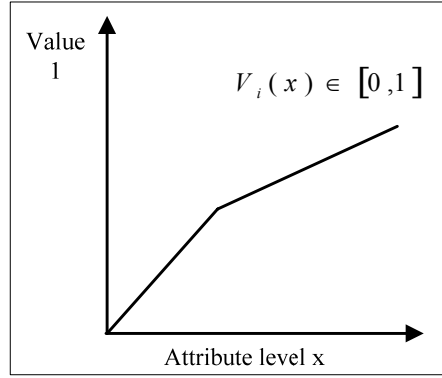


Figure 3-7 Value function

### Overall value of a project

A product or project usually consists of multiple attributes. Now assumed each of these attributes has an corresponding value score, the total score for the entire product or project can be determined by calculating the sum of all attribute-specific value scores.

$$V(x) = \sum_{i=1}^N v_i(x_i) \quad (1)$$

When certain attributes are of higher importance to the customer than others, they can be weighted by using a factor. The total weighted value of a product or project consisting of several attributes  $X_i(a) = x_i \ (i=1..n)$  can be identified by using the following equation:

$$V_1(x_1, x_2, \dots, x_n) = \sum_{i=1}^n w_i v_i(x_i) \quad (2)$$

Where:  $w_i(x_i)$  = relative weight of the attribute  $x_i$

### Value for money (VfM)

The Value for money concept is a comparison between the money spent for a product or project versus the return of value to the customer. The VfM concept compares a value score to the investment. VfM may be represented by the expression (OGC 2007):

$$value = \frac{benefits}{investment \ (price)}$$

“Value is always increased by decreasing costs (while, of course, maintaining performance). Value is increased by increasing performance if the customer needs, wants, and is willing to pay for more performance” Miles (1989) on VfM.

## Overall VfM of a project

In the theory of VfM, the total costs of a construction project are distributed to its individual components. For each alternative combination of components, the total benefit (for the client) can be found based on the sum of the values of the different functionalities. According to theory, each total benefit for a client corresponds to a certain investment (price) and their interrelationship is highlighted in Figure 2-9.

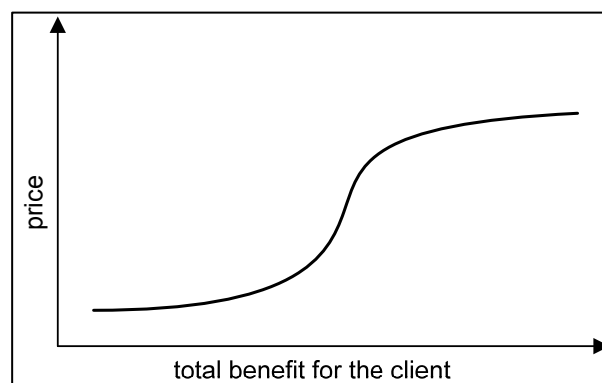


Figure 3-8 Benefit corresponding to price in VM

## Functional breakdown structure

A functional breakdown structure can be used to model the value of a product and to visualize which product aspects are of importance to the client.

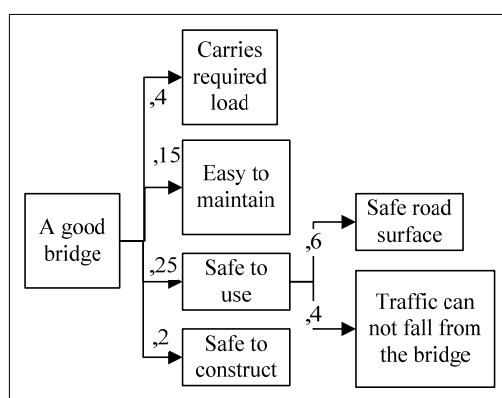


Figure 3-9 Functional breakdown of a bridge

[Source: Madigan, D. (1996)]

### 3.3.3 Development of Value generation theory

The Value Management (VM) theories originate in the manufacturing industry. The theories can be traced back into the 1940s where Lawrence D. Miles, at that time purchase manager at General Electric, realized that a systematical methodology to manage value and related technical innovations could lead to a competitive advantage for General Electric in its market field. The Concepts of Value Management soon gained popularity in the U.S. and in the mid 1960s; they were recognized by Europe's manufacturing industry. In the 1960s, Germany's VDI (engineering research association) was among the first to issue Value Management standards for manufacturing industries (DIN 69910). The German Value Management standards have continuously improved over time and instructions for implementation have been identified and standardized within [VDI 00, VDI 95] codes.

The construction industry discovered the potential of these ideas in the early 1960s and since that time, Value Management ideas were applied on a significant number of



construction projects in several countries (Norton and McElligot (1995)). In contrast to the manufacturing industries, it was not before 1988 that Kelly and Male (2001) started to develop a systematically theoretical framework for the implementation of Value Management in construction.

Nowadays, methodologies in construction VM have become well established in the sense of maximizing value for money. According to the OGC (2007), there are techniques available that can be applied to any type of construction project throughout all stages of the projects lifecycle from inception to completion. The OGC supported their thesis by reporting on several case studies conducted on various construction projects where VM had been successfully implemented.

In the light of tough time scheduling, limited resources, limited awareness of concepts, and pressure from clients for shorter VM studies in the construction sector (Kelly and Male (2001)), VM is not often granted the attention necessary to make it an efficient tool. Recent research on VM practice in the AEC sector suggests that even though it is of prime concern for the construction sector to deliver what the client wants it is still uncommon to exercise VM studies.

The latest research on construction VM is directed at optimizing the VM process, in order to shorten the required time, while at the same time improving efficiency. Other research concentrates on the identification of success factors in VM to focus the process on solely addressing relevant issues.

#### **3.3.4 Value generation theory in construction**

The primary goal in construction is to deliver a satisfactory project that is of value to the customer. To guarantee best value for the client the entire building process has to be driven by value thinking. Establishment of value parameters right at the outset of the project (Value design) is of critical importance. Equally important is consequent monitoring of value performance and eventually a readjusting of the original value parameters. Normally, the client has a relatively good idea of which overall objectives or key values should be achieved by the development. Several areas of key concern for a client in the AEC sector are listed below.


**Key value parameters for a client in the AEC sector are:**

i. fit for purpose	the facility supports planned business operation
ii. Capital cost (CAPEX)	the procurement costs for the building are according to expectations/ in-between the limits
iii. Operational cost (OPEX)	The facilities LCC are according to the expectations
iv. Aesthetic	The aesthetics meet client expectations
v. Time	The structure is completed within a certain time frame
vi. Resale	The structure can be sold at estimated value
vii. Soft value	communication, conflict solving, ethics, creating professional working environment for participants
viii. Safety	the project has to be executed in a safe manner (product and worker safety)
ix. Environment	prevention of unexpected significant critical environmental, social or economic impacts
x. Uncertainties /major risks	The risks throughout the development should be at an acceptable level (depends on how risk averse a client is)
xi. Carbon management	carbon emissions have to be at acceptable level
xii. Taxation	maximize the benefits from tax regulations
xiii. Financing	the financing of the project is of key concern for the client
xiv. Exchange rates	The exposure to exchange rate risks has to be minimal

**Value Management procedure**

VM is a systematic process based on a consensus finding between Key stakeholders of a project. The process works top-down, once the key value objectives of the project are established in context with the client's wider business strategy there has to be a VM procedure in place that makes sure that these objectives are achieved. VM is usually executed as a series of workshops at key stages throughout a projects lifetime. A functional breakdown structure can be used to model the value of a certain project.

### 3.4 Flow View theory in construction projects

*“All we are doing is looking at the time line from the moment the customer gives us an order to the point when we collect the cash. And we are reducing that time line by removing the non-value-added wastes.”*

(Ohno, founder of Toyota production system TPS (1988) on the flow theory)

#### 3.4.1 Definition

In Flow View theory, production is understood as a flow of material, labor, equipment and information. The flow begins with the acquisition of raw materials and ends with a finished product. In Figure 3-10 a sample production process as understood in flow theory is presented. A sequence of activities consisting of moving, waiting, processing and inspecting is used to describe the production process over time. In contradiction to the Transformation theory of production, the Flow theory takes notice of what is happening between the transformations. To be precise, the wasteful activities between the actual products processing, described as moving, waiting and inspection, are identified. These non value adding activities are commonly referred to as waste or non value adding work.

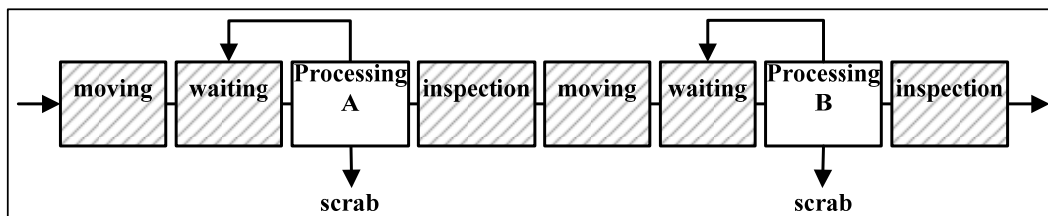


Figure 3-10 Production as a flow process shaded boxes are non value adding activities

[Source: Koskela, 2000]

#### 3.4.2 Eliminating waste - Concept

One of the main concepts in Flow Management theory is to reduce or eliminate wasteful and non value adding activity in a production process. The goal is to create optimal production, understood as flow of only value adding activities, without any interruption. According to this concept, the efficiency of a process depends entirely on how sufficiently waste is eliminated and how efficient the value adding activities are executed. This chapter presents the most important types of wastes in production and gives a short overview of main characteristics and sources.

#### Types of waste and non value adding work

To be able to reduce waste efficiently, it is necessary to identify wasteful activities and their sources. A systematical approach to sort and categorize waste into classes allows focused waste elimination. According to Ohno (1988), one of the world's leading experts on manufacturing practices at Toyota, the world's most profitable automaker waste can be classified into three general groups:

Muri (jap. 無理) or overburden	is unnecessary or unreasonable work done because of poor work organization, this type of work can be pre-vented by appropriate proactive planning. Leads to downtime, mistakes, backflows and waiting
------------------------------	---

Mura (jap. 斑) or unevenness	is uneconomic work due to high fluctuations in the processes, this can be prevented by appropriate work flow design and implementation (smoothing the resources and processes)
Muda (jap. 無駄) or un-useful	is work that interrupts rather than adding value to the process. Organizational and strategically methods can be applied to manage waste.

### The eight classes of Muda:

The waste type ‘Muda’ can be divided into eight subcategories. Seven of these categories were originally defined by Toyotas Ohno (1988) and one category was later added by Womack, Jones (2003). The classes of Muda waste are:

- I. Movement unnecessary empty walks of people or unnecessary equipment moving
- II. Transportation moving materials around that are not required in the process
- III. Inventory all goods that are stored at any time during the process cause unnecessary inventory costs
- IV. Waiting waiting for materials at the next production step
- V. Overproduction producing goods not required by the client
- VI. Over Processing working hours created by using wrong tools and equipment
- VII. Defects The work involved with identifying defects and the effort to fix them.
- VIII. Not meeting value producing goods that don’t meet clients demands (added by Womack and Jones (2003))

### Reducing lead time – Concept

An elemental idea in Flow Management theory is to reduce the Lead-time by eliminating unnecessary or ineffective used working time. Lead time in a production process can be described as the amount of time needed from initiation of the work to the completed product. According to Koskela (2000), Lead time can be represented by the following equation:

$$T_{Leadtime} = t_{processing} + t_{inspection} + t_{moving} + t_{waiting} + t_{redoing} \quad (1)$$

Equation (1) defines the total lead time as the sum of processing time, inspection time, moving time, waiting time and redoing time. According to Berliner and Brimson (1998), who preformed a series of productivity measurements in various US companies, effective processing time only amounts to 10% of the lead-time. Consequently, it can be concluded that 90% of the Lead-time is spent on activities that do not add value to the product. Therefore, a focus on Lead-time reduction holds big potential for cost savings. The ultimate goal is to reduce the Lead-time so that what is left is only value additive processing time (compare Figure 3-11).

$$T_{opt. Leadtime} = t_{processing} \quad (2)$$

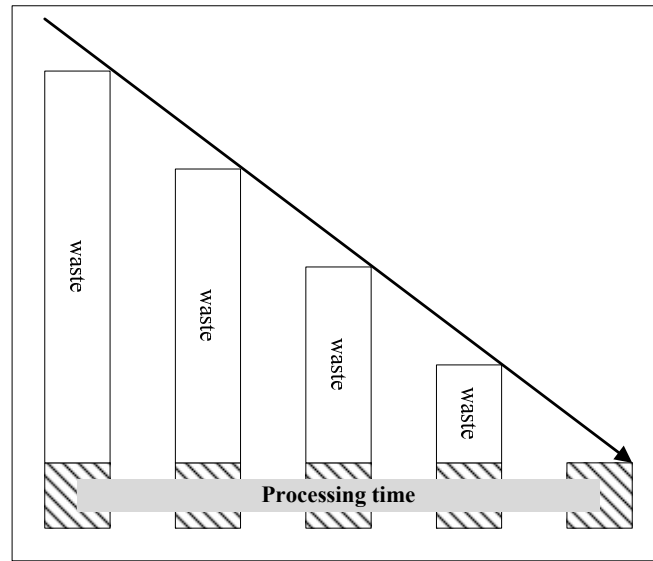


Figure 3-11 Reduction of non value adding activities  
[Source: Koskela, 2000]

### Little's Law and lead time reduction

A second approach to control lead time was identified by Little J. D. C. (1961). Little defined a law in the area of manufacturing management relating lead-time to input-rate and units in production. His theorem is represented by the following equation:

$$L = \lambda W \quad (1)$$

Where:  $L$ = Work in progress;  $W$ = Lead time;  $1/\lambda$ = input rate

Now the formula is shifted around to insulate  $W$  (the Lead time)

$$W = L/\lambda \quad (2)$$

Since Little's law holds true in steady state systems, the following statement holds:

$$\text{Lead time} = \text{Work in progress} / \text{output}$$

From this, it can be concluded that when reducing the amount of work in progress, while keeping output constant, the lead time can be reduced.

### Why reduce lead-time?

Hopp et al. (1990) stated that shorter lead time is beneficial in regard to:

- I. Faster delivery of the product
- II. Reduction of need for forecasts about future demand
- III. Improving quality management by reducing the opportunity for work to be damaged
- IV. Shortening the time between manufacturer and defect detection
- V. Decreasing of disruption of the process due to engineering change orders
- VI. Allowing easier overall management of the facility because there will be fewer jobs to keep track of

## How to reduce lead-time?

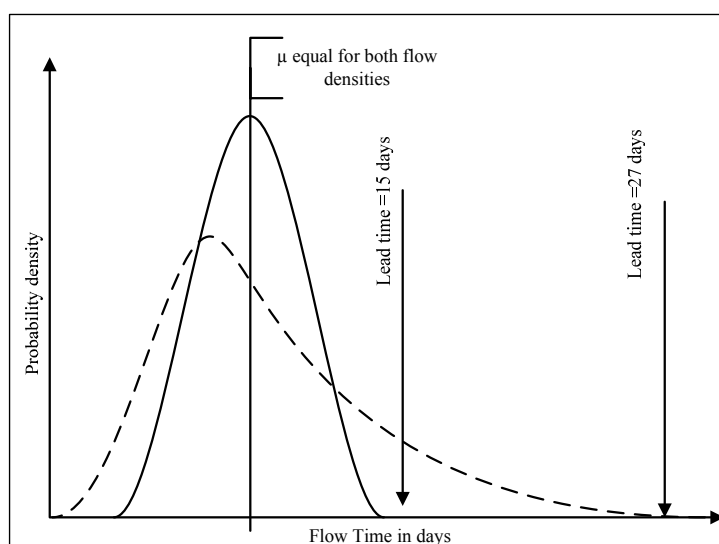
In the following paragraph, some broad recommendations for efficient lead time reduction are given. The list is not complete, but it should be sufficient to highlight how lead time could be reduced.

- I. **t (redoing)** redoing of work can be eliminated by producing the goods in required quality form the outset – it is necessary to have an excellent quality system in place to save time in redoing.
- II. **t (waiting)** waiting time occurs due to imbalances in the process/ A well organized supply chain and well balanced arrangement of working activities reduce waiting time
- III. **t (inspection)** the inspection time can be shortened by implementing and optimizing quality surveillance routines (automatic quality systems in manufacturing)
- IV. **t (moving)** the time consumed for moving materials and people can be reduced by arranging and sorting materials in a way that transport ways are minimized

### 3.4.3 Reducing variability in lead time - Concept

Variability as understood in production theory is the random variation in the processing times or arrival of inputs (Koskela 2004). According to Hopp et al. (1990) lead times depend on the variability associated with flow time and not average flow time alone.

Figure 3-12 shows two different flow time densities with equal  $\mu$  (means) while having different  $\sigma$  (standard deviations). In the flow with the smaller deviation, 99% of the processes are finished within a lead time, shorter than 15 days.



**Figure 3-12 Two densities of flow time with unequal variance**

[Source: Hopp et al., 1990]

In the second flow with the bigger deviation, 99% of the processes are finished within 27 days. These two cases highlight that it is not only necessary to shorten the Lead time but also to control and eliminate the variance in working processes.

### Why reduce variability?

High variability in the Processes can lead (based on Little's Law) to increased WIP, reduction of the output, long lead times and so forth. The process variability within a flow process must be reduced by eliminating the roots of its causes. Hopp et al. (1990) recommend reducing the amount of rework (due to unacceptable quality), improving machine reliability and improving supplier and supply reliability to minimize process flow variability.

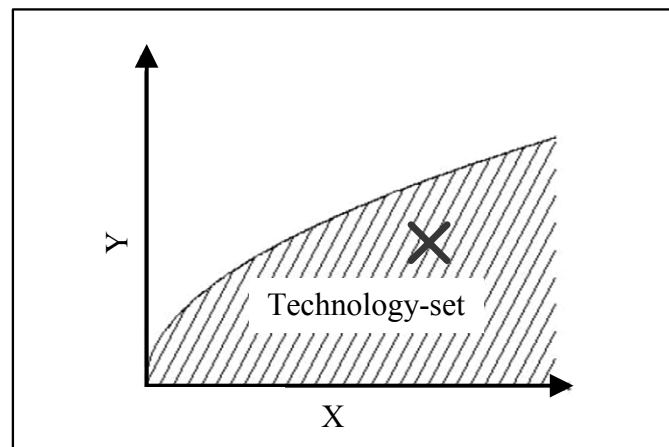
#### 3.4.4 Simplicity - Concept

Simplification in production can be understood as a reduction of components or assembly steps in a production process to improve performance. Any improvement in production starts with an accurate analysis of the production processes in place. Based on the findings, potential for simplification can be identified. Simplifications in production can yield great potential for both time and cost savings. Additionally, the risk of process failure stemming from complex processes can be reduced. Subsequently, it might prove essential to monitor new technological opportunities, available labor resources and the entire institutional environment for possibilities to simplify and improve the current production techniques.

#### 3.4.5 Technical Efficiency or X-efficiency - Concept

Technical Efficiency is the effectiveness with which a company uses inputs to produce outputs. According to Leibenstein (1975), a firm that is producing the maximum output possible based on the resources it uses (labor, plant, and technology available) works technically efficient or x-efficient.

The Technical Efficiency of a production process can be described by the technology-productivity function. The technology-productivity function illustrates a theoretical optimum for a production process based on the set of technology resources used. Figure 3-13 shows a sample of a technology production function. The cross indicates a production point (a specific production process) defined by the available technology set its specific output amount  $y$  and its input amount  $x$ .



**Figure 3-13 Technology set and production function**

[Source: Cantner, et al., 2007]

A production process is regarded as effective when the following two statements hold true (Cantner et al. (2007)): (a) No production point exists, that returns an higher output  $y$  (maximum principle), while keeping the input level  $x$  constant and, (b) no production point exists, that requires for the production of a certain output  $y$  a smaller amount of Input  $x$  (minimum principle)



### 3.4.6 Transparency – Concept

Processes should be transparent, and visual to achieve control in production. A set of tools e.g. visual control systems can be established to create transparency in production. According to Liker (2004) the elemental idea of a visually control system is to make abnormalities in a production process visible at once. The first step on the way to transparency is to tidy the workplaces in the production chain up. Both office workplaces and production workplaces need to be tidy and well sorted so that tools, equipment and materials can be found immediately. A systematical approach to tidy work places up is the Japanese “5S program”.

The five S’s are (Liker (2004)):

- |                                |  |
|--------------------------------|--|
| I. Sort                        | Sort through the items and keep only what is needed                      |
| II. Straighten (orderliness)   | A place for everything and everything in its place                       |
| III. Shine (cleanliness)       | cleanliness as an inspection process preventing machine failure          |
| IV. Standardize (create rules) | Develop rules to maintain the first three S’s                            |
| V. Sustain (self-discipline)   | Maintaining the system as an ongoing process of continuously improvement |

Once the workplaces are tidy, visible control can be implemented. Visible control starts with communicating time schedules and other control instruments to make abnormalities and delays in operations known at once. Visual control goes beyond capturing deviations from a chart; it should support the employees with real-time key information’s about the activities they are performing and, help them to understand when something is missing. According to Liker (2004), applying visual control can reduce errors, defects and injuries and lead to a stable production flow.

### 3.4.7 Development of the Flow View theory

The Flow View of production theories originate in early industrial engineering. Frank and Lillian Gilbreth (1922) were the first to formulate a scientific framework in this theory. The Gilbreths carried out experiments in the field of work sampling and conducted research to optimize process times.

Henry Ford (1922) was first to apply the flow concepts to mass production in his factories. His invention of the conveyor belt is probably the best know innovation in this field. Ford’s production concept was subject to wide interest; however, the template provided by Ford was generally misunderstood and seen as a model belonging to the mindset of transformation theory thinking (Koskela (2000)).

The idea of a ‘Flow View in production’ lived on in Japan, and it was not before thirty years later at the end of World War II that these theories were developed further and actually put into action. Japan’s Toyota was the first company worldwide to implement an entire production strategy based on the ideas of Flow View theory. Their production model was developed by Ohno (1988). The idea in Flow View theory was to achieve a continuous production flow by adopting monitoring measures for each process phase, aiming to reduce inventories and to reduce wastes in the process activities that do not add value to the final product. This strategy made Toyota’s production model superior to the production models widely used in the western societies. Outside of Japan, the understanding of the Flow View production approach was very limited and it was not before the mid seventies that these production ideas started to attain recognized in Europe and the United States (Koskela



(2000)). Since the early nineties, Flow View concepts have emerged as new mainstream concepts in manufacturing.

### **3.4.8 Flow View theory in construction**

The construction industry recognized the potential of the Flow View theory not before the mid nineties. The evolution of Flow View theory in construction started with the first groundbreaking research work produced by Koskela in 1992 where he challenged the construction management society to rethink the time-cost-quality tradeoff understanding of construction. Ballard and Howell started to discover the potential of Flow View theory as time management tool starting in 1994. Koskela (2000) and Ballard et al. (2001) formulated the fundamental principles for implementation in construction at the turn of the new millennium. Flow View theory in construction industry is to a great extent an adaption and implementation of the Japanese manufacturing principles within the construction process, taking the special nature of construction projects into consideration (Bertelsen, (2004)).

Today, Flow management ideas have been tested and applied on a significant number of construction projects. Tools and guidelines for practical implementation in construction have been identified.

Most practitioners in the construction industry did not yet recognize the full potential of the ideas in flow view theory and the biggest hindrance is a mind-set that lean thinking does not work in construction. The critical point is to understand construction as a project based production where the product is generally a prototype.

Research and conducted case studies show great potential for cost savings by implementation of flow view thinking and, according to Sowards (2004), those contractors that have already implemented lean working principles beat their estimates and work to continue to beat them. According to Sowards (2004), the priority for all construction work as understood in the flow view theory is to:

- I. keep work flowing so that the crews are always productive installing product
- II. the work has to be made ready every day and anything that is impeding the crews must be eliminated
- III. reduce inventory of material and tools
- IV. reduce costs

According to Bertelsen (2004), improving flow in construction may not only reduce the time wasted on waiting, but it may also reduce to cost of the building material. Bertelsen refers to a Swedish study implying that one third of the entire building material cost is related to handling, storing, packaging, transporting and getting rid of the packaging.



The primary goal in the flow understanding of construction is to generate a production flow that minimizes the waste of materials, time and effort (Koskela et al. (2002)). Flow management is taking care that the unnecessary is done as little as possible (Ballard (2000)). The most important methods in Flow View theory are shown in Table 3-1.

Tools in construction flow management			
purpose	technique	tools	short description
Waste reduction / Leadtime reduction/ reducing Flow variability	Last Planner	make ready planning/ Six-weeks lookahead/ Weekly work plan/ PPC	The Last planner system[1] tool is focused on systematical 'making ready' of production tasks before execution is probably the most common set of tools used to eliminate waste in construction
Transparency	Five S's	Sort / Straighten / Standardize/ Shine/ Sustain	cleaning up the workplaces in the production chain
	visible control system		making the process visible and understandable
reducing Flow variability /reducing wast / Lead time reduction	supply chain management	structured supply chain tools	A further very essential tool in the mindset of flow view is the implementation of a well structured supply chain management system to create a stable, steady and well coordinated flow of production factors like material, plant, and labor.
reducing waste/ Lead time reduction/ reducing flow variability	quality system		prevents disturbance of the flow and waitingtime
Continuous improvement of the flow process	Kaizen (jap. 改善)	foreman meetings meetings	creating an companywide culture of continuous improvement
[1] The Last Planer system (LPS) by Ballard H. G. is a registered trademark by the Lean construction institute			

**Table 3-1: Methods in Flow View theory of construction**

[Source: Salem et al., 2004]

### 3.5 Theoretical framework in controls

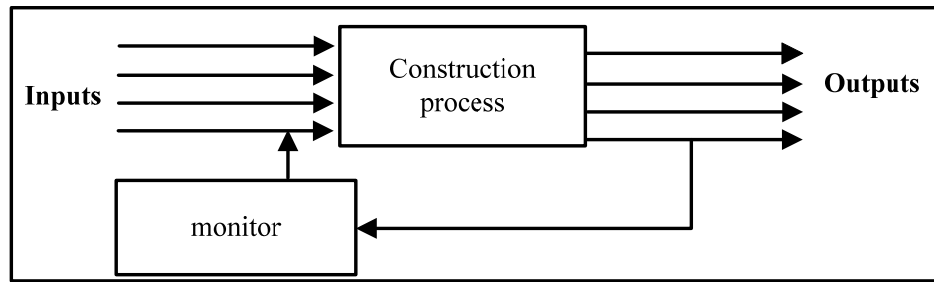
In this chapter, the two main underlying theoretical concepts in controls, their definition and basic ideas will be addressed. The Key Theories discussed are Reactive controls and Proactive controls.

#### 3.5.1 Reactive controls

The classical approach to project control is the Reactive or Feedback control method. The most general model for Feedback control is shown in Figure 3-1. The control objective in this approach is, generally speaking, to make some output behave in a desired way by manipulating some input (Doyle et al., 1990)).

The first step in the process is to establish the goal of the control for example to achieve cost control in a production process. Second, the variables for the control are identified, like cash flow and commitments. The third step is to define performance specifications against which to measure performance for the variables of concern. Then, the controller records feedback signals or information on the variables we wish to control. Typically, deviation between desired performance and measured performance is used as means to implement control. At last, the input is manipulated by corrective action, so that the difference between the

measured performance and the desired performance is systematically reduced. (Dorf and Bishop (2008))

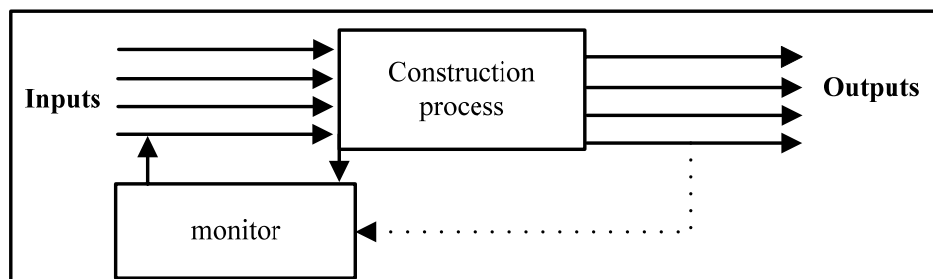


**Figure 3-14 Feedback control**

A construction project is typically controlled by Feedback control mechanism, meaning it is focused on keeping the cost and schedule under control, where the focus is to identify negative variances from the target, so that corrective action can be taken.

### 3.5.2 Proactive controls

A second approach to project control is the Proactive or Feed-forward control. Feed-forward control focuses on the regulation of inputs (human, material, plant and equipment and financial resources that flow into the processes) to ensure that they meet the standards or pre-assigned input criteria necessary for the transformation process. Feed-forward controls are desirable because they allow management to prevent problems rather than having to cure them later. The underlying idea in Feed-forward project control is to plan the processes in great detail and to make sure that any obstacles to a 'smooth' process execution are removed before the process emerges.



**Figure 3-15 Feed-forward control**

Feed-forward control mechanisms are used in manufacturing production control where the focus is to cause events to conform to plan. Lean construction supporters believe that this control technique is also a feasible solution for construction project management.

In the Feed-forward system, the key components are to:

1. set up targets;
2. anticipate problems in meeting targets by discussing with the team at regular intervals before the event;
3. take prior management action in order to avoid or mitigate the problem;
4. monitor the performance to make sure the action has worked (feedback);
5. make further adjustments, if necessary.



### **3.6 Conclusion**

This Chapter has identified a set of theories that could be used to explain management philosophies subject to this research work. Nevertheless, the theories identified in this chapter represent just an extract of the vast amount of research and theories available in this field. The aforementioned theories are regarded as good fit to support the line of inquiry in this thesis and, can be seen as a background to enhance the understanding of project controls.

## 4 Case study: Ístak

*The objective of this chapter is to identify the basis of project management and the tools used to control construction in the Icelandic construction industry. The data collection in this chapter is guided by the explanatory models established in Chapter 3.*

---

### 4.1 Case description

After providing a brief overview of Ístak hf. Construction's structure and project work, this case gives a detailed description of its project management control system. In addition to explaining the mechanics of the controls system in an information rich and detailed manner, the control instruments are categorized in an overview table to establish how they are supported by the theoretical models in construction projects and control established in Chapter 3.

#### Key learning/ research question

The core question to answer is how construction is managed and controlled by the Icelandic construction industry. The case study also seeks to highlight the fit between the theoretically background and control system design.

#### Subjects covered

Material logistics/ Manpower logistics/ Plant and equipment logistics/ Information logistics/ Time control/ Quality control/ HSE control/ Cost control

#### Setting

The observations described in this Chapter were made between June and October in 2009 at a construction project including roadwork and two bridges in Reykjavik.

Location: Vesturlandsvegur crossing Route 1

Client: Icelandic road administration, Vegagerðin

#### Underlying hypothesis and expected findings

Firstly, it is expected to find a traditional structured project controls system based on the ideas of project management without special focus on in process flows and value generation. Therefore, the tools used at project level can most likely be described by Koskela's Transformation theorem for construction projects established in Chapter 3.

Secondly, the control mechanisms expected to be found are feedback controls or reactive controls focused on after the fact performance measurements. Lastly, it is expected to find some degree of maturity in Ístak's project management culture, including certain standardization throughout various projects. Since the contractor subject, in this case study, has a considerably long history of using project management techniques, it is expected to find methodologies that are widely accepted and used by the employees.

## Ístak's structure and project work

The case chosen to provide an insight into current management practice within the Icelandic construction industry is the management and controls system used by its biggest participant, Ístak.

Ístak is a leading contracting company in the Icelandic marketplace, with about 650 employees who work on domestic and international projects. The activities of the contractor include; harbor construction, road tunnels, construction work for commercial buildings, warehouses and industrial buildings, buildings relating to transport, construction work for highways and roads, and construction work for power plant and engineering services.

The management system of Ístak can be regarded as sufficient sample for the population, the Icelandic construction market (compare Chapter 2).

### Data collection

The data is collected through every day participant-observations at project level by the author as a member of the contractor's project management personal, this enables the author to deliver an accurate portrayal of the case study phenomenon.

## 4.2 Observations

### 4.2.1 Construction Input controls

This chapter presents the observations made on those project controls used to manage the inputs to the process tasks. The methodological procedures are examined and explained and the templates and instruments used in practice are presented. Typical inputs to the tasks are material, manpower, plant and equipment and information.

#### 4.2.1.1 Logistics of material

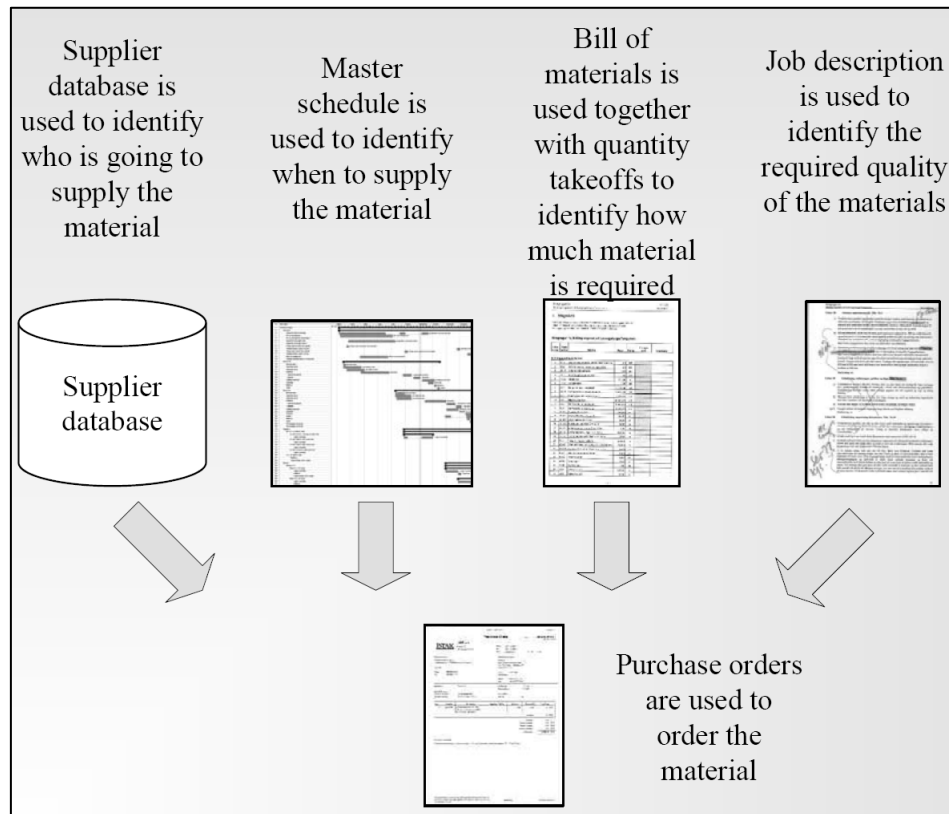
Here, the contractors' approach of managing his material supplies to the construction sites, the logistic of materials, is presented. To guide the reader through this thesis, Figure 4-1 explains where in the explanatory model this chapter is situated.



Figure 4-1 Material input

### Control tools material Logistic

The observation and careful examination of the contractor's main tools related to material supply made it possible to identify functionalities and interrelationships of the tools. Based on these observations the contractor's material logistics system was identified, it is presented in Figure 4.2.



**Figure 4-2 Material logistics system**

The most important tools used by the contractor to control the material supply chain can be explained as follows.

1. The Master schedule is used to identify when the material is required on site. This information is used to time the material deliveries. The master schedule used by the contractor is a Gantt chart (more about Gantt charts see section 3.2.3). The master schedule is defined at the outset of the project.
2. The BOM is a list of raw materials, parts and quantities required throughout the assembly of a project. The bill of materials combined with additional quantity takeoffs on site is used to define the amount of material required.
3. Usually the technical information in the job description combined with a material approval request send to the client's representative are used to identify the required material quality.
4. The contractor uses an Electronic Purchase Order System (EPOS) and one of the features in this system is a supplier database including historical information on the past performance of certain suppliers concerning timeliness of delivery and quality of supplied products. Suppliers that did not meet the requirements are booked on a proverbial 'black list' and are not recommended for further contracting. The database includes addresses, contact details, product range and ranking of suppliers for various kinds of building products and services. The information in the database is widely used to appoint suppliers.



5. The central control instrument that creates an overview of all supplies and their status is the purchase plan. The standard project purchase plan includes information about what has to be ordered by whom, who is responsible for the purchase, who is the supplier and the details about the suppliers contact person, when the items are supposed to arrive on site and, when they arrive in reality. The purchase plan used by the contractor is presented in Figure 4-3.

Project purchase Plan

Project:XX-XXX

Rev.

date

Pos.	description	unit	quantity	responsible at starting point	planned usage date	enquiry	
						enquiry outgoing date	tender recieved number of tenders
1	JARÐVINNA						
	Gröftur						
1.1	Gröftur undan plötu og svæði	m3	0				
1.2	Laus gröftur fyrir úrveggjum	m3	0				
1.3	Laus gröftur fyrir súluundirstöðum	m3	0				

Figure 4-3 Project purchase plan

6. After having defined all necessary information needed to purchase the goods a standardized tender request is generated by using the company's internal EPOS system. Then the tender documents, including technical specifications, are sent to the potential suppliers, the system records the invitation to tender and when it was sent.

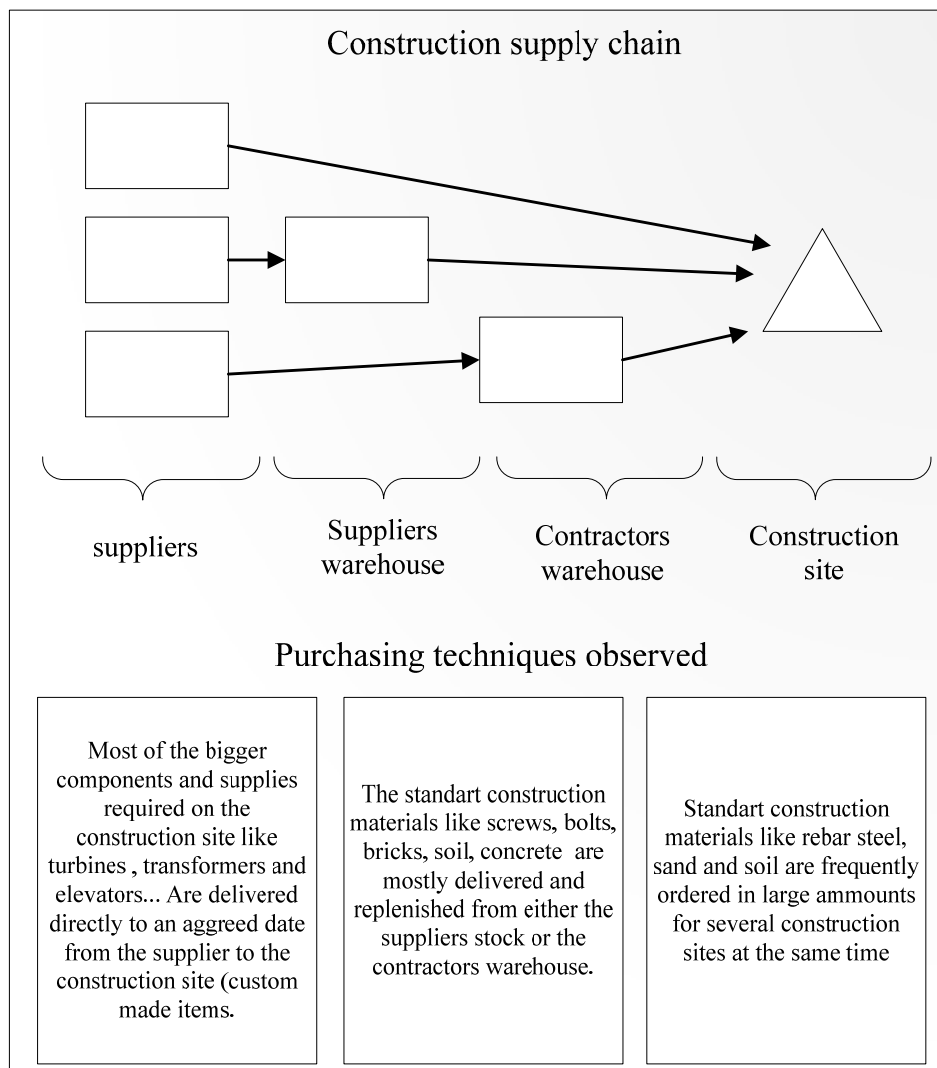
7. Once a supplier is chosen a standard EPOS purchase order PO is placed and when the PO is worth more than a certain limit of money a supplier contract is made. All times and dates are recorded in the EPOS system and, additionally, updated in the Projects purchase plan.



## Construction Supply chain operations

Observations at the project level made it obvious that not all types of materials are purchased in the same way. For example, standard construction materials, such as screws and bolts, are continuously replenished by the company's warehouse while other materials, like major equipment e.g. turbines, transformers and elevators, are ordered according to the purchase plan to the exact date when they are required on site according to the schedule. Also, it could be observed that it is common to purchase regularly used materials like rebar steel for several projects in advance. The three most common supply chain operations that could be identified were: just in time delivery, continuous or regular replenishment and, group purchasing. An overview of the most common techniques can be found in Table 4-1.

**Table 4-1: CSC operations**



## On site logistics of materials

After the arrival of the materials on site, they are usually stored at predefined storage yards. The contractor sporadically conducts an arrival quality check and ‘check in’ of the goods. In general, the material storage areas are assigned in construction site layout plans defined at project initiation. A sample layout can be found in Figure 4-4.

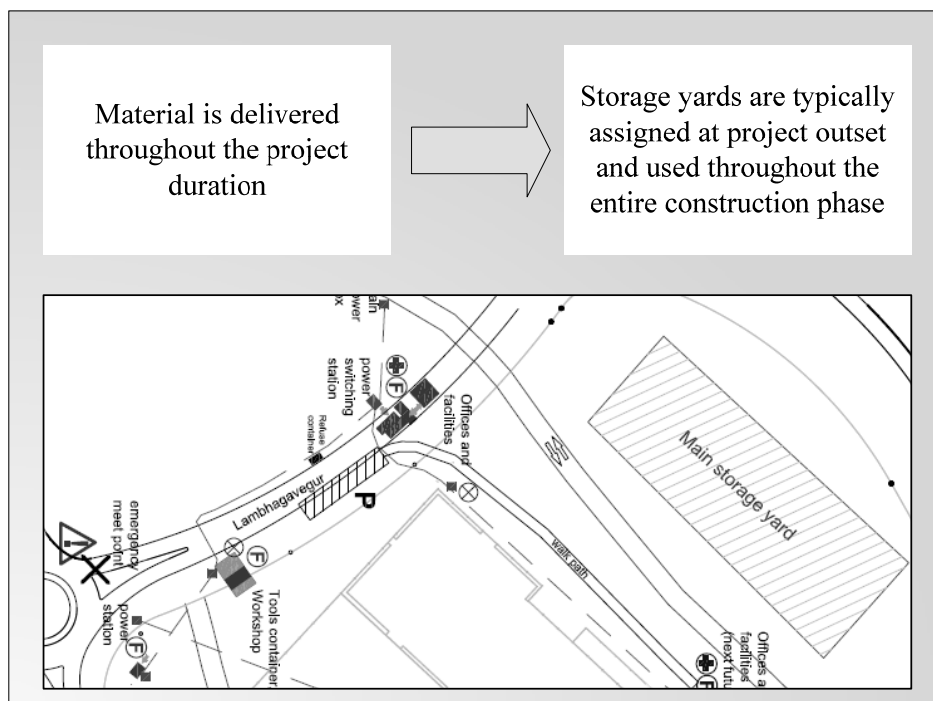


Figure 4-4 On site material storage

### 4.2.1.2 Logistics of manpower

Here, the contractors’ approach of managing his manpower supplies to the construction sites, the logistic of manpower, is presented. To guide the reader through this thesis, Figure 4-5 explains where in the explanatory model this chapter is situated.



Figure 4-5 manpower input

## Control tools manpower Logistic

The logistics of the contractors’ site personnel is controlled and driven by the master plan. The master plan is used to predict required on site manpower over a certain time period. It is common practice, at the contractors, that the site manager contacts the human resource department and requests manpower for a certain period of time. Commonly, these requests are based on estimates and reviews of scheduled activities found in the Master Schedule, Figure 4-6. Additionally, a second approach to manpower logistic is common practice at the contractor in question, the foremen usually do some personnel ‘fire fighting’, which means that they recognize that the site is not appropriately staffed to perform ongoing work and they ask for additional crews. This phenomenon is commonly recognized. To sum up, the



current approach to manpower logistics is somewhere between ‘firefighting’ and utilizing the master schedule.

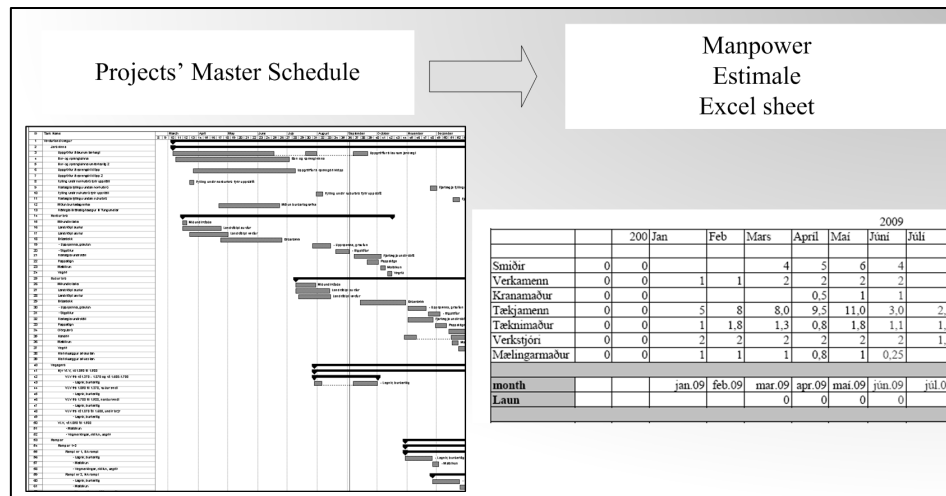


Figure 4-6 Manpower logistics system

### Assigning responsibilities

The staffing of the managerial and engineering crews by the contractor is typically arranged at project outset. To enhance the understanding of responsibilities and to clearly state what work is required from the key players on the construction sites, the contractor typically employs an OBS chart (3) and uses additionally functional job descriptions (2) for each position in the team. Job descriptions are available on the contractor’s internal database (1).

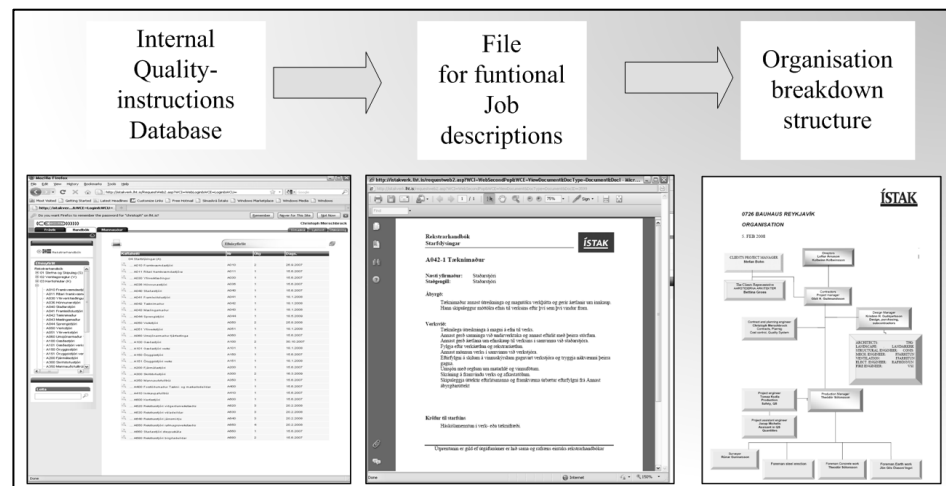


Figure 4-7 Manpower responsibilities

## Employee information database

The contractor uses a central database, which contains key information about the employees' work history (Figure 4-8), educational background, language capabilities, current assignments and more. This database delivers helpful information when assigning employees to projects. It also works as a supportive instrument to choose the right employees for the right tasks.

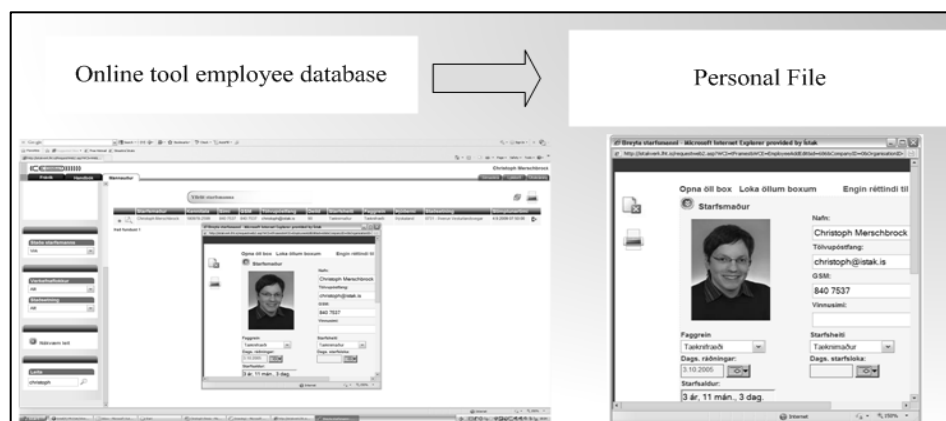


Figure 4-8 Manpower information database

### 4.2.1.3 Logistics of plant and equipment

Here, the contractors approach to managing the supply of plant and equipment to the construction sites is presented. To guide the reader through this thesis, Figure 4-9 explains where in the explanatory model this chapter is situated.

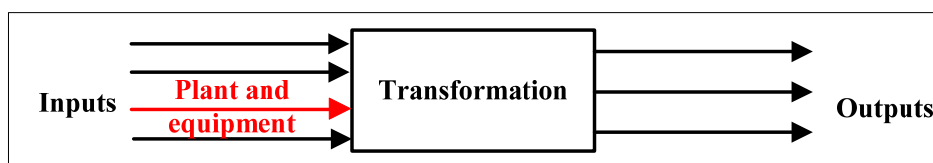


Figure 4-9 plant and equipment input

### Control tools plant and equipment

The main tool that controls the assignment of plant and equipment to a construction site is the master schedule. The master schedule is utilized by the site managers to predict the required plant and equipment throughout construction, based on scheduled activities.

It is common practice at the contractors, that the site manager contacts the company's machinery department to allocate plant and equipment. The contractor holds a machinery park and uses additional rental equipment and the machinery department takes care of both rented and owned equipment. Additionally, foremen request equipment throughout execution, when they recognize that the originally assigned equipment is not appropriate.

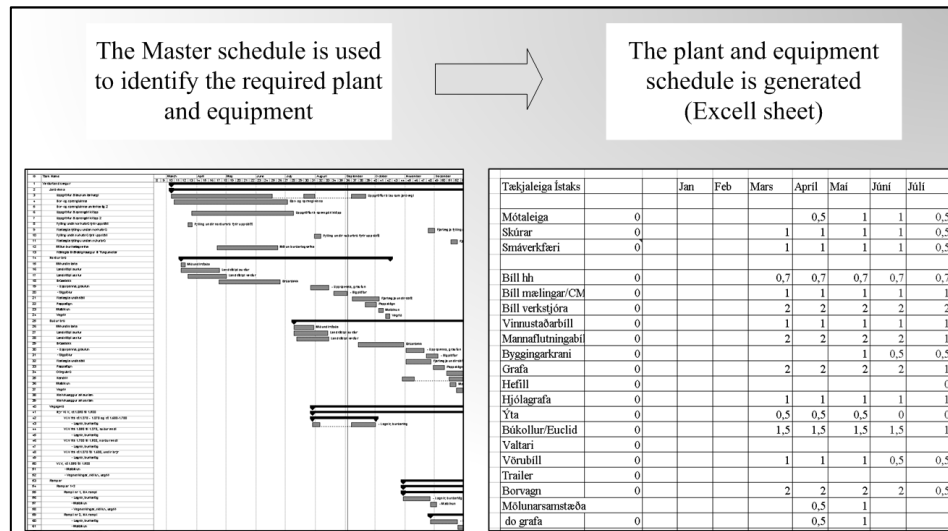


Figure 4-10 Plant and equipment logistics system

### Plant and equipment database

The contractor uses a web platform to communicate which plant and equipment are available within the company's machinery park. This database and personal communication with the machinery department are helpful in identifying appropriate plant and equipment that are available for use. In Figure 4-11, two frequently used tools to identify appropriate equipment are presented.

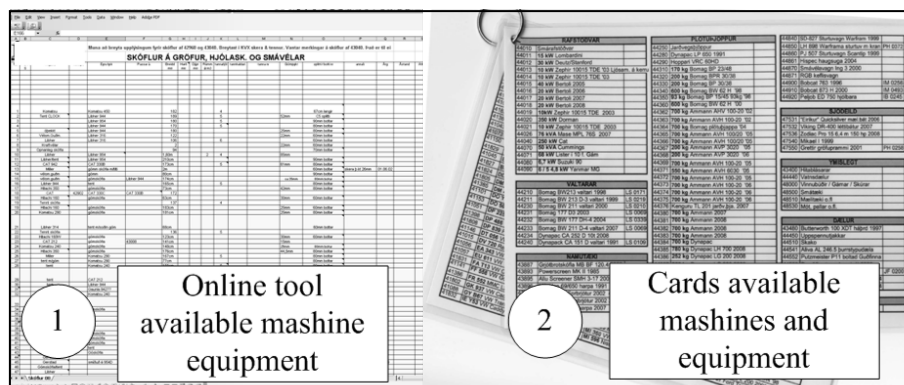


Figure 4-11 Plant and equipment information database

#### 4.2.1.4 Logistics of Information

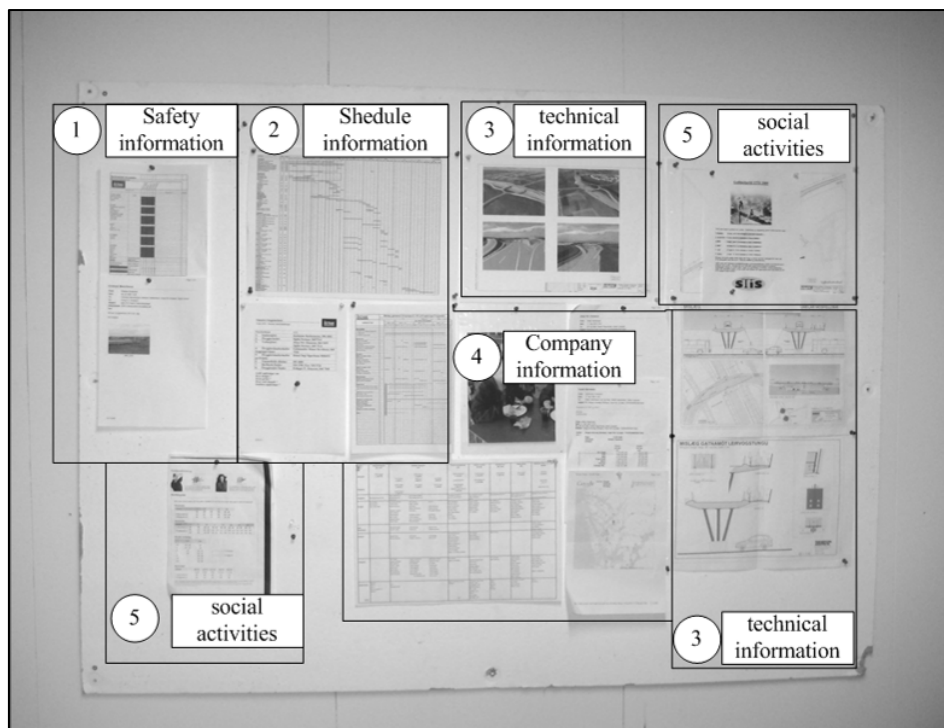
Here, the contractors approach in managing the logistics of information is presented. To guide the reader through this thesis, Figure 4-12 explains where this chapter is situated in the explanatory model.



Figure 4-12 Information Input

### Control tools information

The site project board is one of the information channels between site management and personnel. Usually, the project board is situated centrally on the construction site. Typical information presented on a project board is schedule information, safety information, technical information, company information and social activities. A sample project board is shown in Figure 4-13.



**Figure 4-13 Project board**

Other channels for informational logistics are meetings. Generally, there are several regular meetings held on the contractor's construction sites. These meetings are:

- Weekly site production meetings/ participants are foremen and site management
- Bi/weekly client meetings on site/ participants are clients representatives and site management
- Regular design meetings / participants are project designers and contractors site management
- Monthly site meeting/ participants all workers, site management

The contractor uses a systematic information channel delivering real time work instructions to the site machine operators; several machines are equipped with touch screen monitors and, the site surveyors feed these instruments with working instructions and information. No evidence on other systematic information channels delivering work instructions to the site workers could be found. In general, site workers are instructed by the foremen and, the required drawings and information is delivered throughout the execution of the tasks.

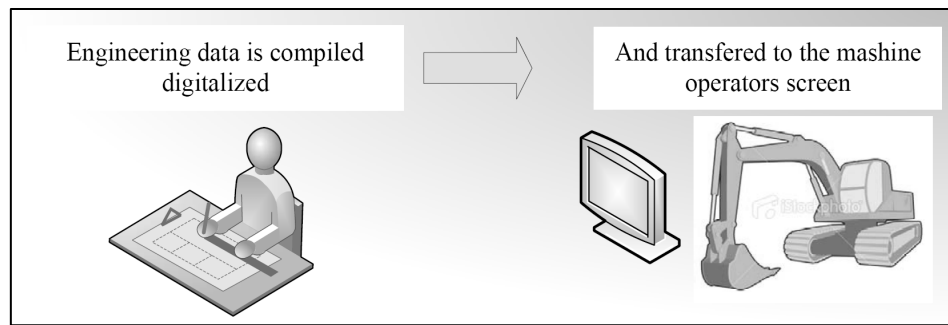


Figure 4-14 Information monitor

## 4.2.2 Construction Output controls

This chapter presents the observations made on those project controls used to manage the outputs of the process tasks. The methodological procedures are examined and explained and, the templates and instruments used in practice are presented. Typical outputs regarding subject, to the contractor's control mechanisms are, the time consumption of the process, the money spend, the quality achieved and health and safety of people involved in the project.

### 4.2.2.1 Construction time control

Here the contractors approach in managing the time spend on a construction project is explained. To guide the reader through this thesis, Figure 4-15 explains where, in the explanatory model, this chapter is situated.



Figure 4-15 Time output

## Control tools for construction time

The contractor concerned uses various time management and control instruments at project level to track schedule performance. The time management tools observed can be subdivided into four major groups or management levels.

1. Proposal schedule – Generally, a preliminary schedule is developed based on the owner's description of the project scope. This schedule contains just enough detail to confirm the timing of major milestones and the overall time frame for the construction work.
2. Baseline schedule – As the project goes ahead and information is refined, the contractor's project manager combines the available information and defines a baseline schedule. This baseline schedule is used for contractual agreements with subcontractors and is the framework normally used by the contractor's site management team to arrange deliverables. The baseline schedule is typically produced as a bar chart, using MS-project or MS-Excel, defining starting and ending points for single activities in a project.
3. Updated baseline schedule – The updated baseline schedule is used as an instrument to control the actual schedule performance against the planned performance, and to identify deviations. Usually, the current status of a project is represented by a red line in the bar chart indicating to what extend the task of concern is completed.

4. Three Week look-ahead schedule – The three Week look-ahead schedule is a tool used as an addition to the baseline schedule, where construction site foremen plan ahead what tasks are to be executed in the next three weeks. This schedule is typically created every three weeks by the construction site foremen, supported by the baseline schedule

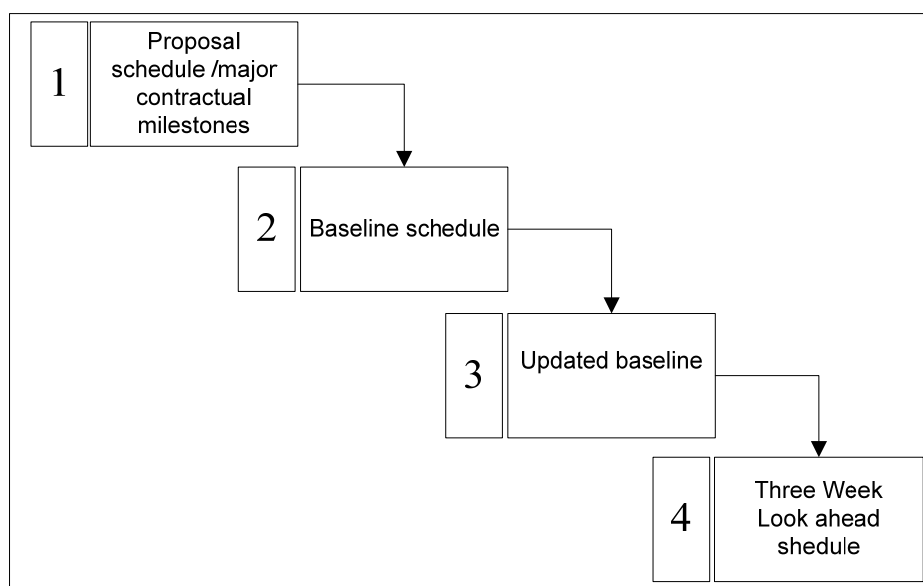


Figure 4-16 Time management tools

### Project Control Time

The contractors time Project Control (PC), as observed at project level, works as a Feedback control system. The time performance is measured and then corrective action, in form of adjustments to the construction inputs, are undertaken if necessary. The project control takes place after a time deviation or clues for irregularities are detected.

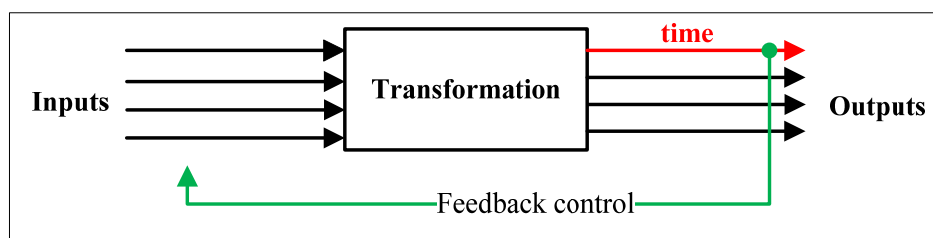


Figure 4-17 Time PC

#### 1. Measuring the construction time output: Is PC required?

Usually, the baseline schedule is updated in a regular manner, to monitor whether activities are taking longer than planned. Also, general clues like technical difficulties and increased project scope can trigger corrective action. The contractor, subject to this research, uses merely ‘primitive’ indicators to tell whether time performance is off track. ‘Primitive’ indicators fail to take into account completed unscheduled work. A typical updated baseline schedule, utilized by the contractor to track schedule performance, includes information about the percent completion of the preformed tasks. A sample for an updated baseline schedule is shown in the figure below.



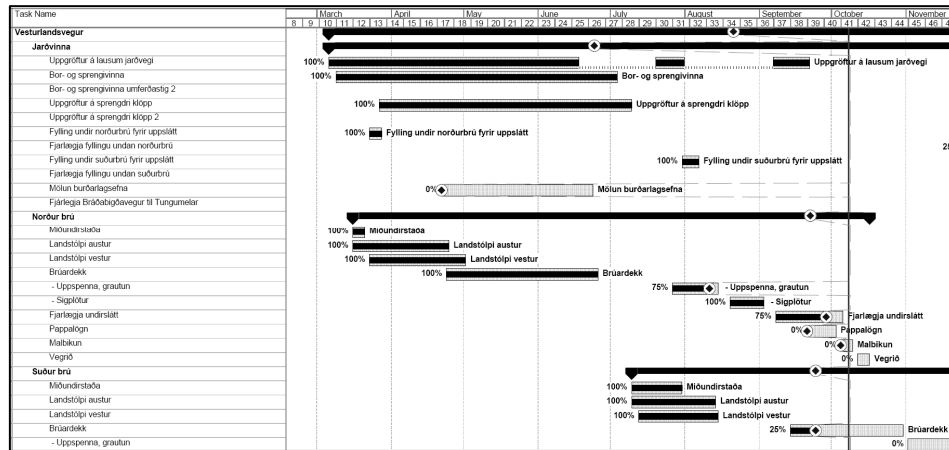


Figure 4-18 Updated baseline schedule

## 2. Implementation of corrective action: Resources for PC

Once a deviation is detected at project level, the contractor's construction manager decides whether and to what extent corrective action is required. The resources available at project level to bring the project back on track are Money, Manpower, Material and Machines. Therefore, the inputs are adjusted to enhance the construction performance.

### 4.2.2.2 Quality control

Here, the contractors approach to manage the quality performance of a construction project is explained. To guide the reader through this thesis, Figure 4-19 explains where in the explanatory model this chapter is situated.



Figure 4-19 Quality output

## Control tools for construction quality

The contractor's quality control system, as observed at project level works foremost as a feedback control system. The main instruments used at site level are the quality control plan and after the fact control checklists.

### The quality control plan

At the contractor of concern, it is very common to assess the activities involved in the construction project under quality considerations before project execution. The required quality standards and the methods for documentation and control are identified based on contractual agreements, technical standards and requirements. Included in the quality control plan are tolerances, response abilities, names of activities that need to be subject to control, a methods statement, the required intervals of control and the documentation required.

Quality control plan							
Project: AA00 - Project Name							
Task Nr.	Task description	method	interval	threshold	threshold value	responsibility	recorded by

Figure 4-20 Quality control plan

### Quality checklists

The quality of the work performed is recorded and controlled after execution of the activities by using quality checklists. The contractor uses an online platform to provide all construction sites with a standardized set of quality checklists. These checklists cover various different construction activities from rebar installation and concreting to plumbing and air-conditioning checkups and much more. The checklists used are designed very carefully so that all quality relevant issues are addressed. In the case that required quality is not achieved, corrective action is taken i.e. items that fail in quality checkups are, repaired or replaced. The quality checkups are usually conducted after the fact, meaning that the work, on an activity, is usually finalized when a checkup is conducted.

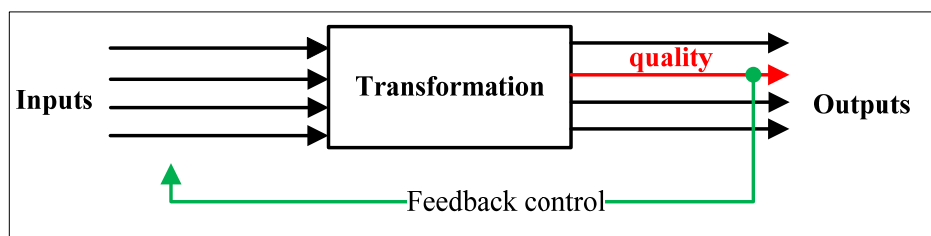


Figure 4-21 Quality feedback control

Figure 4-22 shows the contractors' online database for quality checklists. The checklist shown on the right side of this screenshot is a checklist for formwork. This checklist includes preparation work, like checking whether the drawings used are up to date or, if the formwork panels are clean or, whether the rebar is installed according to design and, so forth. The person responsible for checking the quality has to verify whether all quality relevant issues are fulfilled by conducting on site visual checkups. The checklists are printed and stored on site in folders available for the site personal.

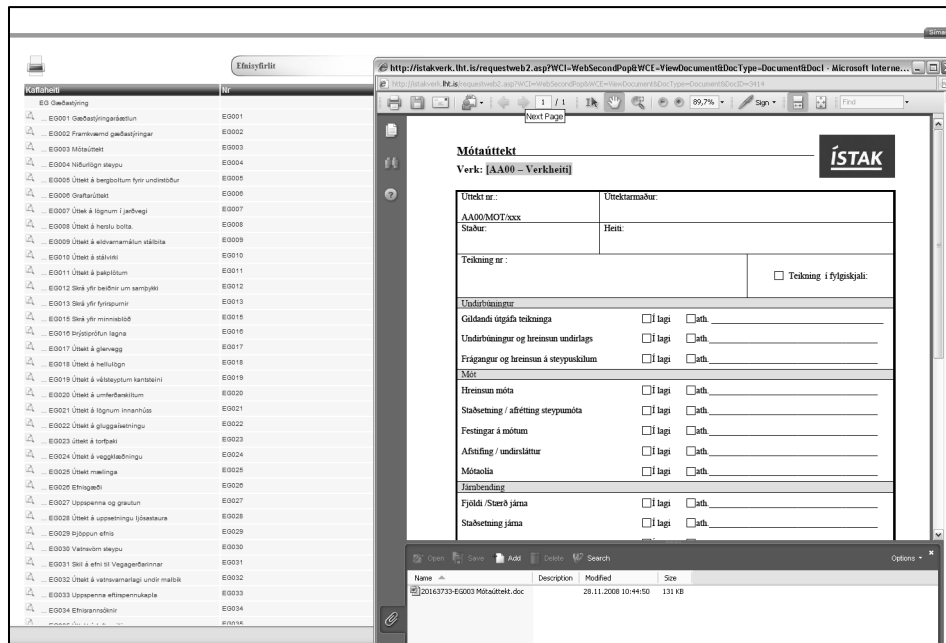


Figure 4-22 Database for quality control checklists

#### 4.2.2.3 Health and safety control

Here, the contractors' approach to managing health and safety on a construction job is explained. To guide the reader through this thesis, Figure 4-23 explains where in the explanatory model this chapter is situated.



Figure 4-23 HSE output

#### Control tools for construction HSE

The controls system for the construction site safety and environmental control used by the contractor can be defined as a feed forward control system, as it seeks to prevent accidents from happening. The main tools used are the site Safety handbook, hazard reports, regular staff safety meetings, assignment of a safety team, safety signs placed on site, weekly safety inspections and safety reports.



Figure 4-24 HSE feed forward control

#### 4.2.2.4 Cost control

Here, the contractors approach to manage the cost performance on a construction project is identified. To guide the reader through this thesis, Figure 4-25. explains where in the explanatory model this chapter is situated.

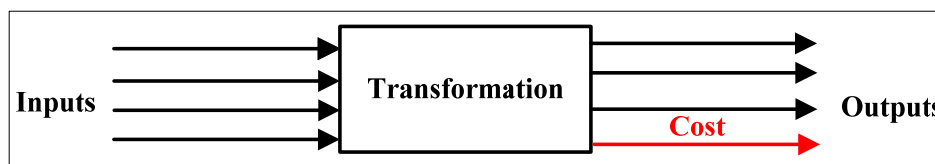


Figure 4-25 Cost output

#### Control tools for construction costs

The contractor subject to this study uses several instruments to record and control the costs at project level. The actual cost performance at a certain point in time is usually tracked against the contractor's cost estimate made at project initiation. The cost estimate is based on a detailed breakdown of the projects activities featuring cost figures for manpower, material and plant and equipment adjusted for risk and contingencies.

Usually, the contractor's site managers have to prepare monthly cost status reports to keep the senior management updated. These status reports include a cost statement from bookkeeping (including figures from the electronically payroll system and paid bills booked on the project) and a prediction of the money needed to complete the project. Fundamentally speaking, the status report used by the contractor is based on a Budget at completion BAC estimate. A sample cost report sheet, as typically used by the contractor, is shown in Figure 4-27. The data for the occurred costs is filled in the sheet by the booking department. The estimation figures for costs until completion are filled in by the contractor's site manager.

The tools to generate cost estimates until completion are:

1. Wages - To define the costs of wages for the project until completion an actual manpower prediction sheet derived from the updated baseline schedule (Figure 4-6) is used to identify how many hours will be used to completion. This number is then multiplied by the hourly wage rates for the personal required.
2. Material to the project - The prediction for the cost of the material required to completion is made based on the purchase plan (when the material is bought) and based on offers and contracts from suppliers and, the value for yet to contract items are estimated by the project manager.
3. Material one way use - The figure filled in this field is often just based on experience/ historical figures of what a project of a certain size consumes in money terms e.g. plywood and formwork panels.
4. Subcontractors - The estimated cost figures for subcontractor costs are usually generated by listing already committed contracts adding information about estimated contract costs based on the updated baseline schedule.
5. Machinery rental Ístak - The machinery schedule (Figure 4.10) is used to estimate the hours for the plant and equipment used at the project level. The company's rental rates for machinery equipment and the availability of company owned machinery are given and therefore the plant and equipment rental costs can be estimated based on these figures.

6. Service departments Ístak - Here the cost of required services bought from internal service departments throughout the project's lifetime are generated and predicted. The service departments are, for example, the precast factory or the steel manufacturing. The updated baseline schedule is used to define the point in time when these services are required.
7. External rentals - After checking the availability of machinery in the company internal machine park the costs of rental machines over the project lifetime are accessed and included in the cost prediction.
8. Operational cost - The costs of the construction site operation are accessed and estimated for the lifespan of the project based on the updated baseline schedule.

After having defined the BAC the control measures take place. When the BAC deviates critically from the budget estimated for the project, the contractor seeks for explanations and causes to identify possible corrective action or to allocate additional financial resources. The first and most critical aspect is to identify deviations and to report them to generate possibilities for action. The cost control mechanism used by the contractor is a Feedback control mechanism.

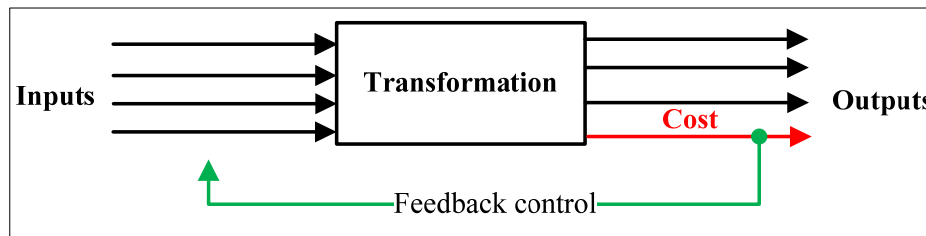


Figure 4-26 Feedback control



Figure 4-27 Cost status report

Projected costs															31.05.2009				06.10.2009 CM			
project nr	project name		wages		material to the project	material one way use	sub-contractors	machinery rental ISTAK	service departments ISTAKS	external rental	operational cost	payment combined	income combined	income-payments	Cash Flow							
2009	Jan																					
	Feb																					
	Mar																					
	Apr																					
	Mai																					
	Jún																					
	Júl																					
	Agú																					
	Sep																					
	Okt																					
	Nov																					
	Des																					
combined to date																						
prediction to completion																						
2010	Jan																					
	Feb																					
	Mar																					
	Apr																					
	Mai																					
	Jún																					
	Júl																					
	Agú																					
	Sep																					
combined from date to completion																						
Total																						
D/B =																						
BAC/Bid prize ratio D/B																						
Bid prize 1																						
Cost control pr. 31.03.04																						
corrections from the last cost statement																						
	wages																					
	material to the project	0	0	0	0	0	0	0	0	0	0	0	0	0	0							
	material one way use	0	0	0	0	0	0	0	0	0	0	0	0	0	0							
	sub-contractors	0	0	0	0	0	0	0	0	0	0	0	0	0	0							
	machinery rental ISTAK	0	0	0	0	0	0	0	0	0	0	0	0	0	0							
	service departments ISTAKS	0	0	0	0	0	0	0	0	0	0	0	0	0	0							
	external rental	0	0	0	0	0	0	0	0	0	0	0	0	0	0							
	operational cost	0	0	0	0	0	0	0	0	0	0	0	0	0	0							
	payment combined	0	0	0	0	0	0	0	0	0	0	0	0	0	0							
	income combined	0	0	0	0	0	0	0	0	0	0	0	0	0	0							
	income-payments	0	0	0	0	0	0	0	0	0	0	0	0	0	0							
	Cash Flow	0	0	0	0	0	0	0	0	0	0	0	0	0	0							
	correction site manager																					
	corrections since last statement 31.03.04																					
comments project manager:																						



### 4.3 Findings of the case study

Table 4-2: Case study findings

Observation of control instruments at Istak case study									
Item subject to control	control tools	focus of control				type of control		timing-/ control interval	
		Transformation		Flow	Value	feed-back	feed-forward		
		Input	Output						
material	Master schedule / BOM / Job description /Purchaseing plan/ supplier database/ tender documents/ Purchase orders/ Electronically purchase order system/ Just in time/ continuous replenishment/ Group purchasing organisation/ site layout plan	x						continuous/ not regulated	
manpower	Master schedule/ Manpower estimate/firefighting/ OBS/ Functional Job descriptions/ manpower information database	x						continuous not regulated	
plant and equipment	Master schedule/ plant and equipment estimate/ online tool for available machine equipment/ machinery cards	x						continuous not regulated	
information	project board/ meetings/ information systems (excavators)/ delivery of work instructions to the site personnel	x						continuous not regulated	
time	proposal schedule/ major contractual milestones/ baseline schedule/ updated baseline schedule/ three weeks look ahead schedule		x				x	monthly	
quality	quality control plan/ quality checklists/ regulations and contractual agreements		x				x	continuous	
health and safety	weekly site inspections/ report on site safety/ safety signs/ trainings and meetings/ safety meetings/ information board		x					weekly/ continuous	
cost control	monthly cost control/ forecast statement BAC/ manpower prediction/ plant and equipment prediction / booking data/ commitments/ electronically payroll system/		x				x	monthly	



## Summary of the observations

The observations made at the project level support to some degree the expectations at outset. But also some unexpected observations have been made. The observations made and the information gathered is presented in the overview Table 4-2. The table categorizes the control instruments in a logical way to create an overview where the actual focus of control lies e.g. which project theory defined in Chapter 3 explains best the working methodology of each control. Moreover, it is identified whether the actual control mechanisms work as feedback or feed forward controls.

Findings according to expectations:

1. The identified control tools focus foremost on managing the inputs to the project and the control mechanisms seem to be largely focused on measuring the process outputs.
2. Little evidence could be found about the existence of management tools that focus on process flow optimization or systematic waste reduction.
3. Also, no management tools that systematically create value for the client could be identified.
4. The Master schedule is utilized as a key instrument in controlling the inputs to the processes. The detection of time deviations is guided by the updated baseline schedule.
5. Control instruments used are based on the ideas of traditional project management.
6. The control instruments are used in a similar manner throughout the corporation and on multiple projects e.g. a high degree of standardization could be identified.
7. Extensive use of online platforms grants use of similar control instruments throughout the company.
8. Project controls are foremost exclusively feedback control instruments (compare chapter 4).

Less expected findings:

1. Construction time is controlled without making use of the critical path method (CPM), but with just focusing on detected deviations in the updated baseline schedule.
2. Solely the Budget at completion estimate (BAC) is used as a control instrument in cost controls. No evidence for the practical use of the Earned value method (EV).

## Conclusion:

The Icelandic construction Industry uses first and foremost control instruments based on the ideas of traditional project management. Nevertheless, the observations made gave reason to believe that the techniques used in practice do not make full use of the potential project management techniques have. For example, the CPM and EV methods are not widely used in daily practice.



## 5 Lean project controls template/ Practice examples

*This chapter introduces a project controls template aligned to the lean construction paradigm that could be used by Icelandic construction companies.*

---

### 5.1 Introduction

The first efforts in implementation of Lean construction have been undertaken by a number of corporations in neighbouring Nordic countries like MT Højgaard a/s (Denmark), Skanska AB (Sweden), NCC (Sweden), Hochtief A.G. (Germany) and Boldt Company (UK). Additionally, Japanese contractors like Fukuda Corp. streamlined all of their companywide processes by implementation of lean construction production systems inspired by Toyota. This chapter seeks to present some of the tools aligned to the lean production paradigm used by the aforementioned contractors.

Due to the limited time available for this research work only some contractors using lean techniques were contacted. Therefore, the data cannot be regarded as representative for the entire population; it is rather intended to give insight into the most important ideas in Lean construction when applied at the project level.

#### **Definition: template**

The term template describes, for the purpose of this thesis, a set of project control tools. This set of tools seeks to address the most important issues in the production process, overarching inputs and outputs as well as quality safety, cost, time and performance. The tools presented in this thesis are aligned to the lean paradigm. It is important to note that the tools described here could be used as a complement to the tools utilized in traditional project management.

#### **Key learning / research question**

The research objective of this chapter is to identify a construction controls' template aligned to the lean construction paradigm that could be used by Icelandic construction companies.

#### **Subjects covered**

Material logistics/ Manpower logistics/ Plant and equipment logistics/ Information logistics/ time control/ quality control/ HSE contro

#### **Expected findings and theoretical background**

When identifying a template of lean construction production management techniques the author expects to find a production system that facilitates both Flow and Value in the construction project. The lean construction paradigm seeks to create both value for the client and a Flow of construction activities (TFV theorem chapter 3).

All control instruments introduced here are designed to systematically prepare the construction tasks and to remove possible obstacles to production. The aim of the lean template is to create a steady work cycle production. Therefore, it is expected to find tools focused on systematic waste reduction.

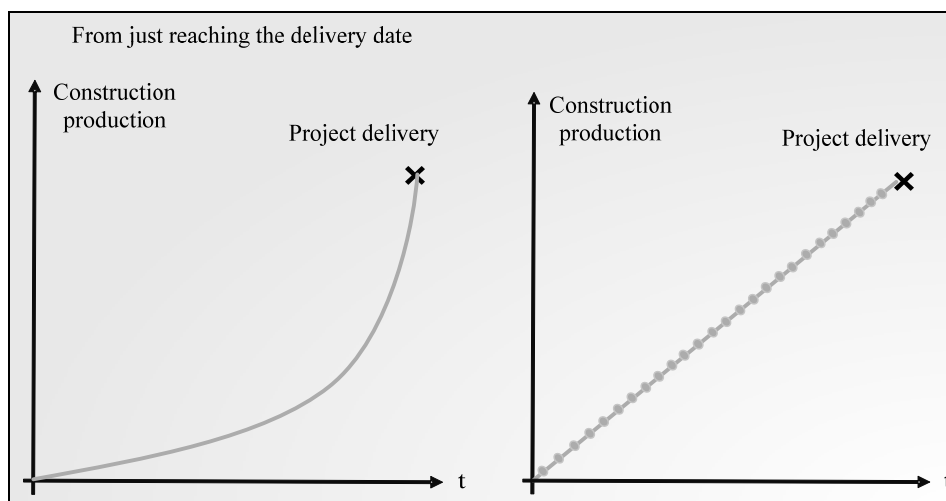


Figure 5-1 Work cycle production

### Data collection

The controls presented in this chapter are identified by literature research on lean construction techniques at the site level, and by using information provided by companies that work with lean construction techniques outside Iceland.

Major sources for the data presented in this chapter are the contractors, Hochtief (Germany) and Turner construction (USA), and the Lean Construction Institute (UK). Some of the illustrations presented are the property of the aforementioned contractors and institute. The illustrations are solely reprinted with the kind permission of Hochtief, Turner and the LCI.

The data presented in this chapter is collected by using secondary sources instead of direct observations; this might lead to decreased objectivity.

## 5.2 Practice Examples

### 5.2.1 Lean Construction Input controls

The inputs in lean construction can be handled by using the ideas of LBS (Location Based Scheduling) and JIT (Just In Time) supply chain management supported by scheduling tools like Ballard's Last Planner technique (see LPS in the Lean time control chapter).

- Location based management (LBS) techniques provide, according to Jongeling and Olofsson (2007), a promising alternative to activity based management techniques especially when supported by 4D CAD techniques.
- Andersson and Christensen (2007) conducted three LBS case studies at project level on residential projects carried out in Denmark and they concluded that these techniques lead to improved schedule overview, establishment of workflows and improved project control. The contractors involved were Pihl & Son, MT Hojgaard and NCC. The case studies were supported by 4D CAD tools from Vico software.
- Kenley and Seppänen (2009) conducted a series of case studies about LBS and they came to the conclusion that LBS can lead to significant improvements in construction performance.
- The techniques presented in this chapter are used by the contractors, Hochtief and Turner, at the site level to control material, manpower and equipment logistics. Their approaches rely heavily on LBS techniques supported by 4D CAD (Vi-Con).

### 5.2.1.1 Lean construction material logistics

Here, the approach to lean material logistics used by the contractor, Hochtief, is explained. The model for construction as a flow process established in Chapter 3 is used to create clarity, where this chapter is situated in the explanatory model. The lean tools aim to reduce the time wasted moving material on site and the waiting time for material supplies, therefore the ‘boxes’ in the model for moving and ‘waiting’ are crossed by red lines.

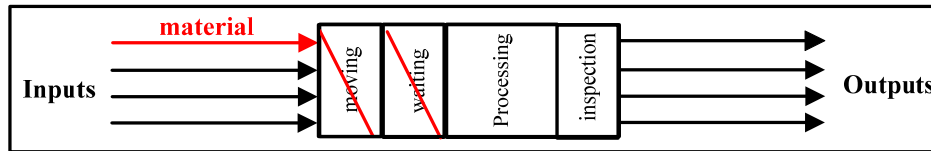


Figure 5-2 Material input in flow theory

### 5.2.1.2 Lean construction supply chain

The key consideration, in Lean construction supply chains, is to reduce the storage costs within the contractor of concern. Meaning reduction of both on site storage and the minimization of the throughput through the contractors owned warehouses. The key technique in doing so is to employ a Just in time (JIT) delivery system. The storage costs are outsourced towards the suppliers.

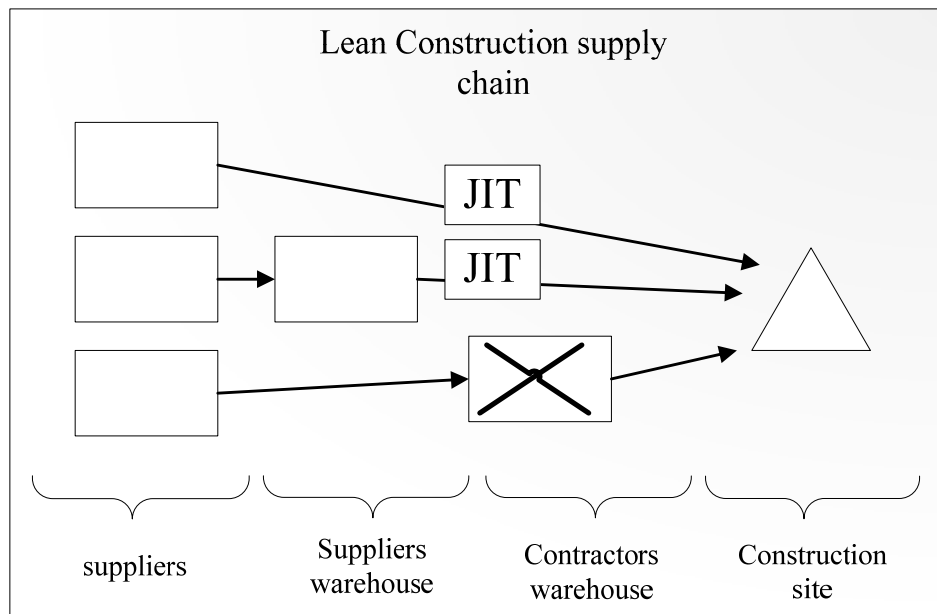


Figure 5-3 Lean construction supply chain



## Lean control tools for material logistics

The underlying idea is to only receive on site deliveries when the construction site is ready to receive them. The aim is to reduce the lay down space for the material and to reduce the onsite material handling and transport movements to a minimum. Also, the waiting time of the workers for materials is reduced and therefore, the productivity enhanced. The JIT delivery of materials is ensured by the following techniques.

### Tools at operational level:

A tool to identify how precise the construction schedule is and whether it can be used to trigger material deliveries is explained below.

#### Control tool: Plan maturity check

##### Goals:

1. Early identification if scheduled activities can start according to schedule or if deviations are likely to occur.
2. Creation of proactive control possibilities before an activity gets a deviation in its starting point.

##### Procedures:

1. Guidance of the process planning and scheduling from the very beginning
2. Brief screening of all the execution drawings for logical scheduling conflicts (e.g. are the load bearing columns scheduled before their foundations are finalized?)
3. Detailed listings and categorization of progress vs. schedule conflicts generating lists and numerations.

##### Working tools:

1. Excel sheet "plan maturity checkup"
2. Vi-Con tools (e.g. Hochtief internal BIM tool)
3. Checklists

##### Responsibility:

1. Project progress manager

A second control instrument used to identify whether the proactive controls used worked, after conduction of the Plan maturity checkups, is the work preparation time control.

#### Control tool- Work preparation – Time control

##### Goals:

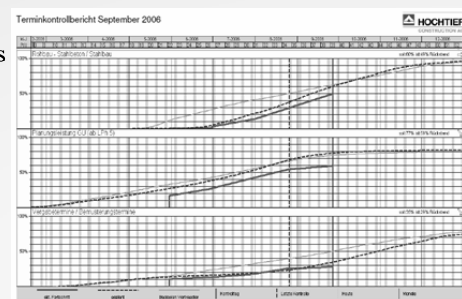
1. Timely identification of disturbance/ deviations
2. Create a base for proactive control
3. Effective assessment of conducted proactive control

##### Procedures:

1. Regular "plan maturity checkups" of critical activities
2. compiling of the actual schedule performance
3. Prognoses/ prediction of the total schedule performance

##### Responsibility:

1. Project progress manager



Focused 'lean' material logistics controls need a mature logistic concept. The approach to the development of a logistic concept used by the contractor, Hochtief, is presented here.

### Control tool- Logistics concept /Logistics planning

#### Goals:

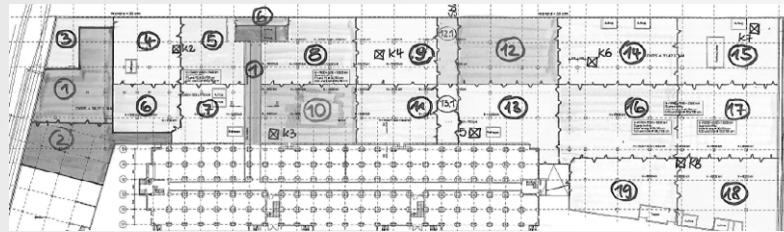
1. Creation of a basis for a structured project progress
2. preventing waste

#### Procedures:

1. Generation/ adjusting Logistic concept
2. Planning of deliveries, transports and storage area occupations

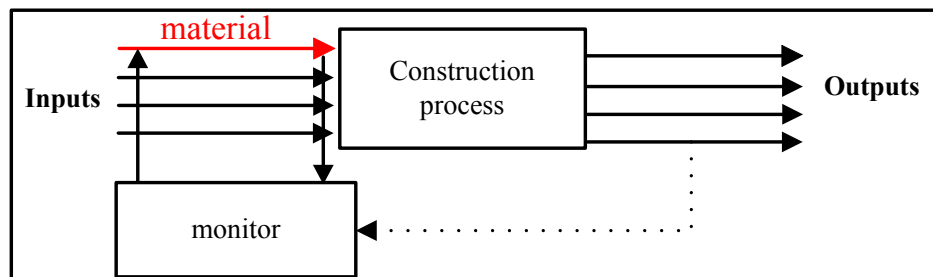
#### Working tools:

1. best practice experience
2. finalized production plan (Last planner tool) indicates the exact delivery areas



**Sample area occupations plan**

The lean construction control tools presented in this chapter can be categorized as Feed-forward mechanisms. The explanatory model in Figure 5-5 shows that all three controls are conducted before the material is ordered for onsite delivery.



**Figure 5-4 Lean feed forward material input control**

The contractor, Hochtief, actively uses these tools on several projects and they created an engineering position called 'progress manager', signifying that these controls are time intensive and require additional on site engineering power.

### 5.2.1.3 Lean construction manpower logistics

Here, the approach to lean manpower logistics used by the contractor, Turner, is explained. The model for construction as a flow process, established in Chapter 3, is used to create clarity where in the explanatory model this chapter is situated. The lean tools aim to reduce the downtime wasted by having personnel overcapacities on site and, the waiting time caused by having personnel under capacities. Thus, the ‘boxes’ in the model for downtime and ‘waiting’ are crossed by red lines.

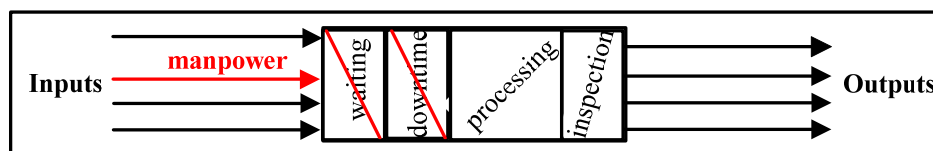


Figure 5-5 Manpower input in flow theory

### Lean control tools for manpower logistics

The manpower logistics in a lean managed construction project is driven by the 6 weeks look ahead plan. This plan is generated by using Ballard’s Last Planner System utilizing the onsite execution personnel, including the subcontractors, to schedule the production. The crews are assigned to construction tasks and construction site areas by using the weekly work plan and work area plans. Typically, the workers are instructed in short briefings in the mornings, in which information about the tasks to be executed are shared. This method of manpower assignment is called location based crew logistic.

The tools used for manpower assignments in lean construction are presented in Figure 5-5. The underlying idea in this approach to manpower logistics is to make sure that the material, the required equipment and, the needed manpower are in the exact point in time in the same place on the construction site.

The control instruments described above can be categorized as lean Feed-forward control mechanisms. Since it is controlled beforehand, which and exactly how many crews are required where on site at each point in time to guarantee optimal process flow.

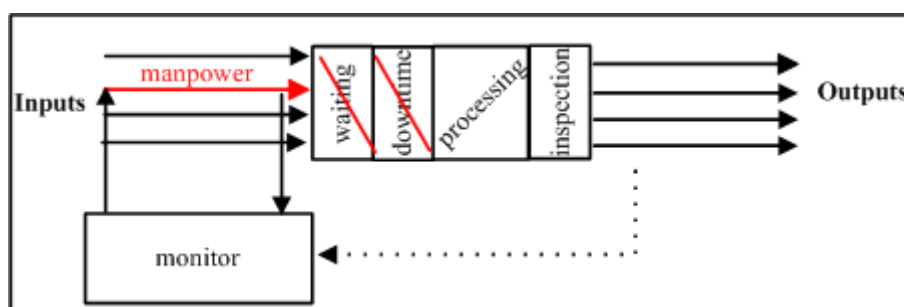


Figure 5-6 Lean manpower input control

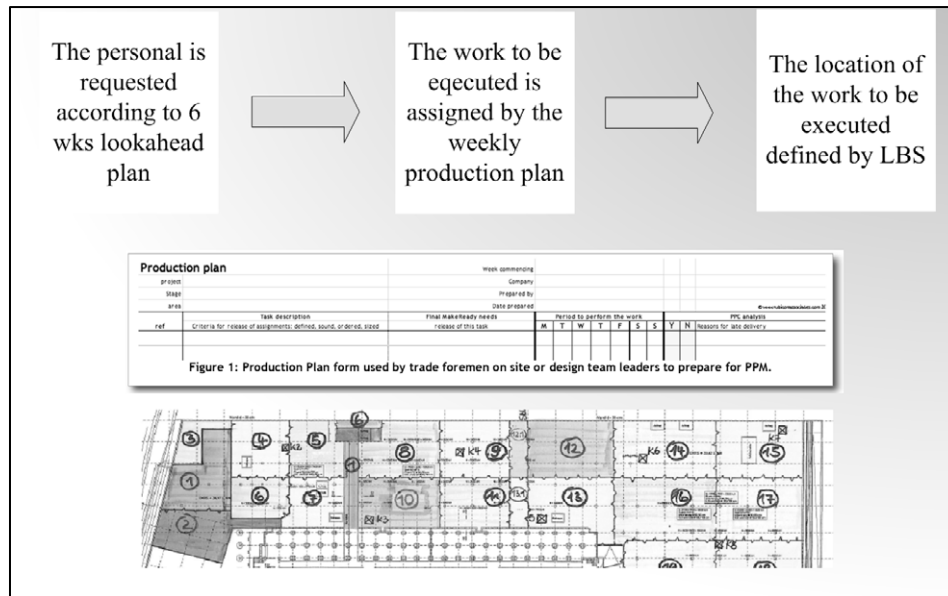


Figure 5-7 Lean manpower input tools

#### 5.2.1.4 Lean construction plant and equipment logistics

Here the approach to lean plant and equipment logistics used by the contractor, Turner, is explained. The model for construction as a Flow process established in Chapter 3 is used to create clarity where in the explanatory model this chapter is situated. The lean tools aim to reduce the downtime wasted by having not enough or inappropriate machinery on site, therefore, the 'boxes' in the model for downtime and 'waiting' are crossed by red lines.

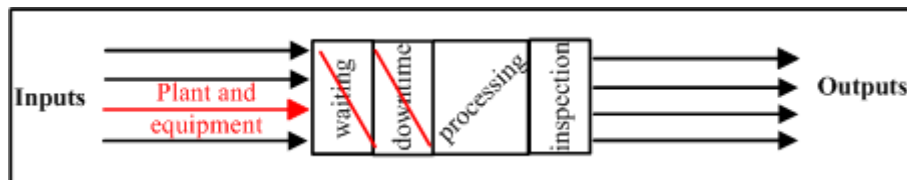


Figure 5-8 Lean plant and equipment input

#### Lean control tools for plant and equipment logistics

The plant and equipment logistics in a lean managed construction project is driven by the 6 weeks look ahead plan. This plan is generated by using Ballard's Last Planner System using the onsite execution personnel, including the subcontractors, to schedule the production. The crews are assigned to construction tasks and construction site areas by using the weekly work plan and the work area plans. The tools used for plant and equipment assignments in lean construction are basically the same as used for the manpower allocation presented in Figure 5.4. The underlying idea in this approach to plant and equipment logistics is to make sure that the material, the required equipment and the needed manpower are in the exact point in time in the same place on the construction site.

### 5.2.1.5 Lean construction information logistics

Here some approaches to lean logistics of information are presented. The practices presented are based on observations made by Blumenthal (2008) from Turner Townsend, on a trip to Japan to identify lean construction techniques used by Japanese contractors. The lean tools aim to reduce the downtime wasted on having personnel seeking for instructions and technical information concerning assembly and the waiting time caused by waiting for technical clearance. Therefore, the 'boxes' in the model for downtime and 'waiting' are crossed by red lines. Additionally, early information on to be executed tasks the inspection time after the task could possibly be reduced.

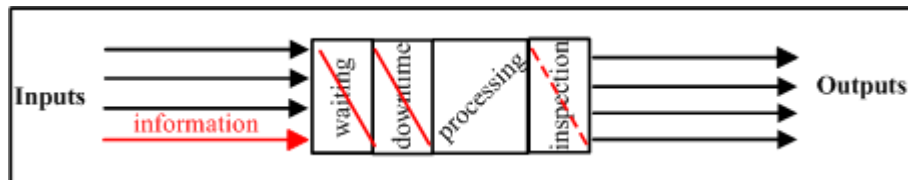


Figure 5-9 Lean information input

### Lean construction information logistics tools

A central element in Lean construction is to create a flow of information, helping everybody understand at a glance what work he is expected to produce, what quality requirements are to fulfill and where safety risks are. The positive effect of having an informed workforce is not only that the executed work is of high quality but that the workers are happier in their daily work. The contractor's project manager briefs everyone on site, from team leaders to laborers, every day at 7.45am before work starts at 8am. In these briefings, the most critical and important events on the day to come are shared, and the crews are informed about handovers and material deliveries.

#### Control tool- project board

The project board is central to each project. It has a clock in its centre, includes a mission statement and health and safety information. It shows where everyone on site should be and when. Each day's schedule is set during a planning meeting before lunchtime the previous day.



Project briefing board:  
Setting for daily  
briefings  
of site personal  
[Blumenthal, 2008]

According to Blumenthal (2008), Japanese contractor's plan the scheduled tasks to a great extent and prepare method statements for each and every task before the work is executed. This technique demands great effort from the sites technical personal and, normally Japanese contractors use a database that includes the most important information. These task information sheets are communicated by the supervisors.



### Control tool -Task information

#### Goal:

1. To equip the crews beforehand with sufficient information for their daily work e.g. method statement. Including required quality and assembly information.
2. enhance quality preventing defects, reduce un useful work, create flow
3. preventing waste

#### Procedures:

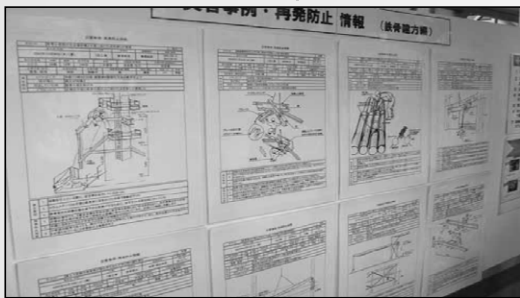
1. Preparation/ collecting of task relevant information
2. Preparation of method statement /task information sheets
3. daily briefing of the crews

#### Working tools:

1. area occupation plan
2. weekly production plan (Last planner tool)
3. task information/ database/ sheet
4. project briefing board

#### Responsibility:

1. Construction site manager



Task information sheets used by Japanese contractors: Sheets include quality, assembly and safety information [Blumenthal, 2008]

## 5.2.2 Lean construction output controls

This chapter presents the lean project controls that could be used to manage the outputs of the process tasks. The methodological procedures are examined and explained and the templates and instruments used in practice are presented.

### 5.2.2.1 Lean Construction time control

Here the approach of Turner Construction to manage the time spent on a construction project is explained. To guide the reader through this thesis, Figure 4-15 explains where in the explanatory model this chapter is situated. The Lean scheduling techniques aim to prevent waste by systematically making ready of the tasks.



Figure 5-10 Lean time output



### Lean construction time control tools

The Last Planner system of schedule control is probably the most common lean scheduling technique. Several field studies have been conducted to identify its capability of process improvement. The system is called Last Planner System® (LPS) because the last person who supervises the day-to-day work of a crew, designers or builders, is the person who controls what work will actually be accomplished. They are the Last Planner for their work and frequently are not involved in the initial planning of the job and may not have much ownership of performing the work to someone else's plan. The Last Planner must always react to daily changing conditions on the site. Involving the Last Planners in developing the plan, and then scoring them on the specific commitments they make in the weekly work plans, increases accuracy, reality, ownership, pride of accomplishment, and therefore more reliable, smoother work flow. The Last Planner system for project time control can be used in addition to the conventional used scheduling tools.

Some examples from practical cases where Last Planner Techniques have been applied:

- The Danish project managers, Thomassen and Nielsen (2004), working at contractor MT Hojgaard reported on several case projects where reverse phase scheduling and Last planner scheduling methods have been used. The Vildbjerg School in Denmark is a good example of successful application of Last Planner and Lean construction. Despite the hard winter, the school was handed over after only 12 months. This project proves according to Hojgaard that Lean construction is an efficient tool for improving efficiency in the building process.
- Palczynski (2008) Project manager at Bechtel Ltd. reported on an Railway construction project where Bechtel applied Lean Planning techniques due to the tight schedules given. According to Palczynski, Lean construction approaches work, and project time performance could be significantly enhanced.
- The largest project managed by Lean construction ideas, including the Last Planner System to date, is probably the Heathrow terminal 5 project (Lane et al (2002)).
- Mace Ltd is currently implementing the Last Planner system in the construction of Wessex Water New Operations Centre in the UK. The project is part of the Movement for Innovation test projects in the UK.<sup>5</sup>
- The contractor, Turner, uses the last Planner system on its Lean managed construction sites, namely: reverse phase schedule, revised baseline schedule, Six weeks look ahead schedule and weekly work plan.
- Turner reported that the use of an innovative combination of Building Information Modeling (BIM) and Lean construction practices on the 555,000 sq. ft. Middle Tennessee Medical Center (MTMC) in Murfreesboro, Tenn. resulted in the delivery of \$3 million in budget costs savings below the owner's initial target at the beginning of the project and an additional projection of nearly \$1 million in savings from BIM-enabled prefabrication alone by the end of the project. (Reuters (2009)).

The structure of Turner's scheduling system aligned to the Lean paradigm is presented in Figure 5-11.

---

<sup>5</sup> More practical implementations and case studies on Lean and Last Planner in the UK can be found at: <http://demos.constructingexcellence.org.uk/knowledgebase>

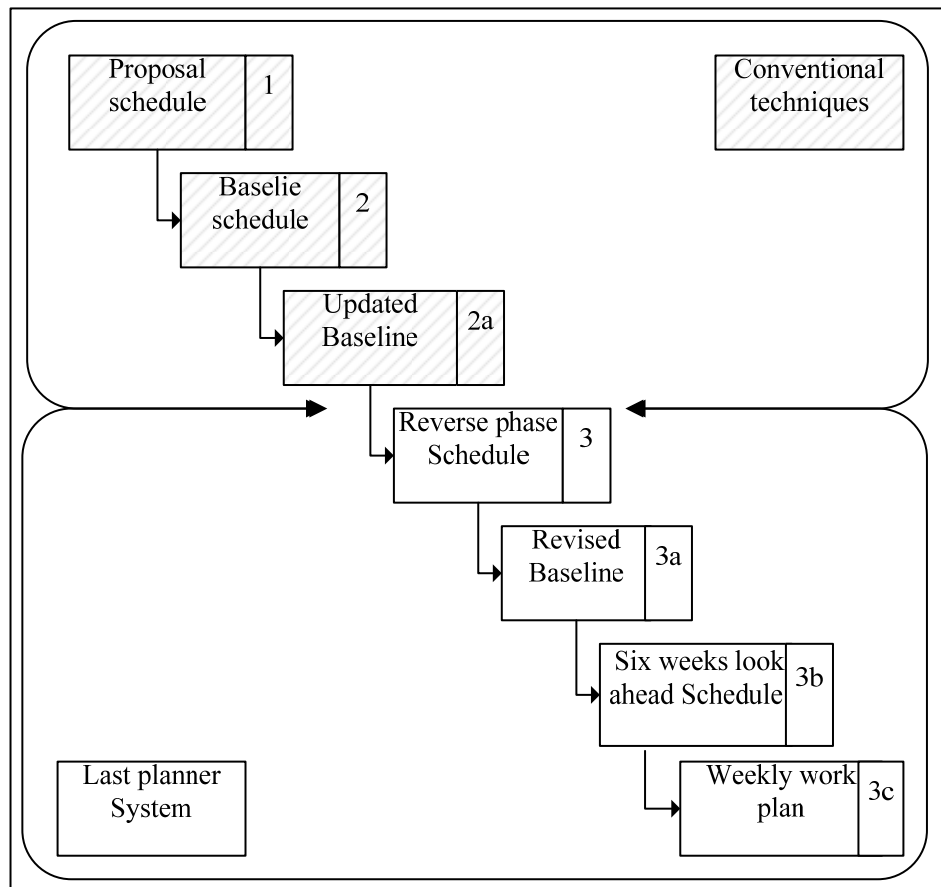


Figure 5-11 Lean scheduling system Last Planner



The scheduling instruments used on Turners Lean paradigm construction sites and their working methodology is explained in the following texts. Here the process steps and the practical applications are explained to enhance the understanding of these methods.

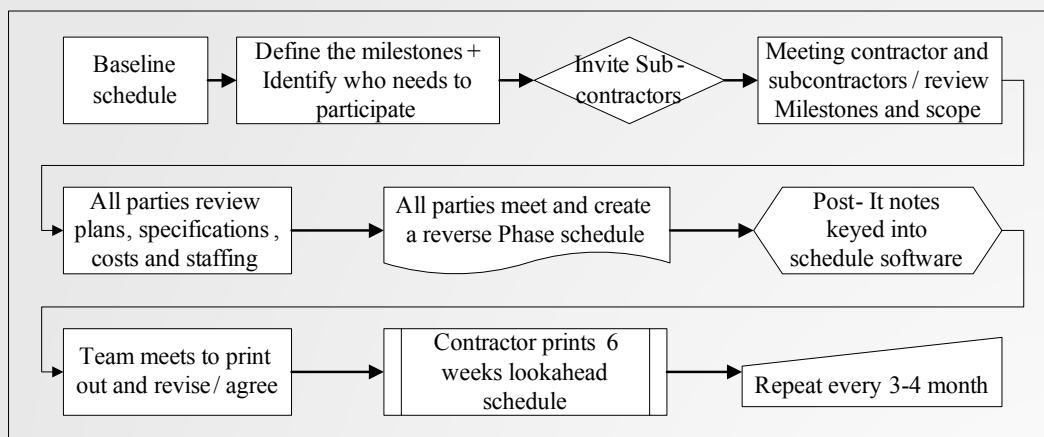
### Control tool- Reverse phase schedule/ revised baseline/ 6weeks lookahead (3/3a/3b)

Goal:

1. Program compression /optimization of production sequence
2. This is to plan work with more accuracy and detail than the Updated Baseline Schedule may show.
3. Additional details of future phases are developed collaboratively about 4 to 6 weeks before work of that phase is to start with all stakeholders in a big room.
4. reducing waste

Procedures:

1. Developed collaboratively with all stakeholders in room at once.
2. Covers a 3 to 4 month duration / group of activities.
3. created on wall chart paper working in reverse from the milestone on the right toward the beginning of the phase to the left.
4. Each new activity is added to the left using the “pull” concept, asking who, what, and how each predecessor activity must be done so the activity in question may begin.
5. Specialists who supervise the work of each phase create their plan with more understanding, accuracy, detail, and ownership.



Lean reverse phase scheduling



Reverse phase scheduling meeting at Turner construction

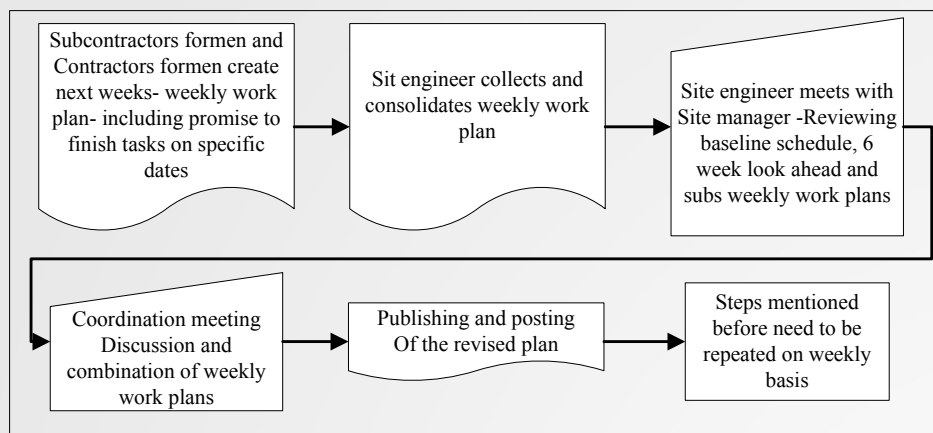
### Control tool-Weekly Work Plan 3c

#### Goal:

1. Systematically 'making ready' of the tasks
2. creation of a plan that can really be done
3. reducing waste

#### Procedures:

1. Supervisors running contractors crews fill out a Weekly Work Plan for each future week in the project.
2. This adds specific detail – day by day, to the tasks originally outlined in large durations in the Reverse Phase Schedule, now shown in the Revised Baseline Schedule.
3. The project team must look at the activities on the Weekly Work Plan to ensure they are occurring at the pace and timing originally promised in the Reverse Phase Schedule meeting.
4. The reliability of the team's plan is scored by checking if activities occurred on the date promised, or not.



#### Lean weekly scheduling

( NEXT WEEK'S )		WEEKLY WORK PLAN ( WWP )											
CONTRACTOR		CURRENT CONSTRUCTION		ALL LOCATIONS OF WORKING						TOTAL ACTIVITIES			
PROJECT NAME	PROJECT LOCATION	CONTRACTOR	CONTRACTOR	1	2	3	4	5	6	7	8	9	10
CONTRACT NUMBER	PLANNER NAME	CONTRACTOR	CONTRACTOR	1	2	3	4	5	6	7	8	9	10
* TASK / WORK ASSIGNMENT DESCRIPTION		COMMENTS		Any requests to make this reliable and efficient?						PPC ANALYSIS			
Criteria for release of assignments Safe - Defined - Sound - Proper Sequence - Right Size - Able to Learn													
SUBCONTRACTOR COMPANY:		SUB'S PLANNER:											
* List tasks for an area of work that you will complete in 5 days or less. Place "X" on days you will work on this task. Remember the benefits of small batch sizes -smaller chunks of work.													
* These tasks will be tasks on your Phase Schedule ( 6 week look ahead plan), OR, more detail of the activities on your Phase Schedule.													
* Examples to make this weekly plan for next week by filling this out and submitting to Times each Tuesday by end of day. Please prepare with your 6 Times before then. This should be done 4 weeks.													

#### Lean weekly work plan

The contractors' time Project Control (PC) at project level works as a Feed-forward control system. The control instruments aim foremost to control the project through careful beforehand preparation of the single production tasks to be executed on a weekly basis by the construction supervisors.

Additionally, the time performance is measured after the fact to see whether all the preparation measures worked and if corrective action in form of adjustments to the construction inputs is necessary. The project control takes place after a deviation or clues for irregularities are detected.

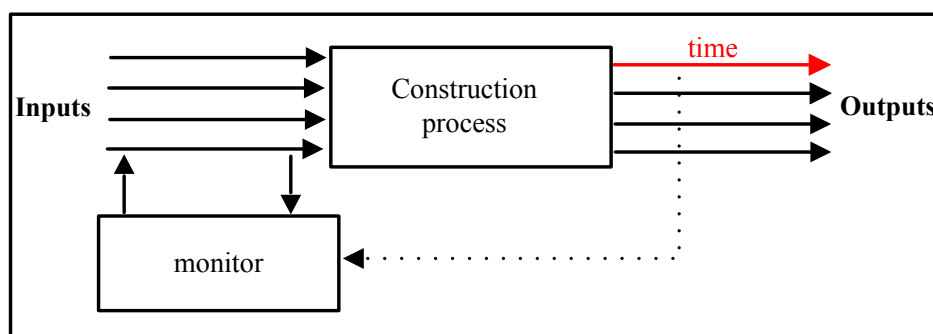


Figure 5-12 Lean feed forward construction time control

### Feedback Control tool - Percent Plan complete Analysis

In the Last Planner system the performance is assessed by using the Percent Plan complete (PPC) ratio. Where the total amount of activities scheduled on the weekly work plan is divided by the really preformed activities. Additionally, the PPC's reasons for variances that occurred to make focused decisions about the corrective measures.

Feedback Control tool- Percent Plan complete Analysis																																																																																									
In the last planner system the performance is assessed by using the percent plan complete (PPC) ratio. Where the total amount of activities scheduled on the weekly work plan is divided by the really preformed activities.																																																																																									
Additionally to the PPC also the reasons for variances that occurred are identified to make focused decisions about the corrective measures.																																																																																									
<table border="1"> <thead> <tr> <th colspan="6">CATEGORIES OF VARIANCE</th><th colspan="2">TOTAL ACTIVITIES</th><th colspan="2"></th></tr> </thead> <tbody> <tr> <td>1</td><td>Scheduling / Coordination</td><td>8</td><td>Contracts / CO's</td><td></td><td></td><td>ACTIVITIES COMPLETED</td><td>14</td><td></td><td></td></tr> <tr> <td>2</td><td>Engineering / Design</td><td>9</td><td>Submittals</td><td></td><td></td><td>PERCENT PLAN COMPLETE ( PPC )</td><td>74</td><td></td><td></td></tr> <tr> <td>3</td><td>Owner Decision</td><td>10</td><td>Approvals / Permits</td><td></td><td></td><td></td><td></td><td></td><td></td></tr> <tr> <td>4</td><td>Weather</td><td>11</td><td>Equipment</td><td></td><td></td><td></td><td></td><td></td><td></td></tr> <tr> <td>5</td><td>Prerequisite Work</td><td>12</td><td>RFP's</td><td></td><td></td><td></td><td></td><td></td><td></td></tr> <tr> <td>6</td><td>Labor</td><td>13</td><td>Space</td><td></td><td></td><td></td><td></td><td></td><td></td></tr> <tr> <td>7</td><td>Materials</td><td>14</td><td>Site conditions</td><td></td><td></td><td></td><td></td><td></td><td></td></tr> </tbody> </table>										CATEGORIES OF VARIANCE						TOTAL ACTIVITIES				1	Scheduling / Coordination	8	Contracts / CO's			ACTIVITIES COMPLETED	14			2	Engineering / Design	9	Submittals			PERCENT PLAN COMPLETE ( PPC )	74			3	Owner Decision	10	Approvals / Permits							4	Weather	11	Equipment							5	Prerequisite Work	12	RFP's							6	Labor	13	Space							7	Materials	14	Site conditions						
CATEGORIES OF VARIANCE						TOTAL ACTIVITIES																																																																																			
1	Scheduling / Coordination	8	Contracts / CO's			ACTIVITIES COMPLETED	14																																																																																		
2	Engineering / Design	9	Submittals			PERCENT PLAN COMPLETE ( PPC )	74																																																																																		
3	Owner Decision	10	Approvals / Permits																																																																																						
4	Weather	11	Equipment																																																																																						
5	Prerequisite Work	12	RFP's																																																																																						
6	Labor	13	Space																																																																																						
7	Materials	14	Site conditions																																																																																						
<table border="1"> <thead> <tr> <th colspan="6">STARTING ON</th><th colspan="4">PPC ANALYSIS</th></tr> <tr> <th>Mon</th><th>Tue</th><th>Wed</th><th>Thu</th><th>Fri</th><th>Sat</th><th>DONE?</th><th>REASONS FOR VARIANCE</th><th>Category</th><th></th></tr> <tr> <th>06-Aug</th><th>07-Aug</th><th>08-Aug</th><th>09-Aug</th><th>10-Aug</th><th>11-Aug</th><th>YES NO</th><th></th><th></th><th></th></tr> </thead> <tbody> <tr> <td>X</td><td>X</td><td></td><td></td><td></td><td></td><td>X</td><td></td><td></td><td></td></tr> <tr> <td></td><td></td><td>X</td><td>X</td><td>X</td><td></td><td>X</td><td>Painter not ready</td><td>05</td><td></td></tr> </tbody> </table>										STARTING ON						PPC ANALYSIS				Mon	Tue	Wed	Thu	Fri	Sat	DONE?	REASONS FOR VARIANCE	Category		06-Aug	07-Aug	08-Aug	09-Aug	10-Aug	11-Aug	YES NO				X	X					X						X	X	X		X	Painter not ready	05																															
STARTING ON						PPC ANALYSIS																																																																																			
Mon	Tue	Wed	Thu	Fri	Sat	DONE?	REASONS FOR VARIANCE	Category																																																																																	
06-Aug	07-Aug	08-Aug	09-Aug	10-Aug	11-Aug	YES NO																																																																																			
X	X					X																																																																																			
		X	X	X		X	Painter not ready	05																																																																																	

Lean Percent plan complete (PPC) analysis

### 5.2.2.2 Lean construction quality control

Here the lean construction approach to on site quality management is described in the aim of this approach which is to reduce the defects delivered and to increase the quality of the delivered construction product. The main techniques used by Japanese contractors according to the observations from Blumenthal (2008) are presented here:

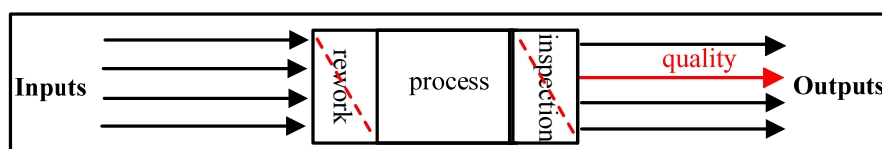


Figure 5-13 Lean construction quality control

### Lean construction quality control instruments

The Japanese construction industry seeks to build quality in the product, meaning they focus on training and information delivered beforehand to each and every worker. One of the essential ideas is to create an atmosphere of responsibility and commitment within their workforce. The Japanese contractors try to create this commitment by extensive training of their crews before they start to work on the construction sites.

**Control tool- Staff training****Aim:**

1. To create a unification of the responsibility to guarantee quality
2. creation and indoctrination of business values
3. create high staff retention

**Procedures:**

1. Staff training for a full year before starting work on site
- Schooling in business values

A second very important instrument used to build quality in the product is to deliver technical and quality relevant information in a timely manner to the executing workers. The tools described below addresses this matter.

**Control tool- feed forward of design to construction****Aim:**

1. Supply the workers with quality relevant information before work starts

See: Lean construction information logistics

Additional to the feed forward control used concerning staff and staff information, a major idea in lean construction quality improvement is the onsite or offsite preassembly. A product produced inside a manufacturing facility or on the ground is usually of higher quality than a product produced in place. The exposure to weather and dirt influences the quality of a product and the time used for assembly significantly. In Lean construction it is tried to source as many activities as possible away from onsite construction to manufacturing facilities. A high degree of offsite or onsite preassembly reduces the exposure to the risk and uncertainties of a construction environment and supports a more stable flow of onsite construction activities.

**Control tool- Preassembly****Goal:**

1. grant better flow of on site construction activity
2. improve quality
3. reduce waste

**Procedures:**

1. Production techniques considerations in design
2. on site or off site preassembly
3. generation/ identification of pre assembly possibilities



**Preassembly yard on a Japanese construction site [Source: Blumenthal, 2008]**

Finally a documentation of quality and progress performance needs to be undertaken.

### Control tool- quality and progress database

Aim:

1. To record quality performance in a systematically manner
2. To document progress
3. To report performance in real time

Procedures:

1. Take a picture of every task when completed and quality checked
2. Use a 'quality board' on the pictures to document what is seen on the picture save the pictures in a central database



Lean quality and progress documentation [Blumenthal (2008)]

The lean construction control tools presented in this chapter can be categorized as foremost Feed-forward controls. The underlying idea in lean construction quality control is to 'build' the quality in, meaning to arrange and create beforehand an environment that supports the quality of the building product.

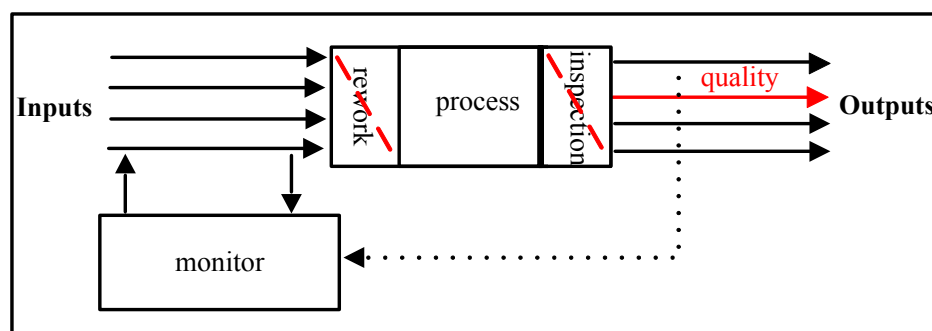


Figure 5-14 Lean construction feed forward quality control

In Figure 5-15 the four main quality considerations in lean construction are summarized.

Quality	Unification of the responsibility for the guarantee of quality
	Production techniques used for design
	Early feed forward of design to Construction
	Feed back of Construction technology to design

Figure 5-15 Lean construction quality considerations [Source: Blumenthal (2008)]



### 5.2.2.3 Lean construction HSE control

Great sources for accidents are untidy and unorganized construction sites where waste and materials are all over the place. In lean managed construction sites where the inbound material logistics is very well organized and the outbound logistic is also well considered, the sources for accidents are significantly reduced.

**Control tool- daily outbound logistic****Aim:**

- 1.to reduce the source of accidents
- 2.to keep the construction site clean

**Procedures:**

- 1.appoint contractor for outbound logistics
- 2.instruct the crews to behave responsible and to tidy their workplace up after daily work



**Figure 5-16 Lean outbound logistic**



### 5.3 Findings lean construction template

Table 5-1: lean construction template findings

Lean construction control instruments									
Item subject to control	control tools	focus of control				type of control		timing-/ control interval	
		Transformation		Flow	Value	feed-back	feed-forward		
		Input	Output						
material	Plan maturity check /Work preparation - Time control /Logistics concept- Logistics planning			X			X	continious/ not regulated	
manpower	6 weeks lookahead/ weekly work plan/ location based crew logistics			X			X	continious weekly	
plant and equipment	6 weeks lookahead/ weekly work plan/ location based plant and equipment logistics			X			X	continious weekly	
information	method statements/ project board			X			X	every day	
time	Reverse phase schedule/ revised baseline/ six weeks lookahead/ weekly work plan / Percent plan complete/ Last planner			X			X	continious weekly	
quality	Staff training/ feed forward of design to construction/ Preassembly/ quality and progress database			X			X	continious	
health and safety	outbound logistics			X			X	continious weekly	
cost control	-n.a-						X	monthly	

**Summary of the observations**

The observations made while looking into the construction techniques aligned to the Lean paradigm support to some degree the expectations at outset. In addition, some unexpected observations have been made.

The observations made and the information gathered is presented in the overview Table 5-1. The table categorizes the control instruments in a logical way to create an overview where the actual focus of control lies e.g. which project theory defined in Chapter 3 explains best the working methodology of each control. Further, it is identified whether the actual control mechanisms work as feedback or feed forward controls.

Findings according to expectations:

1. The identified control tools focus foremost on managing the projects Flow and the control mechanisms seem to be largely focused on feed forward control.
2. Tools are largely focused on in process waste reduction.
3. The Last Planner system is used as key instrument to control the inputs to the processes.

Less expected findings:

1. Little evidence could be found about the existence of management tools that focus on systematically value creation.
2. The ideas of LBS (Location based Scheduling) are used to arrange the logistics of material, manpower, plant and equipment

**Conclusion**

The Lean construction tools used by the Industry seek foremost to create Flow and to reduce waste. The observations made gave reason to believe that the techniques are not specifically designed to support a systematic value creation in the production process. Therefore, the claim of Lean construction supporters that Lean controls are focused on value creation is not supported by the observations made.



## 6 Interviews / acceptance of Lean project controls template

*This chapter seeks to identify the likely acceptance of the lean controls template and the appreciation of Lean construction techniques within the Icelandic construction industry. First, the layouts of the interviews and the questionnaire are discussed and then the results of the conducted interviews are presented.*

---

### 6.1 Introduction

The research targets of this chapter are:

- (1) Assess the likely acceptance amongst Icelandic construction companies of the project controls' template.
- (2) Determine the current appreciation of lean construction within the Icelandic construction industry.

The method chosen to achieve the research targets at this stage is to conduct a survey consisting of structured interviews accompanied by questionnaires. The questionnaire is a structured means for gathering data in the enquiries with practitioners. The interviews are targeted at a select number of practitioners, resulting in a limited number of respondents. The author is fully aware of basic statistical concepts and that a limited number of respondents could lead to criticism in the sense of statistically relevance. Nevertheless, a limited number of respondents is regarded as sufficient for the purpose of this thesis. Moreover, talking to ten or four more people would not significantly add to the purpose, since the research target at this stage is to gain appreciation of the likely acceptance of the concepts and ideas and, therefore, not meant to be statistically representative.

#### **Target group:**

The survey is targeted at individuals having a commanding role within the Icelandic industry, for the purpose of this research; construction project managers will be interviewed. Their professional work has to involve responsibilities in overall project management. Their work focus should be on planning, inter-coordination and directing construction sites. For the purpose of this thesis, four senior project managers at Iceland's biggest contractor have been selected to be interviewed.

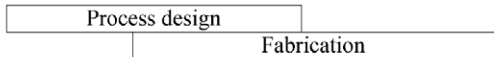

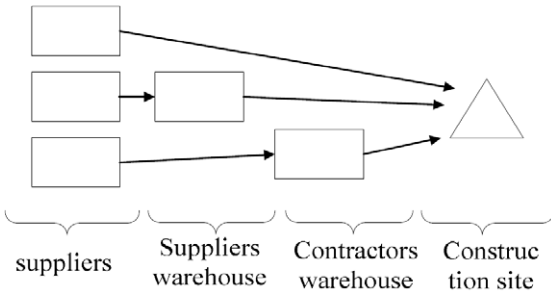
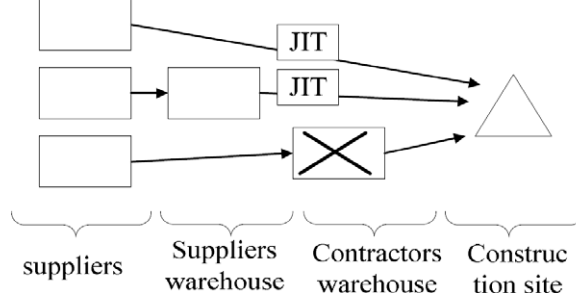
#### **Setting of the interviews:**

The interviews take place at four major construction sites within the Reykjavik city area.

#### **Background to the interviews:**

At this point it is beneficial for understanding to revisit both of the construction management systems studied in the previous chapters of the thesis. It is critical to understand what management system the respondents are currently working with since this is their 'background' to the subject and to b) understand the key characteristics of the Lean construction system to which they are supposed to give their opinion. Therefore, a side by side comparison of the systems (Table 6.1) summarizing and highlighting the key characteristics of both systems is regarded as necessary at this point.

**Table 6-1: comparison of the management systems**

<b>case study: Ístak</b>	<b>Lean project controls template</b>
1. Focus of control Input/Output no special focus on productivity	1. Focus of control Flow/ waste reduction focus on high on site productivity/ production speed
2. Type of control predominantly feedback	2. Type of control feed forward/ feedback
3. Type of Management Project management	3. Type of Management Lean production construction
4. Key planners: site manager	4. Key planners: site manager + foremen + subcontractors
5. Key Techniques expected to find CPM MSPProject/ EV/ PERT	5. Key Techniques expected to find Last Planner system and JIT
6. Key Techniques identified MSPProject/ revised baseline schedule	6. Key Techniques identified Last Planner system/ Location based scheduling/ JIT
7. Tools identified compare overview table 4.2	7. Tools identified compare overview table 5.1
8. Theoretical Background Transformation theory	8. Theoretical Background Flow theory
9. Design fabrication Interface 	9. Design fabrication Interface 
10. Supply chain  Construction supply chain 	10. Supply chain  Lean Construction supply chain 
10. Requirements for delivery system sufficient space on the construction site contractor warehouse (usually required)	10. Requirements for Just in time delivery system suppliers need to be able to deliver with short notice suppliers need to deliver smaller shipments portions suppliers need to be highly reliable suppliers need to have well equipped stock reduces required storage space
11. Cost to run and maintain the system cheaper than the lean system, less planning manpower required	11. Cost to run and maintain the system comparable expensive due to additional planning manpower required

### The structure of the interviews:

Before the questionnaires can be answered sufficiently the underlying context and key terms such as waste, lean and last planner need to be introduced to the participants. Additionally, to receive valid statements concerning the control instruments these need to be explained and introduced. To create a basis for systematic knowledge creation, the interviews need to be structured and arranged.

The structure of the interviews can be found in Figure 6-1. The interviews consist of three parts, firstly, the research project and research work will be briefly introduced, secondly, the main terms in Lean construction and the main concepts will be introduced briefly and lastly, the questionnaire will be filled out by the participants. The duration of the interviews is about one hour for each; the interviews will be conducted on the construction sites.

<b>Introduction to the research work</b> <ul style="list-style-type: none"> <li>• Background</li> <li>• Aim</li> </ul>	<b>Time: 5 mins</b>
<b>Short introduction to Lean construction</b> <ul style="list-style-type: none"> <li>• Origin</li> <li>• The flow process</li> <li>• waste</li> </ul>	<b>Time 5 mins</b>
<b>Introduction of Lean construction control tools</b> Lean construction time control <ul style="list-style-type: none"> <li>• LPS</li> </ul> Lean material logistic <ul style="list-style-type: none"> <li>• Tool Plan maturity check</li> <li>• Tool Work preparation – time control</li> <li>• Logistics concept/Logistics planning</li> </ul> Lean manpower logistic <ul style="list-style-type: none"> <li>• Tool LPS 6 wks lookahead</li> <li>• Tool WWP</li> <li>• Location planning</li> </ul> Lean plant logistic Lean construction information logistics Lean construction quality control	<b>Time 15-20 mins</b>
<b>Assessment</b> Questions on control tools to identify their potential	<b>Time: 20-30 mins</b>

Figure 6-1 Interview structure



## The interview questions

The questionnaire design is discussed in the Research methods Chapter 2 and the full questionnaire can be found under Appendix A.

## 6.2 Interview write up

### The participants:

The people chosen as interview participants were construction project managers with considerable experience in their profession. Table 6-2 provides an overview on the participants, their experience and current career level.

Background participants				
participant	1	2	3	4
position/ career level	senior project manager	site manager	senior project manager	site manager
experience	25 years	13 years	35 years	30 years
current construction site	sewage infrastructure project ABK Akranes/ Bogranes/ Kjalarnes	Natturfraeðihús /House of nature and science Reykjavik	Háskólinn í Reykjavik/ new Reykjavik University	Roadwork and two bridges in Reykjavik

Table 6-2: interview participant

### The questionnaire:

**Question 1** – Are you familiar with Lean production construction ideas/ concept?

Type of question – Knowledge based /closed end question / dichotomous yes/no question

Responses – Three responded yes with comments; one responded no.

Comments given – Participants that answered yes mentioned that they have not been familiar with the concepts prior to the interviewer introducing them just before the interview took place.

Conclusion – None of the participants had been aware of the Lean construction concepts prior to the interviews.

**Question 2** – Identify which; in your opinion are the biggest sources for waste?

Type of question – opinion based/ closed end question/ multiple answers Likert scale

Responses – The answers to this question were assessed by using a Likert scale. The scale ranged from 1 (no source for waste) to 4 (very significant source of waste). In the overview Table 6-3 the waste sources were ranked descending from the highest average score. The most significant waste sources identified in the interviews were: procedures/ working protocols (Ø score of 2.75) followed by the Allocation of equipment (Ø score of 2.5). Next on the significance scale, is a group of four waste sources including Material deterioration, waiting for others to complete their work, clients clarification and the transportation of workers, equipment and material (all Ø score of 2.25).



**Table 6-3: answers question 2**

significance of sources for waste						
rank	type of waste	scores given				average score
1	procedures/ working protocols	2	4	2	3	2,75
2	Allocation of equipment on site	2	2	2	4	2,5
3	Material deterioration/ damaged during construction period	2	2	2	3	2,25
4	waiting for others to complete their work	2	2	3	2	2,25
5	waiting for clarification from client	2	2	2	3	2,25
6	time to transport workers, material and equipment	2	3	1	3	2,25
7	Allocation of material on site	2	2	2	2	2
8	Allocation of workers on site	1	2	2	3	2
9	resting time of the workers	1	2	2	3	2
10	Accidents on site	1	2	2	2	1,75
11	waiting for material to be delivered on site	2	2	2	1	1,75
12	time for supervising and inspecting the works	2	2	1	2	1,75
13	Material loss/ stolen from site during construction period	1	2	1	2	1,5
14	waiting for equipment to be delivered on site	1	2	2	1	1,5
15	time for instruction and communication among workers	1	2	1	2	1,5
16	waiting for skilled workers	1	2	1	1	1,25

**Question 3** – Do you think lean construction is beneficial for both small and major construction projects?

Type of question – opinion based/ closed end question/ dichotomous yes/no question

Responses – All participants answered yes to this question, one responded with a comment

Comments given – One participant commented on this question and his statement was that Lean construction could save both money and time in both settings.

**Question 4** – Do you think that lean construction techniques could improve productivity in construction?

Type of question – opinion bases/ closed end question/ dichotomous yes/no question

Responses – All participants answered yes to this question

Comments given – One participant commented on this question and his statement was that good scheduling is always helpful when accurately done




---

<b>Question 5</b>	– Do you think that lean construction techniques could improve the quality of the construction product?
Type of question	– opinion based/ closed end question/ dichotomous yes/no question
Responses	– Three responded yes; one responded with a maybe

---

<b>Question 6</b>	– Do you think that lean construction when used at site level could generate cost savings?
Type of question	– opinion based/ closed end question/ dichotomous yes/no question
Responses	– Two interviewees responded yes to this question, one responded with a maybe and a comment and, one responded with a no and a comment.
Comments given	– The respondent answering with maybe reasoned that this technique might only generate cost savings in bigger projects. The respondent answering with no stated that the cost for the additional tools and the manpower necessary to run the system is higher than the costs for correcting mistakes, but it might generate cost savings in big Projects.

---

<b>Question 7</b>	– Which statement is in your opinion closer to the truth: Problems in conventional project management occur due to: a) wrong usage of the project management tools (right tools in wrong hands); CPM...? b) failure of traditional management tools to manage the in process flows? c) none of the before mentioned, neither a nor b?
Type of question	– opinion based/ closed end question/ multiple answers
Responses	– One interviewee thought that a) is the most suitable answer. Two interviewees thought that b) is closer to the truth. One interviewee thought c) is the most sufficient answer.
Comments given	– One of the interviewees answering b) commented that practitioners do not spend enough time in planning and therefore we have problems in project management.

---



---

<b>Question 8</b>	– Do you think lean/JIT material supplies are a suitable solution in construction?
Type of question	– opinion bases/ closed end question/ dichotomous yes/no question
Responses	– Two interviewees responded that Lean/JIT delivery is a suitable solution. One interviewee responded that Lean/JIT delivery is not at all suitable in Icelandic construction. One interviewee has undecided as his response.
Comments given	– The interviewee responding with no reasoned that in Iceland Lean/JIT supply is not possible due to the limited stock of Icelandic suppliers. One of the interviewees responding with yes made a comment that JIT/ Lean is only a good idea on major construction sites. The undecided interviewee commented on his answer and stated that in his opinion Lean/JIT is suitable for some projects.

---

<b>Question 9</b>	– Do you think the Last Planner scheduling system could replace the critical path method?
Type of question	– opinion bases/ closed end question/ dichotomous yes/no question
Responses	– Three responded yes and one responded with a maybe.
Comments given	– One of the interviewees commented on his answer and stated that the replacement of the Critical Path Method by the Last Planner technique is only possible when ‘you have the money and manpower available to do so’.

---

<b>Question 10a)</b>	– Which of the following techniques and control instruments yield in your opinion the biggest potential for improvement?
Type of question	– opinion based/ closed end question/ multiple answers Likert scale
Responses	– The answers to this question were assessed by using a Likert scale. The scale ranged from 1 (no potential for improvement) to 4 (great potential for improvement). In the overview, Table 6-4, the control tools were ranked descending from the highest average score. The highest overall score and, therefore the highest potential for improvement in the opinion of the interviewees, was given to three tools, the plan maturity check, the work preparation time control and increased preassembly (Ø score of 3.25). The next highest scores went to the Last Planner system and the Project board daily briefing tools (Ø score of 3). The tool with the least potential for improvement according to the interviewees is the intense staff training (Ø score of 1.5).

---

**Table 6-4: answers question 10 a)**

potential of control techniques for improvement						
rank	type	scores given				average score
1	Plan maturity check	3	4	4	2	3,25
2	work preparation - Time control	3	4	3	3	3,25
3	Increased preassembly	3	4	3	3	3,25
4	Last Planner system	3	3	3	3	3
5	Project board- daily briefing	4	2	3	3	3
6	area base logistic concept	3	4	2	2	2,75
7	Systematically daily reverse logistics	2	2	3	2	2,25
8	Method statements for all tasks/ feed forward of design to construction	3	2	2	2	2,25
9	Quality and progress database (Quality board)	2	2	1	2	1,75
10	Intense staff training	2	1	1	2	1,5

**Table 6-5: answers question 10 b)**

ease to use and implement the control techniques						
rank	type	scores given				average score
1	area base logistic concept	4	3	3	2	3
2	Project board- daily briefing	3	3	3	3	3
3	Increased preassembly	3	4	3	2	3
4	work preparation - Time control	3	2	3	3	2,75
5	Plan maturity check	3	2	3	2	2,5
6	Last Planner system	3	2	3	2	2,5
7	Method statements for all tasks/ feed forward of design to construction	3	1	3	3	2,5
8	Quality and progress database (Quality board)	4	1	1	2	2
9	Systematically daily reverse logistics	4	1	1	2	2
10	Intense staff training	2	1	1	2	1,5



---

<b>Question 10b)</b>	– Which of the following techniques and control instruments are, in your opinion easy to use and to implement?
Type of question	– opinion based/ closed end question/ multiple answers Likert scale
Responses	– The responses to this question were assessed by using a Likert scale. The scale ranged from 1 (difficult to use and to implement) to 4 (easy to use and implement). In the overview, the control tools were ranked descending from the highest average score to the lowest. The highest score for use and implementation was reached by three tools, namely the area logistics concept, the daily briefings project board, and the increased preassembly (Ø score of 3), followed by the work preparation Time control with an average score of Ø 2.75. The tool that is most difficult to use according to the interviewees is the intense staff training with an average score of 1.5.

---

<b>Question 11</b>	– Which statement is in your opinion closer to the truth? Applying techniques from manufacturing to construction is a) possible (with adjustments) b) is like fitting a round peg in a square hole. c) none of the before mentioned, neither a nor b
Type of question	– opinion based/ closed end question/ multiple answers
Response	– All participants thought that a) is the most suitable answer.
Comments given	– One interviewee commented upon this question that there are significant differences between manufacturing and construction because in construction only one product is produced while in manufacturing thousands or millions pieces of the same product are produced.

---



### Summary of the additional comments given

Some interviewees made additional overall comments during the interview and after the final interview question was asked, to express their overall opinion on the subject. In Table 6-6 some of their comments are listed sorted by pros and cons for the new techniques.

**Table 6-6: additional comments**

Comments Pro Lean techniques	Comments contra Lean techniques
usefull in some projects	In Iceland the design is often done parallel to production
some tools could improve the projects when used additional to the tools already used	The late design makes detailed process planning very difficult
good scheduling is always helpful when accurately done	An indicator for this late design is the huge amount of extra works in Iceland, meaning usually $\approx 20\%$ of the bid prize is extra works
We could learn from some of the tools	The weather uncertainty makes detailed process planning very difficult e.g. easier in Japan.
Might be usefull in big projects	Suppliers are usually very far away (mainland Europe)- makes JIT delivery difficult
JIT can help us in planning big projects	Very high costs to set this system up
LPS could replace the CPM when money and manpower is available to do so	additional planning manpower required
Daily site meetings could be helpfull when only the key workers are briefed	Only possible on large scale projects
	Suppliers in Iceland do not have enough goods in stock to use JIT techniques
	Intense staff training not required- we hire professionals
	The costs for running this systems are higher than the cost of correcting mistakes.
	One comment was: we are already doing many of this tools today

### **6.3 Discussion of the results**

The first research question to answer at this stage is:

(1) Assess the likely acceptance amongst Icelandic construction companies of the project controls' template.

- The results of the interviews show that the construction managers recognized that some of the techniques introduced in the controls template could hold potential for improvement in the construction process. The tools most favoured by the managers interviewed, were the plan maturity check tool and the work preparation-time control and, increased preassembly.
- However, not all of the tools introduced were seen as beneficial to the construction process. The tool seen as most critical was the intense staff training tool.
- The results of the interviews show that the construction managers interviewed regarded some of the tools introduced as easy to use and implement, while others were seen as more difficult to use and implement.
- Two respondents mentioned that some of the tools could improve the projects when used in addition to the tools already used.
- It was repeatedly mentioned throughout the interviews that the techniques are only useful in large scale projects, due to the fact that the setup of the system and tools are regarded as costly and manpower intensive.
- The respondents repeatedly raised concerns about the manpower and funds needed to execute the techniques.
- One respondent mentioned that, in Iceland, detailed process planning is very difficult due to the fact of high weather uncertainty.
- It was mentioned that JIT delivery systems in Icelandic context are difficult to use due to the fact that the suppliers usually do not have enough goods in stock and that many supplies need to be shipped from mainland Europe.



The second research question to answer at this stage is:

(2) Determine the current appreciation of lean construction within the Icelandic construction industry.

- The results of the interviews show that none of the construction managers had been aware of the Lean construction concepts and ideas prior to the interviews
- When asked about sources of waste in construction projects the responders overall gave rather low scores e.g. 90% of the given answers ranged between 1 (no source) for waste and 2.
- All of the respondents agreed that Lean construction methods can be beneficial for both small and major construction projects.
- All respondents see possible improvements for productivity when using Lean construction techniques.
- Most of the respondents see possible improvements for the quality of the construction product when Lean techniques are used.
- The potential for cost reduction was discussed controversially by the respondents. Some of the respondents state critically that the additional resources (both planning manpower and tools) needed to implement and, running the system might be higher than the cost savings. One respondent mentioned that a Lean system might only generate cost savings in bigger projects.
- Perhaps the most important question to identify the appreciation of Lean construction is question 7, where the respondents were asked to give their opinion on the question 'why do problems in conventional project management techniques occur?' Two respondents see the cause of problems in the failure of conventional project management to manage in process flows. One responded that the techniques fail because practitioners fail to use them right; another responded that problems in conventional construction management occur due to the fact that practitioners just do not spend enough time in planning.
- All respondents thought that an application of manufacturing techniques in construction is possible with adjustments taking the nature of construction into account.



## 6.4 Conclusions

To sum up the findings, the respondents regarded some of the techniques as helpful in improving construction management practices but, they also expressed concerns about the practicability of these techniques.

Major obstacles to the implementation of a lean construction control system, according to the project managers are:

- a) funding and manpower required to set such a controls' template up and to run it
- b) the remote location of Iceland and Icelandic construction sites, making JIT delivery exceedingly difficult.

Therefore, the practitioners see the potential of the tools introduced in the lean construction template but they do not really regard them as practicable in Icelandic construction context at this point in time.

When identifying the appreciation of Lean construction ideas it is important to identify the respondent's awareness of waste in construction. Since the idea of waste reduction is central to the Lean paradigm and the real motivation behind Lean construction. Almost all of the respondents evaluated the waste occurring on construction projects as rather insignificant. Considering this, it can be doubted that the respondents regarded the Lean construction instruments as really necessary.

Nevertheless, respondents agreed on the statements that Lean construction techniques could prove beneficial to increase productivity and quality throughout the construction process. Most of the respondents were undecided about whether cost performance could be enhanced by using Lean construction methods and some respondents considered the additional planning manpower and funds required as an obstacle to Lean construction. This observation could be explained by looking into the respondent's awareness of waste in construction projects, since Lean construction techniques are only financially interesting when a significant amount of costly waste exists that could be eliminated by these.

Here the 'camp' classification described earlier (in Chapter 1.3) is used to identify the appreciation of lean construction ideas within the respondent's group. The respondent's appreciation could be identified to be evenly distributed into two groups. Half of the respondents can be said to be supporters of the Lean construction ideas. This group saw the reason for problems in current project management in the failure of the methods to manage the flow in construction projects. While the others regarded the conventional project management tools as sufficient to manage construction projects, when done correctly and enough time is spend in planning.



## 7 Conclusions

*This chapter is a summary of the key findings obtained in this research work. The research objectives are revisited and it is stated where these were covered within the thesis. Additionally, further recommendations for future research work and a prognosis of future practice are given.*

---

### 7.1 Summary of the research work

Here all research stages are revisited and the Key findings at each stage are summarized.

Firstly, this thesis has established the basis of project management tools used to control construction within the Icelandic construction industry. A case study identifying the project management tools used at Ístak, Iceland's largest contractor was carried out as means to obtain an Indicator for wider project management practice within the Icelandic construction industry. The case study write up can be found within Chapter 4. Key findings of the case study were that Ístak manages their projects based on management tools inspired by traditional project management.

Secondly, this thesis established a project controls template aligned to the lean construction paradigm that could be used by Icelandic construction companies. This work was produced by identifying practice examples of how the construction Industry outside of Iceland applies management controls aligned to the Lean construction paradigm at site level. The lean construction controls practice examples are combined in a management template addressing the most critical management considerations at site level. The template is presented within chapter 5. The tools identified are foremost focused on the creation of flow in the construction activities and on systematically waste reduction. The key control instruments identified at this stage are the Last Planner system, Location based scheduling and Just In Time delivery considerations.

Lastly, this thesis identified the likely acceptance amongst Icelandic construction companies of the controls template and the current appreciation of lean construction within the Icelandic construction industry. The two aforementioned research questions have been answered by conducting interviews featuring verbal administered questionnaires as a structured means for data collection. The interviews were directed at a select number of practitioners. The write up of these interviews is presented in chapter 6. The key findings at this research stage were that practitioners recognized the potential of lean construction ideas and tools to improve practice but, on the other hand, they identified many obstacles to a site implementation of these techniques in the Icelandic construction context.

### 7.2 Concluding discussion

#### Case study discussion (conventional vs. Lean)

The case study at Ístak identified practices that can be said to be 'inefficient or wasteful' when thinking of them in the terms of lean construction. However, some of these techniques are logical and enable the projects to be delivered efficiently. These techniques were for example a) stockholding and b) batch purchasing. It is reasoned below why these considerations have their place in construction.



a) JIT efficiency considerations in the use of resources could lead to out-of-stock situations, signifying, in the worst case, that the construction projects run out of material when just one member in the supply chain fails to perform sufficiently. This is especially true in construction projects which are subject to significant variation and major disruptive influences e.g. high uncertainty. Therefore, it is crucial for construction companies to use safety stocks as a buffer against uncertainty. Uncertainty, in this context, is the time variations between Point of Order and on site delivery. The safety stock is a means of ensuring that the construction materials are in place when needed. In the mindset of 'Lean' a safety stock is regarded as unnecessary waste, but nevertheless it can be a logical decision to have one.

b) Also purchasing goods in bigger batch sizes, e.g. making use of economies of scale and ordering materials to make use of discounts, is according to the lean construction considerations the creation of useless 'waste', but it can be logical and wise to do so.

To sum it up, despite all the benefits a lean supply chain could offer it has to be carefully considered in which context or at what kind of construction project these techniques are helpful and when they rather cause difficulties with regard to project delivery. Sometimes, even practices that appear wasteful at first might prove as practical and logical at the project level.

The case study at Ístak identified a management system based on the ideas of traditional Project management. Furthermore, it became evident that certain management techniques associated with Project management like CPM and EV are not frequently used at site level. When thinking about improving construction performance in the Icelandic industry the establishment of best practice project management could be an alternative to the implementation of a 'leaner' management system.

### **Interview discussion**

Despite the positivistic opinion of the respondents about Lean construction ideas and their potential to improve practice and the positive appreciation of some of the control tools, several major drawbacks in this technique have been identified. These are, for example, that more planning effort is required and Lean can only be sufficiently done when production planning ideas are promoted already during design enabling further modularization and industrialization. Furthermore, when thinking of a practical implementation of Lean construction techniques it could be beneficial to improve supplier contractor relationships to establish a more reliable supply chain.

Besides it can be doubted that Lean construction methodologies are applicable in every construction setting. One of the major concerns Icelandic construction managers had about Lean construction was the remote location of their construction sites and therefore, the limited access to supplies. Also, the weather uncertainty was mentioned as an obstacle to Lean construction in the Icelandic construction context.

### **7.3 Final Conclusions**

Construction as it is today can be said to be a project centred form of production as opposed to a process centred form of production in manufacturing. The goal of Lean construction is a further industrialization of construction. The lean project controls identified, intend to increase process planning precision from a macro level of accuracy towards a micro level of accuracy. The controls template identified made it evident that lean construction tools seek to enhance production efficiency in the sense of a faster, more dynamic and, more precise execution of single construction tasks. Some Lean construction supporters are very

optimistic about these control techniques to reform or even revolutionize project management by creation of more efficiency and profitability in construction.

What became clear, after having assessed what lean construction has to offer at site level, is that some of the tools yield potential for improving the construction process efficiency at site level but, it also became evident that a significantly higher amount of planning work is required to ready and prepare the tasks. In addition, it was revealed that these techniques cannot be said to be applicable to every construction setting, e.g. some construction sites will always need stock to some degree to mitigate for uncertainty. Therefore, it can be concluded that today's Lean construction tools need to incorporate many of the already existing management techniques.

In the author's opinion, a real effective project management system should take a more balanced approach and integrate both construction management philosophies. Moreover, a more customized approach to integrating Lean construction ideas in project management has to be chosen to fit each project's specific management situation. The author expects, assumed a more integrated, customized approach to implementation of Lean construction techniques is taken, that a faster production process and improved profitability in delivery of a construction project can be achieved.

Nevertheless, the statements by Lean construction supporters can be seen as overly optimistic, these techniques could gradually improve current management, but this technique is not the 'silver bullet' to cure all problems in construction management.

#### ***7.4 Prognosis for future practice***

Despite the positive reactions of practitioners towards the Lean controls template, the author does not expect a rapid implementation of these techniques within the Icelandic industry. But in the long run, with the implementation of more sophisticated planning instruments like 4D and BIM, planning tools like the MS Project Gantt chart will possibly be replaced by other instruments like LBS and the planning accuracy will be increased. These changes will lead to a 'leaner' form of construction management, but due to the very nature of construction the degree of leanness will probably never, in the near future, be anywhere close to the lean paradigm production as exercised in manufacturing.

#### ***7.5 Proposal for further research***

This thesis identified a project controls template that could be used by the Icelandic construction industry and assessed the likely appreciation of this template. Furthermore, research should continue from here and, the most promising tools should be further tested at site level by conducting Action research. It would be interesting to conduct a series of case studies where similar construction projects are compared when managed by traditional project management techniques vs. Lean construction techniques. These case studies could deliver information on whether Lean construction can improve overall project performance in Icelandic construction context. The long range goal is to gain knowledge about whether these techniques should be implemented and used in wider practice.



## References

- Al-Jibouri Saad, H. (2003) *Monitoring systems and their effectiveness for project cost control in construction*. International Journal of Project Management 21 (2003) 145–154, University of Twente, CT & M
- Andersson, N. and Christensen K. (2007) *Practical implementations of location based scheduling*, Department of Civil Engineering, Technical University of Denmark
- Arbnoor, I. and Bjerke, B. (1997) *Methodology for creating business knowledge*, 2<sup>nd</sup> Edt. SAGE Publications Ltd. London
- ASCE, 106 (1), 23-25
- Ballard, H.G. (2000) *The last planner system of production control*, doctoral thesis Dept. of Civil Engineering University of Birmingham, May 2000
- Berliner, C. and Brimson, J.A. (1988), *Cost Management for Today's Advanced Manufacturing: The CAM-I Conceptual Design*, Harvard Business School Press, Boston, MA
- Bertelsen, S. (2004) *Lean Construction: Where are we and how to proceed*, Lean Construction Journal #1, Volume 1
- Birrell, J. (1980). *Beyond the Critical Path*. J. of the Const. Engr. And Mgmt. Div.,
- Björnfort, A. and Stehn, L. (2004) *Industrialization of construction – a lean modular approach*, 12<sup>th</sup> Annual Conference on Lean Construction, Copenhagen
- Blumenthal, A. (2008) *Lean Logistics, lessons learnt from Japan* LCI-UK Summit on Lean logistics in integrated project delivery, London
- Cantner, U., Krüger, J. and Hanusch, H. (2007) *Produktivitäts- und Effizienzanalyse: Der nichtparametrische Ansatz*, Springer, Berlin
- CURT (2004), *Construction Project Controls: Cost, Schedule, and Change management*, User Practice UP 201 Construction Users Roundtable, Ohio
- Dorf, R.C. and Bishop, R.H. (2008); *Modern control Systems*, 11<sup>th</sup> edn, Prentice Hall engineering, New Jersey
- Doyle, J. and Francis, B. Tannenbaum, A. (1990); *Feedback Control Theory*, Macmillan Publishing Co., 1990 Toronto
- Euroconstruct (2008) Euroconstruct annual country report 2008
- Fellows, R. and Liu A. (2003) *Research Methods for Construction*, 2nd edn, Blackwell Science, Oxford
- Ford, H. (1922); *My Life and work*, Kessinger Pub Co (2004)
- Freedman, D.H. (2000) *Corps business: The 30 management principles of the US Marines*, Harper Business, New York
- Gilbreth, F.B. and Gilbreth, L.M. (1922). *Process Charts and Their Place in management*. Mechanical Engineering, January, pp. 38-41, 70.
- Gillham, B. (2000) *The research interview* Continuum London

- Gray, C.F. and Larson, E.W. (2008): *Project Management the managerial process 4e*, McGraw-Hill, New York
- Green S.D. (1999) *The dark side of lean construction: exploitation and ideology*, Proceedings International group for Lean construction IGLC-7
- Grubbström R.W. (1995) *Modelling production opportunities – an historical overview*. Int. J. Production Economics 41 (1995) 1-14
- Gustafsson, J. Salo, A. and Gustafsson T. (2001) *PRIME Decisions: an Interactive Tool for Value Tree Analysis*, in Multiple criteria decision making in the new millennium, Springer-Verlag Berlin
- Hopp W.J., Spearman M.L. and Woodruff D.L. (1990) *Practical Strategies for Lead Time Reduction*, Manufacturing Review, Vol. 3, No 2, June 1990
- Hughes, W.P. (1991) *Effective control of construction projects*, UK Paper to 7th Annual ARCOM conference, University of Reading.
- Humphreys, K.K. (2005) *AACE Project and cost engineers' Handbook*, 4th edn, CRC Press, New York
- Ikedo, Y. (2006) *Léon Walras and the English Classical School: Walras's Production Theory Revisited*, Keio University, Japan
- Illingworth, J.R. (2000) *Construction Methods and Planning*, 2nd edn, E&FN Spon, London
- Jongeling, R and Olofsson, T. (2007) *A method for planning of work-flow by combined use of location-based scheduling and 4D CAD*, Automation in Construction, Volume 16, Issue 2, March 2007, Pages 189-198
- Kelly, J. and Male, S. (2001) "A quick approach to task fast diagrams", SAVE international
- Kenley, R. and Seppänen, O. (2009) *Location-Based Management for Construction: Planning, Scheduling and Control* (Spon Research)
- Kerzner, H. (1988) *Pricing out the Work Project*, Management Handbook, Van Nostrand Reinhold, New York
- Koskela, L. (1992) *Application of the new production philosophy to construction*, CIFE Technical Report: 72. Stanford University. 75p.
- Koskela, L. (1999) *Management of production in construction: A theoretical view* 7th Conference of the International Group for Lean Construction, IGLC-7. Berkeley, 26 - 28 July 1999, pp. 241 – 252
- Koskela, L. (2000) *An exploration towards a production theory and its application to construction*, doctoral dissertation, VTT Building technology Publications 408 Espoo, Finland
- Koskela, L. (2004) *Moving-on – beyond lean thinking*, Lean construction Journal, Vol. 1, No.1 October 2004
- Koskela, L. and Howell, G.A. (2002): *The underlying theory of project management is obsolete*, Project Management Institute
- Lane, R., Lepardo, V. and Woodman, G. (2002) *How to deal with dynamic complexity on large, long Projects* 27th International Air Transport Conference, June 30 - July 3, 2002, Orlando, Florida



- Leibenstein, H. (1975) *Aspects of the X-efficiency theory of the firm*, Bell Journal of Economics 6: 580–606
- Leontief, W.W. (1928) *Die Wirtschaft als Kreislauf*. Archiv für Sozialwissenschaft und Sozialpolitik, 60; 577-623
- Liker, J.K. (2004) *The Toyota Way-14 Management principles from the worlds greatest manufacturer*, McGraw-Hill, New York
- Little, J.D.C. (1961) *A Proof for the Queuing Formula:  $L = \lambda W$*  Operations Research, Vol. 9, No. 3. May-June 1961, pp. 383-387
- Lædre, O. Hauge, T.I. (2001) *Use of project partnering in construction*
- Madigan, D. (1996) *Business Process Modeling techniques for civil engineering*, Agile construction initiative, University of Bath
- Menger, C. (1871) *Grundsätze der Volkswirtschaftslehre, erster allgemeiner Theil*. Wilhelm Braumüller K.K. Hof- und Universitätsbuchhändler (1871), Vienna
- Miles, L.D. (1989) *Techniques of Value Analysis and Engineering*, 3rd edn, published by Eleanor Miles Walker, Lawrence D. Miles Value Foundation, Washington, D.C.
- Nielsen, A. and Thomassen, A. (2004) *How to reduce Batch-size* Conference of the International Group for Lean Construction, IGLC-12. Copenhagen, 03 - 05 Aug 2004
- Norton, B.R. and McElligot, C.W. (1995). *Value management in construction a practical guide*, Macmillan, Basingstoke  
Norwegian University of Science and Technology, Trondheim Norway
- Ogata, K. (1967) *State space analysis of control systems*, Prentice-Hall Inc, Englewood Cliffs, NJ
- OGC (2007) *Value Management in construction case studies* CP0152 Office of Government Commerce, London
- Ohno, T. and Mito, S. (1988) *Just-in-time for today and tomorrow* Productivity Press New York, NY
- Ott, M. (2005) *Wertemanagement im Mittelpunkt*, deutsches Baublatt Nr. 313, Juni 2005
- Richard Palczynski (2008) “*Lean*” in the Delivery of a Major Railway Construction Works LCI-UK Summit 2008 “Lean Logistics in Integrated Project Delivery”
- Rolstadas, A. (1995) *Planning and control of concurrent engineering projects* International Journal of Production Economics 38 3-13 University of Trondheim, Division of Production Engineering, Trondheim, Norway
- Salem, O., Genaidy, A., Luegring, P.E., Paez, O. and Solomon, J. (2004) *The path from lean manufacturing to lean construction: implementation and evaluation of lean assembly*, IGLC 12<sup>th</sup> annual conference of lean construction Aug. 2004, Copenhagen
- Senior, A.B. (2007) *Implications of Action Theories to Lean construction applications* Proceedings IGLC-15, July 2007, Michigan, USA
- Shah, R. and Ward, P. (2003) *Lean Manufacturing: Context, Practice Bundles, and Performance*. Operations Management, 21 (2) 129-149

- Shen, Q. and Liu, G. (2003) *Critical Success Factors for Value Management Studies in Construction*, Journal of construction engineering and management ASCE/Sep/Oct 2003, pp. 485 - 491
- Smith, A. (1776) *An inquiry into the Nature and Causes of the wealth of Nations*. Edited by S.M. Soares. MetaLibri Digital Library May 2007 pp 15-16
- Sowards, D. (2004) *5S's that would make any CEO Happy*, Contractor Magazine, 2004
- Statistic Iceland (2009) *Manufacturing and Construction Iceland in figures / Publications* Statistics Iceland
- Thomas, H.R. and Sinha S.K. (2002) *Are Construction sites and Manufacturing facilities the same?* The Organization and Management of Construction 10th International Symposium (2002)
- Thomassen, M.A., Sander, D., Barnes, K.A. and Nielsen, A.(2003) *Experience and results from implementing Lean construction in a large Danish contracting firm*, ICLA annual conference 2003, Copenhagen
- Turner, J.R. (1993) *The Handbook of Project-based Management: Improving for Achieving Strategic Objectives*, McGraw-Hill, London
- Varkevisser, C.M., Pathmanathan, I. and Brownlee, A. (2003) *Designing and conducting health systems research projects* WHO International Development Research Centre, Amsterdam
- Womack, J. P. and Jones D.T. (2003) *Lean Thinking Banish Waste and Create Wealth in Your Corporation* Free Press. p. 352
- Porvaldsson, Ó.T. (2008) *Awareness and Application of the earned Value Method among construction managers in Reykjavik*, Master thesis Reykjavik University

## Online Sources

- Leeds (2009) [http://iss.leeds.ac.uk/info/312/surveys/217/guide\\_to\\_the\\_design\\_of\\_questionnaires/2](http://iss.leeds.ac.uk/info/312/surveys/217/guide_to_the_design_of_questionnaires/2) 2009-11-18 16:28
- Mishra (2007) *A Brief History of Production Functions*, North-Eastern Hill University (NEHU) Shillong, India. Available at SSRN: <http://ssrn.com/abstract=1020577>
- Reuters (2009) <http://www.reuters.com/article/pressRelease> 2009-08-12  
*Turner's Utilization of BIM and Lean Construction on Middle Tennessee Medical Center in Murfreesboro, Tenn. to Save Project Millions of Dollars*

## Appendix A

Here the questionnaire used to support the interviews is presented.

School of science and engineering	construction management
 <b>HÁSKÓLINN Í REYKJAVÍK</b> REYKJAVÍK UNIVERSITY	
Interview. No 1	date:
<b>Appreciation of Lean construction Methods in Icelandic construction</b>	

Definition of terms as understood in the questionnaire	
Lean production construction	production philosophy originating in manufacturing focused on in process flows
waste	wasteful, and non value adding activity in a production process
Last planner system	shifting planning responsibility to foremen, systematically making ready of tasks, high level of detail, several levels of planning

Respondee	
Position /career level	
experience	
current construction site	

**Question 1:**

Are you familiar with Lean production construction ideas/ concept?

☐ yes    ☐ no

Reason:

**Question 2:**

Identify which, in your opinion, are the biggest sources for waste in Icelandic construction?

	no source for waste (1)	(2)	(3)	very significant source (4)
Allocation of equipment on site	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
Allocation of material on site	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
Allocation of workers on site	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
procedures/ working protocols	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
Material loss/ stolen from site during construction period	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
Material deterioration/ damaged during construction period	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
Accidents on site	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
waiting for others to complete their work	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
waiting for equipment to be delivered on site	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
waiting for material to be delivered on site	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
waiting for skilled workers	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
waiting for clarification from client	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
resting time of the workers	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
time for supervising and inspecting the works	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
time for instructions and communication among workers	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
time to transport workers, material and equipment	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>

**Question 3:**

Do you think lean construction is beneficial for both small and major construction projects?

☐ yes    ☐ no

Reason:

**Question 4:**

Do you think that lean construction techniques could improve productivity in construction?

☐ yes    ☐ no

Reason:

**Question 5:**

Do you think that lean construction techniques could improve the quality of the construction product?

☐ yes    ☐ no

Reason:

**Question 6:**

Do you think that lean construction techniques when used at site level could generate cost savings?

☐ yes    ☐ no

Reason:

**Question 7:**

Which statement is in your opinion closer to the truth:

Problems in conventional project management occur due to

- a) wrong usage of the project management tools (right tools in wrong hands); CPM...
- b) failure of traditional project management tools to manage in process flows
- c) none of the before mentioned, neither a nor b

Reason:

**Question 8:**

Do you think lean/JIT material supplies are a suitable solution in construction?

☐ yes    ☐ no

Reason:

**Question 9:**

Do you think the Lean Last Planner scheduling system could replace the Critical Path Method?

☐ yes    ☐ no

Reason:

**Question 10:**

a) Which of the following techniques and control instruments yield in your opinion the biggest potential for improvement?

	no potential (1)	(2)	(3)	great potential (4)
Plan maturity check	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
Work preparation - Time control	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
area based Logistic concept	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
Last Planner System	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
Method statements for all tasks / feed forward design to construction	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
Project board- daily briefing	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
Intense staff training	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
Increased preassembly	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
Quality and progress database (Quality board)	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
Systematically daily reverse logistic	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>

b) Which of the following techniques and control instruments are, in your opinion easy to use and to implement?

	difficult to use (1)	(2)	(3)	easy to use (4)
Plan maturity check	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
Work preparation - Time control	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
area based Logistic concept	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
Last Planner System	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
Method statements for all tasks / feed forward design to construction	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
Project board- daily briefing	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
Intense staff training	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
Increased preassembly	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
Quality and progress database (Quality board)	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
Systematically daily reverse logistic	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>

**Question 11:**

Which statement is in your opinion closer to the truth:

Applying techniques from manufacturing to construction is

a) possible (with adjustments).

b) is like fitting a round peg in a square hole.

c) none of the before mentioned, neither a nor b

Reason: