



Master's degree thesis

LOG950 Logistics

**Efficient material delivery and site management;
A lean construction perspective. Case study at
Statsbygg.**

Daouda Dao

Bernt H. Follestad

Number of pages included the first page: 114

Molde, 2009-05-25



Publication agreement

Title: Efficient material delivery and site management; A lean construction perspective. Case study at Statsbygg.

Author(s): Daouda Dao and Bernt H. Follestad

Subject code: Log950

ECTS credits: 30

Year: 2009

Supervisor: Harald M. Hjelle

Agreement on electronic publication of master thesis

Author(s) have copyright to the thesis, including the exclusive right to publish the document (The Copyright Act §2).

All theses fulfilling the requirements will be registered and published in Brage HiM, with the approval of the author(s).

Theses with a confidentiality agreement will not be published.

I/we hereby give Molde University College the right to, free of charge, make the thesis available for electronic publication: yes no

Is there an agreement of confidentiality? yes no

(A supplementary confidentiality agreement must be filled in)

- If yes: **Can the thesis be online published when the period of confidentiality is expired?** yes no

Date: 2009-05-25



STANDARD AGREEMENT

This agreement is between (students) *Bernt H. Follestad (23/06/1980)*, *Daouda Dao (24/05/1983)*, *Harald Hjelle* (Faculty Advisor at Molde University College), *Statsbygg* (Company/Institution), and Molde University College/Office Manager

concerning the use of specifications and results reported in the Master’s degree thesis in accordance with the study plan for the Master’s degree program in Logistics at Molde University College.

1. The student shall complete the work assigned for the Master’s degree thesis at:

Statsbygg (Company/Institution)

The title of the thesis is: *Lean Construction at Statsbygg. (Preliminary title)*

2. The student has copyrights to the thesis. Those copies of the thesis submitted for evaluation along with descriptions and models, such as computer software that is included as part of or as an attachment to the thesis, belongs to Molde University College. The thesis and its attachments can be used by the College for teaching and research purposes without charge. The thesis and its attachments must not be used for other purposes.

3. The student has the right to publish the thesis, or parts of it, as an independent study or as part of a larger work, or in popularized form in any publication.

4. The company/institution has the right to receive a copy of the thesis with attachments, and the College’s evaluation of it. The company/institution will have three (3) months from the time the thesis is submitted to the College for censoring to determine whether a patent is possible and to apply for a patent for all or part of the results in the thesis. The specifications and results in the thesis can be used by the company/institution in its own activities.

5. A separate confidentiality agreement may be entered into between the parties, if the company/institution so desires.

Place.....

Date.....

Students

Faculty Advisor

Company/Institution

Office Manager

Acknowledgement

There are many people we would like to thank for their support during the process of this master thesis.

First and foremost, we would like to thank Associate Professor Harald M. Hjelle for his supervision, advices and professional guidance throughout this thesis.

We would also like to record our gratitude to Associate Professor Svein Bråthen for his kindness and guidance at the very early stage of this thesis.

We are heartily thankful to Karolis Dugnas, Research assistant at Molde Research Center for his advices and personal concern for this thesis. His support from the start to the end has been outstanding.

Our gratitude convey to Statsbygg for giving us the opportunity to write this Master thesis with them. Special thanks go to Hans Thomas Holm for his personal involvement in this project.

It is also a pleasure to pay tribute to the respondents who kindly took the time to respond to our survey.

Many thanks go to Cristina Ciobanu, Research assistant at Molde Research Center and David S. A. Guttormsen at the University of Leeds for their useful comments.

We would also like to address some special thanks:

From Daouda Dao

I am eternally indebted to my parents. To my Father Dao Maze Souleymane who passed away some years ago and my beloved Mother Fatoumata Sessouma, I would like to say thank you for their unconditional love and prayers.

Words fail me to express my profound gratitude to the Ministry of State for Plan and Development of the Ivory Coast, M. Paul Antoine Bohoun bouabre for his support in achieving this milestone. May God assist you in your outstanding service for the country.

I owe my deepest gratitude to Doctor Ibrahim Lokpo, Director of the department of follow-up and evaluation of development project in the Ivory Coast for believing in me.

The last but not the least, I am grateful to Professor Aka Joseph, Director of cooperation at the University of Cocody in the Ivory Coast for being at the beginning of this journey.

From Bernt H. Follestad

I would like to thank my family and friends for their support throughout this endeavour.

Abstract

Mossman (2007) suggests, good logistics is absolutely crucial to the building process as it “allows builders to get on with what they are good at - building, and not how the material actually arrives on site”. Failing to allow a continuous flow of material toward the construction site or improper site management can result in different kind of wastes. For a construction site with limited storage capacity, the situation can be even more challenging. The purpose of this paper was to determine where the problems lie in term of material delivery and site management for a single construction site in an urban area and give recommendations for improvement based on lean construction methods. Using a single case study and a qualitative research methodology to collect and analyze the data, results are drawn that provide pragmatic lean solutions for future projects.

Keywords: Lean construction, Lean supply chain management, 5S, case study.

Contents

1. Chapter 1 Introduction.....	8
1.1 Background	8
1.2 Objective and Scope of the Study.....	10
1.3 Research Problem	11
1.4 Organisation of the Study.....	12
1.5 Summary of the Research Process.....	12
Chapter 2 Literature Review	13
2.1 Lean Thinking	13
2.1.1 Lean Production.....	13
2.1.2 Eight Lean “Wastes”	14
2.1.3 Lean Principles	16
2.1.4 Lean Tools	19
2.1.4.1 5S.....	19
2.1.4.2 Kaizen.....	20
2.2 Lean Construction.....	20
2.2.1 History	21
2.2.2 Essential Features of Construction.....	22
2.2.4 Lean Construction versus Traditional Construction	24
2.2.5 Waste in the Construction Industry.....	29
2.3 Supply Chain Management	30
2.3.1 Supply Chain Management: Concepts and Developments	30
2.3.2 Construction Supply Chains	33
2.4 Lean Supply Chain Management in Construction.....	35
2.4.1 Pulling to Site Demand and Just-in-Time	36
2.4.2 Information Sharing and Collaboration.....	37
2.4.3 Supply Chain Coordination through the Management of Commitment	38
2.4.4 Planning Delivery and Material Management.....	40
2.4.5 The Last Planner System	42
2.4.6 Variability and Reliability Issues in Construction Supply Chains	45
2.5 Summary of Relevant Studies	46
2.6 Theoretical Model.....	48
Chapter 3 Research Methodology	49
3.1 Case Study as a Research Strategy	49
3.2 Case Study, Sample Size and Sample Selection	50
3.3 Research Design	51
3.3.1 Research Approach	51
3.3.2 Sources of Data.....	51
3.4 Data Analysis.....	52
3.5 Summary and Recommendations	53
Chapter 4 Case Study	54
4.1 Project Description	54
4.1.1 Introducing Statsbygg	54
4.1.2 Domus Medica.....	55
4.1.3 Background of the Field Study (IFI2).....	57
4.2 Data Collection.....	58
4.3 Limitations in Data Collection	61
Chapter 5: Findings from the Case Study.....	62

5.1 Respondent's Profiles	62
5.2 Material Delivery and Management	64
5.3 Just-In-Time versus Push	67
5.4 Site Management	69
5.5 Information Sharing, Collaboration and Coordination	71
5.6 Planning of Material delivery	73
5.7 Variability and reliability issues in construction supply chains	74
5.8 Summary	74
Chapter 6 Discussions and Recommendations	76
6.1 Shaping workflow: identify and removing constraints	76
6.1.1 Information sharing	77
6.1.2 Coordination, commitment and reliability	79
6.2 Planning.....	80
6.3 Rapid Learning Measurement	81
6.3.1 Just-In-Time Delivery	81
6.3.2 Material and Site Management	83
6.4 Summary of Recommendations.....	85
6.5 Conclusion.....	86
Chapter 7 Limitations and Future Research	87
7.1 Limitations	87
7.2 Future Research	87
References	88
Appendix.....	94
Appendix 1 Org. chart D-Medica.....	94
Appendix 2 Org. chart IFI-2	95
Appendix 3 Questionnaire	96

Figures

Figure 1: The Research Process (Adapted from Nel 2004).....	12
Figure 2: “The TPS house”. (Source: Liker 2004, p. 33).....	14
Figure 3: Lean Principles (Source: Womack and Jones 2003).....	17
Figure 4: Flow of traditional Project Management (Source: LCI Seminar 2002B).....	28
Figure 5: Work Flow of Lean Production Management (LCI Seminar 2002B).....	28
Figure 6: Myriad of construction supply chains (Source: Cox and Ireland 2002).....	34
Figure 7: The commitment loop (Source: Denning and Medina-Mora 1995).....	40
Figure 8: The seven preconditions of a construction task (Source: Koskela 2000).....	43
Figure 9: The Last Planner System (Adapted from: Ballard and Howell 1997; Bertelsen 2007).....	43
Figure 10: Model for Lean SCM.....	48
Figure 11: Aerial photo © Google with improved drawing of D-Medica (Adapted from Statsbygg 2008).....	56
Figure 12: The Construction Supply Network.....	57
Figure 13: IFI2 under construction	58
Figure 14: Architectural Lego™ of IFI2	58
Figure 15: Respondents organisations roles in the construction industry	63
Figure 16: Respondents’ roles.....	64
Figure 17: Challenges related to material delivery	66
Figure 18: Too much material stored on site at IFI2.....	68
Figure 19: Too much material stored on site for projects in general	68
Figure 20: Storage place inside the building.....	69
Figure 21: Allocated place for bricks inside the building.....	69
Figure 22: Place for consumables on the floor	69
Figure 23: Access roads for delivery vehicles	69
Figure 24: Staging area outside the building	69
Figure 25: Importance of site layout for material handling and delivery	70
Figure 26: Opinions on communication issues	71
Figure 27: Participants taking part in meetings	72
Figure 28: Ways of information sharing.....	73

Tables

Table 1: Transformation/Flow/Value (Source: Ballard 2000).....	26
Table 2: Comparison of Lean and Traditional construction (LCI seminar 2002B).....	27
Table 3: Traditional and Supply chain management approaches compared. (Source: Cooper and Ellram 1993).....	32
Table 4: Summary of relevant studies	46
Table 5: Respondents organisations roles in the construction industry	62
Table 6: Respondents’ roles.....	63
Table 7: Summary of findings	75

1. Chapter 1 Introduction

This chapter is divided into five sections. The background of the thesis is presented in the first section. The second section discusses the research problem. Objective and scope of the study are given in the third section. The fourth section explains the organization of the study and finally the research process is depicted.

1.1 Background

The construction industry is without any doubt a very important constituent of the Gross National Product (GNP) of a country. Construction can be regarded as a mechanism of generating employment, and offering job opportunities to millions of workers around the world. Therefore it plays an essential role in the socio-economic development of a country. Hampson (1997) argues that construction performance affects productivity across all sectors of the economy. According to Ortiz (2000), the construction industry is one of the most sensitive activities within any country's economy. Two of the most noticeable factors affecting the construction industry are the internal market variables and the consumers' demand. Such market variables are among others; employment rate and Gross Domestic Product. On the other hand, by generating employment opportunities and thereby income for the labour force, the construction industry will directly or indirectly influence consumers' spending and therefore provide a growth impetus to other sectors of the economy and ultimately the wealth of the country. Recently, in the United States of America, the stimulus package proposed by President Obama in his attempt to revive the US economy gives an illustration of this fact. A big share was earmarked to the construction industry in order to create jobs and encourage spending.

In Norway, the construction industry represents 12.5% (SSB 2009A, 2009B) of the Gross Domestic Product and employs around 173,910 (SSB 2008A) workers. In 2007, the total volume of all construction work in Norway was valued at over 6,601 million Norwegian kroner (NOK) (SSB 2008B) whilst wages and salaries amounted for 59,212 million NOK (SSB 2008B). Statsbygg plays an important role in this sector.

Furthermore, construction appears to be one of the most complex industries in the world. There are a multitude of issues which the construction industry is facing. Among other factors, the construction industry has a fragmented nature, lack of coordination and communication between participants, adversarial contractual relationship, lack of customer supplier focus; price-based supplier selection, ineffective use of technology and is based on temporary project organisations (for example, APCC 1997; DIST 1999). According to Haugen (1998) the construction industry in Norway is in a vulnerable situation due to unfavourable conditions linked to the geographical conditions (nature and weather) of the country. Haugen reports that productivity and quality problems are recurrent in Norway incurring more often than not projects' delays and exceeding budgets.

Due to the forces of globalisation and strong competitive environment in all sectors of the economy, the construction industry is looking to overhaul its business processes in order to improve performance. According to Horman and Kenley (1996), improving performance has two key components: "*doing it more effectively and doing it more efficiently*". Effectiveness refers to the process of maximizing value of the product, whereas efficiency refers to the process of minimizing or eliminating non-value adding items in the production line. Performance is achieved if value is attained effectively and efficiently. Lean thinking is a concept where the focus is to achieve the same kind of performance in areas where it has been applied.

As a concept, Lean thinking evolved from the car manufacturing industry in Japan with its roots in the Toyota Production System. It is a production philosophy which seeks for the elimination of waste of all kind in the production process. Whilst Lean thinking was successful in the car manufacturing, its applicability in the construction industry was questionable due to the fundamental differences between mass production and one of a kind type of production. Subsequently, several authors have studied its implementation in the industry and its encouraging results. According to Picchi (2002), the construction industry has been one of the first sectors to discuss Lean thinking in an environment different from where it has been developed.

The Lean movement in the construction industry began in 1992 with the creation of the International Group of Lean Construction (IGLC). Since then, the concept has gained raising popularity with many construction companies trying to implement the philosophy in their current form of project management. However, according to Zimmer et al. (2008), in their attempt to implement lean practices in their construction process the focus for most of the construction companies is in the field of operations whereas Lean philosophy focuses on the entire value stream of a construction project. They argue that one area in this value stream where waste and inefficiency are still apparent is along the supply chain. Studies in the construction industry performed by Bertelsen (1993) suggest that poor supply-chain design regularly increases project cost by ten percent.

Applications of Supply Chain Management techniques in manufacturing environments have not only improved companies' processes, but also saved a lot of money for companies applying it. Since contractors and suppliers production involve a large share of construction project cost, supply chain approaches may accomplish similar benefits in this sector (Arntzen et al. 1995).

1.2 Objective and Scope of the Study

Previous studies in Lean construction in Norway have been focusing on the actual construction process which means the building operations. In this thesis, the focus is on investigating improvement opportunities in the construction industry, utilizing the practice of Lean supply chain management.

The objective of this paper is to analyze the material delivery management and site material management of an ongoing construction project (IFI2). The thesis will also provide recommendations for an upcoming project (Domus Medica) where the concern is to find a strategy for Just-in-Time delivery of material and proper site management due to constrained construction site with limited storage capacity.

1.3 Research Problem

Bertelsen and Nielsen (1997, p. 1) assert:

Studies of logistics show that a substantial increase in productivity can be obtained by delivering building materials [...] 'Just-In-Time' and 'packed for the work process'. The additional cost [...] can easily be covered by the savings gained on the construction site.

An interesting reflection on Bertelsen and Nielsen's work clearly indicates that good logistics is absolutely crucial to the building process as it *“allows builders to get on with what they are good at - building, and not how the material actually arrives on site* (Mossman 2007, p. 199).

In comparison to other sectors, such as manufacturing, construction's main contractors remain relatively unsophisticated in their approach to the supply chain (Briscoe, Dainty, and Millett 2001). As for logistics, a big difference between the industrial and the construction sector is that quite often, construction projects take place where sites are very crowded; this situation is recurrent for projects located in urban areas. In big cities where virtually no storage space exists, a good management of supply chains in order to get materials, people, information, machines, and equipment to the workforce in a Lean manner (Just-in-Time) is vitally important to project success (Mossman, 2007). Our case study at Statsbygg (the Norwegian Directorate of Public Construction and Property) is concerned with a project located in a city with very limited storage capacity.

This thesis aims to investigate improvement opportunities in the supply chain of construction projects, utilizing Lean methods. Hence, the following research question:

“How can the implementation of Lean methods improve logistics planning, delivery and the handling of materials when storage space in a construction site tends to be limited?”

1.4 Organisation of the Study

This thesis consists of seven chapters. Chapter one consists of an introduction, the research process, the scope and objective of the study and the research problem. In chapter two, relevant literature is reviewed. The research methodology used for this study is discussed in chapter 3. In chapter 4, the case study is introduced and the procedure for data collection is discussed. Limitations in data collection are also pinpointed. The data collected are analyzed in chapter 5. Chapter 6 is dedicated to the discussions and recommendations as well as the summary of the recommendations and draw the conclusion of the study. Chapter 7 displays the limitations and future research derived from the study.

1.5 Summary of the Research Process

This section describes the research process from the start to the end. The section explains the step by step methodology the authors used in order to answer the research question. In the first step, the objectives and scope of the study were determined in collaboration with Statsbygg. The second step consisted of formulating the research question based on the challenges pointed out by Statsbygg. Following the research question, an appropriate research design was selected for this specific study. Then a literature review was performed in parallel with the data collection in order to provide a theoretical background connected to the research topic. The two last steps consisted respectively of data analysis and the discussions of results and recommendations. The process of our research can be illustrated as follow:

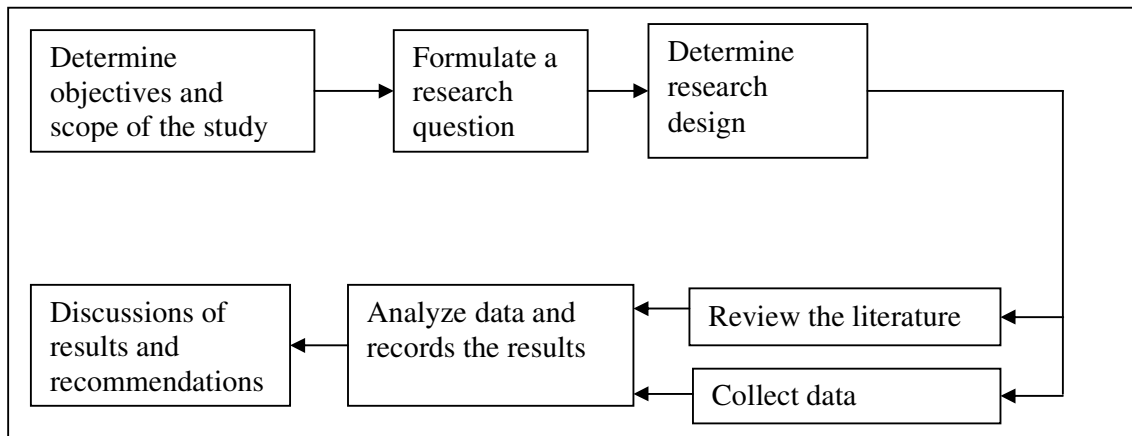


Figure 1: The Research Process (Adapted from Nel 2004)

Chapter 2 Literature Review

This chapter is divided into four sections. The first section, Lean thinking introduces the main philosophy that will be used to carry out this study; the second section discusses the concept of Lean construction. The concept of supply chain management is scrutinized in the third section. Finally, in the last section the concept of Lean supply chain management is discussed.

2.1 Lean Thinking

Lean thinking is a framework and a production philosophy originating from Japan. It is based on different elements derived from the Toyota Production System (TPS). These elements are discussed below.

2.1.1 Lean Production

The term “Lean production” was first coined in the book “*The machine that changed the world*” from Womack et al (1990). This term was used by the International Motor Vehicle Program (IMVP) at Massachusetts Institute of Technology (MIT) to name the Japanese technique of building cars as compared with the traditional Western mass production techniques. Lean production is a form of manufacturing which uses less of everything as compared to mass production. According to Womack and Jones (2003), lean provides a way to do more with less human effort, less equipment less time and less space.

The concept of Lean production was developed by Toyota, led by engineer Taiichi Ohno to cut waste in their production process and improve efficiency. The philosophy spreads into all areas of the manufacturing process including the supply chain.

Lean production system is based on the idea that production should only take place when a need arises from a customer. In this respect, Lean production uses a pull system for

inventory and production control. In the Lean systems, products are manufactured Just-in-Time to satisfy consumers' needs. The figure below depicts the Toyota House from the Toyota Production System. This house entails all elements described in the Lean philosophy.

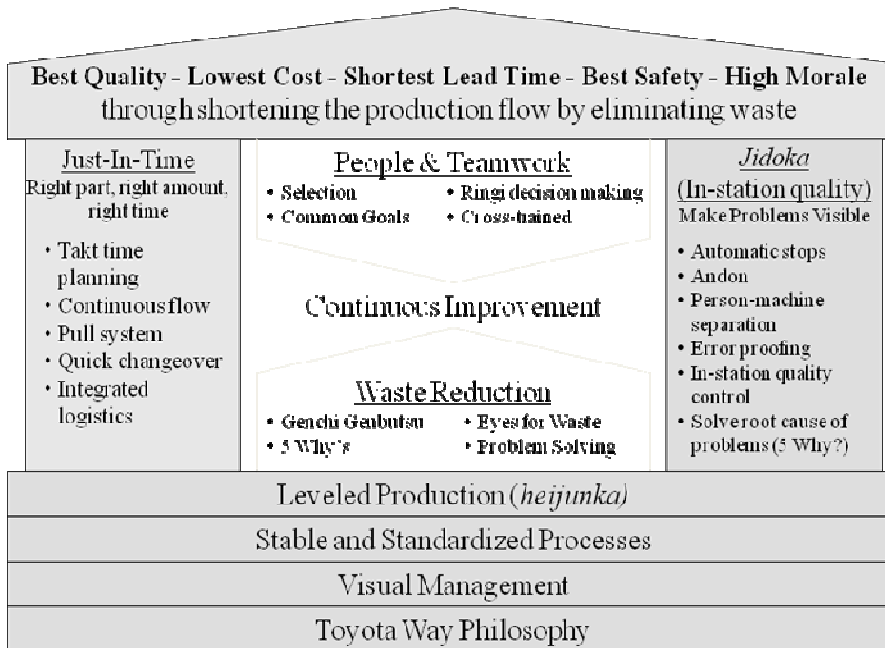


Figure 2: "The TPS house". (Source: Liker 2004, p. 33)

The basic idea behind the house is that every component needs to be in place to keep the house stands steady.

The first step in Lean production is to understand what value is and what activities and resources are absolutely necessary to create that value. Only what is considered as value for the customer should be taken into consideration. Once this is understood everything else is considered as waste. 'Seven plus one' different types of waste are discussed in the Lean philosophy.

2.1.2 Eight Lean "Wastes"

Lean philosophy is a common sense approach that strives for the systematic elimination of waste in the production process. Womack and Jones (2003) define waste as any human activity which absorbs resources but do not create value. Taiichi Ohno (1988) defines

waste into seven categories that are apparent in every manufacturing facility in the world: (1) *overproduction*; (2) *waiting*; (3) *unnecessary transport*; (4) *inappropriate processing*; (5) *unnecessary inventory*; (6) *unnecessary motion*; (7) *defects*. An eighth waste was added by Jeffrey Liker (2004) which is (8) *unused employee creativity*. They are described below.

- ***Overproduction***

This waste is considered as the most serious one as it discourages smooth flow of goods and services and is likely to inhibit quality and productivity. Producing items for which there are no orders generates wastes such as overstaffing, storage and transportation costs. Such overproduction also tends to result in excessive lead and storage times. As a result, defects may not be detected early, products may deteriorate and artificial pressure on work rate may be generated.

- ***Waiting***

This waste is concerned with the ineffective use of time. Waiting occur whenever goods are not moving nor being processed. In manufacturing, this waste occurs whenever workers are waiting for equipment, plans or instructions on how to proceed. This waste affects both goods and workers, each spending time waiting. The best use of waiting time would for instance be to train workers.

- ***Unnecessary transport***

The third waste involves goods being moved around. Carrying work in process (WIP) long distances, creating inefficient transport, or moving materials, parts, or finished goods into or out of storage or between processes. Taken to an extreme, any movement in the factory could be viewed as waste. In addition, double handling and excessive movements are likely to cause damage and deterioration of material.

- ***Inappropriate processing***

This waste is about taking unnecessary steps to process the parts. Inappropriate processing can for instance be depicted as using expensive highly advanced equipment where simple tools would be sufficient to do the work. The over-

complexity generally discourages ownership and encourages the employees to overproduce so that the large investment in the complex machines can be recovered.

- ***Unnecessary inventory***

This can be related to material stored on site too far in advance of when it is needed. Unnecessary inventory tends to increase lead time, obsolescence, damaged goods, transportation, storage costs, and delays. The long lead time prevents rapid identification of problems and discourages communication. By achieving flow between the work stations, inventory can be reduced.

- ***Unnecessary motion***

Any wasted motion employees have to perform during the course of their work, such as stretching or bending. Taken to an extreme, walking can be considered as waste. Such waste is tiring for the employees and is likely to lead to poor productivity and often, to quality problems.

- ***Defects (rework)***

This is considered as the bottom-line waste because defects are direct costs. Production of defective parts or correction is typically a wasteful spending. Repair or rework, scrap, and inspection mean wasteful handling, time and effort.

- ***Unused employee creativity***

This is about losing time, ideas, skills, improvement and learning opportunities by not engaging or listening to employees (Dimancescu, Hines, and Rich 1997; Liker 2004).

2.1.3 Lean Principles

In their war against ‘*muda*’ (the Japanese word for waste), Womack and Jones (2003) describe Lean thinking as a cycle of five guiding principles where the implementation of

the first four lead to achieving the fifth. The ultimate goal is the elimination of waste. The principles are described below:

- ***Specify value***
Value is specified from the standpoint of the end customer. Only what the customer considers as value should be taken into consideration, “*nothing more, and nothing less*”.
- ***Identify the value stream***
When the value is specified, the value stream that creates this value must be identified. This is about identifying all the steps in the value stream in order to determine activities that do not add value and seek for their elimination.
- ***Make value flow without interruption***
In Lean thinking, flow is considered to be the tool used for waste elimination. Value should be created in a flow of activities and processes. This is done by minimizing delays, inventories, defects and downtime.
- ***Use pull logistics***
Produce only in response to a signal from a customer, not based on forecast.
- ***Pursue perfection***
Lean is about continuous improvement. The organisation should continuously strive for improvement. The ultimate goal is to achieve perfection.

The figure below shows the five Lean principles cycle. It shows that “muda” is removed from one step to another and all the steps aim to achieve perfection as discussed above.

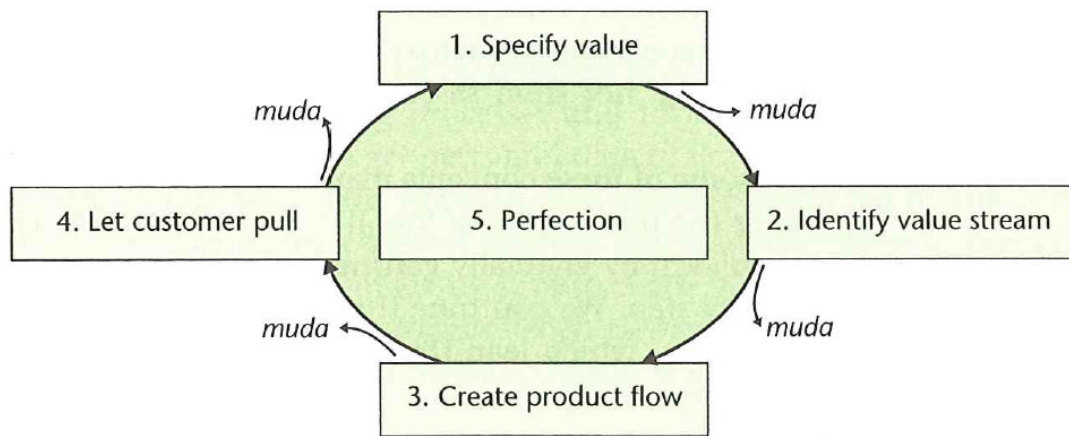


Figure 3: Lean Principles (Source: Womack and Jones 2003)

These five principles of the Lean philosophy have been widely used over the past decades by companies seeking to implement Lean in their production process. Jeffrey Liker (2004) describes a much broader way of implementing Lean through the 14 principles of the Toyota way:

1. Base your management decisions on a *long term philosophy*, even at the expense of short term financial goals.
2. Create *continuous process flow* to bring problems to the surface.
3. Use “*Pull*” systems to avoid overproduction.
4. *Level out* the workload.
5. Build a *culture of stopping the production to fix problems*, to get *quality right* the first time.
6. *Standardized tasks* are the foundation for *continuous improvement* and employee empowerment.
7. Use *visual control* so no problem is hidden.
8. Use only *reliable*, thoroughly tested *technology* that serves your people and processes.
9. Grow leaders who thoroughly understand the work, *live the philosophy*, and teach it to others.
10. Develop *exceptional people* and teams who follow your company’s philosophy.
11. *Respect* your extended network of partners and suppliers by challenging them and helping them improve.
12. Go and see for yourself to thoroughly *understand the situation*
13. Make decisions slowly by *consensus*, thoroughly *considering all options*; *implement decisions rapidly*.
14. Become a *learning organisation* through relentless reflection and *continuous improvement*.

However, Liker (2004) insists on the fact that the equation might be different depending on the organisation. He insists that Lean philosophy is not about imitating the tools used by Toyota in the particular manufacturing process but about customizing the principles and

carefully practicing them to best fit your own organisation. The different tools used in Lean philosophy are discussed in the next section.

2.1.4 Lean Tools

Several tools have been developed along with lean philosophy including, Kaizen, 5S, the Last planner system, and Value stream mapping. Concepts of 5S and Kaizen will be discussed in the following chapter due to their relevance for this case study. The Last planner system which also appears to be of relevance for this case will be discussed in the section “2.4.5 *The Last Planner System*”.

2.1.4.1 5S

In Lean philosophy, the concept of 5S aims at managing the production site in a best possible way. The 5S designation can be translated from Japanese into “*separate, sort, sweep, standardize, and sustain*” which is a philosophy and a procedure of organizing and managing the workspace in order to increase efficiency. This concept was originally developed by Toyota to describe the proper method of maintaining cleanliness and order at the workplace referred to also as *housekeeping*. A 6th S for *safety* is added by some companies implementing lean (Kocakülâh, Brown, and Thomson 2008).

The first step, *separate* consists of evaluating and removing anything which is not necessary to perform a task in a specific area. The next step, *sort*, consists of finding a specific place to keep the remaining items that are required to perform the task in that specific area. The third step *sweep*, talks for itself; everything must be kept clean, free of debris and tools must be placed back in place after use. The fourth step, *standardize*, means keeping things consistent from one place to another. Multiple workstations for the same process have to be set up in the same way. This will support flexibility for employees across all workstations. In the final step, *sustain*, the focus is on maintaining the discipline to keep the area of work clean and in order at the start as well as the end of the day. This is about changing the culture in the way thing works (Kocakülâh, Brown, and Thomson 2008). The fifth S, *sustain*, is the hardest to implement because it takes time to change the

culture of people in an organisation. Sustaining the culture will keep the first four S's going. It can be achieved by emphasizing the necessary education, training and rewards needed to encourage workers to properly maintain and continuously improve operating procedures and the workplace environment. According to them (Kocakülâh, Brown, and Thomson 2008), 5S is the first Lean perspective on making operations flow and layout of the workplace. The ultimate goal of 6S is to sustain a tidy working place, make things visual and maintain a safe working environment.

2.1.4.2 Kaizen

Kaizen is a Japanese word for improvement. This Lean construction tool involves looking at some task in the field and finding out how to do it better, more efficiently, safer and quicker. Liker and Meier (2006) suggested that an important part of Kaizen is that processes are repeatable so they can be measured. Key performance indicators (KPIs) should be determined for this purpose. Standardization of processes is a requirement before starting on Kaizen activities. Three different aspects of standard work have been discussed in the literature.

- (1) Standard work is not static but updated each time a better solution is found.
- (2) Standard work supports stability and reduces variation.
- (3) It is essential for continuous improvement.

Furthermore, management standards should exist for meetings, communication, budget and many other activities (Bicheno 2004; Liker 2004).

2.2 Lean Construction

This section will cover the concept of Lean construction from its origin. It starts with a brief History on construction and gives the origin of the concept of Lean construction. The Essential features of construction, the Transformation-Flow-Value theory (TFV), Differences between traditional and Lean construction, and Waste in the construction industry are discussed.

2.2.1 History

Construction is a very old industry. The need for shelter to fulfil one of the basic necessities of the human being has been at the start of construction. Its culture and many of its methods have their roots in periods before scientific analysis. However, especially after the Second World War, there have been several attempts to understand construction and its challenges and to develop sustainable solutions and improvements methods. Different initiatives have been taken which include: industrialization, computer integrated construction, and total quality management. Different operational and tactical techniques such as project planning and control tools, organisational methods, project success factors, and productivity improvement methods have also risen (Koskela 1992).

For many decades, manufacturing has been used as a reference point and a source of innovations for many sectors including construction. Lean construction has been introduced during the last decade and is based on the Toyota Production System principles. The concept is dedicated to maximizing value and eliminating waste within the construction industry. An important element in Lean philosophy pertains to its focus on improving processes, not individual operations as this can lead to sub-optimization (Shingō 1988).

In construction, the application of the Lean production originated from the work of Koskela in the report “*Application of the new production philosophy to construction*”. In this report Koskela (1992), emphasized the importance of the production process flow, as well as aspects related to converting inputs into finished products as an important element to reduce wastes. He categorized all construction production processes into four consecutive processes: (1) *moving*, (2) *waiting*, (3) *processing* and (4) *inspection*. Only processing was determined as conversion activity and therefore value adding. The other activities are considered as support activities different from conversions because they do not add value to the output, but still exist in all production processes. Koskela (1992) considers these activities as waste and advocates their reduction. However the application of Lean in the construction industry is substantially different from its application in manufacturing due to the peculiar features of construction.

2.2.2 Essential Features of Construction

Construction is a fundamentally different kind of production as compared to manufacturing. The construction industry is unique for its production of one-of-a-kind products, on-site production environment and temporary multi-organisation for each project (Groák 1992; Koskela 1992). Ballard and Howell (1998) suggest that construction's objects possess two characteristics which together uniquely define them: (1) they belong to the category "fixed position manufacturing" in which the product being manufactured eventually becomes too large to be moved through work stations, so the work stations have to move through the product, and (2) they are rooted in place which mean they cannot be moved. Also the production process is essentially project based; every project is unique in terms of specifications, delivery methods, administration and participants. Unlike the manufacturing industry where the same workers perform the work continuously, a construction project involves several different companies which have not necessarily worked together before.

Furthermore, projects in the construction industry vary considerably in terms of the kind of sector they serve (for example, shipbuilding, road construction or house building). Construction projects can also be characterized as slow and quick, simple and complex, and certain and uncertain (Ballard and Howell 1998). Because of these peculiarities; the construction industry is often considered to be, different from manufacturing.

2.2.3 Lean Construction: Definition and Principles

Lean construction as defined by the Lean construction institute is "*a production management-based project delivery system emphasizing the reliable and speedy delivery of value. The ultimate goal is carry on the project while maximizing value, minimizing waste and pursuing perfection – for the benefit of all project stakeholders.*" (LCI 2002A)

Kim (2002) agrees with this definition and adds that Lean construction challenges the general concept of trade-off between time, cost and quality employed in traditional construction. Howell (1999) claimed that managing construction under Lean philosophy is different from typical construction contemporary practice because it:

- Has a clear set of objectives for the delivery process
- Is aimed at maximizing performance for the customer at the project level.
- Applies production control throughout the life of the project

According to Pinch (2005), Lean construction practices include:

- Establishing integrated teams of owners, architects, users, builders, specialised contractors, subcontractors and suppliers;
- Combining project design with process design, simultaneously designing the facility and its production process;
- Stopping production rather than releasing a faulty assignment or product into the construction process;
- Decentralizing decision making, empowering project participants and making the process transparent so any team member can see the progress status of the project; and
- Requiring a simple, direct handoff between tasks in the work stream, with a clear way to request action and receive a response, to eliminate clogs between project phases.

In his attempt to make the construction leaner, Koskela (1992) joined the debate by developing eleven heuristics principles which are applicable to construction:

- (1) Reduce the share of non value-adding activities
- (2) Increase output value through systematic consideration of customer requirements
- (3) Reduce variability
- (4) Reduce the cycle time

- (5) Simplify by minimizing the number of steps, parts and linkages
- (6) Increase output flexibility
- (7) Increase process transparency
- (8) Focus control on the complete process
- (9) Build continuous improvement into the process
- (10) Balance flow improvement with conversion improvement
- (11) Benchmark

The next section discusses the differences between the traditional methods of construction and lean construction.

2.2.4 Lean Construction versus Traditional Construction

Construction is considered to be one of the most change resistant industries in the world. Koskela (1992) claimed that the most general concept seems to be understanding construction as a simple process of transforming an input to an output. This conception is actually shared by both old and newer methods in construction.

The traditional system of construction project focuses more on keeping track of time and cost. Time control is about looking at the progress in the production line, while cost control is primarily concerned with the budget. Cost control tracks if the project is under or over budget. Kim (2002) suggests that in traditional construction, control consists on monitoring against schedule and budget estimates; while in Lean construction control is defined as causing events to conform to plan. Kim (2002) continues on to say that traditional construction focuses more on individual activities. In traditional construction, control begins with tracking cost and schedule, and therefore any effort to improve productivity lead to unreliable work flow due to sub-optimization. As a result, project performance is considerably reduced.

In Lean philosophy, the focus is on how one activity affects the next activity, as all activities are part of the whole system. Ballard and Howell (1998) claimed that the goal in Lean construction is to improve the performance of the whole system. They put forward that where current project management manages projects as more or less independent activities, Lean philosophy works first to assure the reliable flow of work between the tasks. In that perspective Koskela (2000) depicts construction as a continuous flow of materials and/or information instead of just conversion activities (from input to output).

Koskela (1992) states that production concepts used in various industries are of three main types:

1. Transformation view – concept of transforming inputs to outputs.
2. Flow view – materials and information flow in a production process.
3. Value generation view – process where the value for customer is created through fulfilment of his/her requirements.

However, construction has for a long time been managed according to the transformation or conversion concept, thus focusing more on transforming an input to an output. Principles related to the flow and value generation concepts were largely neglected resulting in inefficiency. Koskela (2000) states that it is crucial that the peculiarities of construction are understood and taken into consideration in construction management both from the point of view of Transformation-Flow and Value concept. For Koskela (2000), this tripartite view of construction will foster tremendous improvement in construction. Table 1 on the next page depicts the concept of Transformation Flow and Value.

Table 1: Transformation/Flow/Value (Source: Ballard 2000)

	Transformation view	Flow view	Value generation
Nature of Construction	A series of activities which convert inputs to outputs	The flows of information & resources, which release work: composed of conversion, inspection, moving and waiting	A value creating process which defines and meets customer requirements
Main Principles	Hierarchical decomposition of activities; control and optimization by activity	Decomposition at joints. Elimination of waste (unnecessary activities), time reduction	Elimination of value loss the gap between achieved and possible value
Methods & Practices	Work breakdown structure, critical path method. Planning concerned with timing start and responsibility for activities through contracting or assigning	Team approach, rapid reduction of uncertainty, shielding, balancing, decoupling. Planning concerned with timing, quality and release of work	Development and testing of ends against means to determine requirements. Planning concerned with work structure, process and participation
Practical Contribution	Taking care to do necessary things	Taking care that the unnecessary is done as little as possible	Taking care that customer requirements are met in the best possible manner

The table describes the nature of construction, its main principles, the methods and practices and its practical contribution from the standpoint of each element of the TFV theory. Table 1 is summarized from the **practical contribution viewpoint** depicted at the bottom of the table. “Taking care to do necessary things” in the Transformation aspect can be linked to effectiveness and “taking care that the unnecessary is done as little as possible” in the Flow aspect can be linked to efficiency. By combining these two aspects, value can be obtained which mean “taking care that customer requirements are met in the best possible manner” (Koskela, 2000). As the authors discussed in the general introduction, performance is described in term of attaining value effectively and efficiently, therefore the authors conclude that the TFV-theory represents a huge opportunity for the construction industry in its pursuits to achieve successful performance.

The Lean Construction Institute (LCI) seminar (2002B) summarizes in table 2 on the next page the major differences between Lean construction and traditional form of project management with respect to control, performance optimization, scheduling viewpoint, production system and process, performance measurement and customer satisfaction.

Table 2: Comparison of Lean and Traditional construction (LCI seminar 2002B)

Lean construction	Traditional construction
Control	
Causing events to conform to plan - Steering	Monitoring against schedule and budget projections-tracking
Optimization	
The entire project	A specific activity
Scheduling viewpoint	
<ul style="list-style-type: none"> • “PULL” work schedule • Based on when its completion is required by a successor activity 	<ul style="list-style-type: none"> • “PUSH” work schedule • Based on emphasizing required start dates for activities
Production System	
Flow production system	Conversion production system
Production process	
Effectiveness	Efficiency
Performance measurement	
Percent Plan Complete (PPC)	Work Breakdown structure (WBS), Critical path method, (CPM) & Earned Value
Customer satisfaction	
Successor process satisfaction	Owner or final consumer satisfaction
Planning	
Learning	Knowing
Uncertainty	
Internal	External
Coordination	
Keeping a promise	Following orders
Goal of supervision	
Reduce variation & Manage flow	Point speed & Productivity

The most fundamental difference between traditional and Lean construction can be found in scheduling (Kim 2002). In scheduling, Lean construction uses the “pull” work schedule while traditional construction uses the “push” work schedule. Pull systems schedule work based on demand as opposed to the push systems which schedule work based on system status.

The Lean construction institute (2002) differentiates the two kind of production management in figure 4 and 5.

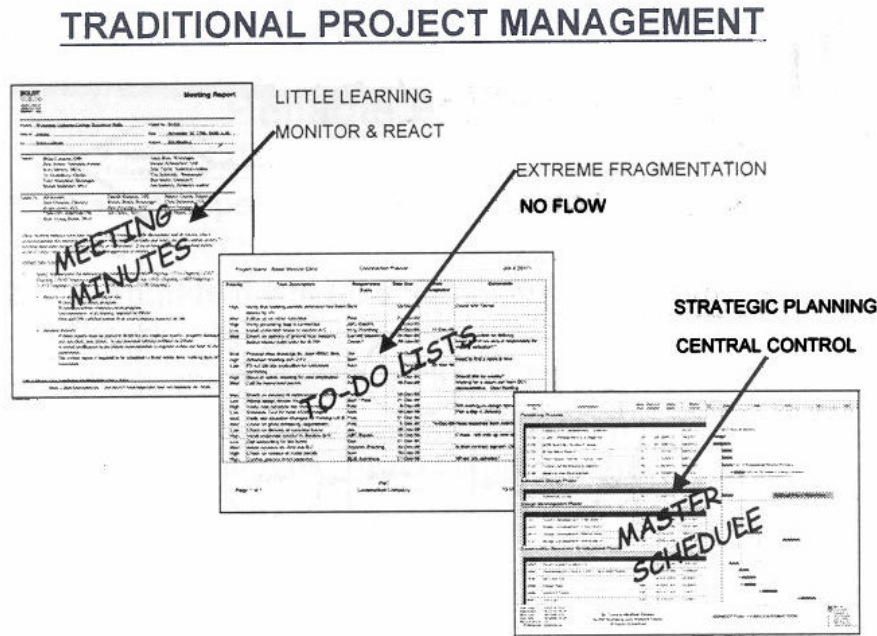


Figure 4: Flow of traditional Project Management (Source: LCI Seminar 2002B)

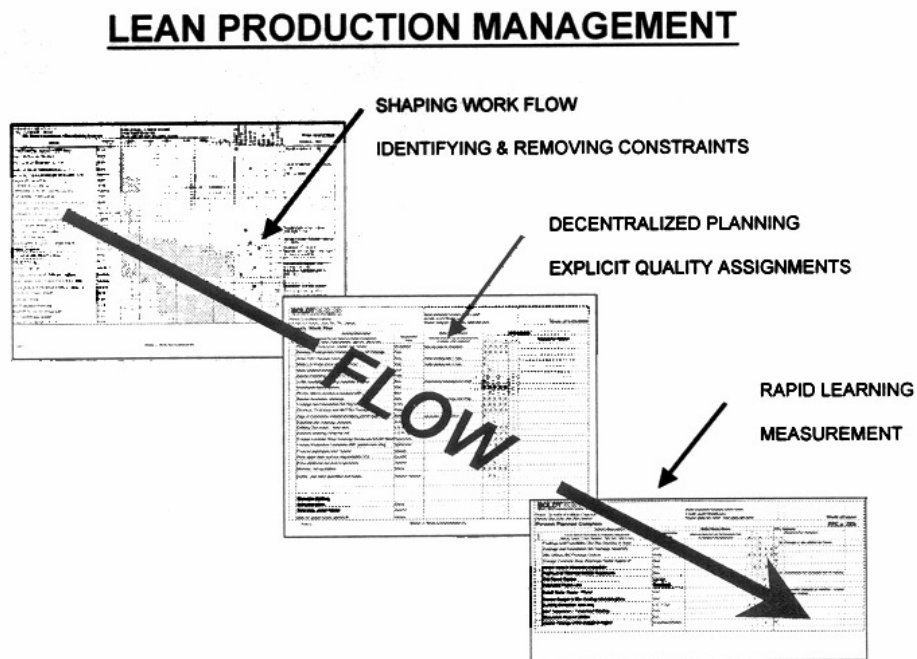


Figure 5: Work Flow of Lean Production Management (LCI Seminar 2002B)

Figures 4 and 5 depict respectively the type of workflow used in traditional and Lean production management. Lean production management has a workflow without interruption while traditional project management has a segmented workflow. The Lean management flows smoothly. The flow helps to build reliability, improve the production management system and obtain commitment from every actor. The work is done in a collaborative manner. On the other hand, the segments in traditional management translate the lack of integration, lack of common language, lack of team commitment and sub-optimization (Kim 2002). This in turn creates wastes in the construction process.

2.2.5 Waste in the Construction Industry

During the construction process, construction managers have to deal with different factors that can negatively affect the performance of the production process, and producing different type of wastes. Wastes can include mistakes, working out of sequence, redundant activity and movement, delayed or premature inputs and products or services that do not meet customer needs (Construction Industry Board 1998).

According to the new production philosophy, waste is defined as any inefficiency that results in the use of equipment, materials, labour, or capital in larger quantities than those considered necessary in the production of a building (Formoso, Isatto, and Hirota 1999). For Koskela (1992), waste includes both the incidence of material losses and the execution of unnecessary work that generates additional costs but does not add value to the product Koskela (1992) argues that the inherent waste in construction is created by rework due to design or construction errors and non-value adding activities in the material and work flows, such as waiting, moving, inspecting, duplicated activities, and accidents. For Low and Chan (1997), construction waste is divided into three principal components, namely: *labour*, *material* and *machinery waste*. Labour waste is about having more workers than required to do the construction work, material waste is about losing material due to excessive inventory and bad handling, finally machinery waste refers to using the machines inefficiently.

In most of the publications and previous studies in construction, measurements of waste have mainly been limited to production on site. The rationale behind that is the fact that most of the resources are consumed on site; as a result wastes occurring in other places are sometimes overlooked. According to Bertelsen (1993), poor supply chain design regularly increases project cost by ten percent and affects the project duration similarly. Forbes and Ahmed (2004) indicated that construction projects in Sweden have a potential for cost saving of 10-17% due to supply chains inefficiencies. Thomas, Sanvido, and Sanders (1989) joined the debate by reporting that 200 hours of work were lost out of a total of 1256 (16%) on a structural steel erection job due to bad material management. Therefore, it is essential that this vital part of the construction industry is nurtured to achieve performance.

The next section discusses the concept of Supply Chain Management.

2.3 Supply Chain Management

This section discusses the concept of supply chain management and construction supply chains.

2.3.1 Supply Chain Management: Concepts and Developments

Supply chain management (hereinafter, SCM) is a theory rooted in the field of logistics. The concept has originated and flourished in the manufacturing industry before spreading to other sectors. Its first visible signs were in the Just-in-Time (JIT) delivery system, which was a part of the Toyota Production System .The system is aimed to regulate supplies to the Toyota factory just in the right amount, the right quality, at the right place and at the right time (Shingō 1988).

The concept of supply chains have been considered from different points of view in different bodies of literature. Various definitions have been proposed and some common points can be identified. In this thesis, the definition from Lau, Huang and Mak (2004) will be considered. They defined SCM as “*coordination of independent enterprises in order to improve the performance of the whole supply chain by considering their individual needs*”. This definition of supply chain implicitly describes the supply chain as a group of companies working collaboratively to satisfy customer needs. One of the main functions of SCM, which is coordination, is also exhibited. This line of exploration is further continued by Vrijhoef, Koskela, and Voordijk (2003) who suggest that current practice of SCM considers the supply chain as an integrated value-generating flow rather than only as set of independent activities. Cooperation and consultation among actors are regarded as paramount in supply chain management.

Christopher (1999) goes further to say that trust, commitment, and willingness to share information among the supply chain participants are prerequisites for making efficient supply chains. However, the construction industry has been slower to employ the concept of supply chain management which has been embraced elsewhere (i.e. manufacturing) (Love 2000). The reasoning for the poor up-take of supply chain management in construction can be linked to two factors: the long-lasting supplier-contractor relation that are subject to vulnerability due to the temporary nature of construction projects and the one of kind nature of the product (Akintoye, McIntosh, and Fitzgerald 2000).

Previous researches have shown that in traditionally managed supply chains, there are considerable waste due to excessive variability and little control (Jarnbring 1994; Wegelius-Lethonen et al. 1996). Cooper and Ellram (1993) describe differences between the traditional way of managing the supply chain which is based upon conversions view of production and the SCM based on a flow view of production. The main differences between the traditional way and SCM are shown in the table below.

Table 3: Traditional and Supply chain management approaches compared. (Source: Cooper and Ellram 1993)

Element	Traditional	Supply chain
Inventory management approach	Independent efforts	Joint reduction in channel inventories
Total Cost approach	Minimize firm costs	Channel-wide cost efficiencies
Time horizon	Short term	Long term
Amount of information sharing and monitoring	Limited to needs of current transaction	As required for planning and monitoring processes
Amount of coordination of multiple levels in the channel	Single contact for the transaction between channel pairs	Multiple contacts between levels in firms and levels of channel
Joint planning	Transaction-based	On-going
Compatibility of corporate philosophies	Not relevant	Compatibility at least key relationship
Breath of supplier base	Large to include competition and spread risks	Small to increase coordination
Channel Leadership	Not needed	Needed for coordination focus
Amount of sharing of risks and rewards	Each on its own	Risks and rewards shared
Speed of Operations, Information and inventory Flows	“Warehouse” orientation (storage, safety stock), interrupted by barriers to flow	“Distribution Centre” orientation, Interconnecting flows; JIT, Quick response across the channel

As seen in the table above, SCM contrasts sharply with traditional methods of managing projects which focus on optimizing individual activities. Unlike the current construction methods, supply-chain management aims to design, plan and manage construction projects in a more collaborative way.

2.3.2 Construction Supply Chains

The concept of supply chains originated in industries where demand is predictable, the requirement of variety are low, and volume is high (Christopher 2000). In the construction industry however, the products are one of a kind, production is on site and the nature of the projects organisation are temporary which means when the project ends, the team disbands and is most likely replaced by a new team with different members in future projects. In addition, the construction industry is characterized by high complexity due to the large number of organisations involved in a single project.

Vrijhoef and Koskela (2000) characterized construction supply chains in terms of structure and function by the following elements:

- For construction supply chains, all materials converge to the construction site where the object is assembled. Unlike manufacturing systems where various products go through the factory, the “construction factory” is set up around a single product.
- It is a temporary supply chain which necessitates temporary flow of material. As a result, the construction supply chain appears to be unstable and fragmented.
- It is a typical engineer-to-order (ETO) supply chain, with every project creating a new product depending on a specific requirement from a client. The product is one of a kind. There is little repetition, but some exceptions exist. The processes can sometimes be very similar during a project of a particular kind.

Briscoe, Dainty, and Millett (2001) pinpointed the adversarial relationships which exist between different members of the supply chain as another party in the supply chain often attempt to earn margin to the detriment of other firms.

Furthermore, Hamzeh and Kaminsky (2007) reveal that the construction industry is characterized by high variations in supply and demand for resources such as material, equipment and services. This uncertainty undermines efficiency and responsiveness of

supply chains and causes supply-demand mismatches leading to increased lead times and inefficient utilization of resources.

This opinion is supported by Cox and Ireland (2002, p.409) who quote: “*construction supply chains have remained contested, fragmented and highly adversarial because of the conflicting nature of demand and supply*”. In addition, research studies have shown that waste is pervasive in construction supply chains (for example, Alwi, Hampson, and Mohamed 2002; Luhtala, Kilpinen, and Anttila 1994; Vrijhoef and Koskela 2000). According to Vrijhoef and Koskela (2000), most of the causes of inefficiency in construction supply chains are related to managerial issues, including the poor management of commitments among their members and the lack of integration along the chain. Furthermore, problems and waste are caused by a “*myopic control of construction supply chain, characterized by independent control of each stage of the chain*”. Cox and Ireland (2002) depicts construction supply chains in figure 6.

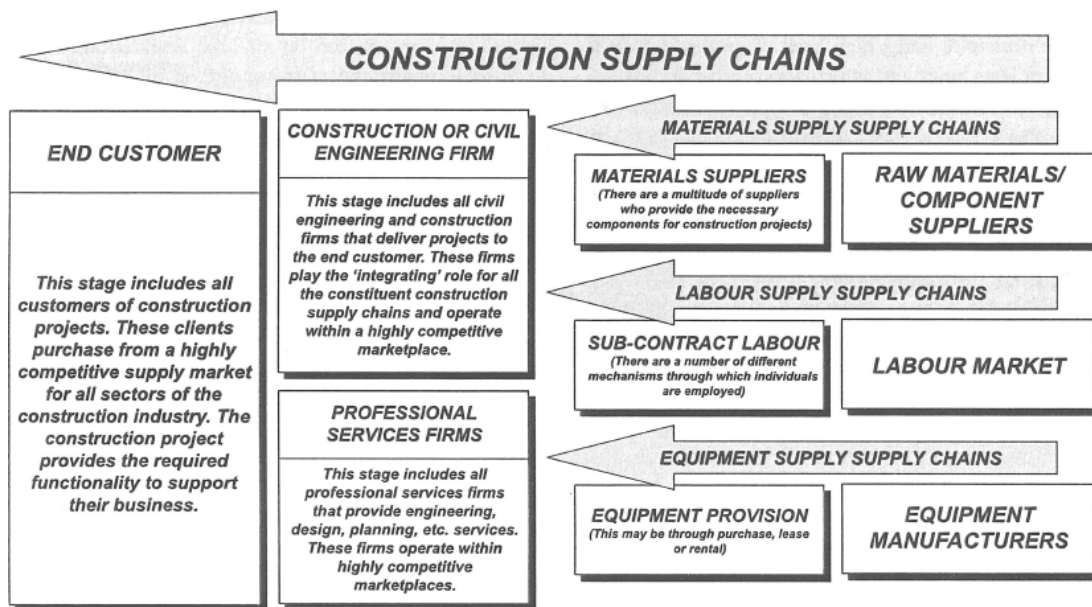


Figure 6: Myriad of construction supply chains (Source: Cox and Ireland 2002)

In the figure above, Cox and Ireland (2002) characterized the construction industry by the following main supply chains; construction or civil engineering firms, materials, equipment and labour. The construction or civil engineering firms elaborate all the planning, engineering and project management functions of the project. Based on the plan,

the required material, labour and equipment is sourced from suppliers to perform the construction work. The construction supply chain ends with the customer. However, for Cox and Ireland (2002), these supply chains display significant overlap.

From this multiple organisation perspective of the construction industry, several questions can be asked:

- *How to organize the work among supply chain members?*
- *How to achieve and maintain cooperation among these firms?*
- *How to coordinate processes among people from different and independent firms?*
- *How to coordinate the delivery of material in order to avoid interferences between contractors?*

Favourable answers to all these questions can be found in the implementation of Lean principles in the supply chain of construction projects. This idea is supported by O'Brien (1999) who argues that Lean supply chain management has been identified as an adequate conceptual framework for improving the performance of the construction sector.

2.4 Lean Supply Chain Management in Construction

In a typical construction project, it can be found several organisations working together to achieve a common goal. Members of this chain include manufacturers, suppliers, distributors and transporters. A high degree of cooperation between those entities is critical for the success of a construction project. The strategy involving the integration and coordination among these different members of the supply chain is called supply chain management. In term of Lean production, supply chain management is closely related to Lean supply (Lamming 1996).

Since its introduction, Lean thinking has been applied to many aspect of the manufacturing industry. Companies around the world have applied the concept to nearly every aspects of their business, including their supply chain. According to Wincel (2004), SCM and the

concept of Lean intersects most significantly in “*profitability objectives, customer satisfaction and quality objectives*”.

The primary goal of Lean supply chain management is to accomplish supply management with the minimum possible waste in construction. Lean supply chain management emphasizes and focuses on improving relationships among project participants. It focuses on the cooperation between all actors involved in a typical construction project for improving the total flow of material.

The remainder of this section will be grouped into discussions under the different areas the authors believe are very important to achieve Lean supply chain management.

2.4.1 Pulling to Site Demand and Just-in-Time

The idea of creating “pull” systems in a production environment is central in implementing Lean principles (Zimmer 2006). Just-in-Time is the most common term used in pull systems. Just-in-Time is described as “*the state in which value can be said to flow through the process with minimum interruptions and waste*” (Kocakülâh, Brown, and Thomson 2008). This definition is supported by Thomas et al. (2002) who assert that any interruptions to the normal flow of materials will result in having bad performance and poor labour productivity at the workplace. Once more the flow concept is pinpointed.

One of the main objectives of Just-in-Time is to decrease inventories and to develop an effective cooperation with the supplier. To achieve Just-in-Time, the delivery rate from suppliers must be compatible with the installation rate in the field of operations. In construction, this aspect of Just-in-Time involves delivering only materials that are ready for installation, in the amount needed, and at the time needed.

The use of Pull systems is deemed to be necessary in the situation where there is little storage capacity for the construction project to be successful. The challenge would be to guarantee material availability without building up unnecessary inventory.

Many researchers in Lean construction give the example of concrete as a typical material that has to be delivered Just-in-Time. When a contractor calls for concrete delivery, he needs to be ready to place that concrete once it arrives. The initiative now is to apply the same system to all kind of materials and equipment going into the workforce.

It would not be appropriate to talk about Just-in-Time without mentioning the concept of Kanban. Kanban is a Lean approach that has been developed by Toyota to pull materials and parts throughout the value stream on a Just-in-Time basis. Kanban means 'card' or 'sign' in Japanese and is the name given to the inventory control card used in a pull system. Two types of Kanban exist: *Transport Kanban* which is used to signal the need to replenish materials from suppliers and *Productions Kanban* which is used to initiate production (PPDT 2002).

2.4.2 Information Sharing and Collaboration

The performance of a supply chain depends to a great extent on how its members coordinate their actions. However, it seems hard to imagine coordination without information sharing (Chen 2003). Communication and coordination are major factors that support Lean implementation because if all people involved in the project openly share information, it can lead to a better site coordination and substantially reduce inefficiencies in the project, two objectives sought by Lean philosophy. Therefore finding ways to communicate more effectively with all participants in the project is an important aspect of implementing Lean principles.

According to Pinho, Telhada, and Carvalho (2007), the large number of organisations working together in a construction project necessitate that the information which flows between them must be reliable and in real time. An information system that can aggregate information related to the needs of materials, equipment is necessary to achieve a better supply chain. Furthermore, improving coordination and communication between the participants in the supply chain is absolutely paramount to achieve a synchronized flow.

Koskela (2000) proposes the use of communication and Information Technology (IT) in the construction industry to support the delivery process of the building. Koskela (2000) states that the use of IT can help improve communication in the construction industry.

Zimmer (2006) asserts that IT provides visibility throughout the supply chain. Nowadays, software systems and online capability have been extensively developed and provide organisations with numerous ways to share information in real time. All parties involved in a construction project can collaborate more efficiently through the effective use of IT. By using IT systems, information is shared in the same format and therefore standardized. According to Zimmer (2006), by using IT, cooperation between site manager and suppliers off-site will be improved because real time communication is established. Owners can also keep themselves informed on construction job completion through IT. Subsequently, paperwork and lead times will be reduced and most importantly visibility about the progress of work will improve.

2.4.3 Supply Chain Coordination through the Management of Commitment

Considering the fact that every construction project involves different parties, a high level of commitment is required from all members for achieving a satisfactory level of performance. According to Azambuja et al. (2006), most causes of inefficiency in construction supply chains are greatly related to the poor management of commitments among their members. As for site coordination, Bennett and Ferry (1990) depict the situation by saying that contractors are “*just thrown together*” on the construction site and have to find ways to sort things out between themselves. This, in turn creates a lot of misunderstanding fostered by a complete lack of both coordination and communication, which plausibly can be assumed to cause a lack of commitment.

Denning and Medina-Mora (1995) see every organisation as a network of commitment. Their view are based on the work of Winograd and Flores (1986) who approached construction supply chains from a theoretical point of view called the *Language-Action Perspective* (LAP). According to Vrijhoef, Koskela, and Voordijk (2003), a basic tenet of

the LAP is that by improving communication in an organisation, the organisation itself can be improved.

Winograd and Flores (1986) defined the theory in three points:

1. In every organisation, people act through language and conversations are used to coordinate actions. Two different kinds of language acts are considered; directives and commissives. Everyone in the organization can induce both directives and commissives. Directives can be considered as requests and commissives as promises.
2. Breakdowns of conversation can occur, for example the promisor can cancel a previously made promise; therefore the requestor needs to be prepared in case of acceptance or rejections.
3. All actions take effect by declaration. People in organisations issue utterances, by speaking or writing, to develop the conversations required in the organisational network.

In practical terms, two directions are pinpointed by Winograd and Flores (1986).

1. Computer systems can facilitate communication and work practices in organisations. Furthermore, computer systems can foster more coordination. Here again, information technology comes into play.
2. By developing better sensibility toward the way their language acts in the participation in a network of human commitment, people can learn to communicate for action.

Azambuja et al. (2006) assert that LAP offers a comprehensive approach to understand and coordinate the work among people and organisations which Denning and Medina-Mora (1995) depict as a “*map of interconnected commitment loops*”. According to them, “*the basic element of a coordination process is a closed loop that connects two parties*”. The loop entails a performer who promises to satisfy a request from the other party, the customer. Figure 7 on the next page illustrates the commitment loop.

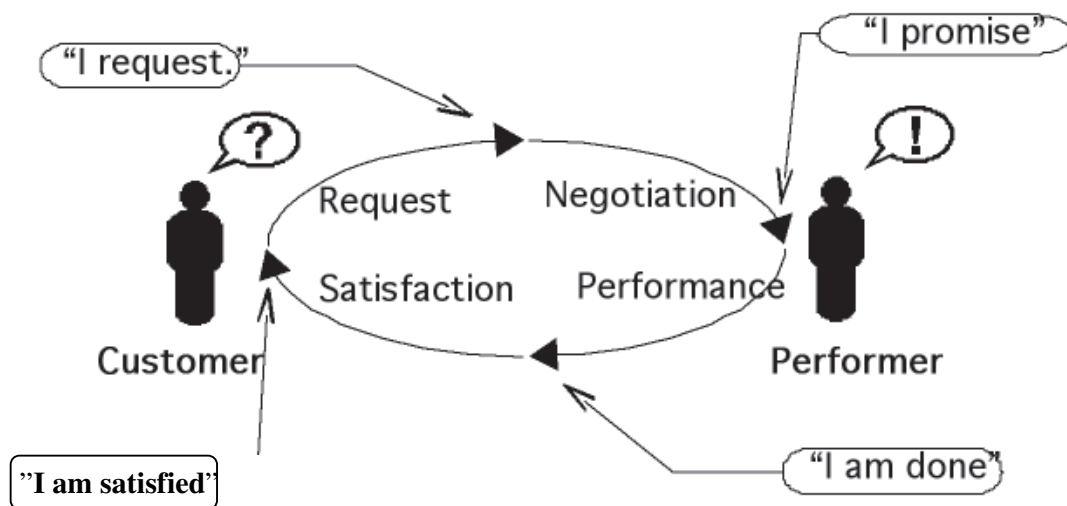


Figure 7: The commitment loop (Source: Denning and Medina-Mora 1995)

It seems evident that when everyone reliably meets their commitments, the overall project proceeds more smoothly. Figure 7 can be described as follow: let's consider the customer as a contractor and the performer as the material supplier. At the start of the loop, conversation is initiated by a request for material from the customer; negotiation occurs in term of both time of delivery and amount of material. The supplier keeps its promises by delivering the right material at the right time and at the right place. The declaration from the requestor that the action is satisfactory closes the loop. This methodology stresses the importance of the completion of commitment loops in order to achieve effective coordination of work as well as Just-in-Time delivery.

2.4.4 Planning Delivery and Material Management

Several studies, for instances CII (1988) and Thomas et al. (2002) have demonstrated that poor material management practice can result in large cost during construction projects. The lack of material on site when required, lack of the "right" materials on site and unnecessary inventory are some types of waste stemmed from bad material management. It is also suggested by Thomas, Riley, and Messner (2005) that site layout and the way materials are managed are closely linked, especially for small construction sites. Stukhart

and Bell (1985) go on to say that the bad management of material procurement on site is one of the biggest causes of construction delays.

According to Illingworth and Thain (1998), material management is a planned procedure that includes the purchasing, delivery, handling and minimization of waste aiming to assure that requirements are met. The purchasing part of this definition is out of the scope of this study. In the same vein, Thomas *et al.* (2005) describe material management as

the allocation of delivery, storage, and handling, spaces and resources for the purposes of supporting the labour force and minimizing inefficiencies due to congestion and excess material movement.

From the definition above, it appears clearly that for a good management of material, the delivery and handling of material should be controlled like site activities, and therefore planned and scheduled accordingly. It is most likely that without proper planning and scheduling, the different contractors involved in a construction project will face chaotic material deliveries such as out-of-sequence deliveries of similar or different materials on the job site, peaks in arrival of materials creating congestion, parallel unloading and poor site organisation. These situations are sources of wastes.

Efficient material planning is a key to high productivity on site. Material planning embraces quantifying, ordering and scheduling. Productivity will suffer if the material planning process is not executed properly (Kaming et al. 1997). Furthermore, Ballard and Howell (1994) emphasized that planning must be extended downward to foremen, sub-crews and individual craftsmen until work has been executed. They developed a new method called the “*Last planner*” which is a tool aimed for better planning and controlling the production process. The Last planner will be discussed in the next section.

Making sure that job sites are in perfect conditions to receive the material to be delivered is also fundamental for Just-in-Time. In the section **2.1.4.1 5S**, the Lean construction tool of 5S has provided the basis for suitable procedures to implement good “housekeeping” and site management.

2.4.5 The Last Planner System

The Last planner system is a planning method considered to be one of the most important tools in Lean construction. In the literature, its application in construction projects around the world has been mostly production oriented, for example, (Ballard 2000), Brazil (Conte 2002; Soares, Bernades, and Formoso 2002), Ecuador (Fiallo and Revelo 2002), Denmark (Bertelsen and Koskela 2002), the United Kingdom (Townsend, Reynolds, and Cole 1999) have studied its interpretation in the construction industry. However it can also be applied to the management of material delivery. In their article '*Material delivery problems in construction projects: A possible solution*' Ala -Risku and Kärkkäinen (2004) propose a solution for the delivery of material without a build-up of unnecessary inventory on site based on the Last planner system.

Ala-Risku and Kärkkäinen (2004) state that the Last planner is a tool that uses the overall project plan as the general framework, but suggests that the day to day activities of the production should be managed by a more flexible approach with regard to the actual progress of the project.

Concept such as pulling production, reducing variability and increasing flow reliability are integrated in the Last planner system (Sterzi et. al. 2007). Basically, the idea behind the Last planner system is to replace optimistic planning with realistic planning by allowing the last person in the process to plan and decide the assignment to be done. Assignments are likely to get done when they are clearly defined, in the right sequence, with the right amount of resources and within the capacity of the crew supposed to do the work (Kim 2002).

Concerning this issue, Koskela (2000) describes seven preconditions for the execution of a construction task which are: (1) *construction design*, (2) *components and materials*, (3) *workers*, (4) *equipment*, (5) *Space*, (6) *connecting works*, (7) *external conditions*. The figure on the next page shows that for a construction task to be performed, the design

(drawings) need to be ready, the right amount of materials as well as equipment should be at hand, the right number of worker in place, the space should be free of clutter and available for the work. In addition, *connecting works* which means the work preceding the task needs to be finished before the work can begin and finally external conditions (for example, weather and holiday.) need to be favourable.

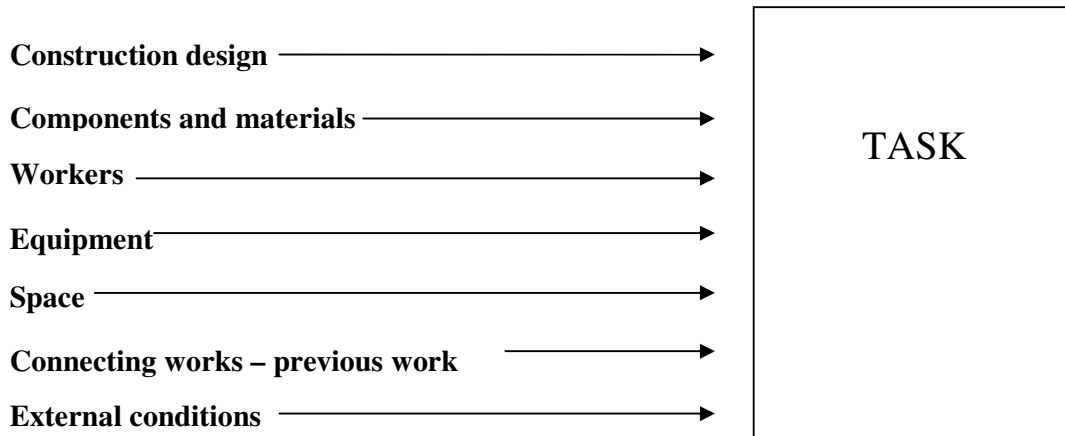


Figure 8: The seven preconditions of a construction task (Source: Koskela 2000)

“A reliable assignment determines what “Will” be done after considering what “Should” and “Can” get done based on the situation at hand” (Kim 2002, p. 28). Figure 8 presents the diagram of Last planner.

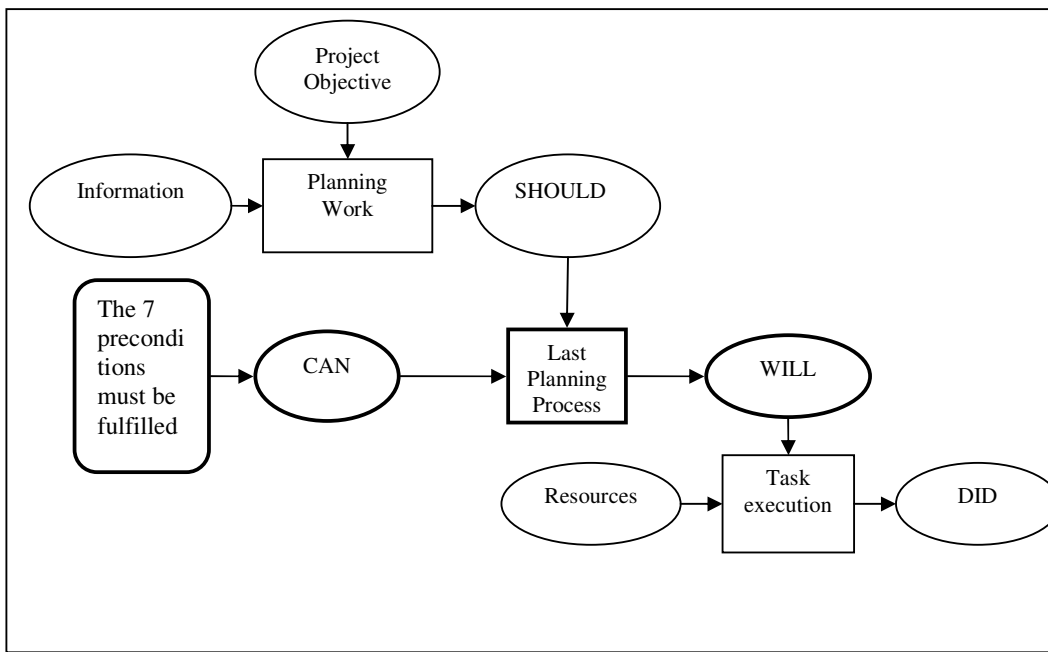


Figure 9: The Last Planner System (Adapted from: Ballard and Howell 1997; Bertelsen 2007)

The figure on the previous page can be described as follow, the project start with an objective, and then based on the information received from different sources such as suppliers for instance; the work that 'Should' be done is planned. After considering what should be done, only task that have all their prerequisites ready 'Can' expected to be done. Then come the Last planner who decides what 'Will' be done based on its assessment of the situation. Resources are therefore allocated and the work is done according to the last planning. Kim (2002) considers 'should' as "hopefully", 'Can' as "Probably" and 'Will' as "absolutely".

Ballard (2000) suggests four levels of planning with the Last Planner System.

- Master Scheduling (Needs to be done)
- Phase Scheduling (Should be done)
- Lookahead Plan (Can be done)
- Weekly Work Plan (Will be done)

The *master scheduling* is the strategic plan with major milestones for the entire project, this plan is usually made by the building owner even before the tendering process begins.

In the *scheduling phase* the contractors are involved, the plan is built for one or just a few phases of the construction process from the master scheduling plan. This plan is more detailed as compared to the master scheduling plan and shows dependencies between activities. The coordination phase of activities is taken into account in the scheduling phase.

After the seven preconditions are checked, the *lookahead plan* is made. This plan serves as a basis for the logistical plan. The lookahead plan may use a rolling basis of 3-6 weeks, which needs to be updated once a week.

The *Weekly Work Plan* is the plan where the Last planner makes commitment to what will be done in the coming week based on the fulfilment of the seven preconditions (Ballard, 2000; Bertelsen 2007).

2.4.6 Variability and Reliability Issues in Construction Supply Chains

Waste removal can be associated with reduction of variability. In the construction industry, sources of variability include late delivery of material and equipment, design errors, change orders, equipment breakdowns, accidents, and physical demands of work (Abdelhamid and Everett 2002).

According to Arbulu et al. (2005), the achievement of Just-in-Time in construction depends on the ability of project teams to control supply and accurately forecast demand. As in every production system, demand and supply are very dependent on each other and any type of variability will influence the effective management of project and subsequently impact on the total production system performance increasing cost and time and reducing quality and safety (Arbulu and Ballard 2004). This situation appears to be common in construction supply chains where complexity and uncertainty are high. As a result significant variations in plans and material delivery may occur at every stage.

Variability plagues construction supply chains and manifests itself mainly in the form of poor workflow reliability between production processes. As an example, if the production system is not reliable, it will be difficult for suppliers to effectively plan the delivery of material on site. According to Arbulu, Koerckel and Espana (2005) workflow reliability in the industry has been repeatedly measured at levels ranging from below 30% to 60%. These figures show that variability can rise up to 70% during the course of a single project.

“In Lean thinking, reliability is emphasized to reduce workflow variability. It can improve total system performance, make project outcomes more predictable, simplify coordination, and reveal new opportunities for improvement” (Kim and Park 2006, p. 382). In other

words improving workflow reliability equals reducing variability and therefore decreasing the volume of non value adding activities.

2.5 Summary of Relevant Studies

The previous chapters were dedicated to describing the concept of Lean construction and Lean supply chain management and their relevance to the study. In order to give a solid background for the case study, it is useful to review some empirical evidence that underpinned the use of Lean supply chain management methods to improve efficiency in the construction industry. Table 4 below presents a summary of studies relevant for this study where the empirical evidences indicate that Lean yield significant benefits for SCM in construction. For simplicity each study is presented in terms of title, objectives and the main results.

Table 4: Summary of relevant studies

Study	Objectives	Main results
Eric Zimmer (2006) <i>“Improving Lean supply chain management in the construction industry.”</i>	This study investigates improvement opportunities in the construction industry utilizing the practice of Lean SCM. Two subcontractors (A and B) denoted SUB A and SUB B were compared in their approach to delivery and management of material on site. SUB A used Lean and SUB B did not.	As a result of Lean implementation in SUB A side, workflow was improved, space effectively used, visual process provided, effective planning, transparency and better communication between site and supplier through IT. The idea of delivering material Just-in-Time has worked for SUB A. By applying Lean principles, better coordination through meetings and better moral for the crew was achieved.
Khalfan et al. (2008) <i>“Application of Kanban in the United Kingdom construction industry by public sector clients.”</i>	This study describes the Lean approach of Kanban for the management of material adopted by Fusion 21, a property manager in United Kingdom.	This approach has brought benefits within the involved supply chain such as waste minimization, product supply Just-In-Time; increase value for money for clients; and increase process efficiency through continuity of work, significant cost savings have been reported by the client on procuring material. An IT system is used (e-procurement) for supply chain integration.

<p>Arbulu, Koerckel and Espana (2005) <i>“Linking Production-level workflow with material supply.”</i></p>	<p>The objective is to present a solution that uses Lean tools for production control and material management called Strategic Project Solutions (SPS) to improve transparency and performance across value streams and minimizing waste through the link of production workflow with material supply. Two case studies have been carried out.</p>	<p>The case studies report a better reliability of supply and demand due to a greater visibility across the value stream. Other benefits like reduction of inventories on site, increase collaboration in the supply chain, realization of Just-in-Time material deliveries, and significant cost benefits are also reported.</p>
<p>Azambuja et al. (2006) <i>“The importance of commitments management to the integration of make to order supply chains in construction industry.”</i></p>	<p>The objective of this paper is to assess how the integration of “make to order” supply chain is affected by the way commitment among chain members are coordinated. Two case studies have been carried out in the building elevator and cut and bend rebar supply chain. Language Action Perspective has been used for analysis</p>	<p>The findings of this study shows that a great part of information flow problems that happen among make-to-order supply chains can be traced back to the way that commitments among people and firms are managed along such chains. Sharply said, poor management of commitment lead to inefficient supply chains.</p>
<p>Horman, Kenley and Jennings (1997) <i>“A Lean approach to construction: An historical case study.”</i></p>	<p>This case study reveals the early employment of flow principles adopted by Jenning’s previously one of the largest house-building organisation in Australia in every aspect of their construction process.</p>	<p>This case confirms the utility of flow principle to construction operations which is one of the cornerstones of Lean. The method adopted has resulted in a growth of the company. The Jennings’ experience offers insight to adopt Lean production and Just-in-Time in construction.</p>
<p>Mota , Mota and Alves (2008) <i>“Implementing Lean construction concepts in a residential project.”</i></p>	<p>The main goals of this paper are to present a case where Lean construction concepts were implemented and to discuss the benefits achieved during the process.</p> <p>The study presented here was carried out in a project that comprised the construction of 18 houses financed by a private investor. The project was constructed and managed by a small sized construction company based in the city of Fortaleza in North Eastern Brazil.</p>	<p>The implementation of Lean principle has led to a more stable workflow. The project was completed a month in advance and allowed the investor to recover his investment sooner than expected.</p>
<p>Ala-Risku and Kärkkäinen (2006) <i>“Material delivery problems in construction projects: A possible solution.”</i></p>	<p>The main goal of this paper is to present a potential solution for managing the material logistics of construction projects.</p>	<p>The study proposes a solution based on the Last planner system. It consists of a tracking based approach for building inventory transparency for short term supply chains and pro-active material delivery model for specific project task.</p>

2.6 Theoretical Model

The fundamental structure of the model is to provide a basis for achieving an ideal Lean supply chain management. The specific factors used in this model have been discussed in the course of the preceding chapter. The assumption behind this model is that if all the variables are mutually and effectively combined, Lean supply chain management could be successfully implemented.

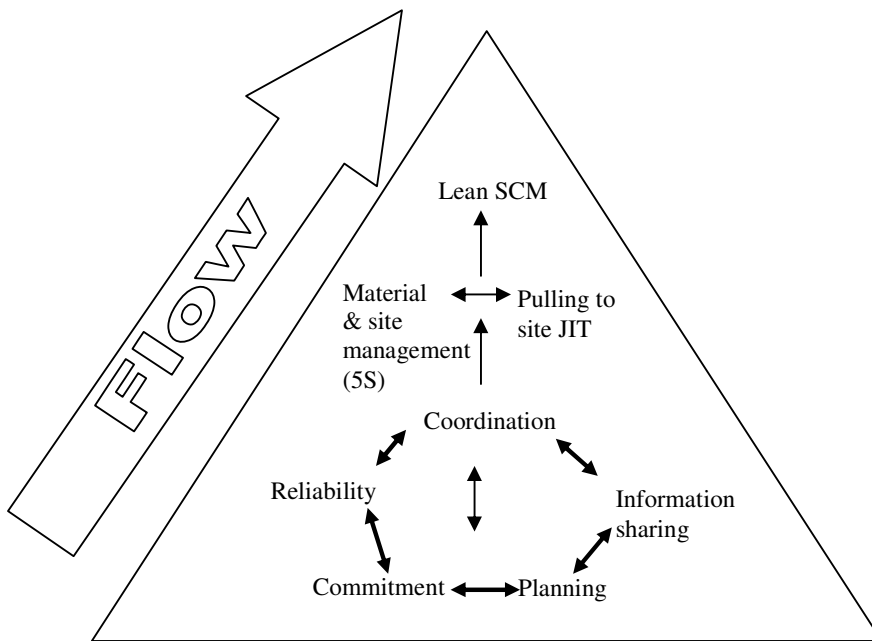


Figure 10: Model for Lean SCM

Figure 10 shows a possible roadmap model for implementing Lean supply chain management. The model shows interdependency between coordination, reliability, commitment, information sharing and planning. If well managed, these variables can help improve the material and site management and foster Just-in-Time delivery. The ultimate goal is to achieve a supply chain with zero waste, described here as Lean supply chain management. However, all these actions need to be achieved in a collaborative and integrated manner, which means through a flow of processes in order to be successful. However, it is noteworthy that Lean philosophy is an endless journey toward perfection.

Chapter 3 Research Methodology

This chapter will mainly focus on the methodological aspect of the study. It will outline the procedures used to conduct the study and describe the sampling procedure as well as give a description of the different sources of data. Finally, the chapter explains how the data will be analyzed in the context of a qualitative research study. The summary and recommendations will be the last component of this methodology.

3.1 Case Study as a Research Strategy

The research methodology applied in this thesis is the case study approach. Case study research focuses on a specific, bounded system in order to understand a complex entity which is embedded in a number of contexts (Stake 2005). In this case, the specific bounded system is a construction site. The focus here is on understanding the dynamics present within a single setting (Eisenhardt 1989), and induce from the findings recommendations for future projects.

Furthermore, Yin (1994) pointed out that a case study approach is appropriate for studies that intend to answer (1) the “*how*” and “*why*” research question, (2) do not require behavioural events and (3) focus on contemporary events. This case meets all three criteria in a way that the authors intend to investigate how the different contractors deals with their material delivery and site management and try to understand why is it so. From there, the authors will suggest solutions for improvements. In addition, the construction project being studied is actually under way, therefore being a real life project.

Stake (2005) identifies three types of case studies: intrinsic, collective and instrumental case studies. In an intrinsic case study, the case itself is the major focus of interest. A collective case study is applied when more than one case is being investigated. An instrumental case study focuses on a particular case or cases mainly to provide insight into an issue and facilitate understanding of a larger phenomenon (Stake 2005). The unique

specificities of the case being investigated will promote understanding or form practice for similar situations. In our case study, while the focus is on understanding the different challenges related to the material delivery and site management at a specific construction site, the suggestion made from the results of our inquiry will be applied in future projects.

From the discussion above, an instrumental single case study has been chosen as a research approach for this study.

3.2 Case Study, Sample Size and Sample Selection

Considering the time and resource constraints, selecting a single in depth case was the best option to achieve the research objective. Although, all the participants in the project are potential key informants, the time constraint did not permit us to access all. However, to ensure sufficient data collected for the analysis, a purposive sampling was used in this study (Ghuri and Grønhaug 2005). In the purposive sampling also known as judgmental sampling, the authors can use their own judgment in selecting the sample. The basis for selecting the sample is that it can yield considerable data that is specific for the research topic.

The authors got access to participants in a single construction project managed by Statsbygg in Oslo. Statsbygg was asked for the list of project participants, and a list of respondents was put together. As stated earlier, the respondents were chosen based on their willingness to participate to the survey and their accessibility. Afterwards, a sample of respondents was chosen to conduct the survey. Based on their judgement, the authors believe that this sample was purposeful and convenient to give insight about the key areas investigated.

3.3 Research Design

A research design is defined as the blueprint and a detailed plan of how research study is to be conducted (Neuman 1997). This section describes the research approach chosen for this case.

3.3.1 Research Approach

For this research, the authors selected a qualitative methodology to collect and analyze data. This methodology is chosen because it provided both the flexibility and the ability to study the situation in the detail which the authors felt was necessary. Another reason for choosing a qualitative approach over the quantitative research paradigm lied behind the statement of Leedy and Omrod (2001) who argued that the qualitative approach is inductive in its reasoning and the findings are communicated with words or narratives. According to Winchester (2000), qualitative methods fall into three categories: textual, oral and observational.

Textual analysis involves written texts, and even landscapes as inputs for discovering, underlying meanings, using tools associated with semiotics (Winchester, 2000). Observational research relies on participation or participatory observations and involves problems of positioning the researcher within the activities of the research subjects (Winchester, 2000). Finally, oral qualitative methods range from individual interviews to structured survey and questionnaires. In this case study, a questionnaire survey and some in-depth interviews have been conducted. Data derived from the survey are used statistically using simple percentages.

3.3.2 Sources of Data

Three different sources of data were used in this study. They are described in the following sections.

Primary Data

A combination of telephone interviews, in depth interviews and an e-mail survey with a questionnaire was used for primary data collection.

Secondary Data

The main source used for secondary data is the articles from the Lean construction websites¹. Other sources like existing books, previous master theses, PhDs dissertations, scientific articles retrieved through ProQuest² and Science Direct³ were also used. Some insights have also been gained from discussions with Molde Research Institute which has previously done some studies in the area of Lean shipbuilding.

Direct Observations

Direct observations were undertaken at the construction site. Due to the short time at hand, these observations were limited to the way the site was being maintained clean and tidy as well as how material were stored. In addition, a visit to the future construction site provided a visual sense of the situation for that project.

3.4 Data Analysis

Yin (1994), suggests that data analysis consists of examining, categorizing or recombining the evidence to address the initial proposition of a study. Furthermore, Patton (1990, p. 347) stated: “*data interpretation and analysis involves making sense out of what people have said, looking for patterns, putting together what is said in one place with what is said in another place, and integrating what different people have said*”. Several authors (de Vos 2002; Neuman 1997) recommend a data analysis procedure based on the following steps:

Step 1: Data collection

Step 2: Managing and organizing data into categories with regard to patterns

Step 3: Reading and summarizing data

Step 4: Describing and classifying data and the interpretation thereof, and

¹ <http://www.leanconstruction.org> and <http://www.iglc.net>

² <http://www.proquest.com>

Step 5: Presenting data in the form of research report

For this case study, a combination of the different procedures proposed above will be more or less followed.

3.5 Summary and Recommendations

According to Bless and Higson-Smith (1995), no research project is completed if recommendations have not been made. The authors also suggest that after a careful explanation of the results, they should be summarized. In the same vein, Leedy (1993) suggests that the summary will serve as a basis for recommendations.

³ <http://www.sciencedirect.com/>

Chapter 4 Case Study

The purpose of this chapter is to introduce the case study. It consists of project description, the data collection and finally the limitation encountered during this phase.

4.1 Project Description

This section introduces Statsbygg, the case at Domus Medica and the background of the study at IFI2.

4.1.1 Introducing Statsbygg

Statsbygg, the Norwegian Directorate of Public Construction and Property, acts on behalf of the Norwegian government as property manager and advisor in construction and property affairs. The organisation is an administrative body responsible to the Ministry of Government Administration and Reforms. Statsbygg manages approximately 2.3 million m² of floor space in Norway and abroad, completes about 30 projects per year, has more than 700 employees, a yearly investment of around 3 billion NOK in buildings, maintains 1500 properties and has about 140 ongoing projects.

Statsbygg is the owner of most civil public on central government level, and is responsible for the management, development and maintenance of these buildings. Examples of building projects conducted by Statsbygg are university-colleges, universities, prisons, courthouses, theatres, museums, Government offices, traffic stations, castles and embassies. Examples of recent famous projects are the Opera building in Bjørvika and the Global seed vault in Svalbard. The organisation offers consultancy and assistance in civil engineering and technical matters to ministries and governmental organisations. Statsbygg is member of the Lean construction network Norway (Statsbygg 2009, 2008).

4.1.2 Domus Medica

The Domus Medica case takes place at the Gaustad campus of the University of Oslo (UiO) and is an extension to the existing university buildings Domus Medica and Domus Odontologica. These buildings are used by the medicine and odontology faculties. The project is estimated to cost 529.9 million NOK and the construction period is estimated to last approximately 2 years. The construction process will start in summer 2009. The site consists of an area of 11.262 m² divided in four main parts:

- The lab (main building); area: 5.370 m²
- The building with classrooms (Rotunda); area: 1.593 m²
- Animal department (cellar in Rotunda); area: 2.213m²
- Parking cellar (underneath the main building); area: 2.086 m²

The site plan is showed in [figure 11](#). It shows that the site has a limited space for material storage and laydown areas and other facilities. The two arrows show the two access roads to the site. The dotted lines indicate a possible drive-through construction road. The long lines demarcate the staging area, and the continuous lines depict the new building. The access road from Slemdalsveien crosses a narrow but reinforced bridge. The access road from Gaustadalléen needs to be kept open because it is a busy road for traffic.

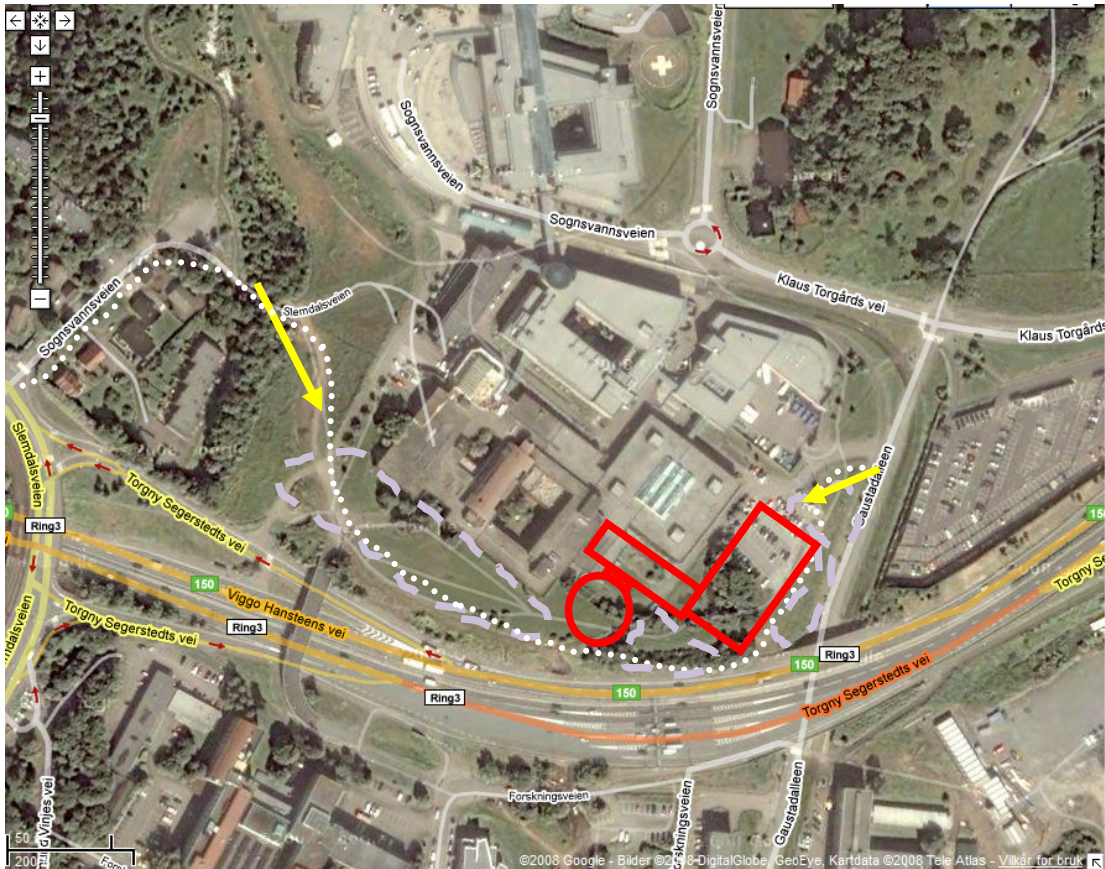


Figure 11: Aerial photo © Google with improved drawing of D-Medica (Adapted from Statsbygg 2008)

It is noteworthy that Statsbygg does not do any construction activity themselves. Basically the procedure starts with the user (University of Oslo in our case) realizing the need for a new building. The user contacts Statsbygg who takes responsibility for carrying the project. An architect is chosen for the preliminary design of the building through tendering. Once the first design done, the architect and some consultants in collaboration with Statsbygg develop a tendering document for the potential main contractor and all subcontractors. The document is then sent out for selection of the different contractor. The organisational chart of the Domus Medica project is shown in Appendix 1. The Latham report (1994) underlined the reliance of the construction sector on competitive tendering for subcontracted work and price based selection. After selection, contractual agreements are signed between the different parties and Statsbygg, which define roles and responsibilities in the project. Some changes in design can happen through comments from the selected contractors, at the end, the best design solution for Statsbygg and the architect

is chosen. The figure below describes a possible construction supply network used by Statsbygg.

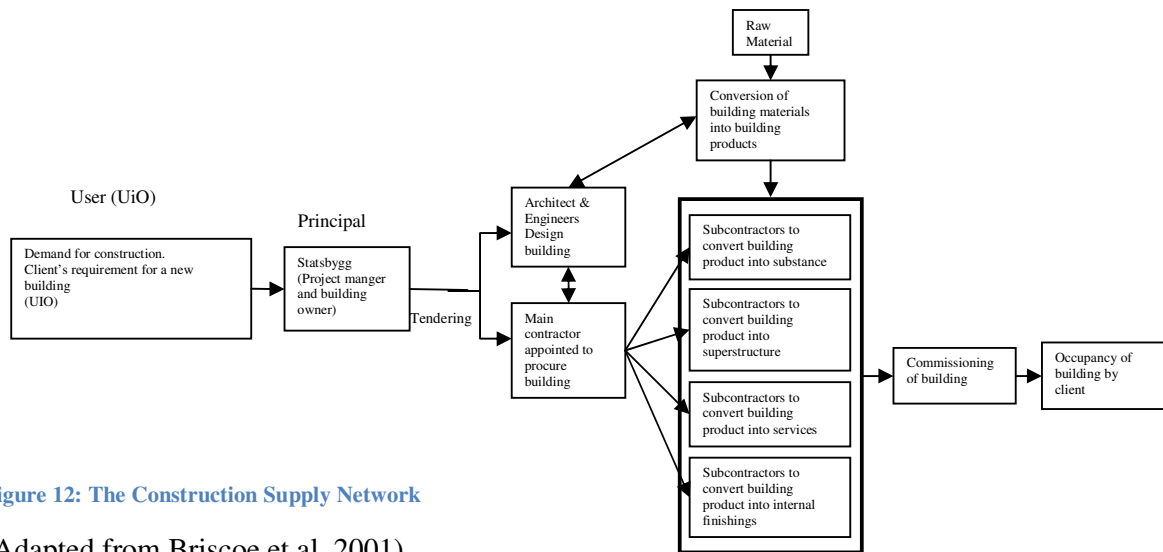


Figure 12: The Construction Supply Network

(Adapted from Briscoe et al. 2001)

In the Domus Medica case, construction is the responsibility of a general contractor under contract to the client. The main contractor has responsibility for the staging area and the construction site. This means tidiness and maintenance of the site as well as providing offices, cranes and other equipment and storing space are under his responsibility. A third party construction site manager has been hired for the project.

4.1.3 Background of the Field Study (IFI2)

Since the different contractors for Domus Medica were not yet selected at the time of this study, a field study was conducted on the construction site at IFI2, one of the current construction projects managed by Statsbygg in Oslo. This project is also for the same customer, the University of Oslo, and is located just south of Domus Medica across the main road and is going to be the new building for the informatics students.

The construction process is assessed based principally on the literature review discussed in section 2.4 *Lean Supply Chain Management in Construction*. This construction site is a 28,500 square meter informatics and computer sciences research building. The project at IFI2 is organized with Statsbygg managing the different contractors operating on the

construction site. No general contractor has been assigned for this project. Sixteen contractors taking part in the project have been assessed in their approach to supply chain management. The organisational chart for the IFI2 project is displayed in **appendix 2**. Figure 13 and 14 give an overview of the building at IFI2.



Figure 13: IFI2 under construction

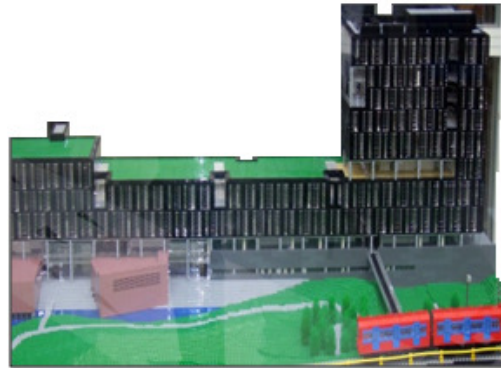


Figure 14: Architectural Lego™ of IFI2

4.2 Data Collection

“Data collection is the heartbeat of the research and the data collection methods consist of a detailed plan of procedures that aim to gather data for specific purposes, that is to answer the research question” (Grinnell 1988, p. 458).

In our case, the data collection procedure was undertaken in three phases. This procedure has allowed the authors to gain a broader view of the supply chain and the different challenges encountered in the planning, delivery and management of material on site.

In Phase 1

The challenges were analysed in general terms. The authors selected the respondents which they believe have high influence in the outcome of the project, the site manager for the future construction at Domus Medica, the project manager as well as the site manager at IFI2. Once the respondents were selected, exploratory interviews were undertaken in order to obtain a general picture about the challenges of material delivery and site management including the challenges of planning, coordination and information flow in

the project. These exploratory interviews combined with the literature review gave the basis for the construct of the questionnaire for Phase 2.

In Phase 2

The authors proceeded on the development and dissemination of a questionnaire survey. A written introduction letter from Statsbygg was attached to the questionnaire to facilitate and encourage participation to the survey. In addition, most of the potential respondents were first contacted by phone to ensure their willingness to participate in the survey. Then the questionnaire was sent out.

The survey was sent out using an online e-survey tool called Questback⁴ to 51 respondents, mainly contractors and suppliers for the IFI2 project. A total of 30 responses were in total returned which represent an average response rate of approximately sixty percent.

The number of respondents for each question depends on previous questions, as there are routing in the survey scheme at Questback. This means the type of companies, roles and involvement in the IFI2 project will affect which questions the respondents get, as well as follow up questions later in the survey depending also on previous answers. As an example none of the respondents did get the opportunity to answer question number 10 which asked “*What will be the reasons for these bad relationships with other contractors*” because all of them answered that their relationship was good with other subcontractors in the previous question 9.

The questionnaire was designed around six different variables questioning about material delivery, coordination, commitment, information, planning and site management issues. During the survey, respondents and company profile were detailed; however the participants and company’s names are not mentioned in the thesis to maintain anonymity. The questionnaire gave each respondent an opportunity to rate their response using mostly five categories: *strongly agree, agree, neutral, disagree* and *strongly disagree*. At the end of the questionnaire, respondents were asked to provide comments and suggestion for improvements.

Most of the responses the authors obtained were from project managers operating in the site. Few responses were obtained from the other participants in the project. This situation has been considered as a limitation in the data collection procedure. Indeed, this situation could bias the analysis since project managers could overlook some problems considered as very important for other participants. Limitations of the data collection are discussed further below.

In Phase 3

After receiving the feedback of the questionnaire, some in depth interviews were undertaken with the site workers and the different architects to augment the data. Data from a broad spectrum of project participants occupying different positions within the project organisation was collected. The requests for interviews were initiated through phone calls. Interviews were structured to gather information about their opinions on the variables mentioned in phase 2.

The interviews were conducted individually behind closed door off-site to maintain anonymity of the participants. It took approximately 30 minutes per participant. Through in depth interviews, more broad and detailed data were anticipated to be collected. Before formally starting the interview, a short description of the case to be investigated was given. The authors also gave a description of the future project at Domus Medica. The questions were addressed during the flow of a seemingly natural conversation. This technique helps to make the interviewees more comfortable and willing to cooperate. The interviews provided for a deepening of the data gathered in the survey. The interviewees could directly describe their own experiences and also provide real world experiences. These experiences are considered to be of significance importance to the outcome of this case study.

⁴ <http://www.questback.no>

4.3 Limitations in Data Collection

The process of data collection did not go without some problems. They are described below:

- Some of the participants found the questionnaire too long.
- Very few participants who responded to the survey took the time to give some comments on improvements possibilities asked in the questionnaire.
- The time for the different interviews was left to the convenience of the participants. Most of the respondents wanted to be interviewed around the same moment. To accommodate this situation, the interview time was shortened and some of the questions could not be asked.
- The list of possible respondents mainly consisted of project managers; this is seen as a limitation since the authors did not have a broader spectrum of participant to respond to the questionnaire survey. In some cases, only one respondent from a specific role answered. This could also be a source of bias.

Chapter 5: Findings from the Case Study

The purpose of this chapter is to present the findings of the case study. The data are reported in the form of text, table and figures located in the body of the chapter. The evidences presented in this chapter are derived from the questionnaire survey and the interviews with the project members. The findings are displayed mostly based on simple percentages that infer either agreement or disagreement with the questionnaire statements.

5.1 Respondent's Profiles

Respondents were asked to give information about their role as well as their organisation's role for the IFI 2 project. The authors knew from the explorative interviews that several companies taking part in the project were both supplier and also construction contractors on site. In this study, they are referred to as "Both supplier and contractor". The table and the graph below show the company's role

Table 5: Respondents organisations roles in the construction industry

Company's role	
Both supplier and contractor	8
Building owner	1
Construction site leader	1
Contractor	14
Supplier	5
Architect	1
Grand total	30

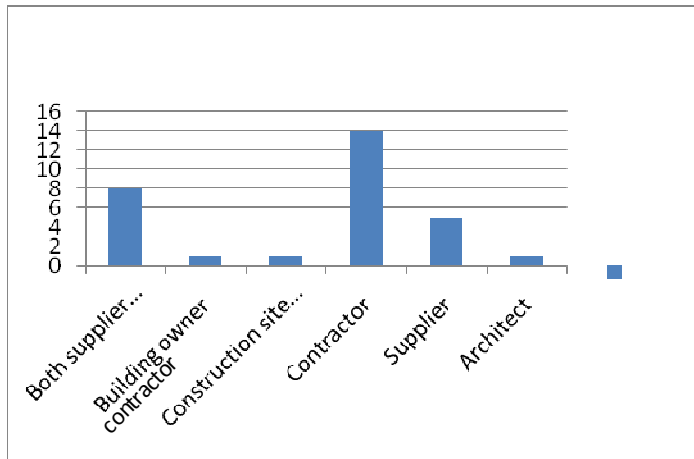


Figure 15: Respondents organisations roles in the construction industry

Data collected shows that 30 participants ranging from General Manager to skilled worker completed the survey. In addition, during the in-depth interviews, the authors also had the chance to talk to some craftsmen as well as gang foremen or crew leaders involved in the IFI2 project. A gang foreman is the person responsible of a group of workers in a construction project.

Table 6 and figure 15 on the previous page show the respondent's roles. All the participants agree upon the relative importance of the IFI2 project for their organisations.

These organisations have had previous working experiences with Statsbygg. When asked about how many projects they have been involved under the responsibility of Statsbygg over the past 5 years, the responses varied from two to twelve.

Table 6: Respondents' roles

Participants' role	Total	Percent
* General manager	1	3%
* Market manager	1	3%
Architect	1	3%
Foreman	1	3%
Managing director	5	17%
Office worker	1	3%
Project leader	16	53%
Skilled worker	2	7%
Construction site manager	2	7%
Grand Total	30	100%

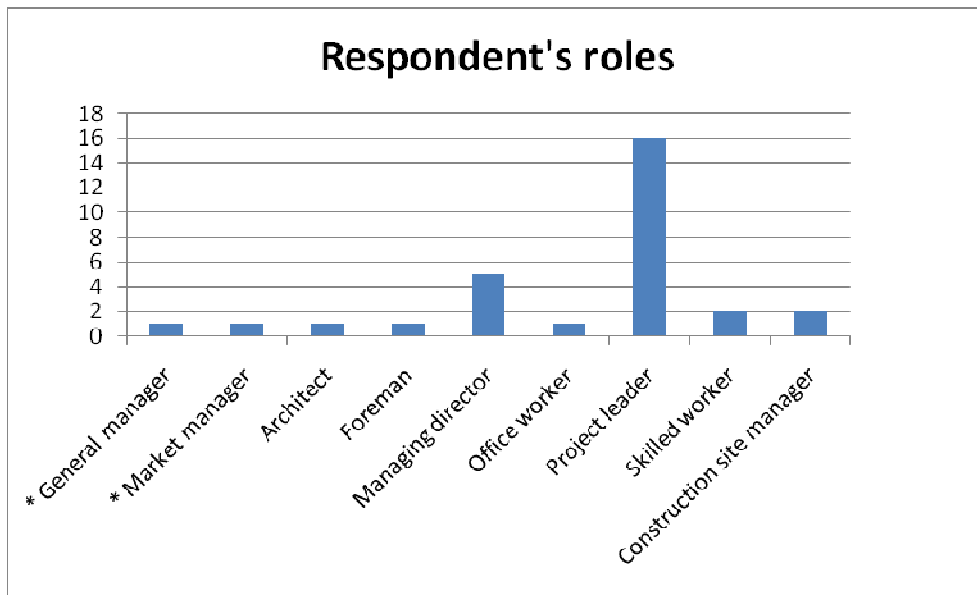


Figure 16: Respondents' roles

Figure 16 and table 6 show that a large percentage (53%) of respondents was project leaders, the managing directors ranked second (17%). Skilled workers and construction site manager ranked third with 7% each. For other roles, only few responses were collected.

To unfold the meanings of peoples' responses in an appropriate and more understandable way, themes are identified and categorized based both on the content of the questionnaire and the model developed in chapter 2. The following themes were chosen: **Material delivery and management**, **Site management**, **Just-in-Time versus Push**, **Information**, **Collaboration and Coordination**, **Planning delivery** and finally **Variability and Reliability issues**.

5.2 Material Delivery and Management

Several questions were asked in order to understand the way the contractors deal with the delivery of their material and the management after reception. At the beginning, respondent were asked how the management of material delivery from other contractors affect their material delivery. 74% of them believe that the material delivery management of other subcontractors greatly affects theirs at the construction site in IFI2; approximately 11% tends to disagree. Not surprisingly, a similar situation applied for construction

projects in general where 80% of the respondents agree that the way other subcontractors manage their material delivery affect theirs and only 10% tend to disagree.

The respondents were asked about potential challenges their organisations have encountered when dealing with material deliveries at the construction site. The authors collected only nine responses regarding this issue. Figure 17 on the next page gives the repartition of the different challenges encounter in material delivery. The figure shows that at IFI2 as well as for construction project in general, the main reasons given for material delivery challenges were linked to inefficient planning and scheduling as well as the bad sequence of deliveries. These causes were rated respectively 44% and 33% for the IFI2 project and project in general. The question was also discussed during the face to face interviews performed in Oslo. During the interviews, the respondents agree upon the fact that inefficient planning and scheduling was one of the most recurrent causes of material delivery challenges, they also pointed out the fact that late decisions taking was often the root cause of inefficient planning and scheduling.

Other challenges include inefficient and inadequate deliveries (11%), late deliveries (11%), and too early deliveries (11%). The situation is quite similar for construction projects in general. Some of the respondents added other challenges such as internal delivery which means transporting material from one side of the construction to another side. The respondents assert that they spend a lot of time moving the material from one place to another. Moving material was done to make free space for other actors to do their construction work as well as opening some areas to unload incoming materials. During the in depth interviews, one of the respondents said that his company was getting paid by Statsbygg for doing this kind of work which he considers as an extra work. However the respondent said that the situation was not so critical in the IFI2 project as compared to construction project in general. During the in depth interviews, respondents claimed that inaccurate information was also a cause of material delivery challenges. Poor quality of materials seems to not be an issue in this project.

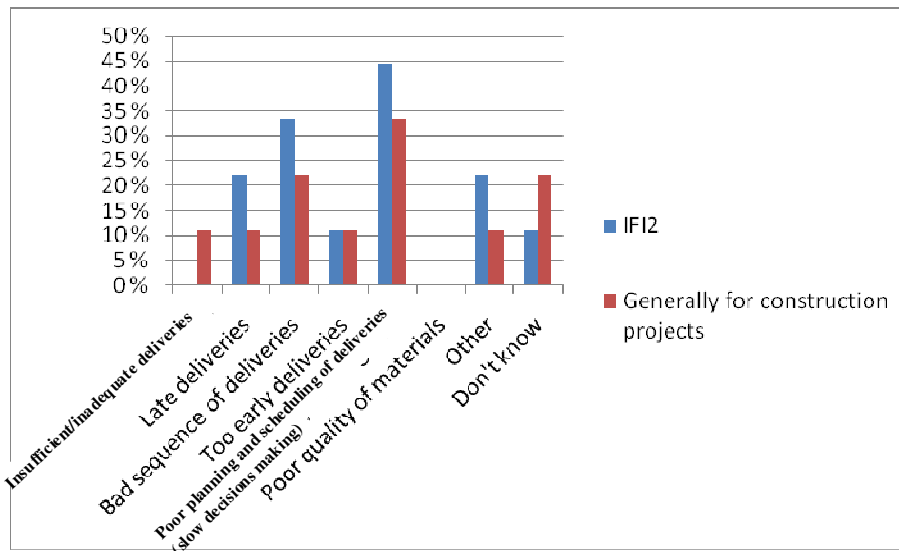


Figure 17: Challenges related to material delivery

When asked to give some recommendations to overcome the challenges they faced in the delivery of material, some of the respondents suggested that their counterparts notified one day in advance the time of delivery in case they are expecting delivery so that they can get faster access to a crane or lift. They also suggested weekly meetings to plan and schedule the delivery of materials. Furthermore, they suggest that following up closely the orders with the supplier can have favourable impact on material delivery. Discussions with suppliers to improve routines for deliveries were also recommended. Making deliveries plans and developing close cooperation, coordination and communication with the suppliers have been mentioned as well.

One interesting finding is that the different respondents knew where their challenges lie but lacked a systematic tool to deal with them. However, they take some actions such as discussing with the suppliers and also with the different contractors trying to solve them. One interviewee said that on another project he had worked, the building owner had hired a third party company to take on internal logistics. They found that this technique brought improvement in their working process as a whole.

5.3 Just-In-Time versus Push

When the authors asked which procedures the respondents were using for the delivery of material, two different alternatives were proposed: building up inventory or Just-in-Time delivery. Both ways seems to be utilized at the construction site. However, most of the respondents' preferred the build up of inventory. According to some of these respondents, saving in transportation cost was one of the reasons for ordering material in large amount (bulk). However, this situation created some challenges for them. 55% of the respondents said they have lost material due to bad handling and re-handling at the construction site.

During the in depth interviews, the respondents agreed that Just-in-Time would be the best solution for material delivery but they could not rely on it. Some other interviewees believed that Just-in-Time solution was unrealistic due to long delivery time and variability issues when dealing with the suppliers. Another reason stated during the in depth interviews for building up inventory was to be able to cope in case of unexpected changes in the construction progress plan, or in case of errors in drawings. They also said they experienced too many delays in previous projects; therefore they needed to have buffers. In addition they pinpointed the fact that the suppliers were not used to Just-in-Time routines.

To ensure having the material at hand when needed, 80% of the respondents used to order material well in advance needed times. Another important reason for ordering material in bulk was linked to transportation cost. By ordering a full truck the respondents said they can save in transportation cost.

During the interview, the contractor in charge of laying the concrete insists that he has no choice but applying Just-in-Time delivery. Since the concrete could not be stored, it was necessary to get everything ready before the truck come in for immediate installation.

The contractor also pinpoints that a close cooperation between himself, other contractors and the supplier was necessary to get the concrete when needed which means Just-in-Time.

Concerning the amount of material stored on site, as showed in the figures below, 17% of the respondents believed that too much material was stored on site and 52% disagreed. The opinion is evenly distributed when it comes to construction project in general. Forty percent of respondents (40%) believe that too much material was stored on site and 40% disagreed.

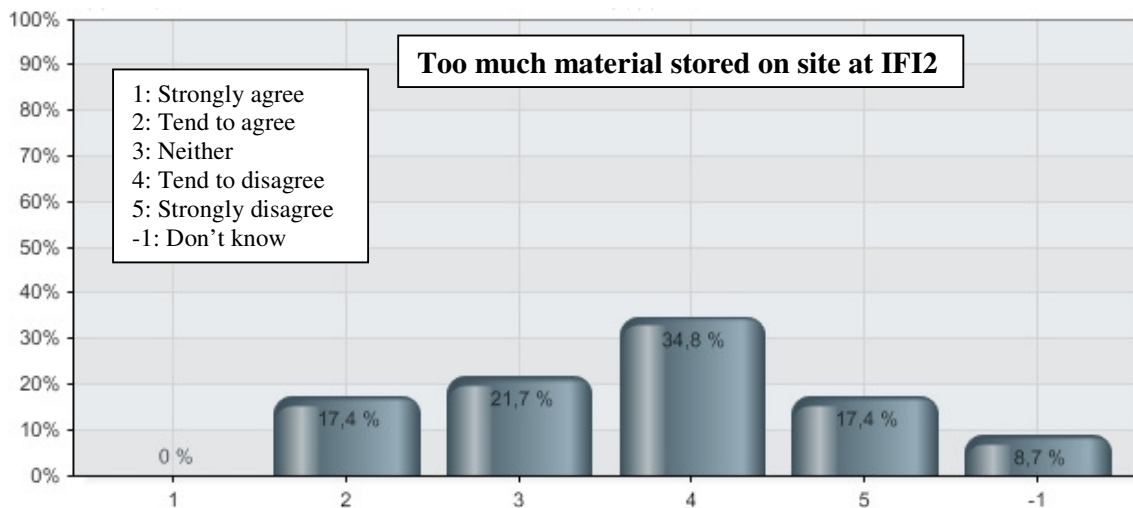


Figure 18: Too much material stored on site at IFI2

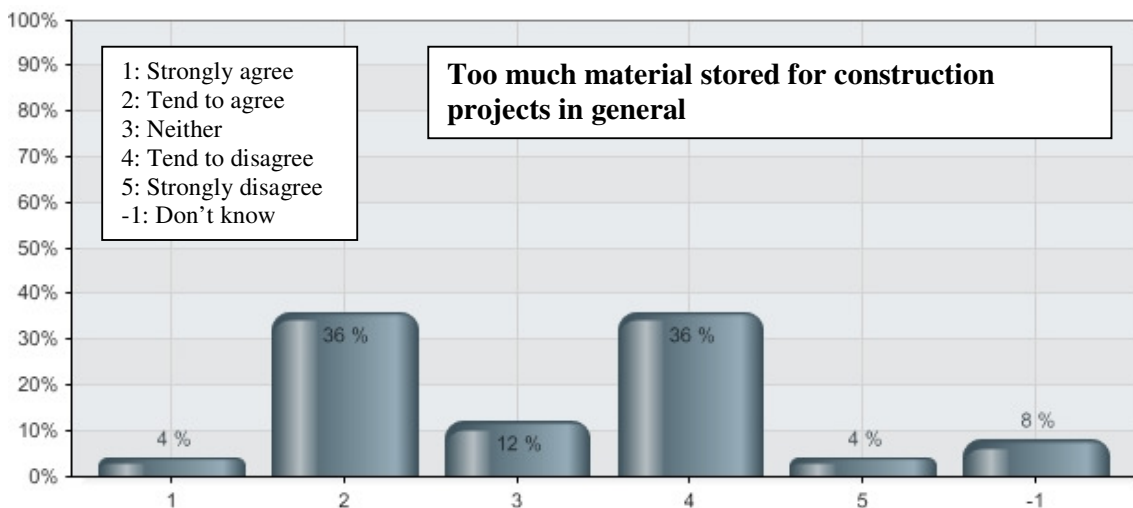


Figure 19: Too much material stored on site for projects in general

During the direct observations on site at IFI2, the authors found that the site was free of excessive material. This opinion is supported by some pictures taken during the visit. The pictures are shown in the next page.

5.4 Site Management

A walkthrough at the construction site assisted the authors to assess the site management. During the walkthrough, some pictures have been taken to illustrate the management of the site. These pictures show factors like traffic routes and material storage Figures 20, 21, 22, 23 and 24 display the observations.



Figure 20: Storage place inside the building



Figure 21: Allocated place for bricks inside the building



Figure 22: Place for consumables on the floor



Figure 23: Access roads for delivery vehicles



Figure 24: Staging area outside the building

The pictures shown give an overview about the material management and site management at IFI2. As we can see materials seem to be handled in a good manner.

Figure 25 shows that almost every respondent (87%) agree that the design of the site layout is an important factor for good delivery and handling of material. However, only 36% of the respondents agree that their logistical concerns were taken into account when designing the staging area or during the design phase of the building. These opinions have been confirmed during the in depth interviews. The respondents supported the fact that, in most of the construction projects, their logistical concern was not taken into consideration during the design phase of the project.

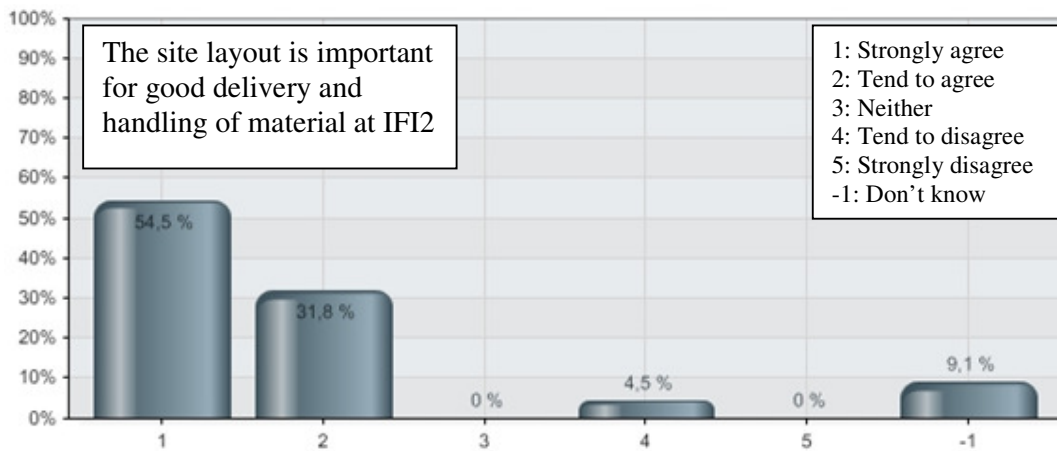


Figure 25: Importance of site layout for material handling and delivery

However, for the project at IFI 2, 55% of the respondents believe that the staging area has a layout that facilitates the good maintenance of the site. Approximately 30% do not share this view.

Concerning internal delivery, almost 80% of respondents agree that materials are unloaded at the site directly where there are needed. However, 70% of respondents agree that materials tend to be moved around in order to create working space as well as space for new incoming material.

Respondents were later asked about any existing material handling procedures as well as procedures for making the site clean and tidy. Approximately eighty percent 80% of them said they have procedures to clean the site and handle materials. When asked if these procedures were followed, the answer was “mostly” at a large percentage. They also tend to agree that these procedures were mostly reviewed at the beginning of the project to

make everyone aware of them. Some respondents believe that the lack of sanctions for not following the procedures created negligence.

5.5 Information Sharing, Collaboration and Coordination

The respondents were asked about the status of their relationship with others in the construction project at IFI2. All the respondents (100%) said their relationship with one another was good. The respondents were quite satisfied with the working atmosphere. During the in depth interviews, this opinion was supported by the interviewees. One of the respondents stated that the meetings have fostered camaraderie and helped to reduce bureaucracy. Almost all the respondents agree that meetings were used as channels to share information.

The respondents agreed that meetings were also the platform to discuss coordination and planning among the project participants. 56% of the respondents tend to agree that responsibilities were clearly defined through the meetings, 36% strongly agreed on this statement and only 8% disagreed. A more precise question was asked about the planning of material delivery. For this question a very large percentage agreed that the actions and plans were coordinated through meetings, only 4% disagreed. However, whether the plan was followed or not was another issue.

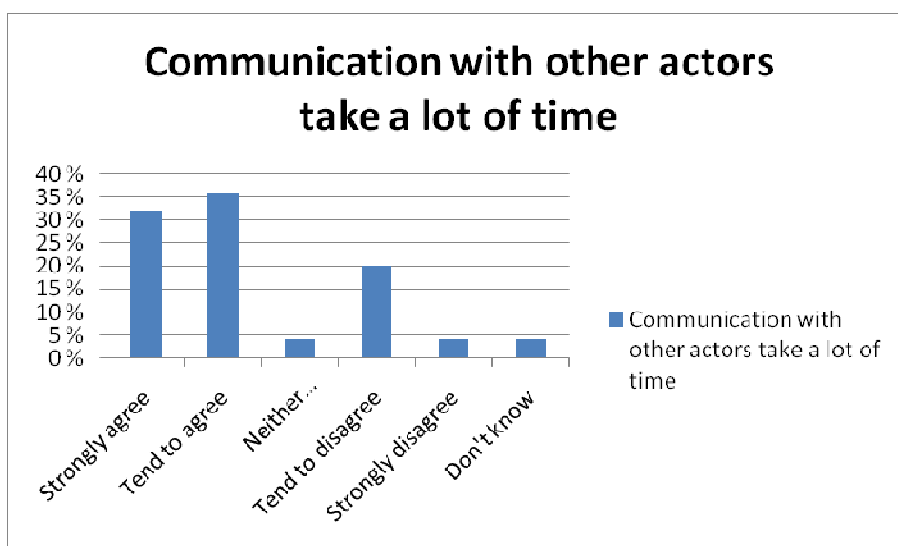


Figure 26: Opinions on communication issues

The meetings were found to be very time consuming for the participants. Figure 26 shows that approximately 65% of the respondents found that communications with other actors were very time consuming. They linked this situation to unclear agenda for the meetings and poor organization during the meetings. For these respondents, this situation is also fostered by the fact that participants in the meetings tend to raise issues that could be discussed in a more informal setting or in different meetings. These opinions are not very different for construction projects in general.

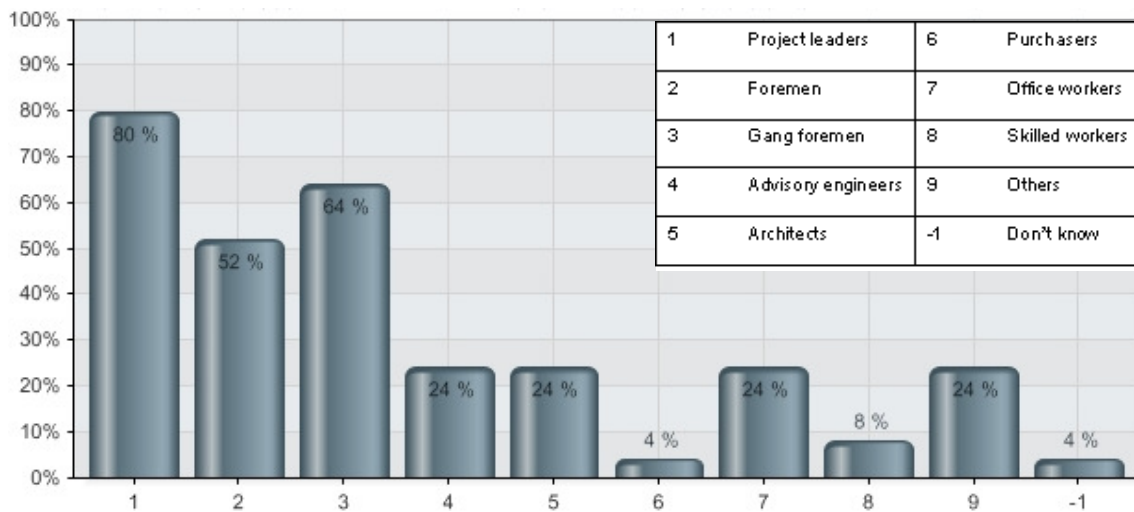


Figure 27: Participants taking part in meetings

During the in depth interviews, the respondents raised another challenge with the meetings, they believed that too many people were involved in a single meeting. For them, this situation was also one of the causes for the large amount of time used during the meetings. Figure 27 shows that participants in the meetings range from project leader to skilled workers. Other participants were also named such as Statsbygg often represented by a progress coordinator. Meetings were mainly hold mostly on a weekly basis and also as challenges arouse.

Besides the meetings, other ways used to share information in the project include e-mails, phone calls and text messages. One of the most used was e-mails. During the in depth interview, some respondents said they prefer to share information through reports. The reason behind that was linked to financial reasons. They wanted to be able to have

evidences of every commitment they made and for them using written reports was the best way to do so. Informal discussions were also used to a very small extent.

Figure 28 below shows the different channels used to share information among project's participants on the construction site, one (1) being the most used in this case and five (5) the least used.

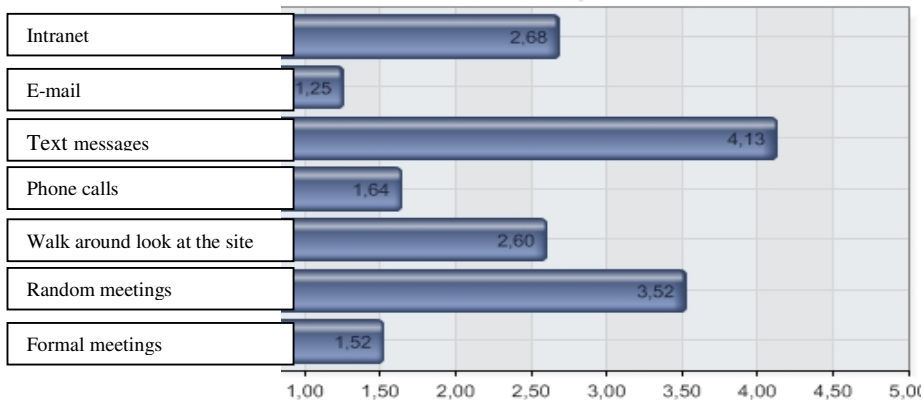


Figure 28: Ways of information sharing

Concerning the information flow between contractors and material' suppliers off site, a large share of respondents (76%) tends to believe that information is accurately transmitted. The respondents stated that their suppliers are kept informed about changes in order, changes in product specification, and other unanticipated changes mostly through phone calls and e-mails. Some contractors use faxes.

5.6 Planning of Material delivery

40% of the respondents agreed that, coordination and planning of the sequence of deliveries is done through an agreed progress plan. As we discussed earlier, meetings seem to be the place for discussing this issue. 12% of the respondents agreed that they are relying on a common sequence plan for material deliveries. This common plan is discussed with other contractors on site. However, the respondents pinpointed that this common plan was not always followed. This opinion was supported during the in depth interviews. During these interviews, there was a common census that the plan was almost never followed in construction projects because variations occur very often.

12% of respondents believe that a short term weekly logistical plan could be the best way to deal with this issue. During the interviews, some craftsmen claimed that they were not taking part in making the plan for delivery sequence but suggested that the plan should be reviewed and updated as often as possible to avoid interferences between contractors.

Concerning the general project plan, at the IFI2 project, 70% of the respondents agree that their organisation's objectives are taken into account in the common progress plan, however for 15% of the respondents, this was not the case.

5.7 Variability and reliability issues in construction supply chains

When we asked if the different actors keep their promises according to the agreed schedule or established plan, the opinion was shared between the respondents. 42% agreed that other participants kept their promises and approximately 27% of respondents tend to disagree. Variability and reliability issues were also discussed during the in depth interviews. The respondents agreed upon the fact that variability occurs more often on the supplier's side. For them, the suppliers were not very reliable in term of delivery time. At the construction site at IFI2, some of the respondents interviewed stated that variability in term of material delivery sequence were not common. Another source of variability was linked to the drawings. Almost every respondent claimed that the drawings were coming too late or with errors and needed to be corrected. They also pointed out that external conditions (weather conditions for instance) were reasons of variability in the progress plan.

5.8 Summary

Table 7 below summarizes the findings. Keywords have been used to display these findings. However, this table should be read with care given the rather crude level of the keywords

Table 7: Summary of findings

Themes	Findings (Keywords)
Material delivery and management	Dependency between actors Inefficient and inadequate deliveries Bad sequence of deliveries Too early deliveries Inefficient planning and scheduling Late decision making Challenge of internal deliveries
Just in time vs. push	Push Saving in transportation cost, Storage on site Material lost JIT Close cooperation needed Lack of knowledge at the supplier' side
Site management	Storage limited No involvement of contractors in the design phase Internal delivery Handling and re-handling Housekeeping procedures
Information sharing, collaboration and coordination	Meetings Interaction and interactivity Time consuming Unclear agenda Poor organization E-mails, phone calls, reports
Planning of material delivery	Meetings Variability Common progress plan
Variability and reliability issues in construction supply chains	Lack of commitment Supplier side Drawings External conditions

The results of this analysis are revealed to be mostly compatible with the theory. Opinions are shared for almost every question which suggests room for improvement. It can also be noticed that most of the contractors use the traditional project management instead of principles of Lean construction. However, one of the contractors the authors have talked with has started implementing some principles belonging to Lean such as the Last planner system. The concept is called “smart” and is believed to have brought some improvements in their processes.

The next chapter discusses the findings and gives recommendations for improvement.

Chapter 6 Discussions and Recommendations

The purpose of this case study was to investigate the different challenges related to the material delivery and site management at the construction at IFI2 and suggest recommendations for the construction of a new building at the University of Oslo with limited storage capacity and limited road accesses. The research question addressed in this study was:

How can the implementation of Lean methods improve logistics planning, delivery and the handling of materials when a construction site tends to be constrained?

This chapter presents a discussion of the research findings focusing on the concept of *flow*. Figure 5 “Lean production management” displayed in chapter 2 will give a basis for discussions and recommendations. As discussed earlier in this paper, flow is considered to be the driving force for value generation. It also provides a clear cut between traditional project management and Lean production management.

Discussions and recommendations will be conducted under the main following sections: **shaping workflow** (identify and removing constraints), **decentralized planning** (explicit quality assignments) and **rapid learning measurement**. However, the key factors identified in the data analysis and the model as affecting the efficient delivery and management of material are considered as subsets.

6.1 Shaping workflow: identify and removing constraints

Identifying and removing the constraints can be considered as a screening process. All constraints preventing the execution of a specific task have to be identified and removed. In this section the authors consider information sharing and the combination of coordination, commitment and reliability to be necessary to identifying and removing the different constraints that could hinder Lean supply chain management. Furthermore, in

order to achieve the 7 preconditions for any task in Lean construction, information need to be shared properly and actions coordinated accordingly.

6.1.1 Information sharing

According to the questionnaire and the interviews conducted for this research, there was a consensus on communication and information flow as well as coordination as an essential element for completing the project on time.

In term of information sharing, meetings represented by far the most important inter-organisational routine activity mentioned by the respondents in the survey and the interviewees. At IFI2, meetings have shown to be a great means of communication and encourage employee involvement. This involvement creates employee empowerment and allows quicker response to problems, as suggested by one of the respondents during the in depth interviews. This finding seems compatible with the theory. It is noteworthy that meetings can help to identify constraints hindering the delivery of material in a Just-in-Time manner as well as efficient site management. By sharing each other's information and discussing what every party has to do for others and needs to obtain from them to complete the work, constraints related to the material delivery or site management can be identified and removed.

An effective Lean meeting will deliver the most optimized planning and scheduling based on communication and coordination among the participants and foster involvement and commitment among subcontractors. The meetings should be mandatory to attend and should include participants from different levels in the organization in order to comprehensively discuss the challenges. However, at IFI2, complains have risen about the very big number of participants for a single meeting. This could be linked to inefficient planning of the different meetings. Meetings should be organized in term of needs and participants. This will allow an effective decision making and more preparedness to deal with unanticipated situations. The weekly meetings should cover discussions related to the progress of the project, the challenges encountered, and the resources needed to handle the challenges. Different kinds of meetings can be held depending on the situation to be discussed.

Besides the meetings, it was deduced from the interviews that quite many participants rely on information systems such as phone calls or e-mails for information sharing. However, information system which integrates all the participants did not exist.

One of the respondents believes that e-mails were not a good way of sharing information. This could be explained by the fact that a single person can have more than 100 different e-mails per day; and the retrieval of the specific email could be unlikely. In addition, by using different information channels, the information transmitted could differ from one participant to another, but also be delivered at different times. It can therefore create a situation where a particular supply chain member has more or less information as compared to other members of the chain. This asymmetric information sharing has negative impact on the project.

Decisions are taken based on information received from another party; if the right information is not transmitted it can result in poor decision making in terms of material needed. Incorrect or insufficient information can hinder the completion of the work resulting in participants not being able to fulfil their commitment.

Concerning this issue, an important point noticed in the findings was that a large percentage of respondents agreed that information was accurately transmitted between themselves and the supplier off site. However, at the same time they face challenges related to material deliveries such as bad sequence of deliveries. This situation shows that the information transmitted is understood in a different way.

The concept of Kaizen which promote standardization of procedures should be applied at this level. Information should be transmitted in the same format through the same channel to assure its accuracy, consistency and also improve its readability. An integrated information system for all participants of the project is required to achieve standardization as suggested by the theory.

Through this common information system, new plans and information about material delivery can flow immediately to the parties involved and quicker and more efficient document transfer can be obtained.

6.1.2 Coordination, commitment and reliability

From the findings it appears that coordination with other actors in the project is time consuming. This situation can be linked to inexistence of standard routines to coordinate actions. By developing routines to coordinate actions, lot of time can be saved and team work can be achieved.

Respondents tend to agree that the material delivery management of their counterpart greatly affect their material delivery management. This rating stresses the fact that the non-respect of the schedule by one contractor is transferred through the entire supply chain and can result in delays and waste of time. This result is consistent with the findings in existing research indicating the causal relationship between problems in one stage in the supply chain causing waste in another stage. Another conclusion that emerges from this statement is the non-respect of commitment of some contractors.

27% of the respondents believe that participants do not keep their promises according to the agreed plan. This uncovers the lack of commitment and therefore fosters preventive action like inventory to shield against variability on the contractor's side. Respondents mainly blame the suppliers for creating such variability. This was also recurrent with the contractor on the construction site.

As we know from the theory in lean construction, workers' performance is evaluated based on their ability to reliably achieve their commitment. To achieve greater performance in material delivery, it would be beneficial to select suppliers who already use Just-in-Time as their approach to material delivery.

The commitment loop based on *Language action perspective* presented in section **3.2.4** can serve as a basis for improvement. Since the language action perspective is based on information systems, it will facilitate the implementation of Just-in-Time delivery as discussed earlier.

In addition, the complexity of a tight construction site requires an extensive collaboration and commitment between contractors and suppliers for an efficient material management. Commitment from the suppliers and the other parties in the project to the agreed schedule

and plan is important to establish reliability. With reliability from every party, Just-in-Time delivery can be implemented.

The commitment issue can also be addressed in contracts with subsequent sanctions in case of deviations. Statsbygg should control the progress plan and coordinate the different contracts. To avoid conflicts between the contractors, it is important to make the different contracts as detailed as possible. Specify responsibility for each task will prevent waste of time dealing with conflicts. The conflict could also extend to Statsbygg, therefore, care need to be given to this issue.

6.2 Planning

From the interviews and the questionnaire, there was a perceptual congruence that plans were not completely followed in the construction site at IFI2. Fifteen percent (15%) of the contractors pinpointed that their organisation's viewpoint was not sufficiently taken into considerations in the common plan. This could explain to some extent why the plans were not followed overall.

As discussed in the theory, much of the waste in the construction industry is related to ineffective planning and particularly to ineffective integration of all parties in the planning system. From the discussion above we can conclude that the integration of all parties in the planning will improve the planning and therefore increase coordination and information sharing. This in turn will facilitate the material delivery process and minimizes interferences between contractors. From the Lean perspective, subcontractors should provide a workable plan first to the general contractor and the general contractor will in turn combine them and develop the most workable plan for everyone.

The Last planner system can be used to assure a more reliable plan. With the Last planner system a look-ahead plan should be developed. From the literature, three to six weeks planning is recommended. A weekly work plan is used to decide what will be done for the upcoming week based on the plan developed for the three weeks ahead. The material delivery planning should be included in the Last planner system.

From our interviews, it seems that the crew leader or gang foreman can play the role of the Last planner because it knows better what can actually be done on the construction site as well as the amount of material needed to do the work on a weekly basis. Since the Last planner is a pull system it assures that all seven preconditions are in place before materials actually arrive inside the construction site.

However since variations occur quite often on the supplier side as stated by the respondents, contractors need to be prepared to deal with this situation. Srinivasan, Gilbert, and Srikanth (2004) suggest that the contractor should buffer with capacity, not inventory. The Last planner system has found a solution dealing with variation without the build-up of unnecessary inventory. It includes in the weekly work some activities that are not critical for the progress plan but have their seven preconditions ready. The working crew can therefore shift to these “workable backlogs” if delays occur in material delivery for instance in order to assure continuity of flow.

6.3 Rapid Learning Measurement

Through planning, learning is obtained to prevent repetitive failure (Kim, 2002). This section discusses Just-in-Time delivery and efficient site management.

6.3.1 Just-In-Time Delivery

By material delivery, the authors mean external deliveries as well as internal deliveries. Materials are not considered delivered until the workers have put their hands on it and start working. As we have seen in describing the eight wastes pertaining to the production process in the Lean philosophy, delivering more products than needed is considered as the waste of overproduction. The same situation can be said in delivering more material than needed for a specific period of time.

One of the rationales behind ordering material in bulk is the savings in transportation cost. From the literature the authors have learnt that in some situations the costs saved in transportation can be offset by the labour cost of double handling. In the project at IFI2,

Statsbygg bears the costs of this re-handling since contractors get paid for moving materials around to create free space to do the construction work.

To achieve Just-in-Time delivery at the construction site at Domus Medica, Lean theory suggests that the suppliers must know and monitor each step of work-in-process; this can be achieved by using information technology as pinpointed earlier. Contractors can give authority to their site management to communicate directly with their suppliers off site. This can be done through the Last planner system described in previous sections.

The deliveries should be properly sequenced to be consistent with the work plan. In addition, the contractor should make sure the delivery rate from the supplier is compatible with the installation rate of the workers on site. By using *Transport Kanban* to signal the need for more material, Just-in-Time delivery can be achieved.

Furthermore, it is important to stress that the sequence of delivery is not only the order in which the vehicles arrive on site, but also the order in which material are unloaded from the vehicle. This seems to be especially important for large elements and for elements that need to be installed in the same place but subsequently. The respondents indicate that if the elements are in the wrong order, this will require double handling. Since they will spend a lot of time moving the material, it means less time doing the actual work; as a result the project may incur delays. This seems even more important for a small construction site with limited storage capacity.

For the concrete delivery, besides the shelf life of the product, it is important to say that it is also the nature of the work which forces the contractor to apply Just-in-Time delivery.

The amount of material that needs to be ordered for a construction project is closely linked to the design of the building. A detailed design from the architect will help the contractor to determine the specific amount of material needed for the project. As for manufacturing, the total amount of material needed for the task is known upfront, only the time of delivery varies depending on the need of material for a specific period of time. Therefore the drawings need to be as accurate as possible to allow the contractors to plan with their suppliers the delivery of material Just-in-Time. From this perspective, drawings appear to

be of critical importance for delivery schedule to be right. In other words, reliable plans depend to some extent on reliable drawings.

However, at IFI2, the contractors complained about the drawings. They said the drawings were often not reliable; the final drawings were sometimes coming too late or coming with errors and therefore creating uncertainty in the amount of material as well as the type of material to order. For improvement, the architect for the Domus Medica project recommends that when the drawings are made available, a thorough review must be done with the working crew so that they can detect the defects earlier. The architect suggests that the comments should be returned four weeks prior to the start of the task which will allow them to have the necessary time to make the changes. To avoid this kind of inconveniences, Lean construction theory suggests an early involvement of the contractors in the design phase of the building. In addition, the contractors should develop routines to check the drawings. It is also crucial that the owner clearly documents its needs to assure accurate design from the architect.

6.3.2 Material and Site Management

An assessment of the construction site at IFI2 has shown that the site was quite well managed. Most of the respondents seemed quite satisfied with the site management, which the authors felt was good. However, some of the respondent did not agree on this. This led to the idea that the observations could have been biased since the project was heading toward its ends and the need for material storage had decreased. Furthermore, since only one visit to the site was conducted, the figures 20 to 24 do not represent strong evidences but rather anecdotal evidences.

To avoid the construction site to become cluttered and therefore hamper productivity and delay the project, continuous care should be taken. Written procedures to handle these issues are important. Lean theory suggests the 5S methodology to keep the construction site clean and tidy. For the construction at Domus Medica the theory suggests that every contractor working on the construction site dedicate a cleaning crew every day in its own area of work and assure their commitment to the task. The crew should be trained to the routines of 5S discussed in the literature. Safety is an important issue in construction

projects. By using the 5S procedures, the construction site will be free of clutter and this will in turn improve safety by reducing jobsite accidents in a constrained construction site.

Again, it is important that the material is being delivered directly at the area of work to avoid double handling, by doing so, a significant amount of labour cost and schedule time can be saved for the contractors and money for Statsbygg. There was a perceptible contradiction about this issue in the survey, a large percentage of respondents said material were delivered directly at the area of work and at the same time they agree that they spend a lot of time moving material around, This situation shows that the material delivered was in larger amount than necessary to do the work. With Just-in-Time, the right amount of material will come directly at the area of work to be installed immediately.

This will improve the working process because no extra material will obstruct movement in the area of work.

The good management of the construction site depends to a great extent on how the site layout is designed. At the project at IFI2, a big share of respondents believes the site layout was not an issue; they linked this situation to the size of the site. They said since the construction site was large enough, the site layout was not a prime concern but agree that the situation could be different in case of limited space.

For a small site with limited storage capacity, this issue needs to be given considerable attention. The site layout needs to be designed taking into consideration the logistical issues of the different contractors. Once again the early involvement of the different contractors in the design phase is crucial. However, it seems obvious that the site plan at the beginning of the project may not be suitable for the latter phases of the project. This will not be a concern if Just-in-Time delivery is applied efficiently since materials will come in the construction site Just-in-Time for installation. However, as the project goes, some materials will have to be stored inside the building; this amount of material should be kept to the minimum as shown by the pictures taken inside the building at IFI2.

6.4 Summary of Recommendations

Based on the findings of the study and the discussions above and taking into consideration that a continuous improvement will require more fundamental changes than the mere adoption of the recommendations mentioned above, a summary of some general recommendations are offered to support the construction of the building at Domus Medica as well as for future projects. These are listed below:

- Statsbygg should develop their own Lean manual and give high consideration during the bidding process to contractors and suppliers that practice Lean construction. The manual will include guidelines about how the material will be ordered, transported, receive, stored. It will support the construction plan with the smallest possible on-site inventory buffer. The use of Lean suppliers can help the achievement of Just-in-Time delivery and the use of Lean contractors can help the achievement of proper site management.
- As one of the contractors who uses a logistic manager, Statsbygg can hire a Lean manager or facilitator to support and sustain the Lean implementation in the management of material and also for the construction activity. The facilitator would have the responsibility to train the key players of the project in material handling tools (5S) and procedures and assists them in developing a pull schedule. At the beginning of the project, the lean manager can help the main contractor and the subcontractors to establish all aspects of Lean construction.
- Statsbygg should collectively work with the main contractor and other contractors to develop the project schedule as well as the project plan in order to be able to anticipate challenges that might occur during the construction period.
- The development of a simple information system which integrates the supplier, the contractors, the owner and the architect is recommended. This system will serve as a basis for information sharing and enable standardization of procedures. This information system could for instance provide real-time feedback regarding

material status on site to the supplier off site and will keep everyone aware of the actual situation on site.

6.5 Conclusion

In this thesis, the authors have studied the challenges related to material delivery management and site management for a construction site with limited storage capacity and located in an urban area. In order to answer the research question, a qualitative, interview based case study research design was used for this study. The findings derived from the data collected suggested room for improvement. During the data collection, an interesting finding was that the respondents knew where their problems lay but did not have a systematic tool to solve them. Based on the theory, and the findings derived from the data collected, the authors believed that the implementation of lean methods into the supply chain of the construction project at the future project at Domus Medica may improve efficiency and better project management. Furthermore, it is important to say that Lean construction is a comprehensive process that should involve every party in the construction project to achieve better performance.

Chapter 7 Limitations and Future Research

7.1 Limitations

In this study, a limitation emerges from the background of the case study. At the construction site at IFI 2, the size of the site as well as the storage capacity appears to be much bigger than the capacity of the future construction site at Domus Medica. The findings may therefore have been influenced by this situation. The narrow coverage and limited observations on the construction site at IFI2 may limit findings generalizations.

7.2 Future Research

This study has pursued to obtain knowledge concerning the problems related to supply chain management on a very limited scale. There is a lot of room for further explorations and research.

- One interest could be in the incentive structure to get suppliers and contractors involved with lean construction. Risks and rewards structure are of interest.
- Building in city is very challenging for many construction companies. A study with a broad sample of construction sites can be of interest.
- Studies related to the different working culture in the construction site can be of interest.
- A comparative study can be undertaken between a contractor implementing lean supply chain management and a contractor who do not. The same situation can apply for suppliers.
- How to transfer knowledge and lessons learned from one project to another taken into consideration the temporary nature of construction projects.
- The system of price-based selection used for supplier and contractor selection is commonly used in the construction industry. An investigation for other practices that could be applied can be of interest.

References

- Abdelhamid, T. S., and J. G. Everett. 2002. Physical demands of construction work: A source of workflow unreliability. Paper read at The 10th Conference of the International Group for Lean Construction (IGLC-10), August 6-8 2002, at Gramado, Brazil.
- Akintoye, Akintola, George McIntosh, and Eamon Fitzgerald. 2000. A survey of supply chain collaboration and management in the UK construction industry. *European Journal of Purchasing & Supply Management* 6 (3-4):159-168.
- Ala-Risku, T., and M. Kärkkäinen. 2004. Material delivery problems in construction projects: A possible solution. *International Journal of Production Economics* 104 (1):19-29.
- . 2006. Material delivery problems in construction projects: A possible solution. *International Journal of Production Economics* 104 (1):19-29.
- Alwi, S., K. Hampson, and S. Mohamed. 2002. Factor Influencing Contractors' Performance in Indonesia: A Study of Non Value-Adding Activities. Paper read at The International Conference on Advancement in Design, Construction, Construction Management and Maintenance of Building Structure., at Bali.
- APCC. 1997. Construct Australia: Building a better Construction industry in Australia. Deakin West: The Australian Procurement and Construction Council Inc.
- Arbulu, R., A. Koerckel, and F. Espana. 2005. Linking production-level workflow with materials supply. Paper read at IGLC -13, July 2005, at Sydney, Australia.
- Arbulu, R.J., and G.H. Ballard. 2004. Lean supply systems in construction. Paper read at The 12th Annual Conference of the International Group for Lean Construction (IGLC-12), at Copenhagen, Denmark.
- Arntzen, B. C., G. G. Brown, T. P Harrison, and L. L Trafton. 1995. Global supply chain management at Digital Equipment Corporation. *Interfaces* 25 (1):69-93.
- Azambuja, B. M. M, E. L. Isatto, S. T. Marder, and C. Formoso. 2006. The importance of Commitment Management to the Integration of Make to Order Supply Chains in Construction Industry. Paper read at IGLC-14, July 2006, at Santiago, Chile.
- Ballard, G. 2000. The Last Planner System of production control, School of Civil Engineering, Faculty of Engineering, The University of Birmingham.
- Ballard, G., and G. Howell. 1994. Implementing lean construction: Improving downstream performance. In *Proceedings of the second Annual Conference on Lean Construction at Catolica Universidad de Chile*. Santiago, Chile.
- . 1997. Improving the Reliability of Planning: Understanding the Last Planner Technique. In *White Paper*. California: Lean Construction Institute.
- Ballard, Glenn, and Greg Howell. 1998. What kind of production is construction? Paper read at Sixth Annual Conference of the International Group for Lean Construction (IGLC-6), at Guarujá, Brazil.
- Bennett, J., and D. Ferry. 1990. Specialist contractors: A review of issues raised by their new role in building. *Construction Management and Economics* 8:259-283.
- Bertelsen, S. 1993. Byggelogistik - materialestyring i byggeprocessen, bind I og II ("Construction Logistics I and II, Materials Management in the Construction process"). Copenhagen, Denmark: Boligministeriet, Bygge-og, Boligstyrelsen.
- Bertelsen, S., and L. Koskela. 2002. Managing the three aspects of production in construction. Paper read at 10th annual conference of International Group of Lean Construction (IGLC-10), at Gramado, Brazil.
- Bertelsen, Sven. 2007. *Håndbog i Trimmet Byggeri*: Foreningen Lean Construction–DK.

- Bertelsen, Sven, and Jørgen Nielsen. 1997. Just-In-Time Logistics in the Supply of Building Materials. In *1st International Conference on Construction Industry Development: Building the future Together*. Singapore.
- Bicheno, John. 2004. *The new lean toolbox : towards fast, flexible flow*. [3rd ed.] ed. Buckingham: PICSIE Books.
- Bless, Claire, and Craig Higson-Smith. 1995. *Fundamentals of social science research : an African perspective*. 2nd ed. / Claire Bless, Craig Higson-Smith. ed. Landsdowne, South Africa: Juta.
- Briscoe, Geoffrey, Andrew R. J. Dainty, and Sarah Millett. 2001. Construction supply chain partnerships: skills, knowledge and attitudinal requirements. *European Journal of Purchasing & Supply Management* 7 (4):243-255.
- Chen, F. 2003. Information Sharing and Supply Chain Coordination. In *Handbook in Operations Research and Management Sciences*. New York: Elsevier Science.
- Christopher, M. 1999. O marketing da logística. São Paulo, Brazil: Futura.
- Christopher, Martin. 2000. The agile supply chain; Competing in volatile markets. *Industrial Marketing Management* 29 (1):7.
- CII. 1988. Project Materials Management Primer. Austin, Texas: Construction Industry Institute.
- Conte, A. S. I. 2002. Lean construction: From theory to practice. Paper read at 10th annual conference of International Group of Lean Construction (IGLC-10), at Gramado, Brazil.
- Cooper, Martha C., and Lisa M. Ellram. 1993. Characteristics of Supply Chain Management and the Implications for Purchasing and Logistics Strategy. *The International Journal of Logistics Management* 4 (2):13 - 24.
- Construction Industry Board. *Lean construction* 1998. Available from <http://www.ciboard.org.uk/lean>.
- Cox, Andrew, and Paul Ireland. 2002. Managing construction supply chains: the common sense approach. *Engineering, Construction and Architectural Management* 9 (5-6):409 - 418.
- de Vos, A. S. 2002. *Research at Grassroots*. Pretoria: J.L Van Schaik publishers.
- Denning, P. J., and R. Medina-Mora. 1995. Completing the loops. *Interfaces* 25:42-57.
- Dimancecu, Dan, Peter Hines, and Nick Rich. 1997. *The lean enterprise : designing and managing strategic processes for customer-winning performance*. New York: American Management Association.
- DIST. 1999. Building for Growth: An action Agenda for the Building and Construction Industries. In *A report for government by the National Building and Construction Committee*. Canberra , Australia: The Department of Industry, Science and Tourism (DIST).
- Eisenhardt, K.M. 1989. Building theories from case study research. *Academy of Management Review* 14 (4):611-629.
- Fiallo, M. C., and V. H. Revelo. 2002. Applying the Last planner control system to a construction project: A case study in Quito, Ecuador. Paper read at 10th annual conference of International Group of Lean Construction (IGLC-10), at Gramado, Brazil.
- Forbes, H. L., and M. S. Ahmed. 2004. Adapting Lean Construction Method for Developing Nations. In *International Latin American and Caribbean Conference for Engineering and Technology (LACCEI'2004)*. Miami, Florida, USA.
- Formoso, C. T., E. L. Isatto, and E. H. Hirota. 1999. Method for Waste Control in the Building Industry. Paper read at Seventh Annual Conference of the International Group for Lean Construction (IGLC-7), at Berkeley, USA.

- Ghauri, Pervez N., and Kjell Grønhaug. 2005. *Research methods in business studies : a practical guide*. 3rd ed. Harlow : Financial Times Prentice Hall
- Grinnell, Richard M. 1988. *Social work research and evaluation*. 3rd ed. ed. Itasca, Ill.: F.E. Peacock Publishers.
- Groák, Steven. 1992. *The idea of building : thought and action in the design and production of buildings*. 1st ed. ed. London ; New York: E & FN Spon.
- Hampson, K. 1997. Construction Innovation in the Australian Context. Paper read at International Workshop on Innovation Systems and the Construction Industry, at Montreal, Canada.
- Hamzeh, R.F., Tommelein, D.I., Ballard,G., and M. P. Kaminsky. 2007. Logistics centers to support project-based production in the construction industry. In 15th Annual Conference of International Group of Lean Construction (IGLC-15). Michigan, USA.
- Haugen, Tore. 1998. The Building Process - challenges in a changing environment. Paper read at Nordic Seminar on Construction Economics and Organization, 12 - 13 April 1998, at Gothenburg, Sweden.
- Horman, M., and R. Kenley. 1996. The application of lean production to project management. Paper read at Proceedings of the Fourth Meeting of the International Group for Lean Construction (IGLC-4), at University of Birmingham, UK.
- Horman, Michael, Russell Kenley, and Victor Jennings. 1997. A lean approach to construction: an historical case study. Paper read at The 5th Annual Conference of the International Group for Lean Construction (IGLC-5), 16 - 17 July 1997, at Gold Coast, Australia.
- Howell, G. A. 1999. What is Lean Construction – 1999. Paper read at 7th annual conference of the International Group for Lean Construction (IGLC-7), at Berkeley, California.
- Illingworth, J., and K Thain. 1998. Material management is it worth it? In *The Chartered Institute of Building ASCOT*. 93, 1-5.
- Jarnbring, Joakim. 1994. *Byggarbetsplatsens materialflödeskostnader: en studie av struktur, storlek och påverkansmöjligheter*. Lund: Institutionen för teknisk logistik, Lunds tekniska högskola.
- Kaming, Peter F., Paul O. Olomolaiye, Gary D Holt, and Frank C. Harris. 1997. Factors Influencing Construction Time and Cost Overruns on High-Rise Projects in Indonesia. *Construction Management and Economics* 15 (1):83-94.
- Khalfan, M. M. A., P. McDermott, A. S. Oyegoke, M. T. Dickinson, X. Li, and D. Neilson. 2008. Application of Kanban in the UK Construction Industry by Public Sector Clients. Paper read at 16th Annual Conference of the International Group for Lean Construction (IGLC-16), at Manchester, England.
- Kim, Daeyoung. 2002. Exploratory study of lean construction: Assessment of lean implementation, The University of Texas at Austin.
- Kim, Daeyoung, and Hee-Sung Park. 2006. Innovative Construction Management Method: Assessment of Lean Construction Implementation. *Journal of Civil Engineering* 10 (6):381-388.
- Kocakülâh, Mehmet C., Jason F. Brown, and Joshua W. Thomson. 2008. Lean manufacturing principles and their application. *Cost Management* 22 (3):16-27.
- Koskela, Lauri. 1992. *Application of the new production philosophy to construction, Technical report (Stanford University. Centre for Integrated Facility Engineering)*. [Stanford?]: Stanford University.
- . 2000. An Exploration towards a Production Theory and its Application to Construction, Helsinki University of Technology, Espoo, Finland.

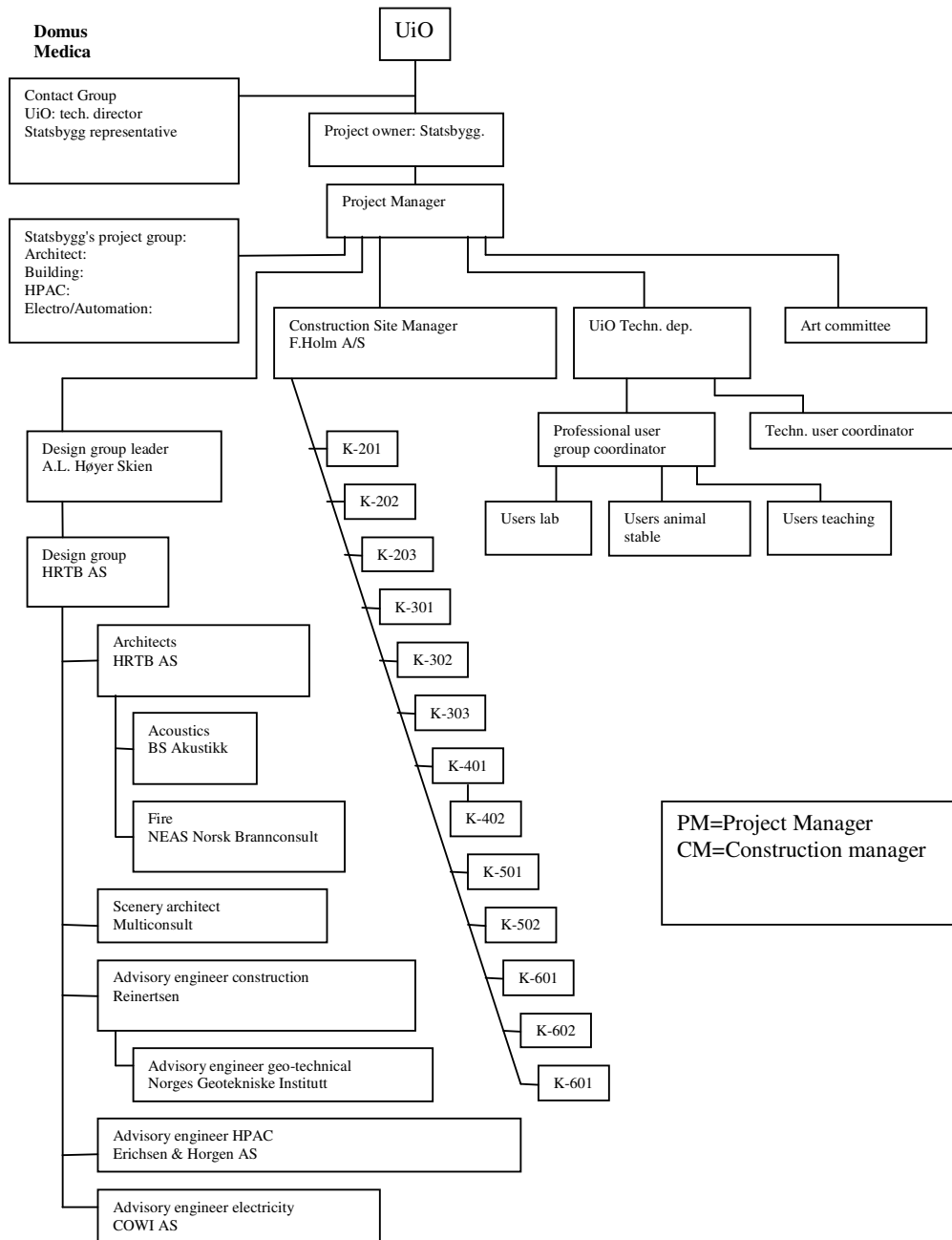
- Lamming, R. 1996. Squaring lean supply with supply chain management. *International Journal of Operations & Production Management* 16 (2):183-&.
- Latham, Michael Sir. 1994. *Constructing the team: final report*. [London]: H.M.S.O.
- Lau, JSK, GQ Huang, and KL Mak. 2004. Impact of information sharing on inventory replenishment in divergent supply chains. *International Journal of Production Research* 42 (5):919-941.
- LCI. Lean Construction Institute (LCI) 2002. Available from <http://www.leanconstruction.org/about.htm> (Accessed, 16 May 2009)
- LCI. Lean Construction Institute (LCI) 2002B. Available from <http://www.leanconstruction.org/>.
- Leedy, Paul D. 1993. *Practical research : planning and design*. 5th ed. ed. New York: Macmillan ; London : Maxwell Macmillan International.
- Leedy, Paul D., and Jeanne Ellis Ormrod. 2001. *Practical research : planning and design*. 7th ed. ed. Upper Saddle River, N.J. ; [Great Britain]: Merrill Prentice Hall.
- Liker, Jeffrey K. 2004. *The Toyota way : 14 management principles from the world's greatest manufacturer*. New York ; London: McGraw-Hill.
- Liker, Jeffrey K., and David Meier. 2006. *The Toyota way fieldbook: a practical guide for implementing Toyota's 4Ps*. London: McGraw-Hill.
- Love, P. E. D. 2000. Construction supply chains. *European Journal of Purchasing and Supply Management* 6 (3-4):145-7.
- Low, Sui Pheng, and Yue Meng Chan. 1997. *Managing productivity in construction : JIT operations and measurements*. Aldershot: Ashgate.
- Luhtala, M., E. Kilpinen, and P. Anttila. 1994. LOGI: Managing Make-To-Order Supply Chains. Espoo, Finland: Helsinki University of Technology.
- Mossman, A. 2007. Lean Logistics: Helping to create value by bringing people, information, plant, equipment and materials together at the workface. Paper read at IGLC-15, at Michigan, USA.
- Mota, Bruno Pontes, Ricardo Rôla Mota, and Thaís da C. L. Alves. 2008. Implementing Lean Construction Concepts in a Residential Project. Paper read at 16th Annual Conference of the International Group for Lean Construction (IGLC-16), at Manchester, England.
- Nel, Erika. 2004. Father-child relationship-dynamics in adolescent chemical dependency, Faculty of Arts, University of Johannesburg.
- Neuman, W. Lawrence. 1997. *Social research methods : qualitative and quantitative approaches*. 3rd ed. ed. Boston, [Mass.] ; London: Allyn and Bacon.
- O'Brien, W. J. 1999. Construction Supply-Chain Management: A Vision for Advanced Coordination, Costing, and Control. Stanford, California: NSF Berkeley-Stanford Construction Research Workshop.
- Ohno, Taiichi. 1988. *Toyota production system : beyond large-scale production*. New York: Productivity Press.
- Ortiz, Gonzalo. 2000. Esquema de la Historia Económica del Ecuador en el Siglo XX. *Revista Gestión* 67 (1):45-61.
- Patton, Michael Quinn. 1990. *Qualitative evaluation and research methods*. 2nd ed. ed. Newbury Park, Calif.: Sage Publications.
- Picchi, F. A. 2002. System view of lean construction application opportunities. Paper read at 10th annual conference of International Group of Lean Construction (IGLC-10), at Gramado, Brazil.
- Pinch, Lauren. 2005. Lean Construction: Eliminating the waste. *Construction Executive*, 24-37.

- Pinho, T., J. Telhada, and S. M. Carvalho. 2007. Definition of supply chain management model in construction- case study. In *Proceedings IGLC-15, July 2007*. Michigan, USA.
- PPDT. 2002. *Kanban for the shopfloor*. Portland: Productivity Press Development Team (PPDT).
- Shingō, Shigeo. 1988. *Non-stock production : the Shingo system for continuous improvement*. Cambridge, Mass.: Productivity Press.
- Soares, A. C., M. M. S. Bernades, and C. T. Formoso. 2002. Improving the production planning and control system in a building company: Contributions after stabilization. Paper read at 10th annual conference of International Group of Lean Construction (IGLC-10), at Gramado, Brazil.
- Srinivasan, Mandyam M., Kenneth C. Gilbert, and Mokshagundam L. Srikanth. 2004. *Streamlined: 14 principles for building & managing the lean supply chain*. Mason, Ohio: Thomson.
- SSB. Statistisk Sentralbyrå. (SSB) 2008A. Available from http://www.ssb.no/english/subjects/10/09/stbygganl_en/tab-2008-10-29-01-en.html (Accessed, April 2009)
- SSB. Statistisk Sentralbyrå. (SSB) 2008B. Available from <http://www.ssb.no/stbygganl/tab-2008-10-29-01.html> (Accessed, April 2009)
- SSB. Statistisk Sentralbyrå. (SSB) 2009A. Available from <http://www.ssb.no/stbygganl/> (Accessed, April 2009)
- SSB. Statistisk Sentralbyrå. (SSB) 2009B. Available from http://www.ssb.no/english/subjects/09/01/regnskap_en/, (Accessed, April 2009)
- Stake, R.E. 2005. Qualitative case studies. In *The SAGE handbook of qualitative research*, edited by N. K. Denzin and Y. S. Lincoln. Thousand Oaks ; London: Sage Publications.
- Statsbygg. 2008. Annual Report Statsbygg 2007 [Årsmelding for Statsbygg 2007]. edited by H. N. Rygh. OSlo.
- . 2008. Letter introducing the research objective for the thesis "Logistic master thesis". Oslo.
- . 2009. Annual Report Statsbygg 2008 [Årsmelding for Statsbygg 2008]. edited by P. Weiby. Oslo.
- Sterzi, M. P, L. Isatto, and C. Formoso. 2007. Integrating strategic project supply chain members in Production planning and control. Paper read at IGLC-15, at Michigan, USA.
- Stukhart, G., and L. Bell. 1985. *Attributes of Material Management*. Austin, Texas: Construction Industry Institute.
- Thomas, H. R., M. D. Horman, U. de Souza, and I. Zavřski. 2002. Benchmarking of labor-intensive construction activities: Lean construction and fundamental principles of workforce management. Rotterdam, Netherlands: International Council for Research and Innovation in Building and Construction.
- Thomas, H. R., V. E Sanvido, and S. R Sanders. 1989. Impact of Material Management on Productivity- A Case Study. *Construction Engineering and Management* 3:370-384.
- Thomas, HR, DR Riley, and JI Messner. 2005. Fundamental principles of site material management. *Journal of Construction Engineering and Management-ASCE* 131 (7):808-815.
- Townsend, M., M. Reynolds, and N. Cole. 1999. Application of the 'Last Planner' Technique. Management of Construction Projects, No. 1. Croner Publications Ltd.

- Vrijhoef, R., and L. Koskela. 2000. The four roles of supply chain management in construction. *European Journal of Purchasing & Supply Management* 6 (3-4):169-178.
- Vrijhoef, R., L. Koskela, and H. Voordijk. 2003. Understanding construction supply chains: a multiple theoretical approach to inter-organizational relationships in construction. Paper read at 11th International Group of Lean Construction Annual Conference (IGLC-11), at Blacksburg, USA.
- Wegelius-Lethonen, Tutu, Samuli Pakkala, Hannu Nyman, Hannu Vuolio, and Kari Tanskanen. 1996. *Guidelines for logistics of construction*. Helsinki: Rakennusteollisuuden keskuisto.
- Wincel, J. 2004. *Lean supply chain management: a handbook for strategic procurement*. Vol. 15. New York: Productivity Press.
- Winchester, H. P. M. 2000. Qualitative research and its place in human geography. *Qualitative Research Methods in Human Geography*. In *Oxford University Press*, edited by I. Hay. Oxford.
- Winograd, T., and F. Flores. 1986. *Understanding computers and cognition: A new foundation for design*. Boston: Addison -Wesley.
- Womack, James P., Daniel T. Jones and Daniel Roos 1990. *The machine that changed the world*. New York : Rawson Associates
- Womack, James P., and Daniel T. Jones. 2003. *Lean thinking : banish waste and create wealth in your corporation*. Rev. and updated [ed.] ed. New York: Free Press.
- Yin, Robert K. 1994. *Case study research : design and methods*. 2nd ed. ed, *Applied social research methods series*. Thousand Oaks, Calif. ; London: Sage.
- Zimmer, Eric R. 2006. Improving Lean Supply Chain Management in the Construction Industry, Department of Civil and Environment Engineering College of Engineering, University of Cincinnati.
- Zimmer, Eric, Ossama Salem, Ashraf Genaidy, and Richard Shell. 2008. Case study: Lean supply chain management in the construction projects. Paper read at 16th Annual Conference of the Internal Group for Lean Construction (IGLC-16), at Manchester, United Kingdom.

Appendix

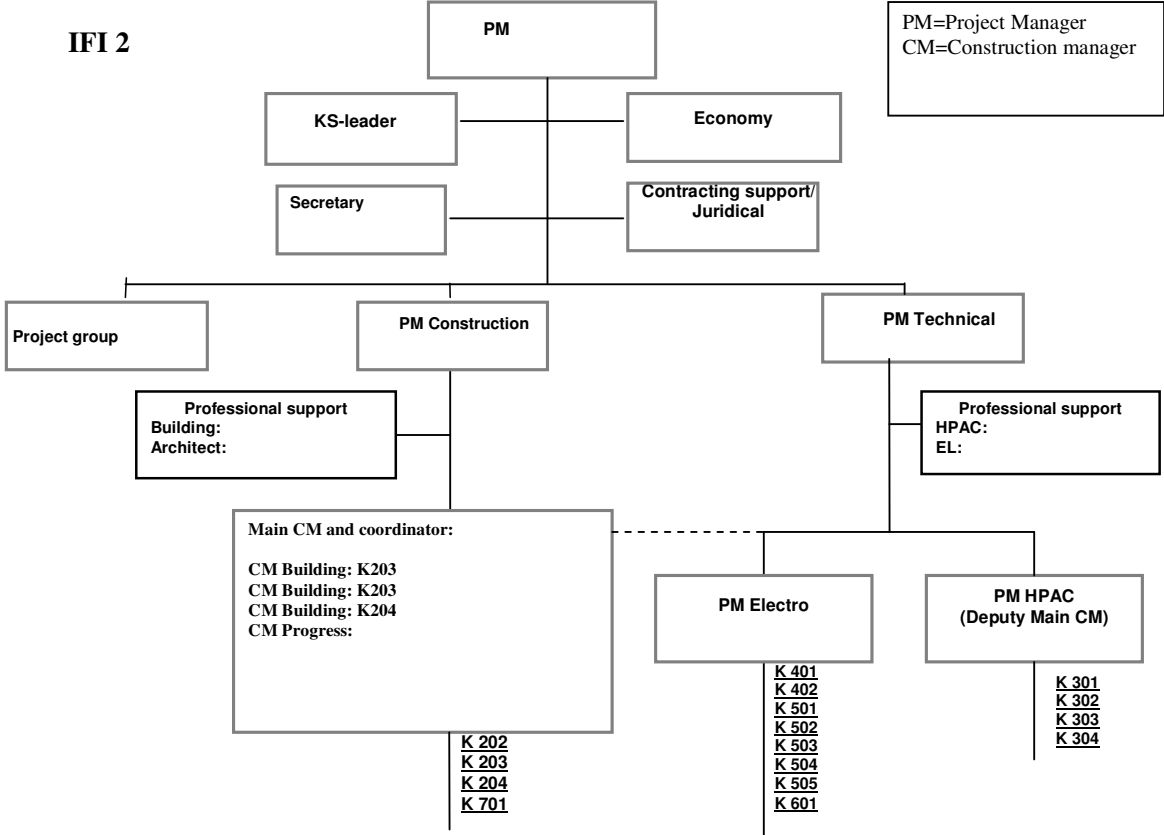
Appendix 1 Org. chart D-Medica



(Organisational chart from Statsbygg Domus Medica project)

The K-XXX in the figure represents the contracts in Statsbygg tendering documents. Instead of using a total contract with one contractor, Statsbygg have split up the contracts according to trade skills, like electro, plumbing, foundation, outdoor landscape etc.

Appendix 2 Org. chart IFI-2



(Organisational chart Statsbygg IFI2 project)

Appendix 3 Questionnaire

Below follows an English translation of the questionnaire:

Survey for Statsbygg / Master Thesis

Statsbygg represented with the project D-Medica wants to investigate and identify the improvement opportunities relating to the logistics in the construction industry. In this connection, two Master's students from the University College in Molde are doing a Master's degree thesis. The task's aim is to find possible solutions to deliver building materials Just-in-Time as well as to find effective methods to control the construction site.

The purpose of the survey is to map the typical challenges concerning the above goals. The responses from the survey will be treated statistically, and individual responses will not be identifiable after processing. The survey is not anonymous then the students - where necessary - would like to be able to come up with questions. We kindly ask you to spend a few minutes to answer the questionnaire and thank you in advance for your cooperation.

Best regards
Hans Thomas Holm
Project Manager, D-Medica
Statsbygg

Guidelines for filling in the form

The company / team are understood as that part of your organisation that are naturally gathered in one place, like a city.

For questions regarding building materials, please give consistent answers for the same building material supplier and answer for the building material that is the most important related to logistics for your company /department.

Since the construction has not yet begun at D-Medica, we are sending this survey to some IFI2 contractors and suppliers. This means some questions are specific to the IFI2 project, others are more general. If your company / team has experience from several projects for Statsbygg, answer the general questions primarily related to that knowledge, else answer the general questions with your background from the construction industry in Norway.

If there are questions regarding the survey, please contact Master student Bernt.H.Follestad@hiMolde.no, telephone 95238638

1) Our Company's name: *

2) My company is a: *

- 2. The options are:**
- Select answer -
 - Supplier
 - Contractor
 - Both supplier and contractor
 - Building owner
 - Construction site manager
 - Other

3) If other, please specify:

4) My role: *

- 4. The options are:**
- Architect
 - Managing director
 - Project leader
 - Construction site leader
 - Purchasing manager
 - Foreman
 - Gang foreman
 - Office worker

Other, please specify:

5) Are your company involved in the IFI2-project? *

Yes No

This box is shown in preview only..
The following criteria must be fulfilled for this question to be shown:
Are your company/department involved in the IFI2-project? - Yes

Tend
Strongly to Tend to Strongly Don't
agree agree Neither disagree disagree know

The IFI2-project is of (relative) large importance for our company/department

This box is shown in preview only..
The following criteria must be fulfilled for this question to be shown:
My company is a: - Contractor
or
My company is a: - Other
or
My company is a: - Construction site manager
or
My company is a: - Both supplier and contractor

7) About how many construction projects have your firm been involved in with Statsbygg over the past 5 years?

This box is shown in preview only..
The following criteria must be fulfilled for this question to be shown:
My company is a: - Contractor
or
My company is a: - Both supplier and contractor
and
Are your company/department involved in the IFI2-project? - Yes

8) How will you qualify your relations with other sub-entrepreneurs for IFI2? *

Good Neutral Bad Don't know

This box is shown in preview only..
The following criteria must be fulfilled for this question to be shown:
My company is a: - Both supplier and contractor
or
My company is a: - Contractor

9) How will you qualify your relations with other sub-entrepreneurs generally in the construction industry? *

Good Neutral Bad Don't know



This box is shown in preview only..
The following criteria must be fulfilled for this question to be shown:
My company is a: - Contractor
or
My company is a: - Both supplier and contractor
and
How will you qualify your relations with other sub-entrepreneurs for IFI2? - Bad
and
Are your company/department involved in the IFI2-project? - Yes

10) What will be the reasons for these bad relationships with other contractors? *

- Differences in culture
- Lack of commitment
- Bad communication
- Poor coordination
- Other
- Don't know

This box is shown in preview only..
The following criteria must be fulfilled for this question to be shown:
My company is a: - Contractor
or
My company is a: - Both supplier and contractor
and
How will you qualify your relations with other sub-entrepreneurs for IFI2? - Bad

11) If other, specify:

This box is shown in preview only..
The following criteria must be fulfilled for this question to be shown:
My company is a: - Contractor
or
My company is a: - Both supplier and contractor
and
How will you qualify your relations with other sub-entrepreneurs for IFI2? - Bad

12) What will you suggest for improvement

This box is shown in preview only..
The following criteria must be fulfilled for this question to be shown:
My company is a: - Contractor
or
My company is a: - Both supplier and contractor
or
My company is a: - Building owner

or
 My company is a: - Construction site manager
or
 My company is a: - Other
and
 Are your company/department involved in the IFI2-project? - Yes

13) How often do you meet to discuss responsibilities or plans (with other sub-contractors)? *

- Each day
- Each week
- Every second week
- As problems arise (when necessary)
- Other, specify how often:
- Don't know

This box is shown in preview only..
The following criteria must be fulfilled for this question to be shown:
 My company is a: - Contractor
or
 My company is a: - Both supplier and contractor
or
 My company is a: - Other
or
 My company is a: - Construction site manager
or
 My company is a: - Building owner

14) How often do you meet to discuss responsibilities or plans (with other sub-contractors) in a general construction projects? *

- Each day
- Each week
- Every second week
- As problems arise (when necessary)
- Other, specify how often:
- Don't know

This box is shown in preview only..
The following criteria must be fulfilled for this question to be shown:
 My company is a: - Contractor
or
 My company is a: - Both supplier and contractor
or
 My company is a: - Other
or
 My company is a: - Construction site manager
or
 My company is a: - Building owner

15) For the following statements please indicate how much you agree for construction projects in general *

		Tend		Tend to		Strongly	
	Strongly	to	Neither	disagree	Strongly	Don't	
	agree	agree	Neither	disagree	disagree	know	
Responsibilities are clearly defined between the actors in the meetings	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
Do you coordinate actions and plans through	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	

meetings with other actors

Coordination with other actors is very time consuming



This box is shown in preview only..
The following criteria must be fulfilled for this question to be shown:

My company is a: - Contractor
or
My company is a: - Both supplier and contractor
or
My company is a: - Other
or
My company is a: - Construction site manager
or
My company is a: - Building owner

16) Who is present at the meetings (including from other actors) *

- Office workers
- Skilled workers
- Advisory engineers
- Gang foremen
- Purchasers
- Project manager
- Architects
- Foremen
- Other, specify whom:
- Don't know



This box is shown in preview only..
The following criteria must be fulfilled for this question to be shown:

My company is a: - Contractor
or
My company is a: - Both supplier and contractor
or
My company is a: - Building owner
or
My company is a: - Construction site manager
or
My company is a: - Other
and
Coordination with other actors is very time consuming - Strongly agree
or
Coordination with other actors is very time consuming - Tend to agree
and
Are your company/department involved in the IFI2-project? - Yes

17) Why does communication with other actors in the IFI2-project take a lot of time? *

- Meetings take too much time due to being unorganized / unclear agenda
- Meetings take too much time due to too much unimportant discussions
- Poor commitment to the project
- Other, specify:
- Don't know

This box is shown in preview only..
 The following criteria must be fulfilled for this question to be shown:
 My company is a: - Contractor
 or
 My company is a: - Both supplier and contractor
 or
 My company is a: - Building owner
 or
 My company is a: - Construction site manager
 or
 My company is a: - Other
 and
 Coordination with other actors is very time consuming - Strongly agree
 or
 Coordination with other actors is very time consuming - Tend to agree

18) Why does communication with other actors in general take a lot of time in construction projects in general? *

- Meetings take too much time due to being unorganized / unclear agenda
- Meetings take too much time due to too much unimportant discussions
- Poor commitment to the project
- Other, specify:
- Don't know

This box is shown in preview only..
 The following criteria must be fulfilled for this question to be shown:
 My company is a: - Contractor
 or
 My company is a: - Both supplier and contractor
 or
 My company is a: - Building owner
 or
 My company is a: - Construction site manager
 or
 My company is a: - Other
 and
 Coordination with other actors is very time consuming - Strongly agree
 or
 Coordination with other actors is very time consuming - Tend to agree

19) What would you suggest for improving this:

This box is shown in preview only..
 The following criteria must be fulfilled for this question to be shown:
 My company is a: - Contractor
 or
 My company is a: - Both supplier and contractor
 and
 Are your company/department involved in the IFI2-project? - Yes

20) For the following statements please indicate how much you agree for the IFI2-project *

	Strongly agree	Tend to agree	Neither	Tend to disagree	Strongly disagree	Don't know
The material delivery management of the other sub-contractors greatly affects ours	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
My organisation encounter problems with delivery of materials	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

This box is shown in preview only..
 The following criteria must be fulfilled for this question to be shown:
 My company is a: - Both supplier and contractor
 or
 My company is a: - Contractor

21) For the following statements please indicate how much you agree for construction projects in general *

	Strongly agree	Tend to agree	Neither	Tend to disagree	Strongly disagree	Don't know
The material delivery management of the other sub-contractors greatly affects ours	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
My organisation encounter problems with delivery of materials	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>



This box is shown in preview only..
 The following criteria must be fulfilled for this question to be shown:
 My company is a: - Contractor
 or
 My company is a: - Both supplier and contractor
 and
 My organisation encounter problems with delivery of materials - Strongly agree
 or
 My organisation encounter problems with delivery of materials - Tend to agree
 and
 Are your company/department involved in the IFI2-project? - Yes

22) Why is it problems related to the delivery of materials? *

	Insufficient/inadequate deliveries	Late deliveries	Bad sequence of deliveries	Too early deliveries	Inefficient planning and scheduling of deliveries (slow decision making)	Poor quality of materials	Don't know	Other:
For IFI2	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="text"/>
Generally for construction projects	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="text"/>

This box is shown in preview only..
 The following criteria must be fulfilled for this question to be shown:
 My company is a: - Contractor
 or
 My company is a: - Both supplier and contractor
 and
 My organisation encounter problems with delivery of materials - Strongly agree
 or
 My organisation encounter problems with delivery of materials - Tend to agree

23) Which actions are usually taken to avoid problems with material deliveries?




This box is shown in preview only..
The following criteria must be fulfilled for this question to be shown:
My company is a: - Contractor
or
My company is a: - Both supplier and contractor
and
My organisation encounter problems with delivery of materials - Strongly agree
or
My organisation encounter problems with delivery of materials - Tend to agree
and
Are your company/department involved in the IFI2-project? - Yes

24) We are frequently working together with the subcontractors to solve problems arising in the delivery of materials *

	Strongly agree	Tend to agree	Neither	Tend to disagree	Strongly disagree	Don't know
For IFI2	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Generally for construction projects	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

This box is shown in preview only..
The following criteria must be fulfilled for this question to be shown:
My company is a: - Contractor
or
My company is a: - Both supplier and contractor
or
My company is a: - Other
or
My company is a: - Construction site manager
or
My company is a: - Building owner

25) How do you coordinate and plan the sequence of deliveries with other contractors for your daily and weekly operations? *

- Coordination is a part of the agreed progress plan
 - Weekly meetings
 - Agreed sequence plan for deliveries
 - "First man to the mill" scheduling plan
 - Don't coordinate deliveries, there is no need
 - Others, specify:
 - Don't know
- 

This box is shown in preview only..
The following criteria must be fulfilled for this question to be shown:
Are your company/department involved in the IFI2-project? - Yes

26) For the following statements please indicate how much you agree for the IFI2-project *

Strongly Tend Neither Tend to Strongly Don't

	agree	to agree	disagree	disagree	know
Our organisations objectives/views are taken into account in the common progress plan	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Actors keep their promises according to the current plan	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

This box is shown in preview only..
 The following criteria must be fulfilled for this question to be shown:
 Are your company/department involved in the IFI2-project? - Yes

27) For the following statements please indicate how much you agree for construction projects in general *

	Strongly agree	Tend to agree	Neither	Tend to disagree	Strongly disagree	Don't know
Our organisations objectives/views are taken into account in the common progress plan	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Actors keep their promises according to the current plan	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

This box is shown in preview only..
 The following criteria must be fulfilled for this question to be shown:
 My company is a: - Contractor
 or
 My company is a: - Both supplier and contractor
 or
 My company is a: - Other
 or
 My company is a: - Construction site manager
 or
 My company is a: - Building owner

28) The most important ways to share information with other contractors are as follows *

	Strongly agree	Tend to agree	Neither	Tend to disagree	Strongly disagree	Don't know
Intranet (web-portal, common file shares, databases etc)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
E-mail	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Short Message Service, text messages via GSM mobile phones	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Telephone calls	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Walk around looking (at the construction site to see progress / what needs to be done)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Talk with people more randomly (during lunch, breaks etc)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
(Formal) meetings	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

This box is shown in preview only..
The following criteria must be fulfilled for this question to be shown:
 My company is a: - Contractor
or
 My company is a: - Both supplier and contractor
or
 My company is a: - Other
or
 My company is a: - Construction site manager
or
 My company is a: - Building owner

29) Other important ways to share information:



This box is shown in preview only..
The following criteria must be fulfilled for this question to be shown:
 My company is a: - Supplier
or
 My company is a: - Both supplier and contractor
or
 My company is a: - Contractor

30) For the following statements please indicate how much you agree for construction projects in general *

	Tend		Tend to		Strongly		Don't
	Strongly	to	Neither	disagree	disagree	disagree	know
	agree	agree	Neither	disagree	disagree	disagree	know
Information is accurately transmitted among contractors and suppliers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>



This box is shown in preview only..
The following criteria must be fulfilled for this question to be shown:
 My company is a: - Supplier
or
 My company is a: - Contractor
or
 My company is a: - Both supplier and contractor
and
 Information is accurately transmitted among contractors and suppliers- Tend to disagree
or
 Information is accurately transmitted among contractors and suppliers- Strongly disagree

31) Why do you think information is not transmitted correctly between contractors and suppliers?

This box is shown in preview only..
The following criteria must be fulfilled for this question to be shown:
 Are your company/department involved in the IFI2-project? - Yes

32) For the following statements please indicate how much you agree for the IFI2-project *

	Tend		Tend to		Strongly		Don't
	Strongly	to	Neither	disagree	disagree	disagree	know
	agree	agree	Neither	disagree	disagree	disagree	know

Do you have a common integrated information system with the other major parties in the project?



This box is shown in preview only..
The following criteria must be fulfilled for this question to be shown:
 Do you have a common integrated information system with the other major parties in the project? - Strongly agree
or
 Do you have a common integrated information system with the other major parties in the project? - Tend to agree
and
 Are your company/department involved in the IFI2-project? - Yes

33) For the following statements please indicate how much you agree for the IFI2-project *

Tend
 Strongly to Tend to Strongly Don't
 agree agree Neither disagree disagree know

Our organisation heavily relies on this common integrated information system for sharing information with other organisations in this project

34) How do you keep the suppliers informed about changes in product specifications, sequence of orders, and time of delivery? *

- Telephone calls
- Suppliers Web-page
- Integrated information systems
- E-mail
- Visit suppliers
- Other, please specify:
- Don't know

This box is shown in preview only..
The following criteria must be fulfilled for this question to be shown:
 My company is a: - Supplier
or
 My company is a: - Both supplier and contractor
or
 My company is a: - Contractor

35) How do you replenish materials *

Tend
 Strongly to Tend to Strongly Don't
 agree agree Neither disagree disagree know

Based on inventory levels

Just exactly as the materials are needed

This box is shown in preview only..
 The following criteria must be fulfilled for this question to be shown:
 My company is a: - Supplier
 or
 My company is a: - Both supplier and contractor
 or
 My company is a: - Contractor

36) Why do you do it this way?

This box is shown in preview only..
 The following criteria must be fulfilled for this question to be shown:
 My company is a: - Contractor
 or
 My company is a: - Both supplier and contractor
 and
 Are your company/department involved in the IFI2-project? - Yes

37) To avoid the risk of not having the material at hand when needed, project materials are ordered with delivery dates well in advance of needed times. *

	Strongly agree	Tend to agree	Neither	Tend to disagree	Strongly disagree	Don't know
For IFI2	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Generally for construction projects	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

This box is shown in preview only..
 The following criteria must be fulfilled for this question to be shown:
 My company is a: - Contractor
 or
 My company is a: - Both supplier and contractor
 or
 My company is a: - Building owner
 or
 My company is a: - Construction site manager
 or
 My company is a: - Other
 and
 Are your company/department involved in the IFI2-project? - Yes

38) For the following statements please indicate how much you agree for the IFI2-project *

	Strongly agree	Tend to agree	Neither	Tend to disagree	Strongly disagree	Don't know
We keep our suppliers informed about the progress of the work so that they can be prepared for future orders	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Too much material are stored on site	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

This box is shown in preview only..
 The following criteria must be fulfilled for this question to be shown:
 My company is a: - Contractor
 or

My company is a: - Both supplier and contractor
or
My company is a: - Other
or
My company is a: - Construction site manager
or
My company is a: - Building owner

39) For the following statements please indicate how much you agree for construction projects in general *

	Strongly agree	Tend to agree	Neither	Tend to disagree	Strongly disagree	Don't know
Too much material are stored on site	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>



This box is shown in preview only..
The following criteria must be fulfilled for this question to be shown:
My company is a: - Contractor
or
My company is a: - Both supplier and contractor
or
My company is a: - Building owner
or
My company is a: - Construction site manager
or
My company is a: - Other
and
Too much material are stored on site - Strongly agree
or
Too much material are stored on site - Tend to agree
and
Are your company/department involved in the IFI2-project? - Yes

40) Why is it stored so much material on site?

This box is shown in preview only..
The following criteria must be fulfilled for this question to be shown:
My company is a: - Contractor
or
My company is a: - Both supplier and contractor
or
My company is a: - Building owner
or
My company is a: - Construction site manager
or
My company is a: - Other
and
Are your company/department involved in the IFI2-project? - No
and
Too much material are stored on site - Strongly agree
or
Too much material are stored on site - Tend to agree

41) Why is it stored so much material?

This box is shown in preview only..
The following criteria must be fulfilled for this question to be shown:
My company is a: - Both supplier and contractor
or
My company is a: - Contractor

42) What do you do in case of lack of materials *

- Move people to other construction sites
- Wait, take a break
- Send people home
- Prepare for other work
- Tidy and clean the site/barracks
- Other, please specify:
- Don't know

This box is shown in preview only..
The following criteria must be fulfilled for this question to be shown:
My company is a: - Construction site manager
or
My company is a: - Both supplier and contractor
or
My company is a: - Contractor
and
My role: - Construction site manager
or
My role: - Purchasing manager
or
My role: - Foreman
or
My role: - Project manager
or
My role: - Skilled worker
or
My role: - Architect
or
My role: - Managing director

43) Who is responsible for taking decisions regarding orders/purchases (when and how much to order)? *

- Managing director
- Project manager
- Construction site leader
- Foreman
- Gang foreman
- Office worker
- Skilled worker
- Purchasing person/department
- Logistical responsible person
- Principal firm
- Other, whom:
- Don't know

This box is shown in preview only..
 The following criteria must be fulfilled for this question to be shown:
 My company is a: - Contractor
 or
 My company is a: - Both supplier and contractor
 or
 My company is a: - Construction site manager
 or
 My company is a: - Other
 and
 Are your company/department involved in the IFI2-project? - Yes

44) For the following statements please indicate how much you agree for the IFI2-project *

	Strongly agree	Tend to agree	Neither	Tend to disagree	Strongly disagree	Don't know
The logistical viewpoint of your organisation is taken into account in the design phase of the staging area and the design of the building	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The site layout is important for good delivery and handling of material	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The drawings that are related to planning and delivery of material being completed on time	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Materials are unloaded at the site directly where they are needed	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The staging areas has a layout that easily facilitates keeping the site tidy	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Materials are available close to the area of work (same floor/building)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
We have procedures for the handling of materials, apart from source segregation procedures	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>



This box is shown in preview only..
 The following criteria must be fulfilled for this question to be shown:
 My company is a: - Contractor
 or
 My company is a: - Both supplier and contractor
 or
 My company is a: - Construction site manager
 or
 My company is a: - Other
 and
 We have procedures for the handling of materials, apart from source segregation procedures - Strongly agree
 or
 We have procedures for the handling of materials, apart from source segregation procedures - Tend to agree
 and
 Are your company/department involved in the IFI2-project? - Yes

45) For the following statements please indicate how much you agree for the IFI2-project *

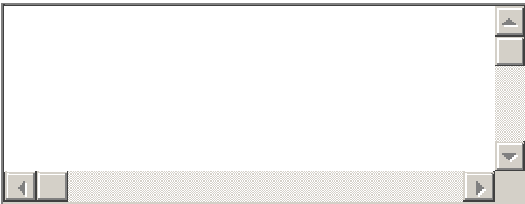
	Fully	Mostly	To some extent	Never	Don't know
Are these procedures followed?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The procedures are communicated and reviewed before	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

the start of each project



This box is shown in preview only..
The following criteria must be fulfilled for this question to be shown:
 My company is a: - Contractor
or
 My company is a: - Both supplier and contractor
or
 My company is a: - Construction site manager
or
 My company is a: - Other
and
 We have procedures for the handling of materials, apart from source segregation procedures - Strongly agree
or
 We have procedures for the handling of materials, apart from source segregation procedures - Tend to agree
and
 Are these procedures followed? - Mostly
or
 Are these procedures followed? - To some extent
or
 Are these procedures followed? - Never
and
 Are your company/department involved in the IFI2-project? - Yes

46) Why are not the procedures regarding material handling always followed?



This box is shown in preview only..
The following criteria must be fulfilled for this question to be shown:
 My company is a: - Both supplier and contractor
or
 My company is a: - Contractor

47) For the following statements please indicate how much you agree for construction projects in general *

	Strongly agree	Tend to agree	Neither	Tend to disagree	Strongly disagree	Don't know
Our organisation is losing materials due bad handling	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The site is free of excessive materials and debris	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Roads for vehicles are clear and maintained	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Materials often need to be moved around to make space for new incoming material or to give access to other actors?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

This box is shown in preview only..
The following criteria must be fulfilled for this question to be shown:
 My company is a:- Supplier
or
 My company is a - Contractor
or
 My company is a - Both supplier and contractor

My company is a: - Construction site manager
or
and
Are your company/department involved in the IFI2-project? - Yes

48) What will be/were the most challenging task for you in the IFI2- project in terms of material delivery management?

49) What would you suggest for overall improvements:

This box is shown in preview only..
The following criteria must be fulfilled for this question to be shown:
Are your company involved in the IFI2-project?- Yes

50) What is different from the IFI2-project compared to the “general Statsbygg project”?

51) Other comments: