Logistics and Skanska Xchange
Supply chain improvements in the construction industry

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Master of Science Thesis
Stockholm, Sweden 2011
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Commissioner: Skanska SXC

Timeframe: August 2010 – January 2011

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Abstract

This master thesis has aimed to answer the question whether logistic solutions for made to order materials should be included in the Skanska Xchange concept. Skanska Xchange is a project that gathers knowledge, methods and expertise from the Nordic countries with the purpose of providing standardized construction methods.

We believe the answer to the thesis’ question is yes. However, Skanska Xchange should initially not invest in developing any new solutions. There are currently several good logistics initiatives within the Skanska organization, but they are never deployed on a company wide basis. Instead, the logistics solution largely depends on who is involved in any given project. It is our belief that Skanska Xchange could help turning said logistics initiatives into standard procedures within the Xchange project.

During our work with this thesis, problems have been identified and analyzed mainly from a lean construction perspective, focusing on eliminating or minimizing what we have classified as waste. Recommended solutions to be adopted by the Xchange concept include the use of terminals and logistics centers, carry-in services, installation packages and kitting. The solutions have also been discussed from two perspectives: solutions to be used during framework assemble and solutions to be used after framework assembly.
Acknowledgements

We would like to express our thanks to our supervisor Anton Leigard at Skanska Xchange. His guidance has been very valuable during the time spent working with this master thesis. The help of our supervisor at the Royal Institute of Technology, Anders Hansson, has also been much appreciated.

Furthermore we would also like to thank everyone who has enthusiastically taken their time to answer our questions during our interviews:

Marie-Louise Lorsell
Sören Petersen
Mattias Karlsson
Susanne Ericsson
Andreas Davidson
Kent Malmgren
Johanna Nilsson
Daniel Rosengren
Jan-Eric Andersson
Hans Carlsson
Marcus Gustafsson
Pia Stålhandske
Lars Ek
Peter Wittefeldt
Hans Berglund
Magnus Lindblom
Hakan Turkyilmaz
Sten Andersson
Marc Trombeta
Anders Bergström
Maria Hellner
Anders Ludvigsson
Per Hellman
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1 Introduction

In this chapter the reader will be provided with a brief background to the master thesis, its research questions, purpose and objectives, delimitations, chosen method for writing it and the report’s disposition.

1.1 Background

All companies want to be as efficient as possible. But how can a big, international company with 50 000 employees accomplish this? The activity of mapping, analyzing and improving hundreds or thousands of different work methods is both time-consuming and expensive. At the same time, wouldn’t it be possible that the company already has a lot of knowledge of world class work procedures in-house? What if companies like that developed standard operation procedures for the entire company out of their most efficient ways of carrying out business? Wouldn’t that make them more profitable? This is at least what Skanska’s corporate management thought when they started the Skanska Xchange (SXC) project in 2007.

The SCX project was created to take advantage of the knowledge within Skanska and use specialized expertise to standardize the best practices. By doing so, Skanska hopes to increase efficiency and predictability in their work. The project is limited to the Nordic residential market and is supposed to cut costs by 15 % in Skanska’s residential construction projects. SCX plans to achieve this by using standardized platforms for choosing construction methods and work procedures. This includes, among others thing, new procedures for purchases and project planning, fewer errors and faster assembly since the product is well known among the working crew (Lindström, 2008).

By 2010 the SCX program had come a long way. The first construction projects that used the Xchange concept were being completed and the SCX team had managed to standardize the most crucial parts of construction procedures. But there were still many areas that needed improvement before it could be considered a complete solution for the Nordic residential market. The SCX concept needed to be more firmly established within Skanska to take full effect, it required more testing in the field and had to include additional construction methods and work procedures. One of the areas that had not been prioritized in SXC was the logistics in between the purchase of a component and the moment of its installation. This gap includes many different activities such as distributing, receiving, repackaging, storing and moving components both indoors and outdoors on a worksite. However, with the SXC project now a lot more mature, interest in logistic solutions have increased. Therefore, SXC has given us the task to investigate whether logistic solutions should be implemented in the SXC project and if so, how.
1.2 Problem statement and research question
In a building process there is no ideal picture of how the logistics in a project should work. Some activities are planned well in advance; others are conducted after the local norm and tradition. However, since there is no known best practice for logistic solutions spread throughout the company, the planning might be conducted poorly. Alternatively, good planning might fail due to unforeseen incidents. With that in mind there is an opportunity to improve efficiency and increase predictability in the construction process. To do this we need to answer the following questions:

- What distinguishes an efficient supply chain?
- What does the supply chain in Skanska’s residential projects look like today?
- What can be considered best practice in Skanska’s supply chain?
- Which parts of Skanska’s supply chain contain problems?
- What is the potential gain in solving said problems?
- How could the activities containing problems be made more efficient, realizing their improvement potential?

1.3 Purpose and objective
The main purpose of this thesis is to answer the question whether logistic solutions for made to order materials should be included in the Skanska Xchange concept. If the answer is yes, which logistic areas should Skanska Xchange focus on? If the answer is no, a description of why will be provided.

In order to answer the question a number of sub-targets have been identified:

- Identify all activities in Skanska’s supply chain.
- Identify waste in the supply chain and find out what is causing it.
- Develop an action plan to improve the supply chain.
- Determine if suggested actions should be part of the SXC project or another Skanska unit.

1.4 Delimitations
- Even though the SXC concept spans Sweden, Norway and Finland, this thesis is limited to Sweden and more specifically to residential development projects in Stockholm. The reason for this is that factors such as population size and number of projects in the area vary between different geographical areas.
The focus of this study is two to eight stories residential development projects. We will analyze other projects (offices, commercial, etcetera) in order to get more input, but the conclusion and action plan is only aimed at the before mentioned projects.

The study will not include all types of products in the supply chain. We will mainly look at so called “made to order” products. Made to order (MTO) products are items that are standardized but not produced before an order has been made. Examples of MTO products are kitchen, doors and bathrooms. One could argue that plasterboards are on the borderline between MTO and another product category; “made to stock”, but since it is a very commonly used material in construction projects, we chose to also include plasterboards in the MTO category. Made to stock typically includes small bulk items such as nails and screws and said category will consequently not be analyzed. The final product category, which will not be thoroughly investigated either, is “made to design”; project unique items like frameworks and floor structure.

The quantification of sub-optimized activities will be based on an indication of interviewee’s estimations, an electronic questionnaire and information available in reports and likewise. We will not conduct any time studies of our own.

Due to confidentiality reasons, financial figures and other sensitive material from Skanska cannot be clearly stated in this report.

1.5 Method

The theoretical foundation is based on previous education from the Royal Institute of Technology, schooling and material from Skanska as well as relevant literature. The literature is mainly based on the concept of lean construction, which is inspired of the more traditional lean production theories. Skanska also has a history of conducting logistics improvement project and as a result, information from previous projects has been used in the theoretical framework. Results from these studies have at times, however, been hard to get access to.

The company specific information needed in the process of writing this report was primarily collected via interviews and meetings with personnel within Skanska’s organization. People with insight in the logistics process were approached after recommendation from our supervisor at Skanska, SXC members or a previous interviewee. Most of the interviews were conducted on worksites in the Stockholm area. The typical interviewees were production managers, foremen and project engineers.

We also conducted phone interviews as well as interviews with personnel at Skanska’s headquarter in Solna. These interviews were mainly with employees within the Nordic Procurement Unit.
Finally, an electronic questionnaire study has been performed. The study was directed at personnel working at construction sites with the purpose of quantifying the problems we had earlier identified. A total of ten respondents answered the 30 questions in the questionnaire.

### 1.6 Criticism of the sources

The theoretical framework for this master thesis is mainly based upon lean construction and supply chain management theory presented in research papers. The authors of the articles are in general well known and respected in their respective research areas. The presented facts in the theoretical framework are often confirmed by at least two independent sources. As a result of this we feel confident in the quality and context of literature presented in the report. To what extent the findings are always applicable to Skanska is however not as certain. A discussion on the matter will typically be provided where so is deemed necessary.

The choice of mainly basing this master thesis on lean construction was partly made as a result of our educational background in manufacturing. At the same time, the process we were to investigate seemed suitable for applying lean theory on. These factors together with the fact that the unit we were connected to at Skanska focused on the development of industrial production made lean construction an obvious choice.

The empirical study is mainly based upon 25 interviews with Skanska personnel from different positions and functions. As with all interviews, there is a risk that the interviewee provides us with a biased focus. However, by conducting a relatively large amount of interviews, this risk has hopefully been offset. A possible improvement area could have been to expand the number of interviews further and to use discussion groups as well.

As for the online questionnaire conducted, a total of 30 employees were asked to answer it. However, only 10 did reply. As a consequence, the results have a larger uncertainty factor than would be ideal. However, we believe that it still serves as a good indicator, especially in combination with the interview results.

### 1.7 Disposition

The report consists of seven chapters and one appendix. In the following chapter, chapter two, an introduction is given to Skanska and relevant Skanska units. Chapter three consists of a run-down of relevant theory, mainly with a focus on lean. In chapter four, previous logistics initiatives by Skanska are discussed. Chapter five describes how the logistics process works today and waste is identified. In the penultimate chapter, possible solutions are discussed and evaluated. The findings in chapter six form the base of a concise recommendation in chapter seven. Finally, the bibliography is presented, followed by an appendix with the results of our online questionnaire is attached.
2 Skanska – A construction giant

This chapter contains a brief introduction to Skanska, one of the world’s largest construction companies, and its history, organization and work procedures. The chapter will provide the reader with necessary information to understand the empirical study and analysis later in the report.

2.1 Skanska’s history, strategy and values

Skanska was founded in 1887 in the southern part of Sweden. Today it has grown to become one of the ten largest construction companies in the world. The company has 53 000 employees and is active in Europe, the US and Latin America.

Skanska’s history began in 1887 when Aktiebolaget Skånska Cementgjuteriet was established. It originally manufactured concrete products but within ten years it had expanded into the construction industry. During the following century it has played an important role in building Sweden’s infrastructure, including roads, power plants, offices and housing. In the mid-50’s, Aktiebolaget Skånska Cementgjuteriet started its first major move on the international market. In the 70’s, it expanded to the US market, which is Skanska’s biggest market today. In 1984 the name of the group was officially changed to Skanska.

During the 90’s, Skanska expanded rapidly. The company’s sales doubled within only a couple of years. This expansion was mostly organic, but a series of successful acquisitions also paved the way for Skanska’s growth into a global company. Today Skanska has changed its focus from expansion to profitability. Operations have become rationalized to construction and development of residential, commercial and infrastructure projects in selected home markets in Europe and America as displayed in Figure 1 (Skanska).

![Skanska’s markets](Source: Skanska).

Figure 1: Skanska’s markets (Source: Skanska).
Skanska aims to be above the industry norm in both quantity and profitability terms. The qualitative targets have its foundation in Skanska’s core values: the five zeros. Skanska aims to have zero loss-making projects, zero accidents, zero environmental incidents, zero ethical breaches and zero defects. These five zeros is the way by which Skanska strives to achieve its financial targets. They are also the background to an ambitious development project within Skanska’s Nordic market: SXC. We will come back to SXC later in this chapter.

Skanska is organized after geographical location and function. The local business units are firmly established in their local market but at the same time they are backed by Skanska’s financial strength, shared knowledge and brand. Some functions, however, span several geographical and functional boundaries. An example of this is Skanska Financial Services that provide financial support in form of analyzing and managing financial risks and insurance matters. Skanska describes its organization as decentralized but integrated. An organization chart is displayed in Figure 2.

![Organization Chart](image)

Figure 2: Skanska’s organizational chart (Source: Skanska).

### 2.2 Skanska Xchange

After Skanska’s rapid expansion during the 90’s, the company entered a phase with focus on profitability. In order to be profitable, companies strive to become as efficient as possible and as a consequence, reducing costs. Classic example of this is economics of scale and standardized operating procedures. In the early years of 2000, Skanska’s Nordic residential units did none of this. There were for example 2250 different concrete stairs in the Nordic market and the Nordic countries all had different experience, expertise and building techniques.
After discussing already mentioned problems in Skanska’s corporate management for two years a decision was finally reached in 2007. A Nordic program under the name Skanska Xchange would gather knowledge, methods and expertise from Sweden, Finland and Norway and consolidate it into one shared system. The initial result of this was one platform for single family dwellings and one for multifamily dwellings. SXC also provided process descriptions and manuals for building homes in a standardized and industrialized way. By doing this, Skanska hopes to increase predictability and cut cost by enabling economies of scale, shorten the projects planning phase and increase building speed. A result of this is, for example, the concrete stairs mentioned previously. Within the SXC concept the number of staircases has initially decreased from 2250 to 30, but the concept still allows a relatively high degree of customization (The times they are Xchanging, 2007). The SXC program was from the beginning planned to only last a couple of years, but today it has become a more or less permanent part of Skansa AB. SXC is based in Skansa’s headquarters in Solna, Sweden. A large segment of the personnel work both from Solna and their home offices in Norway and Finnland.

2.3 Workstructure at Skanska

Skanska is a construction company and like all construction companies its business is conducted in the form of projects. This section of the report is dedicated to describe Skanska’s work structure, both in the construction projects as well as some of the support functions and IT-systems.

2.3.1 Skanska’s project process

As stated, Skanska conducts all its construction in the form of projects. The reason for this is that every construction project is unique in form of location, design, specifications, local regulations etcetera and therefore it is nearly impossible to conduct business in any other way. Unlike the manufacturing industry, where the factory is situated at a fixed position and lead-times are usually relatively short, construction projects have long lead-times and personnel can work on many different worksites in a limited period of time. Figure 3 describes a simplified picture of Skanska’s standardized project process. In reality the different phases are overlapping one another.

![Figure 3: Skanska’s project process (Source: Skanska).](image-url)
1) Bid for a contract: The process of investigating the conditions for construction, customer demand, risk and economy. If all seem acceptable a bid for the contract will be made.

2) Project preparations: In this phase a construction document is established based on customer demands, regulations etcetera. A project plan is also established.

3) Project controlling: Detailed planning of the project with focus on routines, time schedules, quality issues and project objectives is established. Members from all the executing functions, such as procurement and project specific personnel, are involved.

4) Production preparations: Based on the previous specifications a production schedule is established alongside a budget, a purchasing plan and a delivery plan.

5) Production controlling: The project has now entered its executing phase. The objective is to make the production run as efficiently as possible. The production schedule, budget and project plan is broken down into five focus areas: Time, economy, quality, environmental and work environment in order to monitor progress.

6) Delivery: The production phase has come to its end and different controls and surveys are conducted. If all goes as planned the building is handed over to the customer.

7) Warranty period: The period in which Skanska and its contractors are responsible for the function and quality of the product. This period usually ends with a warranty survey.

2.3.2 The production hierarchy

Skanska has a classic hierarchal structure all the way down into the projects. For example, the Skanska Sverige Residential Division is divided into eight geographical areas such as Hus Norr, Göteborg and Stockholm Residential. Stockholm Residential is then divided into smaller districts that are divided into different spheres of responsibility under the so called Project Manager. A Project Manager is responsible for a number of projects and works mostly as an administrator, coordinating different functions and activities. The position responsible for the individual projects is called Site Manager and answers directly to a Project Manager. A Site Manager is responsible for a single project. The Site Manager’s focus is to make sure that the project is on time and within budget. Work related issues, like safety and environmental questions are also the Site Manager’s responsibility. A Site Manager usually has three Foremen and a Project Engineer at his or her disposal. The Foremen are in charge of running the day to day planning and activities. It is the Foremen who instructs the workers and Gang Foremen what to do, how to do it and when to do it. Foremen are also responsible for organizing the receiving of arriving material and where to
put it. The Project Engineer is mostly an administrator who supports the Site Manager and foremen in their daily work by taking care of purchases with long delivery times, monitoring if progress is according to plan, updating schedules etcetera.

So far all personnel mentioned have been Skanska employees. This changes when it comes to the personnel that conduct the actual construction work. At this level in the hierarchy around half of the staff is Skanska's worker and the rest are sub-contractors. The reason for this is that it is not economical to keep that much staff and specialized equipment within the company. Instead, Skanska hires sub-contractors to perform different parts of the construction process. Both the Skanska workers and the contractors are usually divided into gangs by their specialty, for example painters, carpenters, etcetera, and are led by Gang Foremen. The worksite hierarchy is displayed in Figure 4.

![Figure 4: Worksite hierarchy. The categories in the blue area are part of the site management team (Source: Kyhlberg & Persson, 2010).](image)

**2.3.3 The Nordic Procurement Unit**

The Nordic Procurement Unit is a support function that specializes in providing purchasing service for Skanska's projects in the Nordic countries. They are responsible for, among other things:

- Providing knowledge and support in selected sub-contracting areas.
- International purchasing support.
- Negotiating and communicating framework agreements (a framework agreement is an agreement allowing the purchase of a service or a product at pre-determined...
conditions. See 5.1.2 *The ordering process, Framework agreements* for more information).

- Provide education and training to ensure that purchases in projects are done in accordance to defined processes and strategies.
- Logistics solutions.
- IBX, purchasing software provided by the IBX Group AB. For a more detailed description, see 2.3.4 *IBX and purchasing routines*.

The Nordic Procurement Unit in Sweden is based in different locations but have their largest office in Skanska’s headquarters in Solna. Personnel from the unit are involved in the projects’ startup meetings to ensure that all projects have a purchasing plan and to identify support needs within the purchasing area. They can also provide support during the project if problems arise.

The Nordic Procurement unit is organized as displayed in Figure 5. Category managers are responsible for establishing and maintaining framework agreements for a specific type of material, as well as providing the projects with support in regard to their material category.

![Nordic Procurement Unit (NPU)](source: Skanska)

**2.3.4 IBX and purchasing routines**

IBX is Skanska’s standard purchasing tool in Sweden. All purchases at Skanska go via IBX except purchases made with company credit cards or cash. IBX is a program where employees call-off framework agreements from a registry and thus order anything from a pair of work shoes to thousands of tons of concrete. If the requested item is not in the register, or
if it can be motivated in a cost or quality perspective, projects can make a so called “project specific purchase”.

A project specific purchase is supposed to be conducted via a standardized procedure. First purchasing preparations are performed and then a purchasing enquiry is sent to a supplier followed by a job estimate evaluation made by the project alone or with help from the Nordic Procurement Unit. Finally procurement is made. These steps are supposed to be conducted via IBX so that everything follows a standardized form and that all procurements can be traced. The described purchasing activities are illustrated in Figure 6. Delivery addresses, contact persons, invoice addresses, etcetera is all entered in IBX and sent to the supplier.

![Diagram showing the purchasing activities]

Figure 6: Generic illustration of the purchasing activities.
3 Theory

This chapter will provide the reader with the theoretical framework needed to understand the analysis and conclusion in the following chapters. The chapter begins with a presentation of the construction industry in general that includes different approaches and characteristics to construction as well as their supply chains. This is followed by a presentation of lean construction.

3.1 Four approaches to construction

According to Segerstedt and Olofsson (2010), there are four primary ways of constructing buildings. These four, which are closely related to the same terminology in the manufacturing industry, are engineer to order, modify to order, configure to order and select variant. The primary factor that separates the definitions from one another is the customer order point in the process. They are described below and are illustrated in Figure 7.

1. Engineer to order: This construction technique includes the highest degree of customization of the four alternatives and, as a result, enables the least degree of standardization. The design specification process is mainly based on client requirements, norms and standards. Typical products are dwellings, offices, arenas and factories.

2. Modify to order: Modify to order construction projects are based on a so called technical platform. Typically, construction technical platforms have a generic product structure and constraints in measures and type of technical solution to be used, such as standardized floor heights, a selection of approved technical solution of outer and inner walls and window type. The major Swedish construction companies have recently introduced these types of technical platforms on the market, e.g. “Skanska Xchange”, “NCC Bostadsplattform” and “PEAB PGS”. These kinds of building system require cooperation between the principal designer and the principal constructor to ensure successful integration within the systems.

3. Configure to order: This concept is based on standard parts and modules that can be assembled to customer demands. In order for this to work the concept requires access to the customer during the conceptual phase of the construction project. An example of this kind of system is “NCC Komplett”, which was a relatively flexible system with configurable modules with all equipment, fittings, wallpaper and flooring attached to the elements before assembly on-site. The NCC Komplett project was recently aborted due to high development cost and poor return on investment. Configure to order is a relatively uncommon construction system for larger buildings.

4. Select variant: Select variant is the most standardized form of construction. The customer selects a variant from a product portfolio, often with only minor opportunities for
customization. An example of this is the “Skanska ModernaHus” system, which consist of three to eight dwellings with eight possible floor layouts and options including energy performance and exterior design. Just as in the “configure to order” concept, customer access in the conceptual phase is required and the select variant concept needs to be selected in the conceptual phase as well.

![Image of product specification process]

Figure 7: The product specification process for different variants of building system (Segerstedt & Olofsson, 2010).

### 3.2 Characteristics of the construction industry

There are seven constraints, according to Skanska, that a construction projects have to secure in order to carry out an activity. These constraints should be viewed as flows. In order to secure a reliable and effective construction process, these flows need to be constant and well balanced. If one of the flows is not in place a construction process cannot be conducted. The identified constraints are:

- **Material:** Materials are essential in order to construct a building. Materials can be delivered in bulk to be stored in an on-site buffer or via just-in-time deliveries.
- **Crew:** Work personnel is required to carry out an activity. To ensure that personnel are at the right location at the right time is essential to secure efficient production.
- **Location:** The location where work is carried out in the construction is not only changing between projects but, more importantly, during a project. Therefore it is important to ensure that crewmembers have a sufficient work area without conflicting activities.
- Preceding Activity: In order to carry out an activity the preceding activity has to be completed without faults.
- Information: Information is essential to plan, organize and carry out tasks and projects. This can include blueprints, work descriptions and BIM-analysis (see section (3.4.1) *Six core elements of lean; Waste reduction*).
- Tools and Machines: These are supportive resources to minimize work burden on site and support safety and quality.
- External Constraints: These are constraints which a project cannot control, for example weather and a subcontractor’s financial situation. Their influence on the construction process can however be minimized by proactive actions.

The construction industry is often accused of customary time and schedule overruns, as well as quality deviations and poor health and safety of work crew. This has resulted in government funded investigations and research initiatives. Findings from these investigations indicate that the problems originate from the fragmented nature of the industry, lack of coordination and communication between participants, lack of customer-supplier focus, inefficient use of technology and priced based selection (Love, Irani, & Edwards, 2004). Other industries may cope with similar problems but it is often argued that the construction industry is like no other industry. The reason for this is that there are certain peculiarities of construction, like one-of-a-kind products, temporary organization, on-site production and substantial market volatility, preventing the attainment of flows as efficient as in, for example, manufacturing. Another substantial peculiarity from most manufacturing industries is that the construction company that manages a project is only responsible for creating 25 % or less of the total value of the product with its own personnel and production facilities. The great part of the product's value is built with help from suppliers and subcontractors (Segerstedt & Olofsson, 2010).

The construction industry is local. Governmental subsidies, national and local regulations and culture have essentially protected the construction industry from global competition. This limitation in geographical flexibility together with the durability and the long life span of building products creates a situation where the demand varies dramatically over time for construction companies. The more durable a product is the more the demand will oscillate, since the yearly production only adds a small volume of an already existing product (see Figure 8). The business cycle of the construction industry seems to have higher amplitudes than other manufacturing industries. As a result of this, unemployment of construction workers is greater in periods of low business activity than in other industries. Similarly, in periods of higher business activity, the need for labor is often so great that more unskilled
workers are hired in the construction industry than in other industries (Segerstedt & Olofsson, 2010).

Figure 8: Started number of flats in apartment blocks and detached single houses in Sweden from 1950 to 2008 (Source: Statistics Sweden and the Swedish Construction Federation).

3.3 Supply chains in the construction industry

A supply chain can be defined as “the network of organizations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services in the hands of the ultimate consumer” (Lönngren, Rosenkrantz, & Kolbe, 2010). Vrijhoef and Koskela (2000) characterized the supply chain in construction as:

- Converging at the construction site where the object is assembled from incoming materials.
- Temporarily producing one-off construction projects through repeated reconfiguration of project organizations separate from the design.
- Typical made-to-order supply chain, with every project creating a new prototype.

A generic supply chain has been developed by Segerstedt and Olofsson (2010) (see Figure 9). The construction company is situated as the system integrator (SI), or focal point, in the supply chain. It is at the SI point that all material from suppliers and the demand from costumers converge. A difference in the construction industry compared to other industries is
that the construction company rarely talks to the costumer directly. The first tier customer is often an agent working for the second tier, the real costumer.

As stated in 3.2 Characteristics of the construction industry, research has uncovered that the construction industry suffers from poor performance and their supply chains are no exception. Observed problems are among others lack of coordination and communication between participants, lack of customer-supplier focus, inefficient use of technology and priced based selection. Different factors have been identified as root causes for these observed problems. The dominating focus on projects, fragmentation of the industry and the separation of the design and production processes are among the most common factors identified (Bankvall, Bygballe, Dubois, & Jahre, 2010). An effect of these problems is that the productivity increase has been slow in the construction industry. In Finland it is approximately 1 % and in the Netherlands 3 %. This, however, is not enough to compensate for the average increase in labor costs (Vrijhoef & Koskela, 2000). To cope with these problems, supply chain management and its related concepts such as partnering and lean construction have received increased interest from construction research and practice (Bankvall, Bygballe, Dubois, & Jahre, 2010). In the following sections these concepts will be presented and evaluated from a theoretical view.

### 3.4 Lean Construction

Lean production has for a long time been accepted in the manufacturing industry but recently it has also been adopted by the construction industry as a mean of supply chain...
improvement. The transformation from the continuous manufacturing industry to the project based discontinuous construction industry has not been straightforward unproblematic. Therefore lean construction has to be developed and modified to fit the project based context. In the following section a lean construction context, as presented by Eriksson (2010), will be introduced. According to Eriksson lean construction has six core elements. These are: waste reduction, process focus and control, end customer focus, continuous improvements, cooperative relationships and system perspective. A more thorough presentation of these six core elements will follow below.

3.4.1 Six core elements of lean

Waste reduction

The most important core element of lean construction is waste reduction (Eriksson, 2010). There are seven types of waste defined in lean construction according to Lönngren, Rosenkrantz och Kolbe (2010):

1. Defects in products.
2. Overproduction of goods.
3. Excess inventories.
4. Unnecessary processing.
5. Unnecessary movement of people.
6. Unnecessary transport of goods.
7. Waiting time.

These seven types of waste were originally defined in the Toyota Production System and are today widely spread in manufacturing as well as other industries. Many subsequent authors have, however, suggested additions to this list. Koskela (2004) for example argues that there is an eighth category of waste, especially common in the construction industry: Making-do. Making-do refers to a situation where a task is started without all its standard inputs available, or to when the execution of a task is continued although the availability of at least one standard input has ceased. These standard inputs refer to the seven constraints in construction presented in section 3.2 Characteristics of the construction industry. In a conceptual breakdown, making-do is contradictory to buffering. In buffering, materials are waiting to be processed. In making-do the waiting time for a standard input is negative since the processing starts before the input has arrived. This waste occurs as a mean of accommodating the impact of variability in production. For example, the urge to utilize machinery or the belief that starting early will complete the task earlier can make a worker start production before all standard inputs are in place. Observed effects of conducting work
via the making-do approach have been increased processing times, increased operational costs, poor quality and rework.

To minimize the effects of making-do, the root cause of it, variability, has to be minimized. In order to do so, two key elements have been observed: the complete kit and better planning. A complete kit is a way of providing the worker with all the necessary material for an activity in a package (read more about this in section 4.3 Installation packages and kitting) in order to eliminate variability in the material flow. Traditional push planning approaches are also causing making-do since they often fail to take into account the deviation between the planned and real processes, causing problems in input availability, thus leading to making-do in order to cope. Better planning can enable less variability of standard inputs. A part of this can, for example, be the Last Planner system of production control (Koskela, 2004), which will be presented later in this chapter.

Another often talked about waste in lean is the so called +1 category of waste: Latent skill. Latent skill refers to skills that employees may have that are not being utilized. "It is only by capitalizing on employees' creativity that organizations can eliminate the other seven wastes and continuously improve their performance." (Liker, 2004). With these two additions, a modified list of waste in construction could add:

8. Latent skill.

As a consequence of the focus on waste reduction in the construction process, aspects such as housekeeping, i.e. keeping the construction site well organized and clean, and efficient transportation and stockholding, i.e. just-in-time (JIT) delivery are important. From a JIT perspective inventories are regarded as waste and therefore the use of buffers and on-site inventories should be kept to a minimum. In order to accomplish this contractors strive to receive smaller batches of materials. This also reduces the need for double handling of material on-site (Eriksson, 2010). Ballard et al (2003) argue that in order to achieve JIT delivery the contractor needs to focus on lead time. By measuring “percent plan complete” (PPC), which is the percentage of weekly or daily release of work from “supplier” to “customer” compared to what was planned, one can predict how far in advance an advance notice must be made, i.e. one can establish a window of reliability. With regard to engineered-to-order products such as precast concrete, it is important that lead time, the advance notice of need for delivery provided by a construction site, fall within that window of reliability. For example: if a construction site has 80 % PPC looking one week ahead and the supplier’s lead time is two weeks, PPC two weeks ahead may only be 60 %. This might result in that 40 % of all shipments of materials will not be installed, thus building up
unneeded inventories on-site. If lead times do not fall within the window of reliability of the “customer” process, receiving materials from suppliers will unavoidably build up unwanted inventories. If lead times on the other hand are within the window of reliability inventory levels on-site can be reduced. With smaller amounts of inventory on site reduces cost for carrying, material handling and the risk of damage or obsolescence. A way of achieving shorter lead times in production with low demand reliability is to use a decoupling buffer. Products are prepared and stored in the decoupling buffer until a trigger, which is a specific delivery request made a predetermined number of days in advance, activates production and/or delivery (Ballard, Harper, & Zabelle, 2003).

Another important aspect of waste reduction is information technology. IT-tools such as 3D-modeling allow detection and correction of a majority of errors prior to production (Eriksson, 2010). An example of 3D-modeling tools used in construction is Building Information Modeling (BIM). With BIM-modeling designers, engineers and contractors can detect clashes and conflicts early. For example, if ductwork intersects with a structural beam as illustrated in Figure 10, the design can be changed before construction begins, which reduces the need for ad-hoc solutions on-site and therefore saves time, money and improves technology in the projects (Madsen, 2008). IT-tools also enable enhanced integration among supply chain actors and their tasks which increase the likelihood of cost and schedule realization. The last central aspect of waste reduction is off-site manufacturing of components and units, i.e. prefabrication. Prefabrication in the construction has many advantages similar to manufacturing industries, such as reducing material waste, shortening construction duration, improving work conditions, etcetera (Eriksson, 2010).

![Figure 10: BIM-modeling of ductwork intersects and structural beam (Madsen, 2008).](image)
Process focus in production planning and control

A core element of lean production is to approach production management through a focus on processes and the flow of processes. The “last planner” system is a key aspect of this that enables efficient planning and control. A so called last planner is a person responsible for individual assignments. Last planners prepares weekly work plans to control the workflow and if assignments are not completed on time they are responsible for determining the root cause of the delay and an action plan to ensure that does not occur again.

Self control is central in lean construction to prevent defects at the source. This prevents defective products and materials from going through several process steps and utilizing resources and capital before the defect is detected and repaired or exchanged. This aspect should be adopted in all activities in the supply chain.

To enhance focus on schedule and production plans project milestones should be used in construction projects. By clarifying the importance of production milestones and making them explicit to everyone, the project participants will feel more involved in the execution of the project (Eriksson, 2010). This should increase overall efficiency.

End customer focus

End customer focus is a central aspect of lean construction. In order to maximize customer value, contractors need to adopt an end customer focus. Contractors and suppliers must understand the needs of the customer so that they can supply what he or she needs, not only what he or she asks for. Customer satisfaction is not only dependent on the end product but also on the process during which it is created, i.e. service quality. In order to increase customer focus it is important to involve contractors early in the design process. It is also important that integration of design and construction is established through concurrent engineering. Concurrent engineering increases the contractors’ understanding of customers’ needs and improves teamwork and joint problem solving.

According to lean construction it is not efficient to rely on competitive bidding when procuring customized products. A strong focus on the lowest tender price tends to promote self-preservation attitudes instead of attitudes aiming for customer satisfaction. In order to satisfy customer demands, limited bid invitations of trustworthy and competent contractors should, together with soft parameters evaluations, ensure that partners capable of satisfying customer demands are selected (Eriksson, 2010).
Continuous improvements

In order to reduce waste and increase efficiency in a lean construction process over time a long term perspective on continuous improvements is vital. In order to conclude whether or not performance is improving it is important to measure performance on a regular basis. Subsequently the reasons for satisfactory or unsatisfactory performance should be analyzed in order to develop and implement potential improvement actions. Unfortunately site workers involvement in problem solving is generally low compared to other professions and workers often believe that they do not have sufficient opportunity to state their opinions. Therefore it is important that suggestions from workers are taken seriously in order to improve their dedication to continuous improvements.

Since construction is based on temporary projects, long term contracts, i.e. framework agreements, are an important aspect when reducing the traditional short term focus on cost reduction and promoting lasting improvements. By working together in a number of projects instead of changing supply chain actors at a regular basis, transferred knowledge and experience is facilitated and efficiency can be improved.

Knowledge sharing and joint learning among people from different trades is crucial to enhance continuous improvements. Unfortunately, this is seldom done in the construction industry due to lack of suitable methods. Joint learning can be obtained by establishing special interest groups, also called quality circles. In these circles staff members meet on a regular basis to exchange knowledge, ideas, etcetera and thus establishing a foundation for continuous improvements. But it is not enough to just provide the forum for communication. Project staff must also understand lean concepts and its pre-requisites must be improved in order to increase their willingness and ability to contribute to continuous improvements. Hence, relevant training and education is a precondition for effective lean implementation (Eriksson, 2010).

Cooperative relationships

Cooperative relationships among supply chain actors, often referred to as partnering, is another important component of lean construction. It facilitates joint learning by integration of different supply chain actors' competences and efforts. Since a substantial part of a projects' value is accounted for by the use of sub-contractors, it is important to involve key sub-contractors in a broad partnering team. This enables important actors to contribute to the joint objectives. Central to the establishment of such a team is good communication, integration and coordination. This is facilitated by various collaborate tools such as joint
objectives and project office, facilitators and teambuilding. Research has, however, found practical difficulties when trying to involve the wider supply chain in lean construction.

When trying to implement successful cooperative relationships in lean construction it is important that all partners benefit from improved performance. Fair and equitable rewards are especially important for building trust and cooperation among supply chain actors. Therefore an incentive based compensation form, including gain share and pain share agreements which are likely to increase joint objective focus and cooperation, are important in this process (Eriksson, 2010).

**System perspective**

The last core element in lean construction according to Eriksson (2010) is to adopt a system perspective. A system perspective is a requirement to improve overall efficiency of lean construction projects and avoid sub-optimization. A reliable workflow as a whole is more critical than individual activities speed or cost. An important aspect of this is to include the entire procurement process and make decisions that support or complement one another.

By minimizing the number of steps, parts and linkages the construction process can be simplified, thus making it more efficient. A part of this is to integrate construction, design and operation instead of viewing them as separate activities. Large scope contracts are also more desirable compared to dividing a project into small pieces, involving many different supply chain actors during short periods of time (Eriksson, 2010). A tool for adopting a system perspective that has been used in the manufacturing industries for a substantial amount of time is Value Stream Mapping (VSM). In the following section a brief introduction to VSM and how it is used will be presented.

### 3.4.2 Value stream mapping

Value Stream Mapping is a tool when working with Lean. The VSM work process includes mapping the entire flow of a product and then balance it in order to find waste from a system perspective. To improve each process in isolation may result in optimized activities but result in a sub-optimization of the system. To view processes in isolation from one another may also result in funds being used in the wrong place. Through the use of VSM a company can locate the processes with the highest amounts of waste and then deploy resources where they are needed the most.

Change management requires time and money since employees must become used to finding solutions for a problem and since production is likely to be lost when work is restructured. Therefore, a company should begin the process of improvement where the benefit of an improvement is most substantial, i.e. where waste is the most extensive. But in
order to know where waste is most substantial, the work flows first have to be identified (Rother & Shook, 2008).

VSM is performed by starting at the end of the production chain, where the product goes to the customer and then map the flow backwards. The resulting value stream map should include processing times, inventory between processes and capacity. By doing this one can identify the total lead time, which activities create value for the customer, and also discover where in the chain the biggest time losses and bottlenecks are located (Keyte & Locher, 2008). After the study of the current situation and the waste that currently exist in the company, it is time to quantify waste in monetary terms in order to determine which waste is the most extensive. After that a process of trying to eliminate waste in order of descending magnitude begins (Womack & Jones, 2003). This process should result in a calculated profit for the company, monetary or in the form of improved work situations, etcetera, otherwise the improvement suggestions are unfit to carry out. It is important to select a group of improvements that can be implemented in the foreseeable future so that the current team is able to follow them and monitor the results. It is therefore important to choose a few points to improve in a first step. These should include the most substantial waste, or enhancements that provide significant reductions in waste compared to the cost of the improvement. An example of a VSM is illustrated in Figure 11.

![Figure 11: Example of a VSM (Technical Change Associates).](image-url)

After deciding upon a group of improvements it is possible to generate a so called future state, how the production process should look like after implementation of the suggested
improvements. By making a future state one defines a goal that the production processes should strive towards, but in order to get there an action plan has to be generated. The action plan describes the necessary steps to get to the future stage and when they should be performed. It is important not to schedule a lengthy improvement process, since tangible results and follow-up will be too far away. It is also important to monitor the action plan as to see which steps are performed and if the results met the calculated expectations (Rother & Shook, 2008).

3.4.3 Implementation of lean construction

According to Green and May (2005), implementation of lean construction can be divided into three stages. The following segment will summarize three stages that focus on waste elimination, relationships within the supply chain and project governance.

Stage 1: Waste elimination

The first step towards lean construction, according to Green and May (2005), focuses on waste elimination from a technical and operational perspective. In this stage the responsibility is mainly on managers rather than individual workers. Since the aspects related to this stage are of a technical and operational nature they can be adopted in any construction project striving for operational efficiency. Essential parts of this stage are: elimination of needless movements and costs, optimizing workflow and sharing benefits from improved performance with concerned supply chain actors. These factors relate to previously mentioned activities such as housekeeping, just-in-time deliveries, milestones, performance indicators and gain/pain share.

Stage 2: Relationships

The second step towards lean construction focuses on eliminating adversarial relationships and enhancing cooperative relationships and teamwork among supply chain actors. Because of this focus the second step does not go far beyond the concept of partnering. Essential parts are cooperation, long-term framework agreements, workshops and facilitators. These factors relate to previously mentioned activities such as limited bid invitations, soft parameters, long term contracts, collaborative tools and a broad partnering team.

Stage 3: Project governance

The last stage is, according to Green and May (2005), the most sophisticated. It involves a structural change of project governance and its essential parts are: information technology, pre-fabrication, last planner and emphasis on individuals, a rethink of design and construction, decreased competitive forces, long term contracts, training at all staff levels and
a system perspective of both processes and products. Accordingly, aspects of this stage is joint IT tools, pre-fabrication, self control, concurrent engineering, limited bid invitations, soft parameters, long term contracts, special interest groups, training, suggestions from workers and large scale contracts (Green & May, 2005).

3.4.4 Criticism against lean construction

Literature regarding lean construction is in general positive to the concept and rarely mentions negative aspects, deficient evidence of positive effects or failed implementations, etcetera. In the following segment Jorgensen and Stephen (2008) provides arguments against lean construction and its perceived positive effects.

Lean is an established theme within the manufacturing industry and recently the construction industry has started to show interest in the concept. But there are major differences between manufacturing and construction. Manufacturing is producing in volumes significantly higher than the construction industry. Lean is typically applied at processes that are highly standardized and repetitive with the aim to decrease lead-time. Therefore some of the literature regarding lean is not relevant to the construction industry since it has a focus on projects and, with the exception of some repetitive building types, not high-volume production techniques.

Customer focus is a central part of lean. The main principle is to consider all downstream operations as customers, while value is defined only as perceived by the end customer. Value is “only meaningful when expressed in terms of a specific product which meets the end customer’s needs at a specific price at a specific time” (Womack & Jones (2003)). This definition has important implications in lean construction where the end customer is multiple, the construction client rarely can be considered the single ultimate customer and the product continues to deliver value and waste under a long time, maybe over a hundred years. At the same time value in lean construction literature is either unaddressed, or it is largely discussed in the context of the construction project, i.e. the process, not the resulting building, the product.

Jorgensen and Stephen conclude that lean construction literature is still in an early development stage compared to lean manufacturing since it is lacking a critical debate and a coherent philosophy and terminology. But above all other lean construction superiority is not proven with empirical findings. Therefore one should be skeptical of lean construction literature and its claimed advantages until a larger mass of evidence is provided (Jorgensen & Emmitt, 2008).
4 Previous logistic work at Skanska

In this chapter the reader will be provided with a summary of the logistics work already conducted at Skanska relevant to this report. This includes IMS cost analysis, framework agreements of forwarding services, installation packages and kitting, terminals, logistics centers, carry-in services, pilot project Skärholmen and the development of Hammarby Sjöstad. The information in this chapter is presented according to the best possible understanding based on interviews and limited material made available.

4.1 IMS Cost Analysis

An IMS (Inköps- och materialstyrning), cost analysis starts by determining the material cost. After that, the required activities to get the item from manufacturing to the point of installation are identified and it is determined how much each costs. With this information the “real” cost of installing an item is determined and improvement potential is located.

Skanska conducted an IMS Cost Analysis in the 90’s. This analysis included around thirty different material types. The investigation resulted in some substantial changes, primarily effecting procurement routines. Figure 12 is a result of that particular investigation. It displays the IMS cost analysis of plasterboards, which concludes that the additional costs per plasterboard were 142% at the time. The three largest IMS costs were transportation, worksite logistics and damage, spoilage and wastage.

Figure 12: IMS analysis of plasterboards (Source: Skanska).
4.2 Framework agreements of forwarding services

Skanska has recently undergone a substantial reorganization of delivery routines from suppliers. Skanska used to depend heavily on their suppliers forwarding agreements. Only five percent of deliveries were from Skanska’s own agreement. Freight costs were commonly not specified in the cost of purchases and as a result, Skanska had little insight in transportation costs and whether Skanska was actually paying too much for the service. There were indications of this, however, as some suppliers offered the same prices, freight included, in all of Sweden, regardless of proximity to the supplier.

Due to new framework agreements between Skanska, DHL and Skanska’s suppliers, Skanska now has a significantly higher percentage of all transports on their own contract with DHL. This new arrangement enabled Skanska to both reduce and get detailed information about the logistics costs. However, according to the questionnaire for site management, a large part of deliveries to site are still not hauled by DHL. This is illustrated in Graph 1.

![Percentage of deliveries using DHL](image)

Graph 1: The percentage of all deliveries to site transported by DHL. The vertical axis displays the percentage of answers in each category (Source: Kyhlberg & Persson, 2010).

4.3 Installation packages and kitting

The concept of installation packages and kitting is to deliver material organized in accordance to the needs of a specific work area, typically an apartment, at the construction site. The difference between installation packages and kitting is that installation packages often include large, heavy objects, such as plasterboards, beams and kitchen, while kitting includes smaller, lighter objects such as armature. Since installation packages often are large and heavy, up to a metric ton per package, construction projects often try to deliver them onto a floor using tower cranes before the floor above is installed. Materials delivered
this way are often different types of boards and beams. They can, however, deliver them in a later stage using wheel loaders, elevators or manual labor. This approach is often used for kitchen. Kitting on the other hand often includes smaller packages suitable to be delivered close to the time of installation, via elevators or staircases. Materials mentioned in kitting are for example electrical installation items, such as fixtures.

In order to enable installation packages and kitting, the person placing the delivery order must know which types of materials and at what quantity each specific apartment requires. The supplier will receive this information about how to bundle the materials, for example 14 plasterboards to apartment A and 37 to apartment B, and package them according to the specifications. The packages are then labeled with delivery information and apartment number.

The material required for a specific apartment at a certain time cannot always be supplied by a single supplier. For example, supplier A might only be able to deliver plasterboards and supplier B only beams. Since the construction project want both plasterboards and beams in the same installation package, delivery to a terminal (see the following section) has to be used. Other suppliers, such as kitchen suppliers, can often deliver all required materials for an installation in one installation package.

A consequence of using installation packages and kitting is that the need to organize materials at site is decreased. If a project does not use these concepts, workers have to sort materials from an inventory under construction site circumstances before the material can be placed in the correct apartment. This activity is via installation packages and kitting relocated up stream in the supply chain, where it can be performed under better suited circumstances.

4.4 Terminals
A terminal concept has been in development for a few years and will begin to be implemented in projects during 2011. A terminal is a location that works as a transportation node, as illustrated in Figure 13. Terminals have three main functions:

- Multiple suppliers can send their goods to a terminal rather than directly to the construction sites. At the terminal the goods is repacked onto a single truck, decreasing the number of deliveries to the construction site. Conducted pilot studies indicate that the number of deliveries to site can be lowered to one sixth of normal.
- A terminal can be used to stow materials from different deliveries into bundles corresponding to the needs for each apartment or floor in a project, i.e. installation packages.
If a project cannot receive a delivery due to delays in production and a supplier is unable to delay a delivery, a project can use a terminal for temporary storage instead of receiving the material at the work site.

Figure 13: Generic picture of the terminal concept (Source: Kyhlberg & Persson, 2010).

The present day terminal solution for Skanska in the Stockholm region is to use DHL’s facilities, as seen in Image 1. A result of the agreement with DHL is that all pallets with materials have to arrive two days in advance of outbound delivery to enable enough time for reloading. DHL do not open any packages but they can reorganize packages between different pallets according to specifications. To weather proof the newly organized pallets by wrapping them, or to prepare them for a crane lift, is not part of the standard procedures at the DHL terminal, but can be arranged if specified.

Image 1: The DHL terminal (Source: Skanska).

In present day, the use of terminals is a relatively new approach that is not widely spread throughout the organization. Terminals have been used in pilot projects and in large projects in need of specialized logistics solutions. Today the knowledge of terminal services is not widely spread in production and only a few running construction projects have started to use...
the approach in their production. The personnel working with implementing these services
vision that the knowledge and usage of the concept will increase dramatically over the next
few years.

As multiple construction sites are being served by the same terminal, there is an increasing
risk that material gets mixed up and sent to the wrong site. To counter this, new software has
been purchased and modified for Skanska’s terminal related needs. The software keeps
track of when deliveries are expected to reach the terminal and what is supposed to go
where. If an expected inbound transport has not been detected by the system when it has
been meant to arrive, Skanska personnel will be notified. They will also be notified if a
scheduled delivery from a supplier does not have freight booked a couple of days in
advance. That way they can either confirm that the transport will still reach the terminal in
time to get repackaged for the outgoing delivery, or take appropriate actions.

Observed problem areas with the terminal concept, other than the risk of materials being
mixed up, is the risk of damaging goods. On- and offloading and moving material always
includes this danger and since terminals ads extra activities of this sort, compared with
transporting the goods straight to the construction site, the risk of damaged goods is
increased.

4.5 Logistics centers
Logistics centers work in quite the opposite way of terminals. Instead of simply receiving and
re-loading specific material designated to a specific construction site, logistics centers keep
inventories of their own. Inventories are typically kept of the most commonly used variants of
standard products, such as the most frequently used plasterboards. However, more
uncommon material might also be procured if the logistic center is able to purchase it
cheaply from a foreign supplier and the center predicts demand for the product will arise in a
foreseeable future. Logistics centers are also used as a temporary storage facility for
material with very long shipping times, typically purchased from different continents. An
example of this is custom ordered windowsills from China. A generic picture of the function of
a logistics center is illustrated in Figure 14.

Figure 14: Generic picture of a logistics center (Source: Kyhlberg & Persson, 2010).
A purpose of Skanska’s logistics centers is to act as an additional supplier on markets which are not characterized by intense competition. The centers are primarily used by construction projects ordering smaller quantities of goods, allowing the logistic center to gain larger rebates on purchases as larger quantities are bought. For example, a project ordering plasterboards at a lower quantity than a specified weight limit will ideally have them delivered from the logistics center rather than from the supplier directly, as is otherwise standard practice. Logistics centers are used in present day operations, but it is up to individual projects to decide if they are to be used or not in the specific project. Skanska’s logistic centers only provide material for Skanska’s own projects and are not considering adding Skanska’s competitors to the list of buyers.

The logistics centers are currently operated by DHL at handful locations in Sweden. DHL personnel receives orders, pack deliveries and supervise material flow. Value added services, such as providing additional wrapping, can be provided. Skanska personnel keep track of inventories and administrate the billing procedures. Category managers are responsible for which products the logistics centers should keep inventories of.

The main concern with logistics centers from a procurement view is that inventories are in danger of piling up, material going obsolete and locking up resources. This is a result of a substantial variety between products. Even products that seem homogeneous, such as plasterboards, have many different properties of quality and measurements, resulting in a large number of variants in storage. Additionally, logistic centers keep material in stock regardless of whether current projects are expected to purchase from them or not. Projects do not commit to using the logistics center for purchases until the actual purchase is made.

4.6 Carry-in Services
To use a carry-in service means that a project hires an external part to haul material from a delivery truck to a specified area, usually close to the point of installation. This work can be carried out when the production is not active, i.e. between 17.00 and 06.00. The use of carry-in services in residential production is currently not standard procedure, but is not uncommon.

4.7 Pilot project Skärholmen
When Skärholmen Köpcenter, a mall in the Stockholm region, was to be renovated and expanded during 2005 to 2008, Skanska won the SEK 1.7 billion contract. This project was considered to be difficult from a logistic view because of a number of factors:

- The mall was open during the construction period.
- It had a limited area for goods reception and storage.
The project had many participants. This resulted in many actors using building materials.

Due to the size of the mall, keeping track of inventories was hard.

Because of complications as a result of above stated difficulties, Skanska eventually decided to adapt a new logistics model in order to ensure a stable workflow. The solution was to use a terminal to package incoming materials and to deliver the materials via carry-in services when the mall had shut for the day. Material hauled by the carry-in service personnel was placed in pre-designated positions close to the point of its installation, thus decreasing the need for workmen to move around, collecting material.

Materials included in this logistic pilot were:

- Plasterboards
- Steel beams
- OSB – boards
- Insulation boards
- Doors

This logistics pilot project required large amounts of planning and many Skanska employees had to learn new ways of working. For example, since on-site inventories were kept at a low level, construction workers had to order new plasterboards when it was a predetermined number of boards left, rather than waiting until there were none left. This Kan Ban inspired system, as illustrated in Figure 15, was used in order to enable delivery of new boards before the site inventory ran out of material.

![Figure 15: Skärholmen logistic solution (Source: Skanska).](image)

Despite some difficulties, the logistic project was regarded a success. Among the results were:
- Lowered logistic costs: The cost for the required equipment and material handling was lowered by 5 - 10% when the new logistic concept was applied, including the cost for terminals and carry-in services.
- Decreased material handling for Skanska’s construction workers: The need to look for and move materials were reduced in the pilot since much of the required material was placed in the vicinity of the point of installation, instead of being placed in an inventory.
- Increased productivity: As a result of decreased material handling, workers could focus more on the actual installation work and less on logistics. As a result of this, productivity was increased by 15 - 20%.
- Decreased on site transportation: Since most transports were carried out at night and since the material was bundled into predetermined packages, deliveries could be made closer to the point of installation, thus reducing the need for on-site transportation.

### 4.8 The Hammarby Sjöstad approach

When Hammarby Sjöstad was being developed a large number of contractors and construction projects were active in the same area. These factors, together with the limited space for inventories and offloading the area offered, resulted in a joined logistic solution. A logistic center close to the construction area was temporarily used to supply the projects with materials. A majority of all materials arrived at this logistic center to later be distributed when needed via a predetermined rout as illustrated in Figure 16. This approach enabled the projects to function with less on site inventories. The solution was temporarily and was adjusted for the specific conditions of Hammarby Sjöstad. While it should not be confused with the current concept of logistics centers as discussed in 4.5 Logistics centers, the Hammarby Sjöstad approach shows the potential of similar solutions.

![Figure 16: A generic picture of the Hammarby Sjöstad approach (Source: Kyhlberg & Persson, 2010).](image)
5 Present day logistics at Skanska

Skanska’s logistics can be divided into two parts: logistics before the worksite and logistics at the work site. To these two parts one can add a third that lays the foundation for the entire logistical process: the ordering process. The following chapter presents how Skanska works with these steps and where in the logistic process waste has been identified.

5.1 The ordering process and material flow

The ordering process lays the foundation for the logistics work with physical components. It is during the ordering process it is decided which items a construction project needs, at which quantity and at what time. The next step is the logistics process before the worksite, which includes manufacturing, assembling or collecting the required materials from storage, as well as transportation to the worksite. When the material finally arrives at the worksite the last step in the supply chain begins: the logistics process at the worksite, which includes offloading and eventually moving material to where it is to be installed.

In this section of the report a description of the present day state of Skanska’s logistic process is presented. It is primarily based upon some twenty-five interviews with staff from the line organization and personnel from the Nordic Procurement Unit. These interviews are combined with information from Skanska’s intranet and reports in order to create a generic workflow. This workflow may not be accurate for all projects and materials due to the fragmented construction industry, but it serves as a foundation for future arguments.

5.1.1 The ordering process

In this part the ordering process, which lays the foundation for most material flows in a project, is presented. The ordering process is shown in Figure 17.
The ordering process

Master Schedule

The master schedule is the controlling document of a construction project. The person responsible for it is the production manager, but it is common for the production manager to use a foreman as a second opinion during its development. The schedule is organized as a Gantt chart; a common tool in project management which illustrates when an activity is supposed to be conducted, for how long, with which resources and what interdependencies between activities exists. This is illustrated in Figure 18.

Figure 17: Generic picture of the ordering process (Source: Kyhlberg & Persson, 2010).

Figure 18: A master schedule (Source: Skanska).
The master schedule can be broken down into a more detailed, short time horizon chart that is constantly updated. An example of this is look ahead plan. This plan is used when organizing the day to day work and typically has a time span of three weeks, although according to Skanska’s planning procedures it is meant to cover six to eight weeks.

**Procurement plan**

With technical specifications and blue prints, a procurement plan is established within a construction project. The procurement plan dictates which major items are needed during the project. Larger or more expensive items that have to be planned ahead, such as kitchen, concrete and plasterboards are included in the procurement plan. Smaller day to day items such as screws, nails and clothing for the work staff is not the focus of this plan.

**Quantifying material needs**

The quantification of material needs is one of the hardest parts when planning the procurement for a project. Some items, such as concrete elements and staircases are relatively easier to determine the required amount of since it’s just a matter of counting the number to be used. Other materials, such as plasterboards and plywood, are much harder to estimate. The reason for this is that it is hard to determine how much will go to waste due to workers using different methods when, for example, cutting plasterboards. The risk of damage to the inventories during transportation and storage can also be a major reason for deviating material requirements. Plasterboards can get damaged by damp, boards for kitchens and windows might break during transportation and already installed items can still get damaged as other items are being installed. Because of factors like these, the quantifying process of material needs is far from an exact knowledge. Experience and a bit of luck can play a major part when it comes to making a good or bad decision.

**Delivery time plan**

The documents and activities described above together generate the decision basis for the delivery time plan. The time plan is established for all major components needed for the construction phase. Examples of products and materials included are plasterboards, concrete elements and kitchens. The delivery time plan is often visualized in the construction personnel's barracks using whiteboards, as displayed in Image 2. Small deliveries of standard material of low individual impact to the project, such as screws, electrical wiring, etcetera, are in general not included in the delivery time plan.
Framework agreement

Skanska has a large number of framework agreements with suppliers of construction material and services. A framework agreement is a contract between a client and a supplier, which enables the client to buy a product or a service at predetermined conditions. The framework agreements are to be used whenever there is one for the relevant product that is to be purchased. However, exceptions commonly occur, especially if they can be motivated by lower cost or better confirming specifications. Framework agreements cover approximately 50% of all purchases in Skanska’s residential projects in Stockholm and they typically include items such as plasterboards, windows and kitchens.

Project specific purchase

Exceptions from the framework agreements are typically called project specific purchases. There are predetermined company conduct procedures for doing a purchase of this nature:

1. Purchase preparations.
2. Letter of enquiry.
3. Tender evaluation.
4. Procurement.

Integrated Business Exchange

Integrated Business Exchange (IBX) is a purchasing software solution used by Skanska since 2004. It is illustrated in Figure 19. The software contains a database of all framework agreement products and suppliers Skanska maintains. Framework agreement purchases are made directly in IBX and IBX automatically forwards the purchase order to the supplier. A
purchase order contains information such as item, quantity and contact information. A buyer can also attach maps of the construction site so the forwarding agent can find his way.

When project specific purchases have been made they can and should be reported into IBX afterwards in order to provide Skanska with relevant statistics. IBX also supports the predetermined conduct of performing project specific purchases via the function IBX Request.

**Supplier, wholesaler and logistics center**

A purchase order is sent to a supplier, wholesaler or logistics center. It is done either automatically through IBX or manually. An order confirmation is typically returned.

**5.1.2 The material flow**

In this section the physical flow of materials to the worksite is presented. This flow is divided into two categories: Logistics before and logistics at the worksite. A generic illustration is presented in Figure 20.
Figure 20: Generic illustration of the material flow (Source: Kyhlberg & Persson, 2010).

**Terminal**

A terminal is a location that functions as a transportation node. At a terminal, deliveries from several suppliers can be repacked onto a single truck going to a construction site. For a more detailed description, see 4.4 Terminals.

**Arrival at site**

If specified in the purchase, the forwarding agent will notify the construction site an hour in advance before arriving at site. If a notification was not ordered the forwarding agent will typically not contact the construction site before hand under the condition that he will arrive during the agreed upon time window. Once at site, the material gets unloaded either manually, or more commonly, using a tower crane, a wheel loader or similar equipment. Before or during this offloading process the items are inspected and if everything is in accordance to specifications, the delivery is accepted. If goods are damaged, site personnel can refuse to accept the damaged goods and send them back with the forwarding agent. Sometimes this procedure is not possible and site personnel must receive the damaged goods as well. In both cases a complaint process begins and new materials must be ordered. After the inspection the dispatched material is offloaded.

As stated above, offloading at site typically requires machinery such as wheel loaders and cranes. Commonly, a project does not have a wheel loader at the site all the time since they cost a substantial amount of money. Therefore, these wheel loaders are often rented for a couple of hours at a time when goods reception is scheduled. Crane time is often in short supply and has to be planned in advance. Because of this, goods reception that is to be
handled by a tower crane is often planned to timeslots where the crane is not fully utilized, usually early mornings before production starts or as close to it as possible.

**Inventory at the site**

If the material can't be moved into the building right after delivery, it needs to be stored on site. This can be done in a garage under the building, in a tent at the site or simply on the ground. Image 3 displays small temporary storages of material on the ground.

![Image 3: Small inventories at a construction site (Source: Kyhlberg & Persson, 2010).](image)

**Moving material into building**

There are typically three ways of moving material into the building. It can either be lifted floor by floor by the tower crane while the shell of the building is being erected, by a wheel loader through windows or balcony doors, or it can be carried manually using staircases and elevators. Material can be lifted directly from the back of a delivery truck or from an on-site inventory.

The most common way to deliver large bulk materials, such as plasterboards and steel beams, is to use a tower crane to lift the packages on to supporting legs in the area where it is going to be installed later on. In order to do this, access to the designated floor from above is required. Therefore, this sort of delivery is done during the framework construction, before the floor above is installed. Materials that are more sensitive to exposure or would be in the way of other activities, such as kitchen, are not suitable to this way of delivering materials. They are often delivered in a later stage of the construction using machines or are carried in manually, using for example elevators or balcony doors.

**Inventory in the structure**

Since all material can’t be used at once, some typically must be stored inside the building. Ideally, everything is stored in close proximity to the point of installation in the apartment it is later to be used in, but having one inventory per floor is also common. Sometimes it is not
even possible to store materials at the same floor that it will later be used in due to factors like lack of space or that other activities must be completed first, such as plumbing, installation of the flooring or inner walls. In these cases the materials will have to be moved again before installation, either directly to the point of installation or to a new storage area. Temporary storage inside a building is displayed in Image 4.

![Image 4: Inventories in a building (Source: Kyhlberg & Persson, 2010).](image)

**Installation**

The required material is fetched from where it is stored and then installed. The installation is carried out either by Skanska’s own staff or by sub contractors.

**Control**

Once installed, everything is controlled before the apartment is handed over for final external survey.

#### 5.2 Waste in the logistic process

In this section, waste in the logistic process of made-to-order products is presented as identified by Skanska personnel. The focus area of the waste identification process is to identify where materials are in danger of getting damaged, when materials are moved more than needed and unnecessary administrative efforts. In Figure 21 the identified waste areas are presented. The explanations in the textboxes are linked to headlines in the following section.
Figure 21: Waste in the logistic process. The different colors indicate the activities' value for the costumer. Green indicates that it is a value adding and necessary activity. An activity marked yellow may not be value adding for the costumer but might be necessary for the construction process. Red indicates that the process is neither value adding nor necessary for the construction process (Source: Kyhlberg & Persson, 2010).

Previous research presented at Skanska 2008 identified four different types of logistics related costs: Inventories before the construction site, transports, material handling at site and inventories at the construction site, illustrated in Graph 2. This report did not, however, include damaged goods and its effects. Due to confidentiality reasons, exact numbers cannot be presented, but the chart provides a good understanding of how the direct costs in the logistic process are distributed. The logistics cost were estimated to about 10 % of Skanska’s turnover.

Graph 2: Skanska’s logistics costs, damaged goods are not included (Source: Skanska)
**Transportation costs**

Transportation costs from suppliers to construction sites are major cost items in the logistic process. These costs are impossible to avoid completely but work is constantly being conducted to decrease them.

When material is transported on-site, heavy machinery such as wheel loaders and tower cranes are often used. These too cost a substantial amount of money. Personnel costs are also a major cost unit when moving material. It is estimated that 25 % of a construction workers time is spent on transporting material around the construction site.

**Transportation damage**

All form of transportation and movement is potentially harmful to materials. Movement and vibration in a truck or boat can cause shaving or cause items to fall over, damaging themselves and other materials. Damage can also occur while items are being moved by hand or by a machine at site, as well as when materials fall off or bump into stationary items such as walls. During transportation materials might also be exposed to cold and wet weather, which is potentially harmful. The occurrence of transportation damage for three different products, as estimated by site management, is displayed in Graph 3:

![Graph 3: Goods damaged during transportation to site](image)

Graph 3: In this graph the percentage of components that are damaged during transportation to the construction site is illustrated. The vertical axis displays the percentage of answers in each category (Source: Kyhlberg & Persson, 2010).
Terminals

The use of a terminal service will require an additional amount of transportation. Material will also be moved as it is re-loaded at the terminal, which also requires labor. For a further description, see section 4.4 Terminals.

Transport uncertainties

In many cases transport uncertainties, i.e. questions like “will the transport arrive on time?”, “is the material on the way?” and “where is my transport? It should have been here by now”, can cause problems for, primarily, foremen and project engineers. These are not unwarranted questions to ask since a Skanska report concluded that only 70 - 80 % of all transportations are on time. Not knowing if a transportation will arrive on time will sometimes prompt the person responsible for incoming deliveries to call ahead to verify that the transportation is coming. Other times they will think that the transportation will arrive on time and therefore stand prepared to receive it only to find out that it did not arrive on time. This results in personnel standing idle, machinery being rented unnecessarily and extra work for the foreman who has to find out what happened to the transport.

Control difficulties

Arriving goods is always supposed to be controlled for damage. This is typically done visually and damage to the wrapping is normally photographed so the photo later can be used to support complaints. However, due to a tight time schedule and large quantities of materials arriving at the same time, performing a thorough inspection might prove to be difficult, resulting in all damages not getting detected. Additionally, material is commonly moved into the structure where it is stored for some time until it is eventually used. Damages discovered when the material is to be installed might in fact have been caused during transportation or at the supplier. Proving this has been the case can however prove to be difficult if the material has been stored for an extended period of time. See Complaint problems further down in this section for additional discussion.

In addition to above mentioned difficulties, controlling that the material received is in fact the material ordered might also be hard. At times these errors will not be detected until the material is to be installed.

On- and offloading

On- and offloading is a potential danger to materials. Forwarders and suppliers are often accused by site personnel to handle goods carelessly when on- and offloading, causing harm
to both the wrapping and the product. Therefore site personnel strive to minimize the number of on- and offloads an item must go through before it reaches its point of installation.

As mentioned before, on- and offloading often requires machinery such as wheel loaders and tower cranes. When a transport does not arrive on time this machinery and the personnel manning them stand idle, costing money without getting any work done. When it comes to tower cranes the result is that a new timeslot for offloading has to be planned. When it comes to wheel loaders, which are commonly rented, the construction site often places a complaint to the forwarder for the renting cost. This complaint requires time to write, costing the project money in lost work time.

**On-site material handling**

Any kind of unnecessary movement is to be considered waste. Two different types of movement can be identified.

- Personnel moving material to an inventory.
- Workers collecting material at the inventory to bring to where it is to be installed.

In terms of balancing the two types of movement, two extremes can be noted. In the first extreme, illustrated in Figure 22, material is placed at one inventory, all workers going there to gather the material they need for the moment. This will minimize the initial need of material transportation to the inventory, but maximize subsequent movement and transportation as employees move back and forth between where they are working and where the material is stored.

![Figure 22: Generic picture of first extreme (Source: Kyhlberg & Persson, 2010).](image-url)
In the other extreme, as material is moved into the building it is all placed adjacent to the point of installation. This will maximize the initial material transportation and time will be required to sort material and ensure that each work location receives the exact amount that is to be used. However, once all material is in place workers will not have to spend their time collecting material. This extreme is displayed in Figure 23.

Figure 23: Generic picture of second extreme (Source: Kyhlberg & Persson, 2010).

Any combination of the two above mentioned extremes that does not minimize the total need of movement is to be considered to contain unnecessary movements, i.e. waste. As previously mentioned, according to interviews and previous research, approximately 25% of a worker’s time is typically spent handling material. This is a substantial amount of time and as a result, efforts are made to minimize this time spent.

Graph 4 displays how often three different material types typically are relocated on-site. Relocating material does not add any value, but rather increases the risk of damage. Hence, relocation should be minimized. At Skanska worksites, doors are typically relocated more often than kitchen and plasterboards. In interviews with site management, problems with damaged doors have typically been mentioned.
Graph 4: The diagram illustrates how often different material types are being relocated on-site. The vertical axis displays the percentage of answers in each category. As seen in the diagram, doors are typically relocated more frequently than kitchen and plasterboards (Source: Kyhlberg & Persson, 2010).

Wrapping problems

The wrapping around products is, according to many site personnel, commonly inadequate. Due to this transportation damage in the form of shaving occurs more commonly than would otherwise have happened. The main concern is however weather related problems such as water damage. When the wrapping is not adequate, water can leak into the wrapping or condensation might occur, damaging materials such as kitchens, plasterboards, doors, etcetera. The average opinion of the wrapping of three different products is illustrated in Graph 5.
Graph 5: The average opinion of the quality of the wrapping of three different products, where 1 is “very negative” and 5 is “very positive”. As seen, the results are similar for the different products, with doors and plasterboards scoring just below “acceptable” and kitchen just above (Source: Kyhlberg & Persson, 2010).

Inventory damage and consequences

When a construction project stores material on-site or in the structure there is a risk that the material will be damaged. This is because of the hostile conditions on-site in form of bad weather conditions such as rain, snow, moist, wind and cold. Projects try to counter these factors by ordering materials covered in plastic sheeting and moving the materials indoors as quickly as possible. When it is not possible to move vulnerable material indoors they try to cover the materials with tarps or move them into temporary tents. Cold temperatures can also cause problems due to the fact that materials shrink in the cold, which damages some items. In other cases it is hard to install cold materials since they will expand during or after installation in a heated building. Graph 6 illustrates how common it is for different material types to be stored outdoors for at least one night.
Graph 6: The graph illustrates the frequency of material being stored outdoors at least one night before it is moved into the building. The vertical axis displays the percentage of answers in each category. The more valuable items appear to be moved into the building quicker than plasterboards, which more commonly are stored outdoors at least one night (Source: Kyhlberg & Persson, 2010).

Other factors also play a major part in the bad storage conditions. For example, small inventories are often placed in areas where work is being conducted. This results in accidents where personnel damage stored materials unintentionally when performing other tasks. Common materials in storage, such as plasterboards, plywood, etcetera, also have a tendency of “disappearing” as workers move in to a storage area and take what they need without consulting the “owner” of said inventory. This results in uncertain inventory levels.

Inventories also result in other consequences than damages. An inventory causes the need to move more materials at least one additional time. The minimum amount of movement at the worksite is generated when an object is transported directly from a delivery truck to the point of installation. When inventories are used, items must first be moved from the truck to the inventory, then to the point of installation. This extra movement is both potentially harmful to the material and requires extra personnel time.

When materials are stored they utilize space. This is a key factor when planning work and inventory levels at the construction site. Occupied space cannot be used for working and obstacles might get in the way of construction activities, causing production delays and extra costs. At the same time, there is also an opportunity cost in the form of cost of capital associated to tying down resources in inventories.
A last effect of inventories is that they are potentially hard to keep track of. Once specific material is stored it will become increasingly difficult to keep track of what quantity is stored and where. As a result, time must be spent looking for requested items as well as determining how much currently is in store.

**Damaged and incorrect goods from supplier**

It happens that material from suppliers is damaged or incorrect when arriving at site. This can be discovered when it arrives at site or later in the work flow, if so usually at the time of installation. This results in a number of consequences:

- Personnel have to order new materials.
- Production delays due to missing materials.
- A complaint will most likely be filed against the supplier in order to receive financial compensation or a new product.
- All logistics work with the item up to this point has been to no purpose and damage and incorrect items also have to be disposed of. This causes more transportation work and potentially refused material.

According to the questionnaire, this problem is more frequently occurring than for doors and plasterboards. The results are displayed in Graph 7.

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**Graph 7:** The graph illustrates the percentage of kitchen in a construction project that is delivered with wrong, missing or broken parts. The vertical axis displays the percentage of answers in each category (Source: Kyhlberg & Persson, 2010).
Materials can be brought in from a different source, usually from another inventory at the same construction site, in order to keep production running. This only works with common components and not customer specific ones.

Complaint problems

When goods arrive damaged at a construction site, Skanska usually files a complaint in order to receive financial or material compensation. This can however be both a time consuming and frustrating process for the personnel involved. A complaint process is often conducted according to the following pattern:

1. Skanska personnel discover damaged goods.
2. A foreman or a project engineer files a complaint, either via telephone or electronically.
3. The supplier argues that the goods sent were undamaged and that the fault is either with the forwarder or with Skanska.
4. A process of determining and proving where the damage occurred is initiated. This at times results in a situation where Skanska, the supplier and the forwarding agent blames one another.
5. All parties involved spend time on the complaint instead of other value creating tasks.

Poor or missing feedback systems

Skanska lacks proper feedback systems for reporting supplier deviation or performance problems. According to the conducted questionnaire, three quarters of all projects claim they report less than fifteen % of all issues to relevant central Skanska functions, such as the support functions within the Nordic Procurement Unit. Instead of reporting the problem to Skanska, projects have a tendency of solving the problem directly with the supplier, ignoring to afterwards report the issue. Thus, Skanska is not able to keep accurate statistics of deviations and other supplier related problems. Data from the questionnaire on how frequently issues are reported to central Skanska units is displayed in Graph 8. One respondent claims: “Poor feedback to Skanska centrally, since you rarely get any response on your feedback”.
Graph 8: The graph illustrated how frequently issues with a delivered product are reported to relevant central Skanska unit. The vertical axis displays the percentage of answers in each category (Source: Kyhlberg & Persson, 2010).

The control process

Unless accidents happen during it, the control process does not generate any waste of its own to the supply chain. This is of course only true if putting aside the fact that it is a control and in accordance to lean theory all control processes are regarded as waste since they do not contribute to customer value.

The installation process

The installation process is necessary. However, there is also a potential of generating waste in it. Installation techniques might be sub-optimized, personnel might have inadequate training, etcetera. From a logistics perspective the biggest factors that generate waste is unnecessary waiting time, excess inventories and movement of people and goods.

Waiting time is generated when a worker does not know what to do or is waiting for material. This is not that common in the construction industry since companies try to counter this by having inventories on site. These inventories can be situated just next to the point of installation or far away. From a waste perspective, the closer to the point of installation the material is the better.

As a final comment on the installation process, even if workers are not idle, their work might still be considered waste in a making-do perspective. For a theoretical discussion on the subject, see 3.4.1 *Six core elements of lean, Making-do.*
Supplier and wholesaler

Looking into detail of the suppliers’ and wholesalers’ activities, investigating waste and improvement potential in their internal processes, is considered beyond the scope of this report. Therefore the logistics process “starts” when a completed product leaves the manufacturer and is ready to be packaged and loaded onto a truck. The identified risk in this part of the process is mainly damage during loading and as a result of inadequate wrapping.

The potential of improvement and integration between Skanska and their suppliers could, however, be substantial. This is based on the fact that many problems that occur in one project are often observed in other projects as well. If Skanska coordinated observed deviations and improvement potential in their construction projects and worked together with their suppliers, competitive advantages could be achieved. Skanska's frequent use of framework agreements supports this approach in accordance to lean literature. This potential is however wasted in many cases in today’s operations.

Ordering difficulties and incorrect shipments

When ordering materials, there is always a risk of errors. This essentially comes down to two problem areas: One when personnel make mistakes by accident and one when personnel do not know what items to order or in which quantity.

When a mistake has been made in the ordering processes, incorrect materials or quantities arrive at the construction site. If the wrong materials are ordered, problems arise in the form of extra work for handling the said materials and ordering new ones, which often creates long lead times. It is sometimes hard to return the incorrect materials, resulting in sunk costs.

When personnel know which item they need but do not know the exact quantity it is common that extra orders will have to be placed at a later point in time. Ordering too much will result in inventories. In both cases extra work is created. The later extra lead times can also occur if they cannot get new materials in time. This, however, varies since it is often bulk materials, such as plasterboards that, are hard to determine the required quantity. These bulk materials are often possible to take from different inventories, example from a different floor or apartment, to fill a short term need. This action prevents production to grind to a halt but requires extra on site transportation and can result in a situation where it is hard to keep track of inventories.
6 Evaluation of the relevant logistics solutions

In this chapter possible solutions to enhance waste reduction are presented. Some of the solutions are already in use, but not on a wide scale. Since the scope of this report is rather wide the solutions will have a synoptic approach.

Through interviews and literature, we have concluded that there are four primary factors when deciding upon which logistic solution a project should use. The primary factors that are taken into account are:

- The point in time when materials are being delivered: The closer to the time of installation an item arrives, the better. This is a widely accepted thought both among construction personnel and in lean theory. The main advantages are that the risks of damage to the materials correlates to the time spend on the construction site and that inventories occupy space often needed for other activities.
- How close to the point of installation material is delivered: The closer to the point of installation an item is placed, the better. This thought can be traced back to lean theory where unnecessary movement of material and personnel are defined as two types of waste. By placing material as close to the point of installation as possible, these types of waste can be minimized, thus reducing the cost of material handling.
- The risk of damage to the materials: Damaged materials are of no use to a construction project and are therefore supposed to be kept to a minimum.
- How much the logistic alternatives cost: The cost of different logistic solutions must be weighed against the benefits of said solution in order to determine which solution is the most profitable. This factor is generally the hardest of the four to estimate. In this report we are not able to provide a detailed cost analysis due to limited data and time.

6.1 Deliveries during framework assembly

Materials delivered during the framework assembly are delivered to a floor, typically using a tower crane, before the floor above is installed. There are two primary ways of delivering doing this: the default way and via installation packages. In the following section these two methods are presented.

The default way

The default way of transporting large, heavy materials into the structure during the framework assembly is to deliver materials according to type. Plasterboards are delivered separately from beams and so on. Materials can, however, be placed in different areas, for example one
plasterboard bundle in each corner of a floor. The reason the materials are being transported into the structure in this early stage is that it will become more difficult and time consuming to do it in a later stage when the ability to lift the materials in complete bundles are limited or impossible. The benefits and disadvantages of this delivery method are listed below:

Benefits of deliveries during framework assembly:

- The material is transported directly to the floor where they are going to be installed, resulting in:
  - Decreased need to transport materials around the construction site compared with on-site inventories.
  - Decreased risk of transportation damage at site.

Disadvantages of deliveries during framework assembly:

- Material often arrives at the construction site before it is to be used, which leads to:
  - Increased risk of inventory damage since the materials might get exposed to humidity, cold and collisions.
  - The materials is typically stored inside the structure on supporting legs, which means that it is in the way of construction activities such as casting the floors. When the floors are casted the supporting legs will leave holes in the floors, which have to be filled.
  - An increased risk of complications during a complaint procedure, since damages might remain hidden for a longer period of time.

A summary of the benefits and disadvantages of deliveries during framework assembly are listed in Table 1. This method of delivery does not conform to lean theory since it involves large batches, inventories and long lead times. The method, however, is a relatively easy and cost effective (according to interviews with production personnel) way of transporting materials compared to the other primary default delivery method: transporting the material via elevators or wheel loaders.

<table>
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<th>Comment</th>
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<tbody>
<tr>
<td>Time of delivery</td>
<td>Poor</td>
<td>Materials are delivered well before installation</td>
</tr>
<tr>
<td>Distance to point of installation</td>
<td>Acceptable</td>
<td>Materials are delivered to the floor of installation</td>
</tr>
<tr>
<td>Damage risk of material</td>
<td>Acceptable</td>
<td>Risk of inventory damage</td>
</tr>
</tbody>
</table>

Table 1: Summary of default delivery during framework assembly (Source: Kyhlberg & Persson, 2010).
Installation packages during framework assembly

The concepts of using installation packages for large, heavy items that are delivered during the framework assembly have been used for some time in Skanska. This concept has, however, not become standard procedure. In order to have a common ground for a discussion about installation packages, identified benefits and disadvantages of the concept are presented below.

Benefits of installation packages:

- The material is transported directly to a point in the vicinity of installation, resulting in:
  - Decreased need to organize materials at site.
  - Decreased need to transport materials around the construction site.
  - Less need to locate material since it is already close to the point of installation.
  - Decreased risk of transportation damage at site.

Disadvantages of installation packages:

- Material often arrives at the construction site before it is to be used, which leads to:
  - Increased risk of inventory damage since the materials might get exposed to humidity, cold and collisions.
  - The materials is typically stored inside the structure on supporting legs, which means that it is in the way of construction activities such as casting the floors. When the floors are casted the supporting legs will leave holes in the floors, which have to be filled.
  - An increased risk of complications during a complaint procedure, since damages might remain hidden for a longer period of time.
- Increased cost before site:
  - In order to use installation packages, materials must be packaged into specific bundles that are labeled with identification information, i.e. apartment number. This is usually made by the supplier who will charge extra for this service.
  - Time must be spent deciding which quantities go into which installation packages and the location for them must be determined.

The concept of installation packages addresses described problems in section 5.2 Waste in the logistics process both positively and negatively. Identified waste areas that could be positively affected by installation packages are primarily on site material handling in accordance to the identified benefits of said concept. Koskela’s theory regarding making-do
(2004) also indicates that installation packages reduce variability in the material flow, thus reducing the effects of waste related to making-do.

Material handling on-site is Skanska’s largest logistics cost according to a report from 2008. The IMS cost analysis from the 90’s concluded that the transportation cost of the offloaded materials to the point of installation is the largest cost item for plasterboards. Because of these factors, on-site material handling seems to be a suitable focus area of cost reduction and installation packages could be an important part of that process. The approach of transferring site activities upstream in the supply chain is also in accordance with general lean theory and a cornerstone in any attempt to industrialize construction work.

The disadvantages of installation packages can primarily be connected to the following identified waste areas: inventory damage and its consequences, as well as complaint problems. The increased risk of inventory damage is due to the fact that a substantial amount of all installation packaged material arrives earlier than when the material is needed. This is, as mentioned earlier in the report, a consequence of limitations in the transportation process into the structure. The increased risk of complaint problems can be linked to the early deliveries where material is not used for some time. The time window for complaints might therefore be over when a defective product is detected, leaving the project with a product that costs money but can’t be used.

Reports from Skanska, that we due to confidentiality reasons cannot present uncensored here, indicate that using installation packages during the framework assembly are reducing costs and effect production positively. These reports, however, do not include all negative effects that we have observed via interviews and own observations. For example they do not take inventory damages and its consequences into account. In interviews and in the questionnaire it has been indicated that materials delivered early to the construction site are more likely to get damaged than materials delivered shortly before being installed. But installation packages do not alone increase the use of early deliveries. In present construction projects, large bulk materials, such as plasterboards and beams, are already being lifted in during the assembly of the framework. Therefore these types of installation packages do not increase the risk of inventory damage and following consequences, despite the fact that they often require early deliveries. Additionally, as seen in Graph 9, the general attitude towards installation packages is positive among site management.
Graph 9: Respondents opinion about installation packages, where 1 represents “very negative” and 5 “very positive”. The vertical axis displays the percentage of answers in each category (Source: Kyhlberg & Persson, 2010).

Our conclusion about installation packages is that the concept has an overall positive impact for residential construction projects when delivering large, heavy items during the framework assembly, compared to not using them. This positive impact seems to include both financial and production benefits. Pilot projects indicated a financial gain compared to regular procedures, and the advantages of not having to transport materials from a central on-site inventory seems to outweigh the disadvantages of storing them for a longer period of time inside the structure. This approach is, however, in some aspects far from the concept of lean construction, where inventories are supposed to be kept to a minimum. Furthermore the majority of observed negative effects can also be derived from inventory damage and its consequences. Therefore we strongly recommend projects to take other alternatives, such as installation packages after framework assembly and carry-in services, into account when deciding upon how to have their material delivered. The factor to take into account when deciding upon when materials are delivered is primarily the transportation limitations and the space that possible inventories occupy. For a summary of the concept based on the four primary factors see Table 2.
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<tr>
<td>Time of delivery</td>
<td>Poor</td>
<td>Materials are delivered well before installation</td>
</tr>
<tr>
<td>Distance to point of installation</td>
<td>Good</td>
<td>Materials are delivered close to the point of installation</td>
</tr>
<tr>
<td>Damage risk of material</td>
<td>Acceptable</td>
<td>Risk of inventory damage is relatively high</td>
</tr>
</tbody>
</table>

Table 2: Summary of installation packages during framework assembly. Our recommendation is to use this concept when delivering materials during framework assembly (Source: Kyhlberg & Persson, 2010).

6.2 Deliveries after framework assembly

There are four primary ways of delivering materials into the structure after the framework is assembled: the default way, via installation packages or kitting and carry-in services. In the following section these four methods are presented.

The default way

The default way of transporting materials into the structure after the framework has been assembled is to use on-site inventories for storage and elevators and manual labor for transportation. Projects can also use wheel loaders and balcony doors to transport materials from ground level into the structure. These methods often require that the material is first offloaded into a temporary or permanent storage area before being transported into the structure. Workers can then use the delivery approaches described in section 5.2 Waste in the logistics process, On-site material handling.

This way of transporting materials is highly un-standardized and it is therefore hard to make any general conclusions. As a result of that we will not analyze this delivery method any further.

Installation packages after framework assembly

The difference between installation packages during and after framework assembly is mainly the time and method of delivery. From a time perspective, installation packages delivered after the framework is assembled are often delivered closer to the time of installation. This delivery time is, however, still often days or weeks ahead of installation. This results in a situation where materials are at risk of inventory damage and its consequences. The second major difference, the delivery method, is that materials cannot be lifted in directly from above. Therefore transportation into the building is often more complicated and time consuming.
When discussing the concept of installation packages with Skanska personnel, no uniform attitude is given. Instead, the opinion varies depending on what type of material is discussed. The attitude towards installation packages of different materials is displayed in Graph 10.

![Graph 10: Items suited for installation packages](image)

Graph 10: The columns illustrate how often an item is mentioned to be suited for installation packages. The vertical axis displays the percentage of answers in each category (Source: Kyhlberg & Persson, 2010).

Today when Skanska personnel talk about installation packages after framework assembly they mainly talk about kitchen and doors. These products often arrive directly from the supplier. In order to optimize the utilization of transports to the construction site and offloading equipment, such as wheel loaders, projects often receive full trucks in each delivery. This results in the earlier mentioned need to store material before installation. This large batch approach does not follow lean theory, but according to Skanska personnel it is not financially defendable to use smaller batch sizes. On the other hand, the pre-organization of materials corresponds to industrialized construction principles and Koskela’s theory regarding making-do (2004). A summary can be found in Table 3.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Rating</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time of delivery</td>
<td>Acceptable</td>
<td>Large batch sizes leads to inventories</td>
</tr>
<tr>
<td>Distance to point of installation</td>
<td>Good</td>
<td>Materials are delivered close the point of installation</td>
</tr>
<tr>
<td>Damage risk of material</td>
<td>Acceptable</td>
<td>Risk of inventory damage</td>
</tr>
</tbody>
</table>

Table 3: Summary of installation packages after framework assembly. Our recommendation is to use this concept when delivering materials after framework assembly (Source: Kyhlberg & Persson, 2010).
Kitting

The concept behind kitting is closely related to installation packages and they therefore share several advantages and disadvantages. The main difference is that kitting includes smaller and lighter packages which as a consequence can be delivered closer to the time of installation. With that said, one of the biggest disadvantages of installation packages, the often required need for the packages to be delivered well before they are required in the installation process, does not apply to kitting. At the same time, the advantages of installation packages, i.e. the decreased need to organize, transport and locate materials, still apply. Both interviews and theory has indicated that waste in the form of unnecessary movement of people and materials as well as making-do could be decreased by using kitting. At the same time, work control for the foremen could be simplified since, for example, contractors would know exactly what to install in an apartment since the required materials are already located in said apartment. These benefits have to be weighed against the cost of packaging the material before site and the time required to make apartment specific orders.

The recommendation we give to Skanska is that kitting has a substantial potential in reducing cost of material handling on-site for small, light items. This potential, however, must be weighed against the cost of packaging and the development and implementation of the concept. A risk in this is that it is hard to quantify the benefits of the concept compared to relatively easily conducted analysis of the costs. Therefore a pilot project comparing traditional methods to kitting could be very suitable. By using this approach Skanska could evaluate kitting compared to ordinary residential construction approaches and thus gain the proof-of-benefit that is needed for a wide scale introduction. A summary of kitting effects can be found in Table 4.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Rating</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time of delivery</td>
<td>Acceptable</td>
<td>Materials can be delivered close to the time of installation</td>
</tr>
<tr>
<td>Distance to point of installation</td>
<td>Good</td>
<td>Materials are delivered close the point of installation</td>
</tr>
<tr>
<td>Damage risk of material</td>
<td>Good</td>
<td>Short inventory time and few movements</td>
</tr>
</tbody>
</table>

Table 4: Summary of kitting. Our recommendation is to use this concept when delivering small, light materials (Source: Kyhlberg & Persson, 2010).

Carry-in Services

The advantages of using carry-in services can be summarized in:

- Carry-in service personnel typically cost less per hour of work compared to Skanska workers.
• If carry-in services are used there is, according to one Skanska report, no need to use lifting equipment, such as tower cranes and trucks, thus reducing costs. This is, however, unlikely according to interviews with construction personnel. Some equipment should still be needed to offload incoming delivery trucks. Hence, estimating this factor is hard.

• The work is in general carried out when production is not active, resulting in less interruptions to production and increased productivity.

• Materials are often placed close to the point of installation in quantities required to carry out an installation.

• Materials are often delivered close to the time of installation.

Identified disadvantages, mainly based on interviews with production personnel, include:

• Communication problems:
  o Carry-in service personnel often misinterpret instructions from foremen, resulting in materials being misplaced. Identified reasons for this is that carry-in service personnel have no construction experience which results in misplacements and inefficient storage. Communication problems can also derive from language difficulties since carry-in service personnel who do not speak Swedish are common.
  o Site personnel often have initial difficulties with ordering required materials at least a day in advance compared with having an on-site inventory. This can lead to situations where materials are missing.

• Damage: Site personnel often state in interviews that they want to carry their own materials, since they then know that it is handled with care. To let other personnel, especially carry-in service personnel, carry their material is often indicated to cause increase damage, both to the material and the surrounding environment. This is, however, not a general opinion. Both site personnel and staff personnel defend carry-in service personnel and results in our questionnaire are not conclusive. Therefore it is hard to determine whether or not carry-in services increase the risk of damage or not.

• There is also a potential problem with the current employment agreement with Skanska’s construction workers. In the current piece-work contract, the labor of relocating material to the point of installation is included. This is something unions have been reluctant to negotiating about. As a result, Skanska could end up paying for the service of relocating material twice if using carry-in services.
Carry-in services of large and heavy materials, such as plasterboards, are relatively common in commercial projects where factors such as space for movement and production rates, are suitable for this service. Residential projects often have different conditions from commercial projects which do not support this kind of service for these types of materials. These materials are instead often delivered during the framework assembly. Materials that are delivered after the framework assembly, on the other hand, are not hindered by technical difficulties in most cases since they are already carried in by production personnel.

Our opinion about the concept of carry-in services is that it is something Skanska’s residential projects should use to a larger extent for materials that are delivered after framework assembly and that do not require heavy machinery to be transported. We base this conclusion on the advantages of not having to disturb production, since deliveries are made when production is not active, for a lower cost than if Skanska personnel did the work instead. This increases production rates and decreases costs, as shown in pilot project Skärholmen. At the same time, the already discussed negative effect of increased risk of damage to materials has not been proven in neither interviews, nor questionnaire. A key factor for the success of carry-in services is, however, communication. If the communication between workers and foremen does not work, material will not be ordered in time. This can result in missing materials. If the communication between carry-in service personnel and the foremen does not work materials will be misplaced, thus resulting in extra work. Using carry-in services adds an extra part to both planning and execution of a project, which puts extra pressure on the site management team members. But if the concept works according to plan it should deliver financial and production benefits as indicated in Table 5.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Rating</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time of delivery</td>
<td>Good</td>
<td>Materials are delivered close to installation</td>
</tr>
<tr>
<td>Distance to point of installation</td>
<td>Good</td>
<td>Materials are delivered close the point of installation</td>
</tr>
<tr>
<td>Damage risk of material</td>
<td>Good</td>
<td>Short inventory time, unchanged transportation risk</td>
</tr>
</tbody>
</table>

Table 5: Summary of carry-in services and its benefits (Source: Kyhlberg & Persson, 2010).

6.3 Logistics center

For a description of how Skanska’s logistic centers function, see 4.5 Logistic centers. In this section, advantages and disadvantages of using the concept will be listed.

Main benefits of using the services logistic centers provide include:

- Decreased cost for construction projects on low quantity orders.
Since the center serves multiple projects, larger overall quantities enables the import of cheaper materials from foreign suppliers.

Offers Value Added Services such as re-packaging material into installation packages and providing additional wrapping.

The possibility to store custom ordered items up to a month, as well as the different order types (standard, quick and express) offer flexibility when planning fails.

Identified disadvantages with the logistics center concept in use today are listed below.

- Projects will not commit to procuring from the logistics centers until the purchase is to be made. This reduces forecasting predictabilities in terms of how much inventory the center is to keep at a given point of time.
- The full potential of the centers is not realized due to sub-optimized decisions in individual construction projects. Some projects chose not to use the centers because they might at times not be considered cheap enough. However, if the projects at the borderline of profitability started procuring more from the centers, total volumes would increase and offer overall better profitability for Skanska.
- The logistics center is not able to match prices for projects ordering large quantities of goods.
- The use of a logistics center will always result in at least one additional on- and offloading activity, hence increasing risk of damage.

The use of logistic centers is today attractive for projects ordering smaller volumes, as well as for projects ordering custom material from far away locations. There is also, according to us, a future potential of merging the logistics concept with the terminal solution, which will be discussed further in 6.4 Terminals.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Rating</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time of delivery</td>
<td>Good</td>
<td>Materials can be delivered close to installation</td>
</tr>
<tr>
<td>Distance to point of installation</td>
<td>Good</td>
<td>Enables installation packages</td>
</tr>
<tr>
<td>Damage risk of material</td>
<td>Acceptable</td>
<td>Extra on- and offloading, but can provide additional wrapping</td>
</tr>
</tbody>
</table>

Table 6: Summary of logistics centers and their benefits (Source: Kyhlberg & Persson, 2010).

In our opinion, logistics centers fill an important role as a supplier of materials to Skanska projects and are key element in procurement decisions. Logistics centers could also, due to short delivery times, play an important role in enabling shorter lead times of material deliveries, thus laying a foundation for improving lean construction concepts and reducing
waste. This can be observed in Table 6. In order for the concept of logistics centers to be fully developed, their turnover has to be as large as possible. To enable this, individual projects must start looking at the bigger picture and utilize this service when possible.

6.4 Terminals
Implementing a terminal solution as described in 4.4 Terminals brings several benefits as listed below.

- Decreased number of transports to the construction site which leads to:
  - Decreased need to use heavy machinery for offloading (i.e. less need to rent trucks and utilize tower cranes).
  - Decreased number of transports to keep track of from a site personnel view
  - Less manpower spent on offloading.
- Enables additional use of installation packages and the benefits of that concept.
- Due to the integrated tracking system of planned deliveries, transport reliability is increased and the need to call in advance from the construction site to confirm that a scheduled delivery is on its way is reduced.

Disadvantages of terminals are listed below.

- Increased cost before site:
  - Costs of using the terminal and rearranging materials.
  - An extra truck delivery from the terminal to the construction site.
- More detailed planning is required, which takes time.
- Increased risk of damaging material since it has to be on- and offloaded at the terminal as well as being transported inside the terminal.
- Risk of materials being misplaced at the terminal, resulting in missing materials or materials being delivered to the wrong construction site.

The risk of materials being misplaced or delivered to the wrong construction site appears to be effectively countered by the new software under implementation. In addition, the software will also help offset the problem earlier labeled transportation uncertainties. Once implemented, personnel should be able to feel confident that a delivery is on schedule unless otherwise informed by the system. Hence, any need to call suppliers just to verify is eliminated. As seen in Graph 11, site personnel find delayed and too early deliveries to be among the most serious problems in their day-to-day work. Since the terminal concept addresses these problems, it can be assumed that site personnel would benefit from its implementation.

70 (78)
Graph 11: The columns display how often each type of category of problems has been listed as a top 3 priority out of 8 possibilities (Source: Kyhlberg & Persson, 2010).

All in all, the terminal concept developed by Skanska’s logistics department appears to be a solid case for implementation. Pilot studies indicate that the concept increases profitability of a construction project and the new software not only deals with the potential problem of ensuring that material doesn’t get loaded onto the wrong truck; it also deals with issues of uncertainty at the work site. These issues are hard to quantify in terms of costs, but it should always be a target to minimize them. A summary is provided in Table 7.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Rating</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time of delivery</td>
<td>Good</td>
<td>Tracking of one, instead of multiple deliveries</td>
</tr>
<tr>
<td>Distance to point of installation</td>
<td>Good</td>
<td>Enables installation packages</td>
</tr>
<tr>
<td>Damage risk of material</td>
<td>Acceptable</td>
<td>Extra on- and offloading</td>
</tr>
</tbody>
</table>

Table 7: Summary of terminals and their benefits (Source: Kyhlberg & Persson, 2010).

In the future we believe there is potential to develop the terminal concept further. Today Skanska utilize DHL both for their terminal service as well as the logistic center service as described above in 4.5 Logistics center. At Skanska’s logistics department there is a conviction that Skanska, as the use of the terminal services steadily increases, within a few years time period will construct their own terminal in the Stockholm area. A terminal owned by Skanska could potentially offer some or most of the services today offered by the Stockholm logistics center. For example, the same type of bulk material, such as standard plasterboards, could be stored at the terminal rather than the old logistics center. This would
offer the same kind of advantages offered by the logistic center, as well as increased abilities to temporarily store material when a construction project is faced with unexpected problems.

As earlier described, keeping on-site inventories should always be avoided. Typically, this can be avoided with good planning and by ensuring that the project is executed according to plan. However, there are always uncertainties you cannot plan for. In these cases, being able to temporarily store material at a combined terminal / logistics center would be a preferred solution to pushing it to the site. In order to counter abusive behavior, as in temporarily storing material elsewhere instead of putting utmost efforts into maintaining the master schedule, appropriate costs would need to be assigned to the storage option.

6.5 Feedback routines

Through our interviews with site personnel we have concluded that it is uncommon to report supplier deviations to relevant Skanska units, such as the Nordic Procurement Unit. When a product is delivered defective to site or if components are missing, the standard procedure is to simply address this with the supplier directly. This occurrence has also been confirmed by the questionnaire conducted, as displayed in Graph 8 found in 5.2 Waste in the logistics process.

The reason for this behavior seems to be that on-site personnel consider contacting the supplier directly a quicker way to address and solve the problem with the delivered materials than going through the central Skanska organization. While this might be true in the short run, there is a big caveat in the procedure. If all problems are solved by the projects themselves and the issue isn’t later reported to the relevant Skanska unit, which rarely seems to be the case, Skanska will not be able to retain a good understanding of how suppliers are performing and where improvement efforts should be concentrated. Statistics available to personnel responsible for supplier relations will indicate that there are far fewer problems than in reality.

The current procedure is according to us a sub-optimized way of solving issues. While each project considers it the quickest and most efficient way, the end result is that several projects complain about the same problems. Instead, if the problems were reported to the central Skanska organization, Skanska could work directly with the supplier to address the problem or rewrite poorly stipulated supplier contracts. An example of this is the identified problem area of wrapping. As indicated during our interviews, the general opinion of the quality of the wrapping is that it is relatively low. If the wrapping fails to protect the product during transportation, new materials have to be ordered and production rates will decrease due to extra work or long supplier lead times. If the materials are delivered to the construction site
and are exposed to weather the primarily risk is damage by damp. If this happens the entire process up till now has been in vain and new materials have to be ordered.

As discussed in 3.4.1 *Six core elements of lean, Cooperative relationships*, building long term relationships with suppliers to facilitate mutual learning is an important aspect of lean thinking. The same can be said about 3.4.1 *Six core elements of lean, Continuous improvements*. With the current feedback routines, or rather, the lack of them, Skanska is unable to develop their supplier relationships to their full potential, working together to find all sources of deviations. The obvious recommendation to Skanska in this case is to put effort into start utilizing or developing functional feedback routines in order to live up to the company’s own standard as illustrated in this citation:

As a final note on the issue, the software solutions implemented with the terminal concept earlier discussed will address this issue rather satisfactory. The software tracks all deliveries to and from the terminal. If there are any deviations, these will automatically be recorded. Hence, good statistics will be available for all material and suppliers passing through the terminal.
7 Recommendation to Skanska and SXC

In this chapter we present our recommendation regarding logistics solutions relevant for Skanska and SXC. The focus is on responsibility distribution for implementing and running the recommended approaches. Most of the approaches are already tested in Skanska but have not become standard operating procedures.

Logistics of MTO materials during framework assembly

That installation packages have positive effects on production rates, financial outcome and, to some extent, a theoretical damage reduction potential has already been presented in this report. As a result of this, the NPU is presently trying to implement and spread knowledge regarding installation packages during framework assembly in residential projects. A consequence of this is that the use of terminals will increase and be made mandatory for the projects that choose to utilize installation packages during framework assembly. The terminals enable the increased use of installations packages.

We believe that the use of installation packages should be made a standard operating procedure for SXC projects that decide to use material deliveries during framework assembly. We do not recommend, however, that SXC should have anything to with the development of the actual support system that needs to be operational in order to enable these types of deliveries. The NPU already has personnel working with these issues and they are close to developing a complete concept. The concept could also work in all kind of projects, regardless of it being a SXC project or not. Therefore it is not suitable to be developed for a specific construction approach such as SXC. What SXC should do is to assist the NPU in its work by establishing it as a part of the SXC concept that is to be used in all projects that choose to have deliveries during the framework assembly. By doing this SXC could increase the knowledge and usages of installation packages more rapidly and therefore both increase the effectiveness in their own projects as well as in Skanska as a whole.

Logistics of MTO materials after framework assembly

We believe that material handling at site can be significantly reduced if workers are provided with most of the material they need close to the point of installation. Therefore we argue that installation packages and kitting are two alternatives that should always be considered as logistics solutions after framework assembly. The same benefits as using installation packages before framework assemble can be expected when using installation packages and kitting after framework assembly. The solutions have positive effects on production rates, financial outcome and, to some extent, a theoretical damage reduction potential. It
should also be noted that the time of delivery is improved compared to when delivering installation packages during framework assembly. To determine at what point of time to use the installation packages is mainly a question about type of material. Some, such as plasterboards, are suited to be delivered during framework assembly, while others, such as kitchen, are not. This is a matter of how valuable the items are, how they can handle being stored within the structure and whether any other work must have been completed prior to delivering the relevant materials in order to physically place them where they are meant to go.

As any delivery after framework assembly must be done manually or using smaller machines (compared to tower cranes), carry-in services become an alternative. The concept is appealing since it removes the non-value adding activity of moving material from the construction workers. Through planning and clear instructions, it is also easily combined with the concept of installation packages and kitting.

**Terminals**

As mentioned above, terminals help enable the use of installation packages. Additionally, according to pilot studies, terminals provide a positive financial effect on the projects which they are applied to. That alone would motivate the terminal concept to be implemented within SXC. Finally, as discussed in 6.5 *Feedback routines*, the software solution associated with the terminal concept to a large extend solves the issue with poor feedback routines.

**Logistics centers**

In our opinion, logistics centers have an important function to fill as an additional supplier to Skanska projects and should always be considered in procurement decisions. The use of logistic centers is today attractive for projects ordering smaller volumes, as well as for projects ordering custom material from far away locations. Logistics centers could also, due to short delivery times, play an important role in enabling shorter lead times of material deliveries, thus laying a foundation for improving lean construction concepts and reducing waste. Additionally, logistics centers also have a potential in helping to avoid ad hoc solutions due to an unexpected unavailability to receive material at the construction site. This is discussed further below.

**Pull orientated delivery systems**

A key aspect of an industrialized system is, according to lean theory, to use a pull orientated production system. This type of delivery system would address one of the most troublesome logistics problems identified in this report: to receive deliveries that a project is not ready to
receive. Today when projects need to delay a delivery they try to make their suppliers delay a planned delivery which is, according to all sources, the best way of doing it. Sometimes this is, however, not possible and then it is customary to make an ad hoc solution, often placing materials in a terminal or temporary inventories on-site. By adopting a logistics system where it is possible to delay a planned delivery in a terminal or a logistics center, at prefixed financial conditions, Skanska could reduce the need for ad hoc solutions and the risk of inventory damage and consequences.

The development and implementation of such a system could be an ad-on part of the present development of the terminal system. The NPU is responsible for running that project and therefore should also be responsible for developing this service. The hardest part of this is to develop a model that can estimate cost effectiveness or other benefits, as well as developing proof of benefits. As in the case of installation packages, SXC should take an assisting role and support the implementation of the concept with the same motivation.
Bibliography


