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Improving Construction Logistics

A case study of Residential Building Project

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ABSTRACT

This study concerns logistics at the construction projects. Most construction projects suffer from unnecessary activities on site which indicates the need for improving construction logistics. Hence the purpose of this paper was to investigate, through site observations and interviews, the current logistics situation on the construction site and to suggest possible solution for improving construction logistics. The main focus of this study was on material deliveries and time that craftsmen spend on handling materials.

The thesis concludes that skilled craftsmen are transporting the third part of all incoming interior materials by their selves. Due to poor logistics planning workers are also doing lots of rework and extra work. The study showed that, by implementing other logistics solutions, it is possible to reduce the production costs by 65 SEK/m² of living area and also to shorten the production time by 3.3%.

The study actualizes the importance of construction logistics which is often underestimated. The study also showed what consequences ineffective logistics solution could have on the construction project. While, on the opposite, proper logistics planning gives benefits to the project.

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1 INTRODUCTION

1.1 General

The construction industry is one of the most complex industries. The construction process consists of several phases where many different participants are involved during each phase. The uniqueness of this industry is that it is a project based industry, where each construction project could be considered as a temporary organization. However there is a similarity with other industries as well. The similarity is that all industries are interested in high production efficiency while keeping the overall costs as low as possible (Agerberg *et al.*, 2010).

Most construction projects are affected by several factors that have a high impact on the efficiency of the workforce by reducing their overall productivity. This affects quality, time and costs of the project. The reason for that is often poor management of materials, equipment and tools. Proper management of these three important components could increase productivity significantly. These components should be accurately managed on site, in order for the projects to be successful. (Almohsen, Ruwanpura, 2011)

Due to its nature, the construction industry is one of the most challenging to work in. The information flow in construction is complex and the process is affected by various factors. One of these factors is logistics which is defined as the management of the flow of materials, tools and equipment from the point of release to the point of use. (European Construction Institute, 1994). As the construction industry is constantly developing, production costs are rising steadily as well, but the production efficiency and the way of working have not developed that much.

Improving logistics by reducing activities that do not add value to the final product could be one possible solution to lower the production costs. Activities that do not add value to the final product are defined as “waste” which is directly related to the logistics issue. Waste has been studied earlier by among others Josephson and Saukkoriipi (2007) who concluded that it is possible to reduce the production costs with 30-35% by minimizing the total amount of waste.

1.2 Research Question

Most construction projects suffer from unnecessary activities on site. This indicates the need for improving construction logistics. Thus the research questions that have been studied are:

- How does construction logistics of an apartment building project work in practice?
- How much time do construction workers spend on material handling?
- How does the current logistics solution affect the construction process?
- How to improve construction logistics in order to reduce the time workers spend on material handling?

1.3 Purpose

The purpose of this paper is to study construction logistics process and to give suggestion for improvement by optimizing the material delivery process. The main idea is to investigate the current logistics situation on the construction site with the focus on the material delivery process and the time that craftsmen spend on handling materials. The suggestions for improvements have been given based on the results from this case study. The possible economic and production benefit from the proposed solution has been calculated.

1.4 Delimitation

The limitations with our research are:

- The study is based on Swedish construction practice.
- The study is based on two case study of apartment building project.
- The study is focusing on construction logistics for material deliveries.
- The study is focusing on main contractor company only.

1.5 Expectations

According to previous research the need for better logistics solutions in construction projects is evident. Poor logistics not only results in delayed projects but also gives a poor image of the construction industry.

We believe that our work will help the construction companies in Sweden to look on the logistics issue from another angle and realize the possibilities for further improvement within the field of material logistics. This will probably contribute to more effective logistics solutions.

2 LITERATURE REVIEW

2.1 General

The literature review has been done in order to identify and study what has been done earlier within the field of construction logistics management. Exploration of domestic and international books and articles will create a scientific background for the work with the thesis. The literature review for the actual topic of improving construction logistics is a theoretical part of our study and consists of three sections. The first part is where appropriate concepts have been identified and explained. The second part is introduction of third part logistics and how it works. The third part is the study of previous researches giving an insight of what has been done before.

2.2 Concepts and Definitions

According to Winch (2009), construction projects have been managed since time immemorial and traditionally this was the responsibility of the 'master of the works'. Further, Winch states that project management is essentially an organizational innovation meaning the identification of a team responsible for ensuring the effective delivery of the project mission for the client. In the construction management context it could be reasonable to state Frederick Gould's (2009) view on construction. He defines construction as the concept of bringing together materials and products.

2.2.1 Logistic Management

As logistics is the main issue of this paper it is worth to give clear definition of the specific concept. Hence, according to the Oxford English Dictionary (OED), logistics includes the "assembling of supplies, stores, quarters, etc., necessary for the support of troop movements, expeditions, etc". Another definition by the Chartered Institute of Logistics and Transport (2006) in the UK says that logistics is the procedure of designing and managing supply chains including purchasing, manufacturing, storage and transport. The comprehensive definition of logistics given by Taylor (1997) was developed by the US Council of Logistics Management in 1986 "the process of planning, implementing and controlling the efficient, cost-effective flow and storage of raw materials, in – process inventory, finished goods and related information from point of origin to point of final consumption for the purpose of conforming to customer requirements". (Sullivan *et al.* 2010, p. 3, 4)

2.2.2 Supply Chain Management

Supply chain management is an important concept which is closely related to the main topic of this paper. In some literature it is even stated that "logistics management and supply chain management are essentially synonymous terms involving the systematic and holistic approach to managing the flow of materials and information from its raw material state to the end-user's consumption" (Sullivan *et al.* 2010, p.17).

As the SCM concept gained popularity, it has been given various definitions in the past. Many of those definitions describe supply chain management as the link between elements of the manufacturing and supply process from raw materials to the customers. Therefore the summarized definition for SCM could be: “the management of upstream and downstream relationships with suppliers and customers to deliver superior customer value at less cost to the supply chain as a whole” (Pryke, 2009, p.31).

Pryke also argues that SCM is not just another name for logistics and includes elements that are not normally included in a definition of logistics. Examples of those are ‘information system’, ‘integration and coordination of planning’ and ‘control activities’. Logistics mainly deals with the flow in, to and out of companies, with an intra-organizational point of view. SCM, in the other hand, deals with the inter-organizational view of logistics combined with the intra-organizational perspective (Pryke, 2009).

2.2.3 Material Logistics Planning

Material Logistics Planning is defined as a practice that has been designed to support construction projects in order to achieve planned certainty and cost predictability. This is highly appropriate for large and complex building projects (Waste & Resources Action Programme, 2007). Material Logistics Planning deals with the proactive management of the varieties and quantities of materials that are used. This includes supply routes, storage, use, reuse and handling of excess materials. Supply chains and planning controls become more complex as projects get larger. That makes logistics much more important.

The evidence is that logistics now is one of the key factors of the pre-construction planning, serving as a complementary approach to construction project management. Use of logistics become more and more popular and not only on large projects, but also small.

2.2.4 Logistics Techniques

As background some logistics techniques are presented in order to get better understanding of the logistics topic. There are different logistics techniques used by different companies in different countries. Some of these have been published and described by WRAP (2007) in the report *Material logistics plan good practice guidance*. These techniques follow below (Harker *et al.*, 2007):

Construction Consolidation Centers

Construction Consolidation Centers are centers that are used to supply and distribute materials to several construction projects. These centers provide safe and efficient material flows from supplier to the construction site which makes it an effective supply chain management solution. The initial idea with the concept was to supply construction projects in challenging environments such as overloaded urban areas. Construction Consolidation Centers distribute materials in a right time, to the right place and in the required quantity.

This is possible due to goods being combined from multiple part-loads to single shipments. This further contributes to better certainty of supply, reduced number of deliveries to site, reduced amount of stored materials and finely reduced waste. Figure 2.1 illustrates the concept of Construction Consolidation Center.

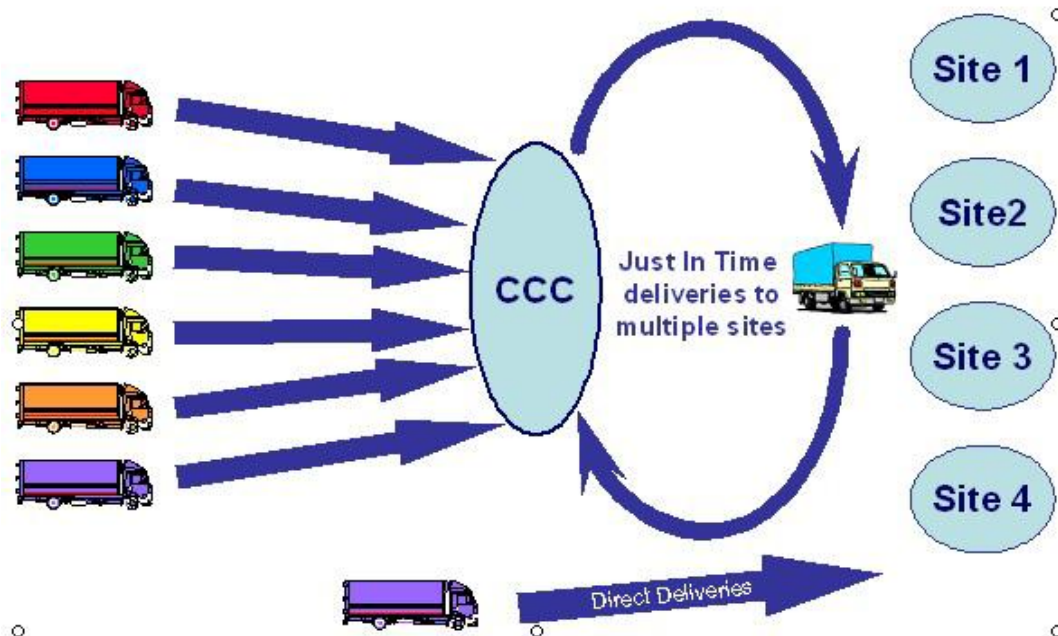


Figure 2.1 Construction Consolidation Center Model (Source: Waste & Resources Action Programme, Harker *et al.*, 2007)

Just-In-Time Delivery

Just-In Time delivery relates to frequent deliveries in work packages or loads delivered in time for usage. That helps to perform the next task without suffering from any delay. The best way of doing that is through a Construction Consolidation Centers or by suppliers themselves. Advantages with Just-In-Time deliveries are that it reduces on-site storage of materials, reduces the risk of damage of materials kept on site and even reduces risk for safety incidents.

Demand Smoothing

Demand smoothing is a way of looking on the project activity plan as the whole and identifying how those activities could be balanced in order to reduce the amount of resources needed for transport, materials and labor to manage the actual task. Demand smoothing could be done both by contractors and clients and at any level in the supply chain.

On-site Market Places

A temporary storage space for consumable materials and small tools is defined as On-site Market Place. This space is only for widely used and shared between contractors materials and tools and includes normally threaded rod, metal channel, nuts, anchor fixings, screws, bolts, small drill bits and similar. Each contractor/subcontractor put their equipment and supplies to the MP for storage and distribution where a store-man is responsible when needed. When stocks become low they are refilled by the contractor individually or by the store-man who will order on their behalf.

With On-site Market Places, contractor/subcontractor will be sure where the required material is located, thus removing with that the need for individual small material storages on site. This results in to higher productivity and lower costs.

Pre-assembled and Offsite Fabrication

It is considered good practice when materials, where possible, arrive to site prepared as far as possible for their final use. For example, it could be prefabricated bathroom modules where everything is installed on the factory including tiles, bathtub, mirrors and cupboards. In a smaller scale it could be materials prepared in packages where each package includes the right material type and right quantity appropriate to a room or a floor. The main point with this is to reduce the amount of thinking time during production stage and to do most of the thinking earlier in the planning stage. Also, doing as much work as possible on the factory contributes to better quality, time saving and lower transport requirements.

2.3 Third Part Logistics

On site construction logistics is an important and often underestimated topic within the construction industry. Third part logistics companies were the first who realized possibilities for financial benefits by focusing on logistics issues earlier in planning stage. The main point with third part logistics services is to create a safe, clean and effective workplace where contractors and subcontractors do not need to transport their materials. This gives more time for skilled workers to do valuable work what makes production more effective.

The most of material transporting on site is done during evenings meaning that lifts and cranes will be more available during the day time. When skilled workers come to their workplace next day, they can start working immediately without losing time for material handling. They have already got their materials in right quantity and on the right place (Svensk Bygglogistik AB, 2012).

2.4 Research in Constructions Logistics

While managing construction projects, according to Almohsen (2011), an integrated process is needed to ensure that the projects are finished on time, budget and within the scope of contract specifications. Here, one of the main factors in construction project management is enhancing workforce productivity which reduces costs and increases the overall productivity. Further, efficient logistics management is a crucial factor in increasing labour productivity. Almohsen also states that effective logistics management systems will also assist the integration and coordination among contractors, sub-contractors and suppliers. That probably will increase construction workers productivity.

Further, the *Improving Construction Logistics* report published on the Strategic Forum for Construction (SFfC, 2005) argues that there are a lot of opportunities for improvements and that the industry is slow to realize the benefits that the application of good logistics can provide. The SFfC also states that there is no need to make large changes in order to obtain considerable benefits while change is possible for both small and larger projects. From the same study follows that on the construction site experienced construction workers are using their skills for less than 50% of their total time on site. Two most usual and non-skilled tasks they are spending time on are moving products around the site and unloading trucks (Strategic Forum for Construction Logistics Group, 2005).

Previous research by Josephson and Saukkoriipi (2007) shows that the cost of material flows to the construction site varies much. It could be from 20% up to 47% of the material price. Josephson, in his research, also calculated that the material flow to the site is often affected by different disturbances. Amongst those are failures in deliveries, failures in unloading, wrong quality etc. These disturbances, according to Josephson, normally cost 4.5% of the material cost. The report "Waste in construction projects" deals with work tasks that do not add any actual value to the final product. To do that, researchers chose to follow individuals during the work day to see how much time they spend on work that does not create value for the project. They report data about how architects, technical consultants, site managers and site workers use working time. Their example is taken from construction of new apartments where trained observer followed a group of construction workers for a total of 22 working days. The result was separated into three groups: work that directly increases value, preparation works and waste. The study showed, according to Figure 2.2, that work that directly creates value was done during 17.5% of the working time. Preparation works take 45.4% of the whole time including indirect work (25.5%), material handling (13.9%) and work planning (6.0%). The last group of activities is waste equally 33.4% of the working time. Here 22.8% was time consumed by waiting and interruptions and 10.4% was unutilized time. (Josephson, Saukkoriipi, 2007)

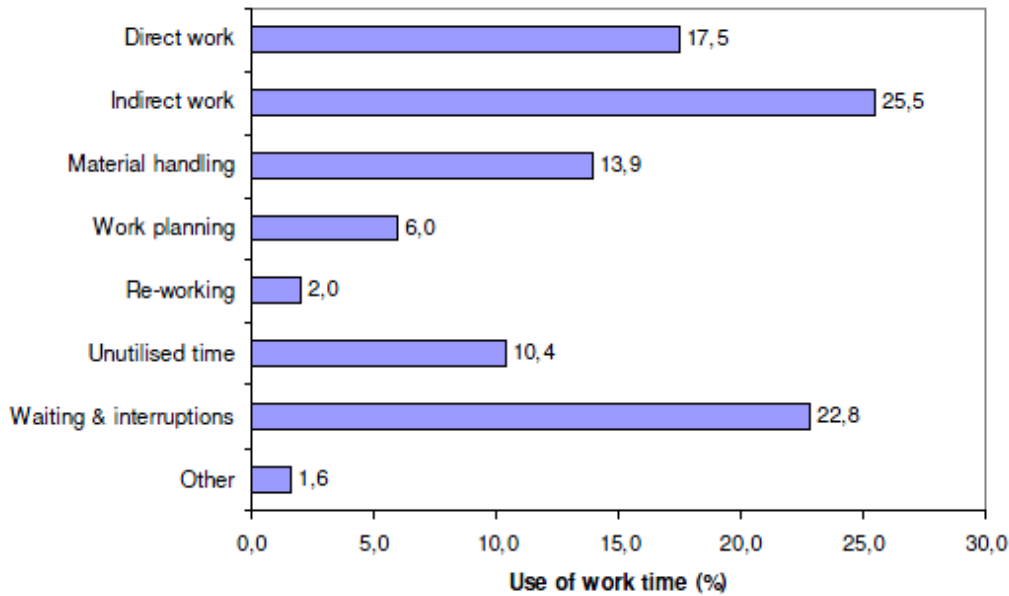


Figure 2.2 Use of work time among construction workers (Source: Josephson, Saukkoriipi, 2007)

Since our focus is on material handling, Josephson's research is appropriate for our study. We are interested of time that workers spend on transporting materials to the working place. Josephson states that material handling takes about 14% of the time workers spend on site. Also, the way how materials are handled affects other parameters as re-working and waiting & interruptions. (Josephson, Saukkoriipi, 2007)

Rising project management methods in construction projects generate new challenges for the delivery process of materials. Alu-Risku and Kärkkäinen (2005) tried to rationalize the delivery process by creating short-term schedules, based on an analysis of resources available for project tasks. The introduced system uses overall plan of the project as the general framework where the day-to-day activities of the production should be managed by a flexible approach that is aware of the factual progress of the project. (Ala-Risku, Kärkkäinen, 2005)

The literature review showed that many studies have been done in the field of construction logistics where different problems have been identified by the researchers. The previous studies also showed that there are a lot of unnecessary costs in construction logistics and that construction workers waste much of their time on site. These studies are appropriate for our research in construction logistics.

3 METHODOLOGY

3.1 General

The literature has been studied. After that the data has been collected from the construction site by direct observations and interviews. As data has been collected, it has been analyzed and evaluated. Evaluated data has been compared to the theory and the conclusions with recommendations have been drawn based on that.

3.2 Research Method

The research method that is used is qualitative where the primary data has been collected in several ways. Amongst these are direct observations on the construction site giving possibility to gather appropriate data that is needed for the current research. Another not less important source for the data collection is interviews, both formal and informal. These have been conducted, not only with management team, but also with site workers who are directly involved in the project.

The main source for secondary data is the literature review which is related to theory and previous research. Another source is existing data and information from the construction site.

3.3 Data Collection

The focus of our study is material deliveries. We have regularly visited the construction site and did observations and documentations of all bigger deliveries to the site. This helped to investigate how material deliveries are handled when coming to site. We have also measured how long time does it take for workers to pick right material and move it to the right place.

3.4 Data Analysis

After the data is collected, the evaluation and analysis of available information has been done. Then conclusions have been drawn based on theory, data, evaluation, analysis and discussion.

4 DATA COLLECTION AND RESULTS

4.1 General

In this chapter collected data with results have been summarized. Information comes from site observations where we, for the period of 2 month, chose to observe each bigger delivery to the construction site. We also followed workers who handled material deliveries. Time that it took for construction workers to carry materials has been documented. Observations have been done during the architectural stage of the project. During our study, interviews have been conducted with people involved in the project, both with workers, supervisors and managers.

4.2 Project Information

For data collection, two projects have been used. Both projects are residential construction projects. We decided to name the projects as Project A and Project B.

Project A

Project A is located in the south part of Stockholm in Hammarbysjöstad. It consists of four seven-story buildings with total of 100 apartments. The building structure is reinforcement concrete structure with prefabricated outer walls. The total construction area is approximately 14 500 m². The construction period is from November 2010 to September 2012. The tenure form is condominiums.

Material deliveries to Project A are organized in a traditional way. Lorries are coming directly from the supplier to the construction site. Such deliveries do not have reserved time and the contractor does not know what time materials are arriving to the construction site.

Project B

Project B is located in the west of Stockholm in Blackeberg. It consists of three nine-story buildings with total of 70 apartments. The building structure is reinforcement concrete structure with prefabricated outer walls. The total construction area is approximately 8 500 m². The construction period is from December 2010 to October 2012. The tenure form is rental apartments.

At Project B, Construction Consolidation Center is used. This center is also called Logistics Center and is primarily used for inside wall materials and windows. All deliveries to Project B have reserved time. For this reason we used mostly Project B for material delivery observations.

Table 4.1 Project information

Project	A	B
Location	Hammarbysjöstad, Stockholm	Blackeberg, Stockholm
Total Area excl. garage (m ²)	14 544	8 585
Living Area (m ²)	8 751	5 148
Number of Buildings	4	3
Number of Floors	7	9
Number of apartments	100	70
Construction Period	Nov 2010 – Sep 2012	Dec 2010 – Oct 2012
Tenure form	Condominiums	Rental apartments

4.3 Observations and Data

Below follows description for different material deliveries with the focus on architectural works and working hours spent on that. With architectural work is meant inside walls, window, floor, door, kitchen, closets etc.

4.3.1 Inside Wall Material Deliveries

Materials as gypsum boards and metal studs are main materials while building inside walls. These materials make up big part of the material flow and are lifted up in to each apartment ongoing while rising up structure of the building, floor by floor. This way of lifting up inside wall materials by tower crane has usually been considered as the simplest one. As our study started in the later stage of the construction process, the structural stage has already been finished. This means that all gypsum and studs have been placed inside the buildings long time ago by the crane. This further means that material has been stored on the construction site for several months (Figure 4.1). We decided to investigate this situation. This could only be done by interviews and not observations. We talked to both workers and engineers involved in the project.



Figure 4.1 Gypsum bundles placed inside the building during the structural stage of the construction project. (Gypsum bundle, Project A, February 2012)

The summary of the current situation follows below:

- Materials are sometimes placed in the unsuitable place making accessibility to the working place difficult. Also the amount of stored material is so big that it is not possible to put it somewhere else. The outcome from that is that carpenters spend some time on moving materials from one place to another.
- Gypsum boards and metal studs could be ordered with needed length while ordering in advance. In one of the studied projects these materials were too long from the beginning. This further means that all gypsum boards and metal studs should be cut before use (Interviews with carpenters, Project B).
- The estimation of needed materials for the inner walls (gypsum/studs) is often not too accurate. This could be found out while working with the material. Often materials are not enough. If it is the case, site supervisor has to order extra deliveries with required materials what takes time. Also workers need to spend time on estimating how much extra material they need and later carry inside delivered materials (Figure 4.2 and Figure 4.3).
- Lorries with extra materials come twice per week. Extra cost for shipping is 700 SEK (Interview with site supervisor, Project B).

- Deliveries with extra materials should come to site as fast as possible. In such a short period of time, the supplier is not able to deliver right material dimensions to the contractor. The supplier could only deliver standard size which is often bigger than needed. For example gypsum boards and metal studs use to be 10-20 cm longer than needed. This further means that carpenters need to cut down every board/stud, which is unnecessary work (Interviews with carpenters, Project A and B).
- There are sometimes 2 gypsum bundles and 1 bundle studs put on each other. This is done when the space is limited. Due to its high, it is difficult to work with the material. This also requires supporting structures under floor due to increased weight of the material.
- As gypsum is stored on site for long time, it is delivered inside plastic folio which should be cut to provide ventilation of the materials. This procedure should not be forgotten in order to prevent moisture damage on gypsum boards.



Figure 4.2 Extra delivery with metal studs placed outside the building (Extra delivery with metal studs, Project A, February 2012)

Handling additional extra materials (gypsum & studs) and doing extra work

The investigation showed that ordering additional deliveries each day takes 0.5 hours from site supervisor (Interview with site supervisor, Project B). Also workers spend some extra

time to handle these deliveries. In average, it takes 4 working hours each day to handle extra deliveries and to do extra work (Table 4.2). Additional deliveries are ordered twice per week with extra cost for shipping. The total period for architectural work is 6 month with approximately 132 working days. The amount of needed material is about 10% of total estimation.

Table 4.2 Working hours spent on handling extra materials, Project B

Title	Task	Hours/day	Days	Total hours
Supervisor	To order deliveries	0.5	132	66
Workers	Additional work & carry inside	4	132	528
Total				594



Figure 4.3 Carpenters transporting additional gypsum boards. (Project A, February 2012)

4.3.2 Interior Material Deliveries

During architectural works, the material flow to the construction site mainly consists of Interior materials as kitchen, closets, parquet, doors, window sills etc. Deliveries with each type of interior material have been observed and documented. Below follows description of such deliveries and time that workers spend to handle those deliveries.

Kitchens

Kitchens are delivered every second week. It used to be two lorries coming directly from the supplier. While coming to the construction site, lorries are unloaded by the truck and four workers. Two workers are ordinary workers and two are hired carrying men. The truck lifts up the pallets with the material directly to the right floor where workers receive it and distribute further between apartments.

Such delivery could take from 8 to 32 working hours (Table 4.3). This variation of working hours depends on how big delivery is and to which floor it should be moved. Figure 4.4 illustrates kitchen delivery to third, fourth and fifth floors. It took 20 working hours to lift up 9 kitchens and place in the right apartment.

Table 4.3 Working hours spent on handling kitchen deliveries, Project B

Observed deliveries	Number of kitchens	Number of workers	Hours	Working hours	Main contractor hours
1st	4	4	2	8	4
2nd	9	4	5	20	10
3rd	11	4	8	32	16
Total for 1 building	24	4	15	60	30



Figure 4.4 Truck lifting up kitchens directly to the right floor (Kitchen delivery, Project B, March 2012)

Closets

Closet deliveries come every second week directly from the supplier. There are totally 9 deliveries for the whole project. While unloading, four workers and one truck are involved. Two workers are ordinary workers and two are hired carrying men. The truck lifts up the pallets with the material to the temporary platform where workers receive it and distribute further by the elevator. The platform is built closely to one of the balconies on the second floor.

Such delivery could take from 8 to 32 working hours (Table 4.4). Number of hours varies much. This is due to different size of deliveries and different distances for transport on site. Figure 4.5 shows how truck is lifting up pallets with closets to the temporary platform where workers further distribute materials between apartments. It takes 3 hours for 4 workers (12 working hours) to transport closets into 4 apartments.

Table 4.4 Working hours spent on handling closet deliveries, Project B

Observed deliveries	Number of closet sets	Number of workers	Hours	Working hours	Main contractor hours
1st	4	4	3	12	6
2nd	9	4	4.5	18	9
3rd	11	4	8	32	16
Total for 1 building	24			62	31



Figure 4.5 Truck lifting up pallets with closets to the temporary platform. (Closets delivery, Project B, March 2012)

Parquet

Parquet use to come on two pallets where each pallet consists of 45 packages. One delivery of two pallets equals 260 m² of parquet. While coming to site, pallets with parquet are placed close to the construction elevator. After that 2 hired carrying men transport parquet by the elevator and put it into each apartment (Figure 4.6). It takes in average 4.5 working hours to take care of one parquet delivery (Table 4.5).

Table 4.5 Working hours spent on handling parquet deliveries, Project B

Observed deliveries	Packages per delivery	Number of workers	Hours	Working hours	Main contractor hours
1st	90 (260 m ²)	2	4	8	0
2nd	90 (260 m ²)	2	5	10	0



Figure 4.6 Packages with parquet transported by the lift and placed in the bedroom. (Parquet delivery, Project B, Mars 2012)

Entrance doors

Entrance doors are divided into 3 deliveries where each delivery is equivalent 22-24 doors. Two pallets with the doors are first transported to the garage (Figure 4.7). Later they are carried by two hired carrying men to each apartment. It takes 9 hours for 2 workers to handle 1 delivery of entrance doors. It is equivalent of 18 working hours for 1 delivery (Table 4.6).

Table 4.6 Working hours spent on handling deliveries with entrance doors, Project B

Observed deliveries	Number of doors	Number of workers	Hour	Working hours	Main contractor hours
1	24	2	9	18	0



Figure 4.7 The pallet with entrance doors placed in the garage before carrying further in to the building. (Delivery of entrance doors, Project B, March 2012)

Doors and door frame

As the entrance doors, doors and door frames are divided in to 3 deliveries. 1 delivery is for one building. Material is placed in to the temporary storage what takes 16 working hours (Table 4.7). Material is stored there and is picked later by the carpenters when they need it.

Table 4.7 Working hours spent on handling deliveries with doors and door Frame, Project B

Observed deliveries	Number of apartments	Number of workers	Hours	Working hours	Main contractor hours
1	24	4	4	16	16

Window sills

Window sills are divided into 3 deliveries where each delivery is equivalent 108 window sills. Pallets with the material firstly transports to the garage. It takes 10 working hours to carry inside all window sills from the garage in to the building. Two carrying men have been hired for this work (Table 4.8).

Table 4.8 Working hours spent on handling window sill deliveries, Project B

Observed deliveries	Number of window sills	Number of workers	Hour	Working hours	Main contractor hours
1	108	2	5	10	0

Baseboards and window/door side cover

Baseboards and window/door side cover is delivered in one large delivery. Material is placed in to the temporary storage. It takes 18 working hours to carry materials inside 1 building. This work is done by main contractor workers (Table 4.9).

Table 4.9 Working hours spent on handling deliveries with baseboards and window/door side cover, Project B

Observed deliveries	Number of Apartments	Number of Workers	Hour	Working hours	Main contractor hours
1	24	3	8	18	18

Other works

Other architectural works as painting and tiling are done by subcontractors where they handle materials by themselves. Mechanical, Electrical, Plumbing (MEP) works (Building Service Engineering) are also done by subcontractors meaning that the main contractor company does not need to handle materials needed for that kind of work.

5 DATA ANALYSIS AND DISCUSSION

5.1 General

In the previous chapter, data from site observations and from interviews has been obtained. In this chapter, results according material handling and working hours spent for that have been studied and analyzed. Also some assumptions and costs calculations have been done.

5.2 Assumptions and Calculations

In the cost calculation label cost per hour has been used as follow: carrying man 270 SEK/h, site worker 350 SEK/h, foreman/site supervisor 350 SEK/h, crane including driver 2 400 SEK/h. (Source: Skanska)

Project B consists of three almost similar buildings. Assuming that buildings are similar we only followed deliveries to one building.

Kitchens

The total number of kitchen deliveries for one building is three. We have observed all three deliveries with 24 kitchens and stated that it takes 60 working hours to handle these deliveries. Totally for the whole project of three buildings it takes 180 working hours to handle all kitchen deliveries. Half of these hours are main contractor hours and half is carrying men hours. This is equivalent of 2.57 working hours per kitchen.

Closets

Closets are delivered in the same way as kitchens. For one building it is three deliveries. We have observed three deliveries with total of 24 closet sets. The time needed to handle these deliveries is almost the same as for the kitchens and equals 62 working hours. Assuming the similarity of the buildings, it takes 186 working hours to handle all kitchen deliveries. Half of these hours are main contractor hours and half is carrying men hours. This is equivalent of 2.66 working hours per closet set.

Parquet

To calculate time needed to handle all parquet deliveries, we used average time for one delivery. We have made observations for two parquet deliveries. The first delivery was to floors 2 and 3. Handling this delivery took 8 working hours. The second delivery that we observed was to floors 7 and 8. This took 10 working hours. The procedure is the same. The variation of working hours only depends on how long workers should travel with the lift. Hence the average time needed to handle one parquet delivery is 9 working hours. Knowing that the total number of parquet deliveries is 21, we simply multiply it by 9 working hours. For three buildings it is therefore 189 working hours needed. This is equivalent of 0.10 working hours per package of parquet (2.9 m²).

Entrance doors

There are three deliveries of entrance doors to the project. We have observed one delivery to one building and got 18 working hours to handle this delivery. For all three buildings we got therefore 54 working hours (Due to similarity of the buildings). This is equivalent of 0.77 working hours per door.

Doors and door frame

There are three deliveries of entrance doors to the project. We have observed delivery to one building where all the material was placed to the temporary storage. It took 16 working hours to do that. To handle all deliveries of doors and door frames it takes 48 working hours (According to previous assumption). This is equivalent of 0.69 working hours per door set for one apartment.

Window sills

There are three deliveries with window sills to the whole project. We have observed one of three deliveries and it took 10 working hours to carry inside 108 window sills. It is therefore needed 30 working hours to take care of all 324 window sills. This is equivalent of 0.09 working hours per window sill.

Baseboards and window/door side cover

There is a one delivery of baseboards and side cover to the project. All the material is placed in to the temporary storage first. Later it took 18 working hours to place this material in to each apartment. By multiplying with 3 we get total number of working hours needed for all three buildings. The total is 48 working hours. This is equivalent of 0.69 working hours per set for one apartment.

Summery

Table 5.1 summarizes all observations and assumptions according to working hours spent on handling inside wall materials and interior materials. From the table it follows that the total number of working hours spent on handling interior materials as kitchen, parquet, doors etc., is 735 hours (10.50 hours per apartment). Here only 1/3 part is spent by main contractor workers. Resting 2/3 part is spent by hired carrying men. Handling additional materials is done by supervisors and ordinary workers of main contractor company. The number of these hours equals 66 working hours for supervisor and 528 for carpenters. The total number of hours for that work is 594 hours. This means that skilled workers waste 8.49 working hours per each apartment.

The total number of working hours, for handling interior material deliveries and additional material for inside walls, equals 1329 hours where 873 hours are main contractor hours. Following rate is 18.99 working hours per apartment.

Table 5.1 Summary of total hours spent on material handling for the project B

Product/Material	Carrying men hours	Main contractor hours	Total of working hours spend	Rate Hours/unit (For total working hours)	Rate Hours/unit (For main contractor hours)
Kitchen (set)	90	90	180	2.57	1.29
Closet (set)	93	93	186	2.66	1.33
Parquet (package)	189	0	189	0.10	0
Entrance doors (unit)	54	0	54	0.77	0
Doors & door frame (set)	0	48	48	0.69	0.69
Window sills (unit)	30	0	30	0.09	0
Baseboards and window/door side cover (set)	0	48	48	0.69	0.69
Total for interior materials	456	279	735	10.50	3.99
Additional ordering/handling	0	594	594	8.49	8.49
Total	456	873	1329	18.99	12.47

5.3 Carrying Services

All material deliveries have been divided in two groups: Inside wall materials and interior materials. Our suggestion, following later in this chapter, is to use carrying services for transportation of these materials on site. The main point is to do that during evenings and helping with that the skilled workers to be more effective during the day time. Involving carrying services offers other benefits as:

- Skilled workers put more focus on their main tasks
- Less waiting time
- Safe and effective workplace
- Shorter production time
- Materials are not stored on site for long time

5.4 Inside Wall Materials

Gypsum, plywood and metal studs/bars are materials used for building inside walls. These materials have been lifted up on to each floor continuously while building up the structure of the building, floor by floor. The analysis of this way of handling inside wall material showed that:

- Storing materials for long time makes investment immobilized.
- Carpenters spend some time on moving materials from one place to another. This is due to huge amount of stored material. In this case worker's efficiency is decreased.
- Placing two gypsum bundles and one stud bundle on each other needs additional supporting structures which are extra costs. It also makes it difficult for the worker to put material down before start working. This leads to lower willingness to work. Also time needed to handle these materials increase. This is extra cost as well.
- All gypsum sheets and metal studs should be cut before use. Extra cost.
- Ordering extra deliveries and handling them is extra time and cost.
- To be more efficient, workers wish to get their materials just before usage.
- If workers sometimes forget to cut the plastic folio, gypsum became bad and could not be used. This is also extra cost.

Extra deliveries and extra work

Cost for handling extra material deliveries and doing extra work is an important issue. Hours needed for this kind of work have been obtained from site observations. This number equals 594 hours. Also shipping costs should be taken in to account. Extra deliveries are ordered twice per week during the period of 24 weeks with the price of 700 SEK per delivery. The shipping cost is therefore 33 600 SEK. The total cost for extra deliveries and extra work is 241 500 or 46.91 SEK/m² of living area. Table 5.2 summarizes hours and costs for doing extra work.

Table 5.2 Working hours and cost for handling extra material and doing extra work, Project B

Title	Working hours	Cost/hour	Total cost (SEK)	Cost/Living area (SEK/m ²)
Shipping			33 600	
Supervisor	66	350	23 100	
Main contractor Workers	528	350	184 800	
Total	594		241 500	46.91

Our calculations show how accuracy of material quantity estimation in the planning stage could affect the project later in the construction stage. We have observed the same picture at both projects and it is possible that other projects face the same problem. 46.91 SEK per square meter of living area is additional costs or waste (Project B), as Josephson defined it (Josephson, Saukkoriipi, 2007). We think that it is possible to avoid this cost by implementing another logistics solution. This could be strengthened by referring to Strategic Forum for Construction (SFfC), which, as mentioned earlier in chapter 2.3, published in 2005 that “it is a lot of opportunities for improvement and that the industry is slow to realize the benefits that the application of good logistics can provide” (Strategic Forum for Construction Logistics Group, 2005).

Actual time and cost for lifting up inside wall material

Gypsum, plywood and metal studs/bars have been moved inside the buildings with the help of the crane and two workers. The time needed for the crane and two workers to lift up material has been calculated. This calculation is needed in order compare the traditional solution for lifting up inside wall materials with the suggested one.

For the whole project of three buildings it took approximately 35 working hours to lift 210 bundles with gypsum and studs (Appendix 1). This further equals 84 000 SEK for the crane including driver and 24 500 for workers. Table 5.3 summarizes estimated time and costs needed for lifting up inside wall materials with traditional method (Appendix 2).

Table 5.3 Working hours and cost for lifting up inside wall material by crane

Title	Working hours	Cost/hour	Total cost (SEK)
Crane & driver	35	2400	84 000
Main contractor workers	70	350	24 500
Total			108 500

Lifting inside wall material early in the construction stage is a common way for many companies in Sweden while constructing apartment buildings. But how could these companies be sure that it is the best way of handling gypsum and studs deliveries? We have carefully analyzed this way of working and concluded that it costs 108 500 SEK to lift up material needed to construct inside walls. The main part of this figure is cost for the crane equaling 84 000 SEK. We are sure that it is possible to lower this figure by using another logistics technique.

Suggested logistics solution for inside wall materials

Our suggestion is not to use tower crane for lifting up inside wall materials. Instead of that, we suggest to transport materials with the help of carrying men during afternoons.

General strategy

- 13:00. Lorries with gypsum/studs coming to the construction site two hours before workers finish for the day. Lorries are coming directly from the supplier and start to unload by themselves with the help of one main contractor worker.
- 15:00. Half an hour before transporting materials inside, two carrying workers come. Workers together with site supervisor are going through what should be done and where material should be placed.
- 15:30. When all construction workers have left, a few more carrying workers are coming and start transporting bundles with material in to the building. Workers divide in teams where one of the earlier arrived workers builds the team with one who came after. Number of workers varies depending on the size of the delivery.
- 18:00. The work is finished.

Strategy for Project B

Gypsum and studs deliveries will start after the structural stage is finished and the architectural begins. The period for building inside walls is approximately 25 weeks. We have 210 bundles (Both gypsum and studs) + 10% to transport inside during this period. Deliveries with gypsum and studs could be ordered every second week. One lorry with gypsum (10 bundles) and one lorry with metal studs (8 bundles). Totally it will be about 13 deliveries to the site. Time needed for two lorries to unload is approximately one hour. To do that one main contractor worker is needed. It is totally 18 bundles per delivery and it takes 15 minutes for two workers to transport one bundle into the building. This means that 4 carrying workers will spend between 2 – 2.5 hours to transport all the bundles. Table 5.4 shows how much it would cost to transport inside wall materials by carrying men during evenings (Appendix 3).

Table 5.4 Working hours and cost for transporting inside wall material during evenings, Project B.

Title	Working hours	Cost/hour	Total cost (SEK)
Crane & driver	0	0	0
Main contractor workers	13	350	4 550
Carrying workers	127	270	34 290
Total			38 840

Cost for suggested logistic solution is 38 840 SEK which is much lower comparing to the traditional way of transporting inside wall material. Cost for traditional solution equals 108 500 SEK. Also it would be possible to avoid extra costs for ordering additional material deliveries and doing extra work. Saving potential for extra work is 241 500 SEK. Therefore total saving potential is 311 160 SEK or 60.44 SEK per square meter of living area (Table 5.5).

Table 5.5 Saving potential for deliveries of inside wall materials, Project B

Title	Total cost (SEK)	Cost/Living area (SEK/m ²)
Extra work	+241 500	
Inside wall material by crane	+108 500	
Inside wall material during evenings	-38 840	
Saving potential	311 160	60.44

Below follow advantages and disadvantages with our suggested logistic solution.

Advantages:

- Reduces waste for the extra work.
- Saving potential comparing to traditional way equals 60.44 SEK/m².
- Possibility to shorten the structural period by one week. (Table 5.3, 35 hours actual crane time is approximately one week)
- Possibility to shorten the period of building inside walls by one week. (Table 5.2, 594hours/15 workers =39.6 working hours which is approximately one week)

- Production time could be reduced by 2 weeks (1 week for structural period + 1 week for inside walls). This could save labor costs, machinery costs and costs for hiring temporary offices on site etc.
- Work will be finished before 18:00 meaning no addition payment for evening works
- No disturbances, noise from the construction site due to late work. Truck gone after 15:00.
- People work alone and do not disturb other workers on site.
- Materials will arrive to the construction site just before use (Just-in-time method, Harker *et al.*, 2007). Advantages with this method are that it reduces on-site storage of materials, reduces the risk of damage of materials kept on site and even reduces risk for safety incidents.
- Materials will not be stored on site for long time. Money could be used for something else.
- Delivered materials will be use directly after arriving to the site which makes it possible to find out directly if the quantity of purchased materials is underestimated or overestimated. Possibility for better control of the process.
- Bundles will be placed one by one. No extra cost for supporting structure.
- No need to think about ventilation of gypsum bundles.

Disadvantages:

- More damage risk comparing to the crane.
- Carrying workers should know exactly where to place materials. This requires effective communication between them and foremen for craftsmen.
- Requires space for unloading materials.
- Method requires significant changings in project planning systems.

We believe that our solution will not only contribute to lower costs but also give a better opportunity for making changes during construction. Alu-Risku and Kärkkäinen (2005) tried to rationalize the delivery process by creating short-term schedules. They argued that day-to-day activities of the production should be managed by a flexible approach that is aware of the factual progress of the project. We agree on that and think that the suggested solution makes the process of constructing inside walls more flexible. Flexibility makes it possible to realize from the beginning if there are any problems with the material.

5.5 Interior Materials

Data analysis showed that main contractor workers do not spend much time for carrying interior materials. They use carrying men for 2/3 part of carrying works (table 5.1). This helps to keep labor costs low and to increase productivity of skilled workers. Time and costs for handling material deliveries is summarized in Table 5.6.

Table 5.6 Actual hours and cost for handling deliveries with interior materials, Project B

Title	Working hours	Cost/hour	Total cost (SEK)
Main contractor	279	350	97 650
Carrying men	456	270	123 120
Total	735		220 770

Main contractor worker, according to our observations, spend 279 working hours for carrying interior materials. By letting subcontractors do this job, carpenter could spend these hours on doing their ordinary work. This would speed up the project and also make savings on labor costs.

Suggested logistic solution for interior materials

Our suggestion is to hire carrying men for all material moving activities. This work will be done during afternoons when ordinary workers leave the construction site. Materials that have been taken in to consideration are: kitchen, closets, window sills, parquet, entrance doors, inside doors and frames, baseboards and door/window cover.

Suggested logistic solution is divided into 2 parts. First part is for kitchens and closets. Second is for other materials. In the first case truck should be involved during the whole process. Materials as parquet, window sills and doors could be unloaded by the truck before working day ends.

General strategy (Kitchens and closets)

- 15:00. Half hour before lorries with the materials arrive, two carrying workers come. Workers together with site supervisor going through what should be done and where material should be placed.
- 15:30. Lorries with kitchen/closets coming to the construction site directly from the supplier. A few more carrying workers come. Truck starts unloading materials where workers receive it and distribute further between apartments. Number of workers varies depending on the size of the delivery.
- 20:00. The work is finished.

Strategy for project B (Kitchens and closets)

Deliveries with kitchens and closets start after the structural stage is finished and the architectural stage begins. Period for interior works is approximately 25 weeks. Cost for the truck and for shipping will be the same as before. That's why it is not included in our suggestion. For our project the total number of working hours needed to handle kitchen and

closet deliveries will be the same as before. The only difference is that the work will be done by carrying men during evenings. To do that four carrying men are needed. One important difference is that deliveries to floor 6, 7, 8 and 9 should be split in two deliveries. The reason for that is that it takes longer time for truck to lift materials to the top floors. It would further result into longer working evenings. This work will take from 3 to 5 hours. Total number of the deliveries is 24.

General strategy (Parquet, entrance doors, doors & door frame, window sills, baseboards and window/door cover)

- 13.00. Lorries with materials coming to the construction site one or two hours before workers finish for the day. Lorries are coming directly from the supplier and start to unload by themselves or by truck.
- 15:00. Half hour before transporting materials inside, two carrying workers come. Workers together with site supervisor going through what should be done and where material should be placed.
- 15:30. When all construction workers left, a few more carrying workers are coming and start transporting materials into the building. Number of workers varies depending on the size of the delivery.
- 20:00. The work is finished.

Strategy for project B (Parquet, entrance doors, doors & door frame, window sills, baseboards and window/door cover)

Deliveries with kitchens and closets start after the structural stage is finished and the architectural stage begins. Period for interior works is approximately 25 weeks. Cost for the truck and for shipping will be the same as before. That's why it is not included in our suggestion. For our project the total number of working hours needed to handle material deliveries will be the same as before. The only difference is that the work will be done by carrying men during evenings. To do that four carrying men are needed. Workers divide in to two teams if needed. Handling one delivery will take from 4 to 6 hours. Total number of the deliveries is 26.

Table 5.7 Hours and cost for handling deliveries with interior materials during afternoons, Project B

Title	Working hours	Cost/hour	Total cost (SEK)
Main contractor	0	350	0
Carrying men	735	270	198 450
Total	735		198 450

Cost for the suggested logistic solution is 198 450 SEK which is calculated by multiplying total number of working hours with cost per hour for carrying workers (Table 5.7). This cost is lower than then the first one equaling 220 770 SEK. The saving potential is 22 320 SEK or 4.34 SEK per m² of living area (Table 5.8). This is not so high. However, suggested solution has other benefits except the costs saving. One of these is reducing time for waiting and interruptions. According to Josephson and Saukkoriipi (2007), Figure 2.2, this time equals 22.8% of normal working time for skilled worker.

Table 5.8 Saving potential for deliveries of interior materials, Project B

Title	Total cost (SEK)	Cost/Living area (SEK/m ²)
Main contractor & carrying men	+220 770	
Carrying men	-198 450	
Saving potential	22 320	4.34

Below follow advantages and disadvantages with our suggested logistic solution.

Advantages:

- Saving potential comparing to traditional way equals 4.34 SEK/m².
- Possibility to shorten the period for interior works by 0.5 weeks. (table 5.6, 279hours/15 workers =18.6 working hours which is approximately 0.5 week)
- Fewer activities during the working days. Less waiting for elevator, fewer interruptions for skilled workers.
- Possibility to shorten the period for interior works by approximately 0.5 weeks due to reduced time for waiting and interruptions.
- Production time could be reduced by 1 week. This could save labor costs, machinery costs and costs for hiring temporary offices on site etc.
- People work alone and do not disturb other workers on site.
- Carrying men use working time effectively. They do not spend time for going to and from breaks.
- Truck does not waste time by waiting for workers during the breaks
- Carpenters carry less and therefore get less tired. Less occupational injury and sick leave.

Disadvantages:

- Possibly some extra cost for evening labor.
- Possibly higher disturbance during evenings due to late work with truck.

- Carrying workers should know exactly where to place materials. This requires effective communication between them and foremen for craftsmen.
- The method requires significant changings in project planning systems.

5.6 Time Saving

According to our calculations, it is possible to shorten the production time by three weeks. The total time for constructing three building (Project B) is approximately 90 weeks. Suggested logistics solution could shorten this period by 3.3 %. The time saving of 2.2% or two weeks coming from improving inside wall material deliveries. The resting 1.1 % or 1 week is from improving interior material deliveries.

5.7 Discussion

The findings in chapter 4 and 5 are representative for this type of project. For the first we used two projects for the case study where all the data have been collected by direct observations and interviews. We have observed all for us valuable deliveries for two months and also interviewed most of construction workers and managers on site. We have also discovered that both projects suffer from the same problems what makes our findings even more reliable. While working with logistic solution to the problem, we conducted interviews with personnel from third part logistic company which has 14 years' experience of managing construction logistics. This experience was valuable.

According to previous research, it is known that it is much waste in construction logistics and that there is a huge potential for savings in this area. New with our research is that we showed what could be direct consequences of poor logistics planning. In the example of the apartment building industry we showed, in the terms of budget and time saving, how big the saving potential is. We also suggest another way of managing material deliveries to the construction site.

We believe that our research will help construction companies in Sweden to realize the importance of careful logistics planning. We, and most of people we interviewed, believe that our suggested logistics solution can help companies to become more successful within logistics issues.

6 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The purpose of this study was to investigate how construction logistics works in practice and what happens to material after it arrives to the construction site. By direct observations and interviews, we found out how much time skilled workers spend on handling material. After that the alternative logistics solution for handling material deliveries has been developed.

Our study showed that the importance of construction logistics is underestimated by construction companies. In Swedish construction industry companies are not aware of how important logistics is and what could be the consequences of poor logistics planning. In the apartment building project example, we have analyzed the costs associated with material handling.

Inside wall materials. During the case study, we have discovered that inside wall material is delivered during the structural stage and is stored on site during several months. This way of handling inside wall materials has always been considered as the only way. Thus our study showed that other ways of doing that could be more effective. The suggested logistics solution helps to cut the costs for transporting inside wall materials to the working place and also avoid unnecessary work. For our case study (Project B) we concluded that direct saving potential is **60.44 SEK/m²**.

Interior materials. Skilled workers spend part of their time on carrying materials to the working place. A third of all materials that arrive to site are handled by ordinary workers and two third is handled by carrying men. We think that it a good idea to hire subcontractor for carrying works. We believe that Construction Company could increase productivity even more if they use carrying men for 100% of all incoming materials. For our case study (Project B) we concluded that direct saving potential for suggested logistics solution is **4.34 SEK/m²**.

Saving potential. Except the direct saving potential, there is a possibility to shorten the time for the entire project. Implementation of the suggested logistics solution could reduce the production time by **3.3%**.

6.2 Recommendations for the Contractor Companies

We recommend Contractor Companies not to use skilled workers for material transport on site. For that work, we recommend to use carrying services or to employ own carrying workers. Another recommendation is to do most of carrying works during evenings.

During our study, many interviews have been conducted. All people we interviewed are working in the apartment building projects and most of them are skilled workers. They all had interesting points of view which should not be underestimated. One general comment was according the material estimation for inside walls. Workers strongly recommend

involving them earlier while planning. Their experience could help managers and site planners to achieve high accuracy at the material estimations and to save costs.

6.3 Recommendations for the Future Research

Our study was focused mainly on large material deliveries and man hours. Our suggestion does not take into consideration cost for all small details and parameters. Thus, for future research, we recommend to put more focus on these things. For example, what are costs for hiring temporary offices and machinery? How much is it possible to save on personnel salaries by reducing the production time?

Another recommendation for the future research is how much time subcontractors spend on handling their materials and how does it affect the production time?

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8 APPENDIXES

Quantity for one building

Gypsum: 1520 sheets (90x2.6), Plywood: 144 sheets (90x2.6), Minerit: 28 units (90x2.6)

Floor framing: 604 m (Dim 45,70, 95), Ceiling framing: 687 m (Dim 45,70, 95)

Studs: 2348 (Dim 45,70, 95, L 2.6), Door studs: 184 (Dim 45, 70, 95, L 2.6)

Appendix 1

Calculating materials for inside walls in to bundles

Gypsum and other sheets use to be packed in to bundles of 42 sheets. Studs use to be packed in to bundles of 100 studs. Floor studs and ceiling studs are 3 meters long and that's why divided by 3. Both sheets and studs are multiplied by 3 to get the quantity for the whole project of 3 buildings.

$$\text{Boards} = \left[\frac{(1520+144+28)}{42} \right] \times 3 = 121 \text{ bundles}$$

$$\text{Studs} = \left[\frac{(604m+687m)}{100 \times 3m} + \frac{(2348+184)}{100} \right] \times 3 = 89 \text{ bundles}$$

Appendix 2 (Figure 5.3)

Calculation of working hours and cost for lifting up inside wall material by crane

We assume (Interviews) that it takes 10 minutes for crane + 2 workers to lift up one bundle. One worker is connecting the bundle to the chain cables and another one is receiving it on the right place.

$$\text{Crane time} = \frac{10}{60} \times (121+89) = \mathbf{35 \text{ hours}}$$

$$\text{Working hours} = 35 \times 2 = \mathbf{70 \text{ hours}}$$

Appendix 3 (Figure 5.4)

Calculation of working hours and cost for transporting inside wall material during evenings

We assume (interviews) that it takes 15 minutes for 2 workers to carry inside one bundle gypsum/studs. Trucks with materials could come 1 or 2 hours before work start and unload the materials. Figure below includes even extra 10% for additional material. This 10% are not included in a calculation of actual crane time. Also 1 hour per each delivery is added for supervision of the carrying workers before work start.

$$\text{Working hours} = \frac{15}{60} \times (121+89) \times 2 \times 1.1 \times 1.1 = \mathbf{127 \text{ hours}}$$