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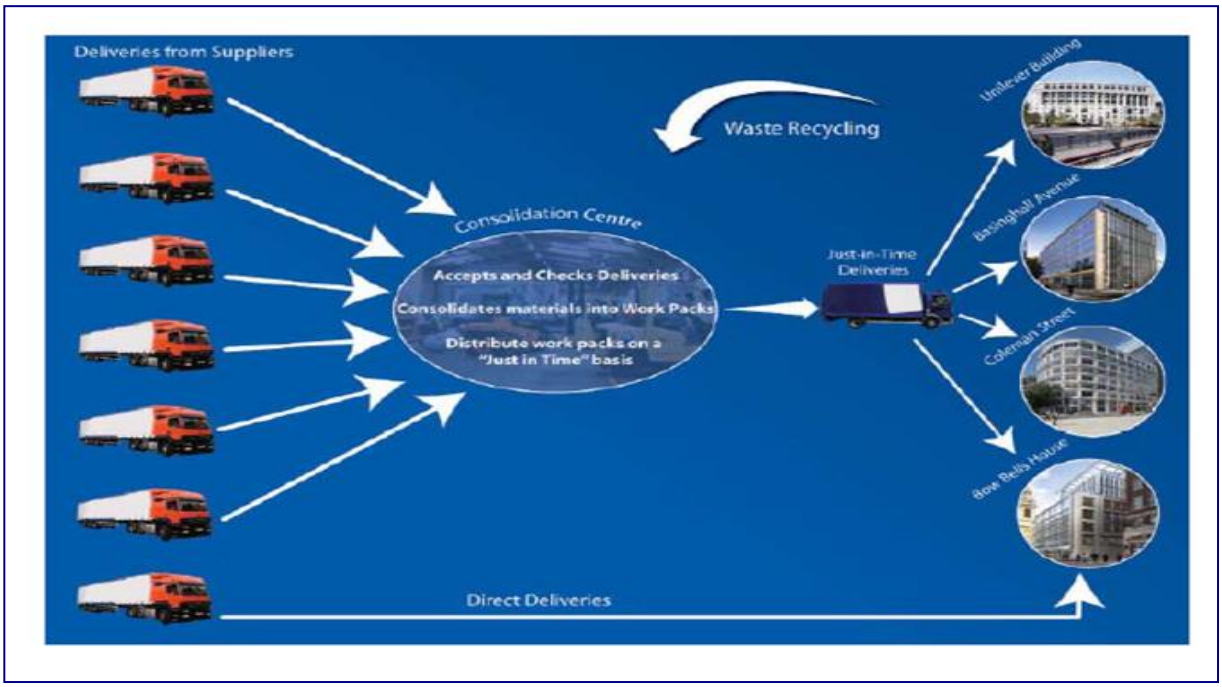

The Future of Construction Logistics

Consolidation Centers in Construction Logistics

Master of Science Thesis in the Master's Programme Design and Construction Project Management

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CHALMERS UNIVERSITY OF TECHNOLOGY
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Cover: Overview of the LCCC operation to the four construction sites (Stanhope and Wilson Janes 2008)

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ABSTRACT

There are poor management of logistics in the construction industry. The poor management of logistics has a negative effect on quality, cause delays to project and cost overruns. Accordingly the purpose of this study is to identify the scope of current methods and techniques of construction logistics being used, both traditional and alternative, and show the role they can play in reducing waste, and to develop an efficient construction logistics management within and outside a construction site. And to show other important points about the use of consolidation centers in the construction logistics. In the literature has been found four methods of construction logistics being used, both traditional and alternative. An alternative arrangement no commonly used in construction site. In alternative method 4 there are seven main logistics techniques. In this study authors are focus on Construction Consolidation Centre and some techniques which support the primary activity Consolidation Centre to take place. Through theory, interview and observation the authors define the reasons of waste in construction industry. Therefore, the intention of the authors is a construction industry without waste, where resources used sustainably; by using construction consolidation centers and Lean tools to eliminate construction waste, saving resource and reduce carbon emissions.

Key words: Construction Consolidation Centre, Logistics, Lean, Supply chain management, Waste

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List Of Abbreviations

Abbreviation	Explanation
DC	Distribution Centre
CCC	Construction Consolidation Centre
EF	Environmental Friendly
JIT	Just-In-Time
HCCC	Heathrow Consolidation Centre
LC	Logistics Centre
LCCC	London Construction Consolidation Centre
RFID	Radio Frequency IDentification
RQ	Research Question
TPS	Toyota Production System
SHCCC	Stockholm Hammarby Construction Consolidation Centre
UK	United Kingdom
VSM	Value stream mapping
WMS	Warehouse management system

Preface

In this study, literature review, interviews, two days conference and one day site observation have been done. The study has been carried out from January 2014 to May 2014. This study is performed in collaboration with Swedish construction companies and Design and Construction Project Management at Chalmers University of Technology, Gothenburg, Sweden.

We would like to thank our supervisor Dr. Goran Lindahl. For his support and we would also like to thank the interviewees for sharing their knowledge with us, this study could never been complete without their assistance.

Goteborg May 2014

SEFERA ALI SHIGUTE, ARAZ NASIRIAN

1 Chapter One

Introduction

The following section comprises the introduction for this thesis work. It starts with "background" which describes the problem in the industry and suggests consolidation center as a solution. It is included the "purpose" of the study and its "objectives" which are the base for decision making regarding "methodology" of the study. Furthermore,, it will be the "limitation" part which explains the obstacles, size and scope of the study. The expectation part represents how this study could contribute for developing current practice in construction logistics. The last part is the "structure" part which simply shows how this thesis work is structured. In the literature review it was shown that waste (non-value added activity), include more than 50 percent in construction processes and the most of the activity that supports value creation is logistics.

1.1 Background

It will take a long time for construction logistics to mature, Karl Hudson and Stephen Bacon (no date, cited by Rick B. 2010). . There are only a few companies who see that expenditures in improved logistics are an investment that will lead to higher profits. Hudson and Bacon (no date) argued that it is difficult for construction companies to invest in logistics since they think the amount of investment will not be compensated by the value which improved logistics will provide, and this issue is the motivation for this thesis work.

Lack of attention and investment in logistics will decrease the quality of logistics service and it is what experts refer to as poor logistics. Poor logistics cost the construction industry at least £3 billion a year (Peter Rogers, Chairman of the UK Green Building Council (no date), cited by Gary Sullivan et al 2010). Inadequate management of logistics has an adverse effect on quality and causes delays to project. Adverse effect of poor logistics on quality could be manifested as an environmental effect. Delayed deliveries result in wasting time of professional workforce as they wait for material to be received. Delay in delivery could also case disruption of other construction activities because construction activities are mainly consequent.

Poor logistics can also result in late delivery which increases the amount of storage on the site, increases storage's tied up capital, adds to the health and safety risks on site, causes material handling by professional work force, disturb other subcontractors by creating obstacles on their way, for say.

There are considerable amount of literature which claim that CC can improve logistics practices and fade all aforesaid pitfalls away. The major contributions that a consolidation center can make are delivering the right material at the time of request to the right place, providing a dry and safe place to avoid materials getting damaged, reducing environmental effect of material transportation and reducing the level of tied up capital in the construction site.

There are studies both in construction industry and manufacturing which show that using consolidation centers (CC) as an easy way to increase profitability, (Sullivan et al 2010 and Jonsson 2008). Although the majority of the aforesaid studies are done in manufacturing there are convincing examples in construction industry as well, like the

consolidation center for London's airport or Sainsbury's consolidation center, Lundesjo (2011).

CCs have been around for about 30 years and developed manufacturing logistics. However, they are only currently used in the construction industry. There is a considerable amount of cost saving in construction logistics by using CC and its major examples are in U.K. Basically, a consolidation center is a warehouse near the construction site which, ideally, has IT coordination with construction site which delivers small amount of needed materials at the time of the request and in the suitable place.

Although, it is difficult to find an academic paper which criticize CC deeply, there are a lot of companies such as construction contractors, construction logistics service providers and material suppliers that either have used CC and made a loss or argue for decreased profitability if CC get used. The experts in the industry argue the most significant pitfall of CC is the high cost of operation and maintenance. These costs include but not limited to costs for developing an IT tool which makes the on-line collaboration, between construction site and CC, possible, salary of personnel who are involved in CC and energy costs. Other crucial flaw is the high amount of rent for the storage place. There are also other problems associated with using CC which will be discussed in later chapters.

Moreover, at the moment, at least to the best of our knowledge, in the Gothenburg context no construction company, logistics service provider or material supplier use a CC. This thesis work raises the question: why CC is considered as the cause of failure in some contexts while there are examples about increasing a significant amount of profitability in other industries.

1.2 Purpose

The purposes of this study are to analysis and compare benefits and pitfalls of using CC in the construction industry. It is estimated that by the end of this study a basic guide line would be provided which will show some factors that influence decision makings regarding using a CC. The main purpose of study is by eliminating waste saving resource and reducing carbon emission.

1.3 Objective

By doing this study the following research questions will be answered

1. How much using of a CC is in accordance with lean thinking?
2. What kind of projects requires a CC.?
3. What kinds of material should be handled in a CC.?

1.4 Limitation

The scope of this thesis study is restricted to big construction projects which involve a broad range of different materials with a huge quantity. It is not relevant to talk about CC in a small construction project like a villa since in such a building the level of complexity in logistics is low and the overall situation of the work is repetitive for

contractor and entrepreneurs. Also, this study is focused on the projects that have a small area for storing materials. When some parts of site could be used as storage area it does not make sense to rent an external storage.

The significant limitation for doing this study was finding suitable interviewees. This study has a broad view regarding construction material and include all the material that has the potential to be handled via CC, however, in the real world some CC are too specific associated with type of material that they work with. Experts in high positions are busy with their own daily tasks and rarely have time to be interviewed and junior engineers although are more free do not possess a satisfactory knowledge regarding the subject. There were also problems regarding poor English level of interviewees and time restrictions.

1.5 Expectations

The authors believe the result of this study would contribute construction companies regarding decision making on whether to use a CC or not to use it. The decision making process take place in two stages: The first stage evaluates possibility if implementation of a CC and the second stage assess profitability of it.

There are construction projects that it is wise for them to have a CC. On the other hand, there are other construction sites which exploitation of a CC is not practical for them. We believe our work could contribute to construction companies to identify the projects which demand for a CC.

Analysis functionality of whether to use a CC or not to use it would be done by considering some factors as follows. These factors are included but not limited to: ownership of supply chain, available spaces for material storage on construction site and size and type of construction materials. If there is not enough space in construction site to store material there CC could be a rational solution.

In such a situation that using of a CC is an alternative, investigations have to be done to see if exploiting a CC will result in profitability or not. The level profitability will be manifested as a comparison of cost savings which are generated by CC and extra costs which are associated with maintenance and operation of a CC. Personnel's salary and costs extra loading and unloading in CC are between examples of costs of maintenance and operation of a CC. Cost saving in this vein is mainly generated as a result of increased efficiency and its measurement is more difficult but a typical example for that could be avoiding professional work force time wasting because of material handling.

1.6 Structure and audience

This study starts with introduction a description of key theories which are consolidation centers and their relationships which comprise the theoretical framework. Afterward, empirical findings from interviews will be taken into account which is components for the results section. Having both the academic and industrial perspective will make it possible to identify the gaps and present a conclusion and suggestions for improvements.

This thesis work could be used for both academic and industrial targets. Reading this study is suggested for students and teachers from logistics, construction and

transportation departments who are interested in new studies regarding CC. It is also recommended to people in industry who face challenges regarding using CC.

2 Chapter Two

2.1 Methods

Research activities include defining business opportunities and problems, generating and evaluating alternative course of action. This process includes idea and theory development, problem definition, searching for and collecting information, analyzing data, and communicating the findings and their implications (Zikmund et al., 2010).

The related literature have found and reviewed. The process of finding and revision of literature has described in details in the following section. By gathering and putting together appropriate material from different literature theoretical framework has been build. The theoretical framework is the basis for constitution of results, since it determined the scope and limitations of results, also the proper technique regarding how to perform the result section. In other words, literature review provided the authors with the possibility of navigating in the data collection task.

Consequently, doing interviews is decided for collecting data and site observations are face time limit. Gathered data is analysed, evaluated and categorized. Having appropriate order of empirical data available, made it possible to make a comparison between theory and practice. This comparison identified the existing gaps. Based on the knowledge gained by doing this study also to discussions with experts in industry and academic methods and recommendations are proposed to bridge the gap. Then areas for further improvement and future research are indicated.

Secondary information is rarely used in this study and it was just in case that was not possible to access to original ones. All insights, knowledge and information which are gained from external sources but employed in this study are referred and gather in the last section of this thesis.

2.1.1 Literature review

The primary purpose of doing literature review was to see what is already done and what is the common knowledge in the field? What kinds of research have been done so far? What kinds of gaps were found? How suggestions for improvement were developed?

To answer aforesaid questions the related literature is found based on some key words which are searched in online searching engines. The key words include but not limited to logistics, construction logistics, consolidation centres and waste in logistics. The main source for finding the literature was online searching engines like scholar.google.com. Also, databases in Chalmers University's online library were explored. The related source is purchased personally.

The sources for the literature study include scientific journal articles, books, guidance, and reports. They were mostly engaged with subject's logistics and consolidation centres, lean both in construction and other industries like manufacturing. Definitions, details of implementations, advantages and disadvantages of aforesaid subjects are investigated. Key factors, concepts, theories and areas of improvement are recognized and used for expanding the literature review and theoretical framework consequently.

2.1.2 Interviews

Interviewing minimum five – fifteen Swedish construction companies; project managers, site managers, trade contractors, owner, logistics specialist and site observations. Direct site observation, construction personal interviews (formal, and informal), are the primary sources of data for this research. Firstly the related literature reviewed. The purpose was to see what is already known and what is the common knowledge in the field, what kinds of researches have been done, how was their methodology, what kinds of gaps are found, what is their suggestions for future studies.

The research method for doing this study was qualitative method since the nature of the study demanded for that. Between different types of the qualitative method doing interviews is decided.

Consequently, doing interviews is decided for collecting data and site observations are face time limit. Gathered data is analyzed, evaluated and categorized. Having appropriate order of empirical data available, made it possible to make a comparison between theory and practice. Based on the gained knowledge through doing this study also discussions with experts in industry and academic methods and recommendations are proposed to bridge the gap. Then areas for further improvement and future researches are indicated.

Secondary information is rarely used in this study and it was just in case that was not possible to access to original ones. All insights, knowledge and information which are gained from external sources but adopted in this study are referred and gather in the last section of this thesis under Appendix.

Site observations are face time limit. All the interviews were semi structured and the questions was open ended. The purpose behind it, was to gain as much as information from interviewee also possibly interviews' perspective on the subject

2.1.3 Others

Also carried out as desk research combined with telephone interviews and a mail/internet

2.1.4 Interview questions

Interviews' main topics originated from theoretical frame work. Interview questions are seeking to satisfy research question, research purpose and its objectives. Answering interview questions by experts in industry gave the authors empirical knowledge regarding definition and function of lean, logistics and consolidation centres and how consolidation centre can serve lean logistics. When, where and how it should be used? What are the challenges and what are the requirements? (For more details see Appendix A)

2.1.5 Interview process

As a whole ten interviews are arranged. It was tried to hold all interviews face-to-face. Because face-to-face interviews not only motivate both interviewer and interviewee it also helps to get non-verbal cues through body language. However, this thesis study is based on Gothenburg and there are not enough interviewees with suitable knowledge.

So, authors had to find other interviewees in other parts of the Sweden. Some interviews are done as Skype or telephone interview.

Except telephone and Skype interviews all of the interviews are recorded and transcribed. Before recording interviewer get permission of recording. Interviewer, also, made interviewees informed about them and company will be kept as confidential. In two Skype and telephone interview voice recorder did not be used, however, interviewer took notes and transcribed them immediately after finishing interview

2.1.6 Revision

After each interview, transcription is analysed and a comparison is made between empirical findings and theoretical framework. This comparison highlighted deficient spots in theory. Therefore, literatures which can modify the spots with deficiencies are found and needed materials are added or replaced. The new theoretical framework prepared the basis for developing interview question. This process repeated after each interview and acted as a cycle which continually helped to improve both theoretical and empirical findings.

3 Chapter Three

3 THEORETICAL FRAMEWORK

This theoretical section introduces the concept of construction logistics, methods and techniques that can be used in order to improve the construction logistics process. Start with explaining fundamental logistics and supply chain management theories, then draws main problem area (reducing waste) by using consolidation Centre, which is further has impact and need for innovation of the logistics and supply chain management in the construction industry. All information cited in this section is the results of literature reviewed.

3.1 Construction Industry

Every major industry except construction uses logistics for improvement. As Karl Hudson and Stephen Bacon (n.d cited by Rich B 2010), noted `Construction industry logistics are immature' and the construction industry simply does not understand how logistics can add value`` (Rick B. 2010). Currently it is only a few companies who see that expense in improved logistics and more effective supply chains is an investment that will lead to reduce waste and higher profits. The strategic forum for construction logistics group (2005), argues that there are many opportunities for change that the construction industry has been slower than other industries to realize. One such example being the benefits that the application of good logistics can provide, According to a Swedish study, Hammarlund (1989, quoted by Bertelsen and Neilsen 1997) showed that about `` a third of the time used by the worker on the building site is spent procuring his materials, mostly, equaling about 10 percent of the total building cost``. Whether the percentage is 10%, 30%, or more there is need for improvements in construction sectors. According to Gary Sullivan et al., (2010), there are four compelling reasons why the construction industry should implement a dedicated approach to logistics. First, to maximize the productivity and efficiency of the skilled workforce on site; Second, to maximize quality of service by enabling a dedicated, trained logistics service team to provide a holistic support service for the construction project. Third to minimize the negative environmental and social impact that construction projects create, and fourth, to ensure that the highest possible standards of health and safety to maximizing the productivity of the skilled construction workforce;

3.2 Logistics and Supply chain management

Logistics is the main issue of this study, so it is necessary to define and explain it. The terms logistics and supply chain sometimes are used interchangeably. In other words, supply chain is broader concept and logistics is narrower. Logistics and supply chain are compared by Pryke (2009) as logistics deals with intra-organizational issues, however, supply chain deals with both intra-organizational and inter-organizational issues. In this study the scope of logistics is considered close to scope of the supply chain the definitions which are presented below are what will be meant by authors regarding these subjects.

Supply chain is a system of organization, people, activities, information, resources and knowledge flows to satisfy end users requirement from multiple linked suppliers, James B. Ayers (2010). The aforesaid definition of supply chain is a new one which considers various changes in environments, such as development of IT (internet), globalization, and sophisticated customers who demand increasing product variety, lower cost, better quality, and faster response.

Supply chain management is planning and management of all activities involved in sourcing and procurement, conversion, and all logistics management activities, Patrik J. (2008). Supply chain management is crucial in a sense that efficient and effective supply chain management increases company performance and adds value by increasing asset usage to gain competitive market advantage, Patrik J. (2008), Arbulu and Ballard 2005).

Logistic is defined by Patrik J. (2008) as the process of planning, implementing, and controlling procedures for the efficient and effective transportation and storage of goods including services, and related information from the point of origin to the point of consumption. Construction logistics can be defined as the management of the flow of materials, tools, and equipment from the point of discharge to the point of use or installation, (Mossman A. 2008).

In general, logistics functions in a construction company can be divided into supply logistics and site logistics, which is illustrated in Figure 3.1

Supply logistics are related to activities in the production process that are repeating. These activities include specification of supply resources (materials, equipment, and people), supply planning, acquisition of resources, and transport to a site and delivery and storage control.

Site logistics are related to physical flow, namely, planning, organizing, directing, and controlling on-site processes. The management of handling systems, safety equipment, site layout, defining activity sequence, and resolving conflicts among various production teams related to the on-site activities are all part site logistics (Fred and Francisco 1999, cited by Hyounseung J. 2003).

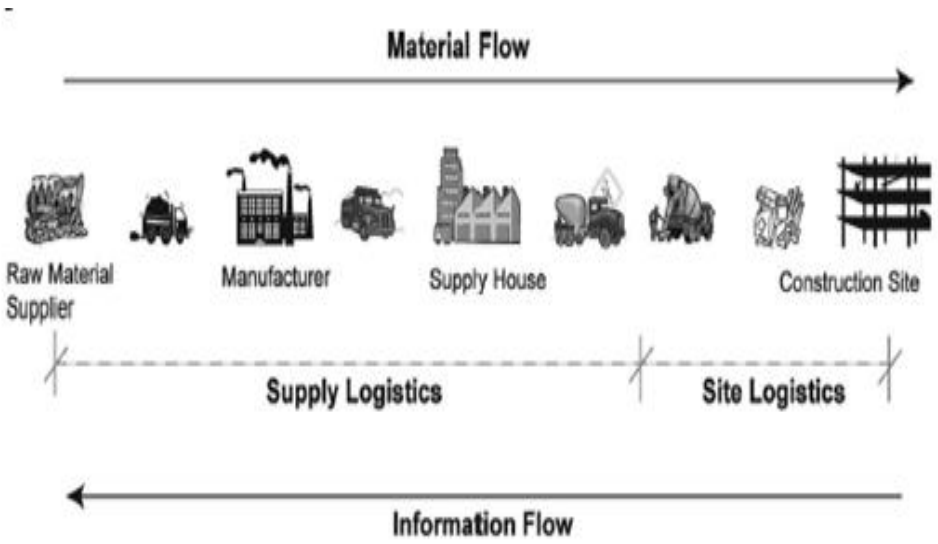

Figure 3.1 Construction logistics activities (Hyounseung J. 2003)

3.3 Deficient construction supply chain and improvement areas

Literature review showed there are a considerable number of researchers who generally blame construction industry for insufficient attention and investment on logistics. Three examples as illustrations come as follow. Construction was criticized by Sullivan et al (2010) because of lack of logistics considerations. Construction is recognized as are slow regarding realizing benefits of proper logistics by the strategic forum for construction logistics group (2005). Major problems in construction logistics are identified by Janaka (2009) as; managing the flow of materials, ensure its quality, controlling the quantity, allocating the storage, coordinating overall process and training the teams

Logistics concerns are crucial in a way that they account for a considerable amount of construction costs. Cost of materials and equipment accounts between 60 and 70% of construction project total budget (Kini 1991, Bell and Stukhort 1986, cited by Abdulmohsen and, Janaka 2009), and transport costs accounts for 10-20% of construction project costs (BRE report 2003, cited by Stanhope and Wilson 2008). Summing up cost of material and equipment with transportation costs, logistics has interaction with something between 70- 90 per cent of construction cost. It could easily conclude that ineffective management of logistics could easily cause huge cost overruns. Also, this is apparently an indication of importance of construction logistics.

One of the most obvious causes of lost productivity is the poor management of materials, equipment, and tools, which means poor logistics management. (Tony Douglas 2007, quoted by Abdulmohsen and, Janaka (2009)), argues that logistics is going to become absolutely crucial to construction industry. Other industries have improved working capital by 20% by getting smart on logistics. The drivers for improving construction logistics are the traditional drivers of cost, time and currently the environment

3.4 Waste in construction process

Construction logistics could be analysed form Toyota's waste perspective. Toyota motors, an acknowledged expert in managing waste, shows how waste and work are linked in a rather unique relationship. In this vein there are three categories of work: Value Adding Activities, Value Enabling activities and waste, Ma Uly (2011). Value adding activities are what clients want. Value enabling activities is what makes deliveries possible (most of this part is logistics) and waste is any activity which does not add value, Anthony H. (2007). Waste is the problem area which needs to be eliminated. The sum of these three categories of work, as the simple formula below shows, equals to the actual work which is done in the construction process.

Work = Value Adding Activities + Value Enabling activities + waste. (1)

Work - is the sum of value-adding activities, value-enabling activities and waste
Value - Adding Activities – what clients want;

Value -Enabling activities – what makes deliveries possible or support (most of this part is logistics);

Waste – problem area what needs to be eliminate, and the reasons found for waste arising in construction are illustrated in table 3.1

Seven common types of waste or non-value added activities are identified by Liker (2004) that are overproduction, inventory, extra processing steps, waiting, transportation, defects, and motion. Eliminating these wastes lead to reducing lead time also eliminates the waste of waiting and it means creating a material flow. Accurate systems, processes, and standards are required to create and maintain this flow and to ensure: reduced cost, reduced working capital, increased productivity, improved quality and lead to higher levels of customer service and satisfaction (Euclides A. Coimbra, 2013).

Table 3.1 waste in construction (Adrian Blumenthal and Adrian Young 2007)

No.	Reasons	Estimated impact by % of value of materials received
1	Waiting	5 -20%
2	Over - ordering	3 – 25%
3	Damage	5 – 10%
4	Packaging	1 – 5%
5	Design Change	1 – 5%
6	Programming and planning	1 – 10%

From the above Table 3.1 it could be seen that wastes (non-value added activity) include more than 50 percent of the whole activity which are done during a construction project. Between aforesaid wastes there are reasons like damage, over-ordering and packaging which directly related to logistics. Also, value enabling activities naturally are tightly entwined with logistics issues. Hereby, by implementing more efficient methods of logistics, amount of waste and value enabling activities could be reduced and the amount of actual work would be closer to value adding activities. In two examples below, increasing profitability will be discussed from two dimensions: material waste and professional work force waste of time, by implementing more effective logistics methods.

There are significant cost overruns which are generated by poor material logistics. By modifying typical logistics routines crucial cost savings are possible. For example, there is some evidence that on a typical construction project about 15 % of the material supplied to the site (by value) is not consolidated, in the construction and it means waste. For some construction site waste can be higher than 45%. A 35% reduction in this material wastage could be achieved by adopting more efficient logistics practices (Adrian Blumenthal and Adrian Young 2007).

Construction logistics could be evaluated from working forces' time consumption. It is shown that about one third of the time used by the workers on the building site is spent for procuring his materials, Hammarlund (1989, quoted by Bertelsen and Neilsen 1997). The time that is spent by professional work force for material handling instead of his/her main duty is considered as waste. In the widest sense one third of the time of professional work force, in the Swedish market, equals to about 10 percent of the total building cost which is a considerable amount. However, proper logistics can decrease the time of material handling by professional work force and transfer this duty to logistics professionals.

3.5 Methods and techniques of construction logistics

Construction logistics task is classified to four major categories by Blumenthal and Young (2007), which three of them are considered as traditional methods and one of them as a modern one. These categories are illustrated in the Table 3.2 Below these four logistics models which be argued according to the aforesaid reference.

Tale 3.2 method of construction logistics, (Adrian Blumenthal and Adrian Young 2007)

logistics	**when**	**Used by**	Remark
Traditional			
Method 1:	The case company goes to the supplier to pick up materials	About 10% of the industry	
Method 2:	The case company has materials delivered to site	About 50% of the industry	
Method 3:	The case company uses portfolio analysis to divide in part ordering processes and call off arrangements	About 35% of the industry	
Alternative			
Method 4:	The case company co-ordinates from a start- to-end process and tags information, people and materials flow	About 5% of the industry	

Method 1, the case company goes to the supplier to pick up the material: this method is followed by about 10 per cent of the industry. This is the simplest method and do not demand for a considerable amount of planning and it is used by a business that takes orders on jobbing basis.

Method 2, the case company has material delivered to the site: this is the routine for about 50 per cent of the industry and is the most popular one at the time. The projects which use this method are larger than the projects which use the first method. Time saving and fleet minimization are between the main benefits of this method. This is used by a business that has materials delivered to the site, typically larger projects with a bulk delivery.

Method 3, the case company use portfolio analysis to divide in part ordering processes and call off arrangements. This method is used by 35 per cent of industry. It satisfies the need of some project at the same time. The main benefit originates from the point that mass purchasing increases monetary saving. This is used by a larger business with a multi-project programme that can procure materials on a company basis.

From Method 1-3 considered traditional construction logistics and illustrated in Figure 3. 2 below

This is used by a larger business with a multi-project programme that can procure materials on a company basis. Companies may have consolidated account or supply basis to reduce administration costs and materials costs through preferential volume

discount. Materials will be delivered to site and waste is reduced by improved processes.

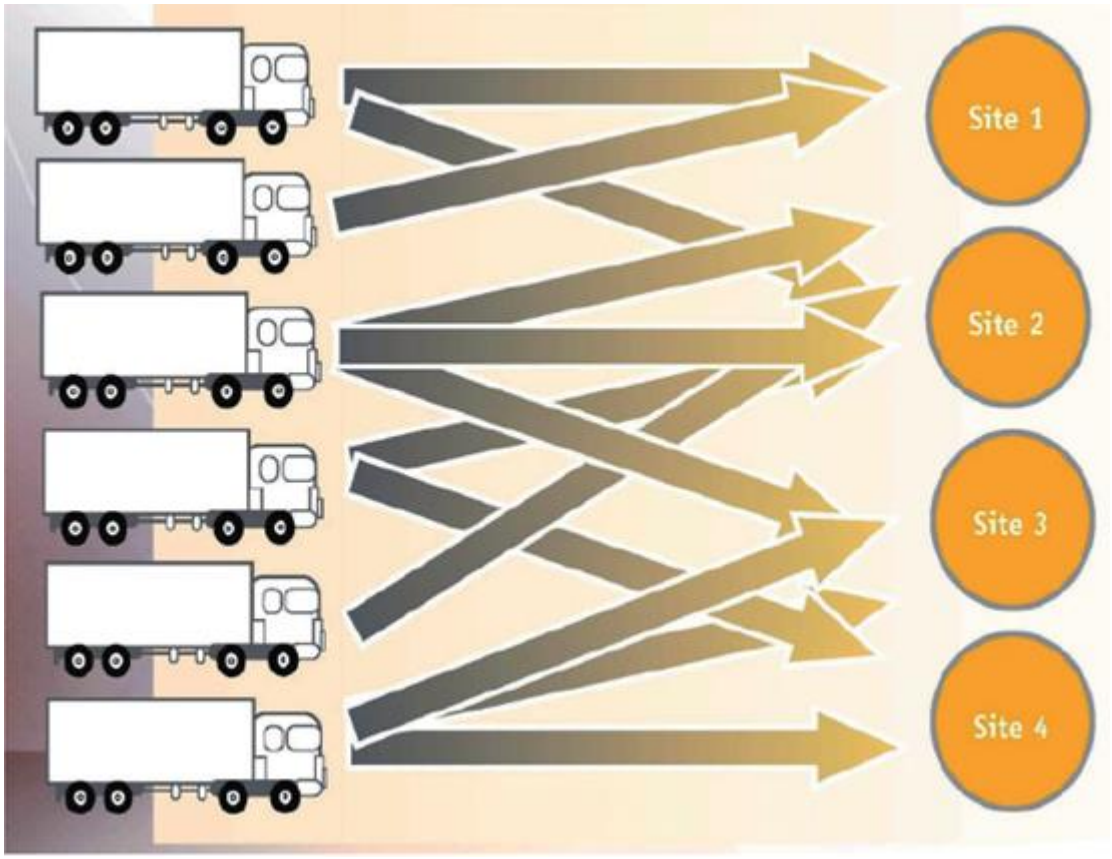

Figure 3.2 the traditional, inefficient and environmentally damaging method of delivering materials to site (Gary Sullivan et al., 2010),

Method 4, the case company coordinate from a start to end process and tags information, people and material flow. This method is used by 5 per cent of the industry. The main pitfalls come from extra costs which are associated with the essence of this method and information sharing deficiencies. However, the cost saving in this method is more in compare with other one, also, environmental concerns are considered.

Method 4 is an alternative arrangement no commonly used in construction site. In this alternative method 4 there are seven main logistics techniques which are indicated below:

1) Consolidation Centre
2) Logistics planning across full supply chain
3) Just-in-time delivery to workplace
4) 4th party logistics (4PL)
5) Logistics specialist on site
6) Demand smoothing
7) Integrated information communication technology (ICT) system across full supply chain

In finding authors is focus on CC to reducing the waste arising from waiting, over-ordering, damage, and design change, planning and programming. Support activities provide also, that allow the primary activities, CC to take place. These include:

1) Logistics planning across full supply chain
2) Logistics specialist on site
3) Just-in-time delivery to workplace

3.5.1 Construction Consolidation Centre (CCC)

This section introduces the consolidation centre concept and how does it function, also, provides some argument for using it in the construction industry based on its successful use over many years in the retail and manufacturing industries. Construction consolidation centre is defined by Greger L. (2011) as a distribution facility that receives materials, tools and equipment, from supplier and delivers to construction site in consolidated loads.

The operation of a CCC, according to Sullivan et al. (2010), starts with material handling inside the CC with appropriate equipment and storing in dry and secure places. On call off from the site, consolidation centre operator makes up consolidated loads and delivers those on a just-in-time (JIT) basis to minimizing on- site storage and sharing transport to minimize traffic and congestion or overload. This process combined with on-site logistics delivering material to the point of use and provides an excellent opportunity to improve the overall resource efficiency of construction project, (Gary Sullivan, et al. 2010).

According to Adrian Young (2004), there are six steps in dealing with materials: (which is also illustrated in Appendix 1)

1) The trade contractor place orders for supplies, specifying delivery to the consolidation centre

2) The consolidation centre agree an inward deliver time and takes delivery

3) About 24 hours before supplies are needed the trade contractor requests delivery, stating exactly what, where and when.

4) The consolidation centre makes up `daypacks` for each task.

5) The consolidation centre delivers the daypacks JIT for each time to undertake that day´s tasks.

6) The consolidation centre removes excess materials from the site every day

When established, this process gains up many possibilities. Using the consolidation centre makes the whole distribution process simpler and more transparent (Adrian Young 2004). This process maximizes the efficiency of distribution vehicles and leads to a substantial reduction in overall vehicle numbers delivering into a congested environment (Gary Sullivan et al 2010). The main feature of the centre is that goods are delivered not just a site entrance – but to specify location as close as is practicable to the workface, by material handling operatives. Trade contractors are left free to concentrate on their main tasks, without worrying about the co-ordination of and supply of goods to site.

Sullivan et al., (2010) pointed out that Consolidation Centres have been used successfully in the retail and manufacturing sector for many years, but it only have

been adopted to use in construction projects. Gary (2010) also, noted that the concept of construction consolidation Centre was specifically developed to serve the materials handling needs of multiple construction sites in busy and challenging environments such as airports and inner city areas. Construction consolidations Centre are essentially buffer storage facilities that hold materials or goods for a limited period (7-10 days). Consolidation Centres are normally situated strategically near to highways or railway stations to facilitate ease of delivery and hold vast quantities of materials or goods. Construction consolidation centres should be located 10 km from site because with 30-45 minute drive to site and load/unload time of between 30 minutes and one hour, each can do two three journeys per eight-hour shift (Gary Sullivan et a., 2010). The Figure 3.3 below show the principle of construction consolidation centre.

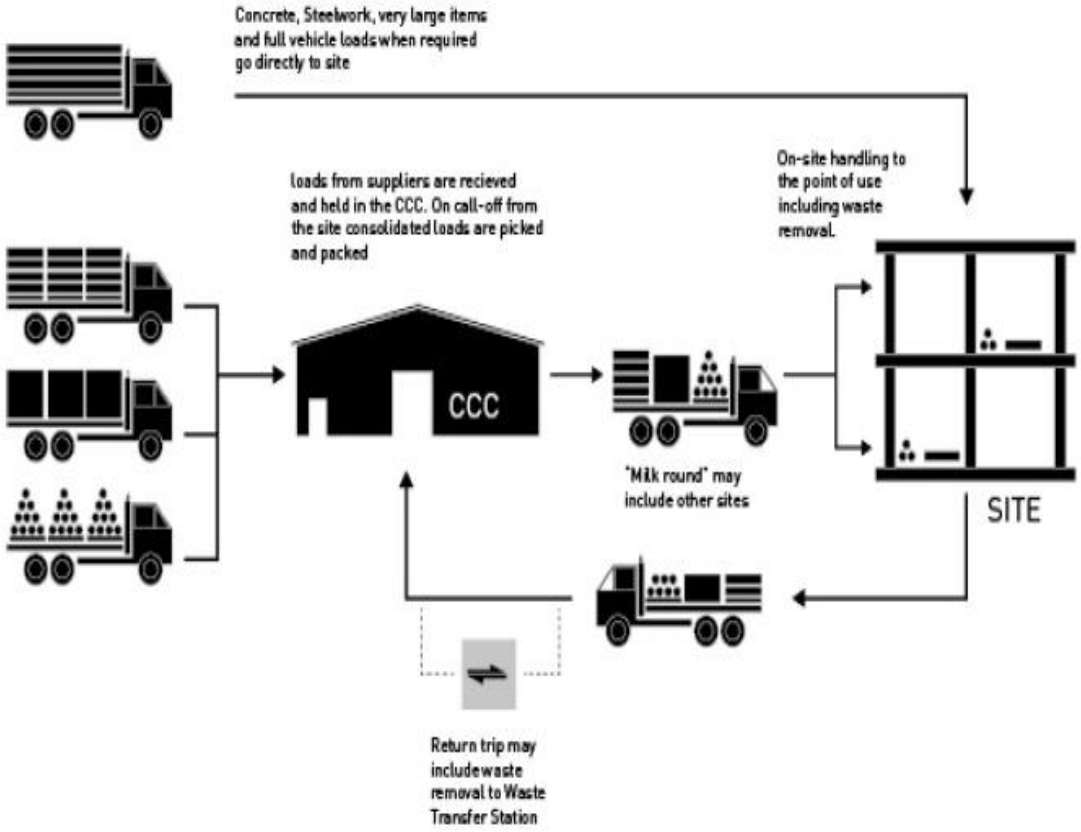

Figure 3.3 the principles of a Construction Consolidation Centre (Greger Lundesjo, 2011),

3.5.2 Classification of Construction consolidation centers

Seven factors which differentiate CC according to how they function are identified by (Scott Wilson 2010). These factors are shown in the next paragraph and a minor explanation is presented in front of each of them. Here the challenge is to identify the right set of conditions that make a consolidation centre appropriate in delivering the benefits that are demanded by the project. One of the most substantive parts of this challenge is to find the formula where the facility is able to operate successfully commercially with the least requirement for on-going financial support (Scott Wilson 2010).

Objectives: - consolidation centers can have single or multiple objectives, like meeting environmental targets;

Financial ability: - in most cases consolidation center require operating subsidy. But introducing value added services can reduce a plan's dependence on public support;

Location:- consolidation centers differ in terms of their distance to the area served, type of location to the transport network;

Dimensional coverage: - some consolidation centers are purposely developed to serve a single site, when others may be regional hubs serving a much hinterland,

Transport types:- many consolidation centers use road transport, but increasing demand is being attached to introducing intermodal facilities between road and rail way;

Flexibility of operations: - while some consolidation centers on fixed schedules, others may be direct towards on-demand operations;

Ownership: - consolidation centers may be privately or publicly owned and involve either a single operator or a joint venture.

CCC is divided into four different categories by Sullivan at el (2010) according to their location, number of construction site which are served by a CC and the party which is in charge of CCC operation. These categories which will be explained as follows were coined: concealed consolidation centre, the communal consolidation centre, shared consolidation centre and virtual consolidation centre.

a) The concealed consolidation center

This consolidation function is performed within the construction site. It can be used when site is not a city center location. There are no space shortages and good quality storage can be provided. Deliveries are received, inspected and stored at the on-site storage. When the principal contractors request materials, deliveries are made on JIT basis to the point of workface. It needs no extra investment up-front and it is all about applying the principles of the CCC. It is operating during only during the day times.

b) The communal consolidation center

The communal CC is so called because it serves numerous single contractor projects at the same time. It is located close to the construction site (maximum 5 km away). Operated by trade contractor or a specialist logistics contractor and using up to 20 people. It is operating flexible hours, receiving deliveries during the day and distributing materials at night and a basic paper – system used to control inventory.

c) Shared consolidation center

The shared consolidation center receives its name from its demand for sharing between different clients and contractors. A consolidation center is serving a number of sites on an ongoing basis. It is being located up to 25 km away from the sites and operated by a specialist logistics contractor by using around 50 people. It could be operational 24 hours a day, seven days a week it is receiving deliveries during the day and distributing materials at night and using a WMS to control inventory.

Operationally it functions like the single user consolidation center but deliveries can be consolidated on ´milk rounds´ to the various sites supported. In this case the fixed cost will be shared across several projects and there is an efficiency of scale. Such an operation can profitably support smaller projects that could not be able to pay the cost of a single user CCC. This form of CC is the most likely to receive government funding.

d) Virtual consolidation center

The CC process is managed by logistics contractor using existing resources in terms of materials management systems, vehicles and storages. In this case a logistics contractor manages all inbound deliveries. Where this differs from the above options is that the logistics contractor will manage the flow from source to the CCC (not only from the CCC to the construction site). This option is the one that can most readily test consolidation opportunities on the supply chain inbound the final CCC.

3.5.3 The benefits of using a Construction consolidation center

The direct benefits of using construction consolidation centres relate to the reduction in construction traffic. Proper management of distribution reduces the number of vehicles (*Scott Wilson 2010).* The table 3.4 below sets out some of the functions associated benefits of using consolidation centre

Table 3.3 Functions and benefits of using consolidation centre ((Adrian Young 2004 and Scott Wilson 2010)

Functions	Benefits
Quality storage space	Secure warehousing and good quality floor highly reduces damage materials and losses
Consolidated transport	During peak time vehicle traffic to site can reduce by 60 – 70%
Removing excess packaging	It reduces waste handling on site, and over-ordering is reduced, An approximate 15% reduction of material waste;
Consolidating pallet for point of use	Goods are delivered as close as is practicable to the workface, repeated on-site handling is reduced and productivity and reduce sit stock holding.
Sequencing material supply to the workplace	This is the main function of the CCC. Improve certainty of supply; Reduce site deliveries. Ensuring the quantities of the right materials are delivered to the point of use on a JIT basis has a great impact on productivity and safety. JIT in construction context, it means supply of one to two day´s usage.
Pre-assembly	By making pre-assembly at the CCC in wide and good working conditions time saved on site

Other Immediate benefits:

1. Trained personnel put materials where they are needed, these reducing manual handling risks

2. Skilled operatives did their work, without disruption of unloading supplies

3. The site is tidier, leading to better productivity and fewer accidents

4. Trade contractors are left, free to concentrate on their core tasks, without worrying about the co-ordination and supply of goods to site,

5. Achievement of delivery performance of 95% of goods delivered, right first time

6. Eliminate internal transportation and disturbances;

(Adrian Young 2004 and Scott Wilson 2010)

3.6 CCC Support activities

3.6.1 Logistics planning across full supply chain

Constructors must have professionally trained logisticians who can plan across ranging, procurement, storage, distribution and back loading activities. And understand all construction work processes (.Adrian Blumenthal and Adrian Young 2007).

3.6.2 Just-in-time delivery to the construction site

Just-In-Time (JIT) is one of the two pillars of Toyota production system (TPS), the other is ``built in-quality`` which is often known as 'Lean`. It is a set of principle, tools, and techniques, which allows a company to produce and deliver product in small quantities, with short lead time, to meet specific customer needs. Simply, JIT deliver the right items at the right time in the right amounts and at right place (Liker 2004). According to Association for operations management (2008), JIT is a philosophy of manufacturing based on planning elimination of all waste and continuous improvement of productivity. It encloses the successful execution of all manufacturing activities required to produce a final product, from design to deliver and including all stages of conversion from raw material onward. The primary elements of JIT are to have only the required inventory when needed; to improve quality to zero defects; to reduce lead times by reducing setup times, queue lengths, and lot sizes; to accomplish these things at minimum cost (.James B. Ayers 2010). JIT is based on the understanding that inventories are not valuable and should be regarded as waste (salem et al. 2006, cited by Per Erik Eriksson n.d),

3.6.3 Logistics specialist on site

Logistics specialist on site is a service delivery and distributes materials, equipment and plant JIT and operatives handle materials only when assembling; specialist at the consolidation Centre must work with trade contractors to help them understand and improve their distribution. To do this Logistics specialist must understand all construction processes from start to the end (.Adrian Blumenthal and Adrian Young 2007).

3.7 Other important activities

3.7.1 Integrated information communication technology (ICT) system across full supply chain

Adrian Blumenthal and Adrian Young (2007), state that ICT is an interoperable information system that tags and tracks materials through take off, manufacture, distributions, assembly and installation. Good communications for successful construction logistics need to happen at several levels (Gary Sullivan et al 2010).

3.7.2 Materials identification systems

This part considers the application of different tools which promote efficient logistics by improving communication of product information throughout the supply chain. There are currently some options:

a. A paper – based system
b. WMS
c. Barcode technology, and
d. RFID systems

All these are distribution techniques that facilitate better logistics management.

Communication tools used, also, radio, telephone and internet and maybe in the future BIM, depends on different levels of sophistication. Where transportation moves people, plant and materials, communications move data and ideas. Both need to work in an effective and timely manner for the project to run simply (Gary Sullivan et al., 2010).

3.7.3 Training and communication

A training and communications program should be developed by the main contractor to ensure all parties understand how they are to report the quantities and types of construction materials they will use throughout the duration of the project. The training should include making sure that everyone is aware of any site specific issues and logistic strategies e.g. the use of a CCC or on-site material plans (Adrian Blumenthal and Adrian Young 2007).

3.8 Consolidation Centres in the Lean Supply Chain

Lean supply chain is a based on the concepts of Lean manufacturing. It is about managing and improving the supply chain process to profitably deliver what the customer need. The aim is to ensure on-time delivery of materials, equipment and information to project sits at minimum cost and maximum value. Consolidation centers are playing an increased role in many supply chains, particularly as feeders to manufacturing operations that produce complex products with many components. Every supplier can't or won't link its operations with its customers. The consolidation center helps this linkage-at least until better suppliers can be found (Michel Baudin**,** 2011)

3.8.1 Principle of lean thinking

In its most basic form, lean manufacturing is the systematic elimination of waste from all aspects of an Organization's operations, where waste is viewed as any unused or loss of a resource, which does not lead directly to creating the product or service a customer want. The fundamental objective of lean is to create and maximize value through the elimination of waste. From the early literature we see that, in many construction processes, such non-value added activity can comprise more than 50 percent of a construction's total activity. Lean Thinking is a methodology to:

1).Specify value,

2) Identify value adding actions in best way,

3) perform these actions without interruptions in a continuous way,

4) Perform these actions in more efficient way,

5) Pursue perfection by Continue improvement of these actions (Liker 2004)

It means that Lean Thinking gives immediate feedback in order to change waste in values

3.8.2 Relation between Lean and CC

The philosophy behind Consolidation Centers is, clearly, informed by the theory of lean supply chain. The aim of both CC and Lean supply chain is to minimize the inventory. In order to achieve waste minimization both process require Just-In-Time delivery and Lean or CC is for elimination of all waste including waste of time. Simple, both Lean and CC is creating more value for customers with fewer resources and improving productivity. In the early, Lean literature seven wastes are described. Eliminating these wastes direct to reducing lead time also eliminates the waste of waiting and it means creating a material flow. According to Euclides A. Coimbra, (2013), accurate systems, processes, and standards are required to create and maintain this flow and to ensure: reduced cost, reduced working capital, increased productivity, improved quality and lead to higher levels of customer service and satisfaction. The main difference between Lean thinking and CC is described in table 3.4 below.

Table 3.4 Difference between Lean thinking and Consolidation Centre

Lean	Consolidation Centre
Perform the action without interruptions in a continuous way.	Bach-and-queue method or action by smaller part.
Some time source of risk	Reduce risk
Not green solution	Green solution
Not easy to adopt in construction process	Not hard to adopt in construction

3.9 Value stream mapping (VSM)

VSM, also known as `value chain analysis` used in the car industry first time as tool for implementing Lean production (Rother and Shook 2003, cited by Gary Sullivan et al., 2010). It is an analytical process for understanding an organization methods based on individual activities at each stage (bocij et al. 2003, cited by Gary Sullivan et al. 2010). Further, Bocij et al. (2003), pointed out that at the aims of VSM is to eradicate waste from the process of production by identifying non-value-adding elements, as determined by the client´s reception of ´value´, to achieve this both the information

and materials flows of a single product and its components are mapped from start to end.

3.9.1 Comparing VSM in the manufacturing and construction industry

The retail and manufacturing industries use VSM to improve the flow of materials from the source to the end user. However, analysis of the VS in construction is limited to final link of the supply chain.

The made-to-order design of building, the specification of non-standardized products and the short duration of most construction projects make it difficult to define a value stream, because of the number and variety of components used (Gary Sullivan et al. 2010). The complexity of the process and number of parties involved also, disturbs knowledge of the supply chain in construction industries. And Figure 3.4 below summarizes the factors which facilitate VSM between the construction and manufacturing industries.

Table 3.5 the factors which facilitate VSM between the construction and manufacturing industries (Gary Sullivan et al. 2010).

Manufacturing	Construction
. Emphasis on the use of standardized products	. Use non – standardized construction techniques
. Single product manufacturing process	. Lack of time and resource between the design and construction stages
. Established and well-defined supply chain	. Level of understanding of the supply chain
. Product design considers ease of manufacture	. Bespoke design of buildings
. Consideration paid to production technique during the design of the product	. use of non – standardized product
. High level of certainty placed on the number of components	. Relatively short duration projects
. Known and established product base	

3.9.2 The cost benefits of consolidation Centre

Consolidation Centre gives significant advantages to a contractor. And it is probable that other parties including principal contractors and material suppliers benefit from using a CC. But their cost saving are difficult to quantify. However, considerable effort at Heathrow airport, two factors have happened cost savings being passed to the client.

1) Few in the construction industry fully understand their logistics cost. This lack of understanding is hiding savings passed on the client.
2) Principal contractors are no agreeing to share financial data for fear that the client will seek to reclaim any saving made (Gary Sullivan et al. 2010).

According to Gary Sullivan et al. (2010) different way in which a principal contractor benefits financially as a result of a CC includes:

. The ability to arrange deliveries in relative bulk

. The reduced need for site- based workforce

. Less damage to materials

. Improved health and safety standards

. Better use of the principal contractor´s skill

Calculating the extent of these savings is difficult because of their dependence upon a different circumstance.

3.9.3 Environmental issues

The main current environmental issues may include pollution, climate change, environmental degradation and resource saving. Climate change caused by global warming (human activity). The largest driver of global warming is carbon dioxide emissions from fossil fuel burning. Fossil burning has produced about 75% of the increase in CO2 from human activity over past 20 years. And climate change cause in the future global food shortage. These are major case to use consolidated transport on construction site (logistics and transport conference Goteborg, 7-8 may 2014).

3.10 Summary of theoretical framework

The literature section of finding help us to understand the concept , method, techniques of logistics and supply chain management and role of Lean in construction industry. The construction logistics is one factor for the successful projects of construction, and supply chain management can add value, it can reduce waste, it can improve productivity, it can decrease environmental impact and the individual companies gain significant competitive advantage from this improvement. Logistics is usually seen as storage and transport management. But leading contractors are

investing in logistics research and development for the following 6 reasons summarized in table 3.4

Table 3.6 Six reasons to invest in construction logistics (Adrian Young 2004)

Logistics system	Reduces waste and cost by:
Reduce the number of suppliers	Reduce the number of transaction
Reduces vehicle movements on site	Reducing congestion and carbon emission
Minimize the materials stored on site	Eliminate damage and losses
Tracks goods, materials, equipment and people	Using resources efficiently
Plans how resources will be used	Ensuring that all needs are meet at the right time and place
Increase profitability	Eliminating waste of materials, and time

Both logistics technique, consolidations Centre and lean literature focuses on aspects that affect effective flow of resources and how to reduce waste. According to pilot studies LCCC reached reduction of material waste up to 15%, achieved delivery performance up to 95% goods delivered right for first time, reduction of CO2, emission from reduction vehicles movement up to 75%, (LCCC) and provide positive financial effect, even it is not easy to calculate gained economic value because logistics – moving materials, people, information, and equipment to the workface create no value. In construction value can only be created when building design, assembly and logistics come together at the workface. In general construction logistics deals with many organizational, technical, and environmental, issues affecting the cost of project, time, and quality of assembling. From literature findings we understand also, the role of good logistics management and Lean supply chain management and how add value by eliminating waste from construction processes by applying those logistics techniques and Lean tools. But according to literature review logistics is immature in construction industry and it takes time to implement this golden opportunity to improve performance, add value, reduce waste, and reduce environmental impact. As Wilson James, which manage the LCCC reported, on completion of one construction project in London, some 38 lorry -26T loads of unused, materials and good quality equipment with a value around £250, 000 were returned from site to the CCC. The benefits of the CCC were that this waste could be controlled and managed, and most of it was reused on other projects. On other; less managed projects, this material would simply have been probably sent to landfill (Rick B. 2010). In general, all the participants in a construction project can benefits from using a consolidation centre. Then, the industry needs more and more logistics focused research to establish the contribution that the disciple can make to reduce

waste, carbon emissions, increase profitability. For more details see Appendix 2 Overview of the best practice in using consolidation centre

Damage to material amount to 5_10 percent of total construction cost (Young, 2007), Ensuring quality of material and its quantity found by (Janaka, 2009) to be a major obstacle in construction logistics. Appropriate material handling and security of storage are indicated by (Greger, 2011) as being provided by consolidation centers. CC is emphasized as safest way of material delivery by Stanhope and James (2008). The figure of 15 percent is presented for reduction in damages and losses by Wilson (2010). He argues the reason of this as material handling is took place by trained personnel risk of damage is reduced.

Poor management of material, equipment and tools are causes of lasting productivity and efficiency. For example, over ordering of material could account for 3-25 % of the cost of project (Young, 2007). There are considerable amounts of literature which shows researchers are agree about the matter that CC can heal the shortcomings associated with ordering and delivering process. For say, JIT delivery is indicated by (Greger, 2011) as one of the main contributions of a CC. Also, Facilitating JIT delivery by CC is emphasized by (Young, 2004) and by Stanhope and James (2008). He further argues regarding simpler distribution process via CC in compare with other approaches. Delivering to the point of use by CC is discussed by (Sullivan, 2010) as an opportunity to enhance efficiency. Reducing site deliveries and over-ordering are stressed by Wilson (2010) as crucial contribution of a CC. Here the major focus is on JIT delivery and after that it comes to site delivery reduction and avoiding over-ordering

4 Results

This is a summary of the interviews which is done during this thesis study. The transcription of the interviews is attached in the appendix B for further inquiries. Also, one sample of interview question is placed in the appendix A. The interview questions were differed according to position and the context in which the interviewee is located. In the attached interview questions it is attempted to gather the whole questions which is ask from all interviews.

As it is said in the above paragraph this section is a reflection of interview transcriptions. What is done here is gathering same information under a unique heading. For example in the first, second and fifth interview the matter of location of the project is discussed. All the relevant information regarding the subject is summarized under the heading "project location".

All the issues which influence functionality of a CC are categorized as either primary issues or functional issues. Primary issues are issues which make implementation of a CC possible. For example authority is a primary issue. It means, for say, the power should be allocated from people in the top of the hierarchy to site manager to make him able to exploit a CC. In this study functional issues mean issues which could be both advantages and disadvantages depending on how a CC functions. For example according to some interviewees environmental concerns are an advantage for CC and in other are disadvantage. However, the authors figured it out that environmental concern is a functional issue for a CC in many big city like Beijing, London, and Stockholm etc.

4.1 Size of project

It is possible to categorize Construction site according to their size to three main categories: small, medium and large. Large size projects are divided into projects with low complexity and high complexity.

According to one of interviewees too big projects in some cases do not demand for a CC. Considering a vast shopping center which is not more than four or five floors will illustrate the point. In this kind of project there is not a big pressure of space limitation and there are lots of entrepreneurs inside who demand for material. Even in case of full truck deliveries the whole material will be used in couple of days. The fast consumption of material in the construction site means material storage will not be in a high level and accordingly will not decrease site efficiency. Basically, this situation will decrease the complexity of logistics and make it simple.

4.2 Space limitation

Basically, in this study storages which are get used during a construction project are divided into two types: in-site and out-site storage. Considering a construction site with capability of storing a huge amount of material, in-site storages are rational to be used. There are four situations that using an external storage would be an alternative which will be explained as follows. This external storage could function as a simple storage or as a CC, co-packing take place in storage as well as storing.

When the construction site is under high pressure of storage space for its daily material consumption an external storage can be used. 2) External storages could be used to meet a Construction site needs for long term concerns. For example when there are predictions about price increment of a material, high amount of related material is purchased and stocked in storages. 3) When the supply chain is too vast, like international supply chain and a CC is used as buffer. This situation is more popular in manufacturing; however, there are minor examples in construction as well. 4) The last situation is when part of assembly should be done outside of the Construction site, external storage is an alternative.

In some cases the construction storage place is too restricted which makes the storage task of daily used material problematic. In such cases an external storage could be bought or rented. In this storage, material would be consolidated in a truck with a volume that is applicable to the storage space of construction site. When the construction contractor demands for the amount of material which is higher than the storage capacity of supplier, and there is not enough available space in the construction site, an external storage could be used for placing the extra material. There are also situations that the construction contractor have access to a storage which is cheaper to rent maintains or operate. In manufacturing the most important function of a CC is to store material which *comes* across the continents and keep them safe prior to distribution. Because if some disturbances happen either for the supplier or for the transportation vehicle and there is no inventory, the production line should be stopped.

In construction the matter of lack of needed material for production is not as crucial as manufacturing in a sense that it does not result in completely stop the production, but it still cause in wasting resources. Like manufacturing supply disturbances are more common in international supply chains.

CC can be more efficiently used as an assembly place for residential buildings. In residential buildings customer customize the design of the property according to his or her personal preference.

The issue of site location includes two sub-issues. The first one is traffic density in the roads which a Construction site is surrounded by. The second issue is proximity of given Construction site location to other site. Finally, it depends in persons who are in the top of hierarchy in project and have the authority regarding how to manage logistics task of a Construction site.

In one of construction sites which is studied in this thesis work there were about 10 or 15 deliveries each day. In the aforesaid project there was enough space inside the construction site to place the truck and unload it. Considering a Construction site which is located in a busy area of a city and has same number of deliveries, the outside traffic should be interrupted 10 or 15 times for truck delivery which result in huge monetary compensation. However, if a CC is used in this situation all needed material for each day can be co-packed in fewer number of trucks, one truck ideally, and traffic would be interrupted once a day. The point which should be considered regarding decision making about a CC is proximity of Construction site to other construction projects. If in an area there are some construction projects which are located with reasonable distance from each other a consolidation center can be shared between them. It is possible that all of construction sites are not big enough to justify costs of a CC by their own, however, together they build a big enough project which is rational to have a CC. Usually in central parts of big cities there are always

construction projects in different kinds. Central parts of big cities are often considered as dealing with traffic congestion issues. Given that Gothenburg is a major city at least in Swedish context it should be always possible to use CC for boosting efficiency and level of EF enhancement. However, this matter demands strong collaboration between different construction contractors which are leading different projects and needs enough trust between dealing parties. Moreover, enough understanding regarding advantages of sharing CC should be available for high position people in companies since these are the people who are deciding regarding using or not using a CC.

4.3 Type of material

There are two interviewees who believe the size of material is a determining factor for using CC. interviewees argues that the material which is handling via CC should be small sized, like screws and nuts. However, the main components of building like façade, roof, walls and gypsum boards especially if they are prefabricated are not appropriate to be handling with a CC. one reason for this issue is that these materials which are mainly prefabricated are usually purchased as a full truck and it does not make sense to extra loading and unloading in CC when they will be used immediately in construction site. The other reason is some construction components are perishable. Given a concrete structure building, it is not possible to store prefabricated concrete on the CC. due to the fact that the duration of concrete transportation cannot exceed special amount of time.

4.4 Storage condition

Having an external storage which can provide a safe storage place would be a wise alternative if there are sensitive materials involved in the construction production or if there is a chance to material to get damped, missed or broken down because the specific situation of Construction site. An external storage can provide higher inventory supervision in compare with Construction site. Here, the aim of using an external storage is not consolidation but it can be used for this purpose as well.

However, it is hard to keep track of material in CC but it is needed to know what exactly is in consolidation center. There are projects which require 20 or more delivery each day. Since, level of material replacement is too high, material supervision is more demanding.

4.5 Supply chain ownership

According to one of logistics managers who is interviewed there are three different kinds of contracts with sub-contractors regarding types of material delivery which results in three different kinds of supply chain ownership. The reason behind this diversity could be explained by matters like monetary issues, nature of the task and construction material.

The first situation is that the company uses its own sub-contractors to do the construction tasks. Currently construction market different tasks are usually outsourced and this situation rarely happens. The second situation is that tasks are

done with external contracts with sub-contractors. These sub-contractors are responsible for providing their own material, machinery and whatever else is needed.. The third situation is that the construction task is outsourced and sub-contractors are hired but it is the main contractor who is in charge of material and machinery delivery.

Even in case of owning the supply chain difficulties are involved. The problematic situation arises from the point that small entrepreneurs do not have a precise plan of their future work. As a result they tend to deliver material as much as they can or. It is in strict opposition with lean concerns. This way everything will be available for the decision which is made at the moment. One logistics coordinator argues the reason for this situation as personnel of sub-contractors do not have a high academic background they are not aware of values of lean. Also, because of the same reason they are unable of planning their future work.

4.6 Environment

There are different in opinions of experts regarding making a comparison between direct delivery and delivering from CC associated with being environmental friendly. Generally, the discussion of being environmental friendly about this subject is mostly the matter of delivering by a full truck. When transportation is done by a full truck it is considered as more environmental friendly.

Considering full trucks deliver material to CC, the norm is needed material in CC will be co-packed in CC and loaded in a full truck. However, in such case the pitfall arises from the matter that the trucks come back to CC are often empty. The fact is that Most of material is used inside the construction site and there is not a lot of material in the construction site to leave it. The most popular item for removing from a regular construction site is waste. Usually the amount of waste which is generated in a construction site is not equal to the amount material which comes to the site.

A truck could be allocated to serve couple of construction sites not only one site. When the supplier is a material selling company the transportation task is done internally. Being environmental friendly in this case depends on if there are enough other projects around the given project to share a truck or not. The other factor is the range of material which is sold by the seller. If the company provides a broad range of material it is possible to mount different kinds of material in a truck which is needed in daily execution of a construction site.

Comparing CC and direct delivery, CC is much younger than direct delivery. In fact, direct delivery is the initial method of material transportation. However, CC came around about 30 years ago in manufacturing industry and afterward appeared in construction. During the period of existing of direct delivery innovations are made to enhance the quality of this method. Being environmental friendly to high extend depends on right planning which is on hands of parties which are involved. The right planning process in two ways can be taken into account.

4.7 Ordering and delivery process

All interviewees have consensus regarding the subject that CC relays the number and volume of cargo delivering to the site. Numbers of deliveries to the site decreases to a considerable amount with using CC. This is beneficial for the cost saving of the project in a respect that each time a delivery is supposed to be received by the

Construction Site some personnel have to get ready and prepare the perquisites for doing unloading and material handling. If there are more deliveries the process of preparation would be repeated more. Preparation task is non value adding activity by itself and should be avoided. The other point regarding CC delivery is not only the number of deliveries is limited but also the time of delivery is predetermined as well..

Large volume deliveries of same material to the construction sites are problematic and its reasons are completely discussed in the theoretical framework also in different parts in results section. On the other hand, if the deliveries of same material are too small volume it brings its own drawbacks. In such a setting small volume of cargo will be compensated by continuity. There are continuous deliveries of small amount of material to the site because of the nature of the project. Such a situation will result in spending significant amount of time and concentration to delivery handling. Because, each time preparations have to be made, some amount of time should be wasted as waiting time and etc. If these small deliveries consolidated in one delivery less effort will be spent for delivery handling.

If the CC is planned in a way that all kinds of material are stored inside the unpredicted lead time will be less than same delivery time by direct delivery. Because in CC all the material are available and they will just loaded to next truck and mounted to the site.

Both direct delivery and delivery from CC can be JIT. Delivery from CC is well-known to be JIT and expensive by its nature. Direct delivery can be JIT as well. But, when supplier delivers materials JIT it charge the construction contractor extra fee. When materials come JIT contractor is sure about availability of person has to unload it, unloading resources and material handling personnel. All of these increase efficiency on the construction site because no one waited and no waste is produced. This way, the extra fee which is paid to supplier for JIT delivery could be compensated by more efficiency.

4.8 Costs

When it comes to disadvantages of using a consolidation center all interviewees have consensus regarding extra costs which are entwined with using a CC. The costs which are generated by a consolidation center at its basic level are costs for energy consumption, more material handling, material supervision, salary of personnel, rent of storage, and amount of tied up capital, which will be discussed in the following section, associate with price of inventory.

The best place for storing material is by the supplier because value will be added to material when it comes further in the supply chain. These services demand their own machinery and experts and are capital consuming. Suppliers especially factories have their own experienced personnel for loading truck with the material which are produced in that specific company.

However, there are direct cost saving in using CC like less administration work for contractor which means customer can call one place and order for some different kinds of material instead of calling for couple of different places. It is attractive for customers because they can receive combined deliveries. Furthermore, it is reducing administration work for customers and is cost and time efficient for them.

Extra costs of a CC are unavoidable. Spending money on operating and maintaining of a CC center would make sense if costs would be compensating by the efficiency which results in cost saving provided in the construction site.

5 Analyses

The analysis is structured and divided into seven sections, of which the first, three sections corresponds to the RQs. Additionally, the potential benefits and impacts have been pointed out.

Research questions

5.1 RQ1 how much using a CC is in accordance with lean thinking.

The main research question of this thesis is to state conflict between Lean thinking principles; making value flow without interruptions in a continuous way and the CCC, - batch-and-queue delivery methods. During the study focus was on how in the construction process can eliminate waste by using logistics techniques and Lean tools without conflict.

The literature and empirical findings show that, not easy the implementation of Lean thinking in construction 100 percent; because of the industry´s characteristics, like working culture, working environment, uniqueness of results, use of non – standardized product and relatively short duration of project. Therefore, there is no direct conflict between these two techniques, Lean thinking and consolidation center. The philosophy behind Consolidation Centers is, clearly, informed by the theory of lean in literature. And JIT is also delivery by smaller part. Therefore, it has been authors´ intention to keep batch-and-queue instead of make value without interruptions in a continuous flow in construction process. Lean is a useful tool, but construction is still a very much based on human action or people centered process. According to Gary Sullivan, et al., (2010), the planning process used in construction is affected by external influences such as weather condition, environmental factors and site topography, therefore impossible to automate the construction process.

5.2 RQ2 what kind of projects demands a CC.?

In most cases a CCC is used when the principal contractor forced down or on-demand. These demands are usually space restriction on site such as limiting storage or limiting vehicle assess. In this case don´t need size or kind of project to define a CCC. From literature and empirical finding pointed out that, construction managers with no experience of using a CCC claim that it is a relevant logistics solution only for very large projects. But those with experience of using CCC say, very small projects can benefits as much as large project. Wilson James (no date) quotes the convenience store in London where during an eight-week installation two deliveries were made three days per week; and the CCC work just as well as for small projects with a program of just eight weeks. Also small projects can be supported by a CCC within a shared facility.

5.3 RQ3 what kinds of material should be handled in a CC.?

A consolidation Centre (CC) is capable of handling the vast majority of materials and equipment used on a construction site except, critical items such as ready - mixed concrete, heavy items such as steel - frame components or precast concrete members, must be delivered direct to the site.. For this reason, it would be appropriate to impose a weight limit for materials to suit the lifting capacity of forklift trucks etc. to ensure the efficient and cost - effective use of mechanical resources. Any materials that exceed this weight limit would need to be delivered directly to site (Greger Lundesjo 2011).

There are two interviewees who believe the size of material is a determining factor for using CC; interviewees argue that the material which is handling via CC should be small sized, like screws and nuts. However, the main components of building like façade, roof, walls and gypsum boards especially if they are prefabricated are not appropriate to be handling with a CC. one reason for this issue is that these materials which are mainly prefabricated are usually purchased as a full truck and it does not make sense to extra loading and unloading in CC when they will be used immediately in construction site. The other reason is some construction components are perishable. Given a concrete structure building, it is not possible to store prefabricated concrete on the CC. due to the fact that the duration of concrete transportation cannot exceed special amount of time. In these cases both literature and interviews support each other.

5.4 Benefits

The goal of this study is to understand and demonstrate the potential benefits and impact the CCC could provide. The main benefits of CCC summarized in Table 5.1 below,

Table 5.1 the potential benefits and impact of using CCC according to several studies

Category	Benefit
Environmental	Reduce – carbon emission, congestion, pollution, and noise.
Productivity	Reached up to 3% reduction of construction cost
Material waste	Reached up to 15 percent reduction
Damage and loss	Relocation material buffer to CC reduce risk

5.5 Environmental effects

The direct benefits of a CCC relate to the reduction in construction traffic on site and city centre location. The environmental benefits of reducing construction traffic lead to: a reduction in congestion, noise, pollution and carbon emissions (Greger Lundesjo, 2011). Reduction of local vehicle movements, decreasing congestion and noise;

- Reduced congestion – principal contractors and suppliers deliver to the fixed point of the CC. in addition CC distribution teams know exactly where to distribute materials and all these activities reduce vehicle movement, which reduce Carbon emissions.
- Reduced waste - materials delivered to site ´JIT´ reduce on- site damage. If damages are being reduced, less material has to be order which decreases also CO2emission.

From the interviews there are various opinions of experts regarding make a comparison between direct delivery and from CC associated with being environmental friendly. Generally, all case companies have a nice environmental policy, but practically they give less attention to environmental issues. And they claim all the time about perceived cost of using CCs.

5.6 Economic benefits

Difficult to identify and share these benefits, because of:

- Logistics is moving materials, people, information, and equipment to the workface create no value it self.
- Few in the Construction industry fully understand their logistics cost and
- Trade contractors are not agreeing to share financial information.

From literature reviewed, measured in LCCC potentially 8% of construction cost was saved, from which 0.5% - 3% is CC service cost (for details see figure 5.1 below)

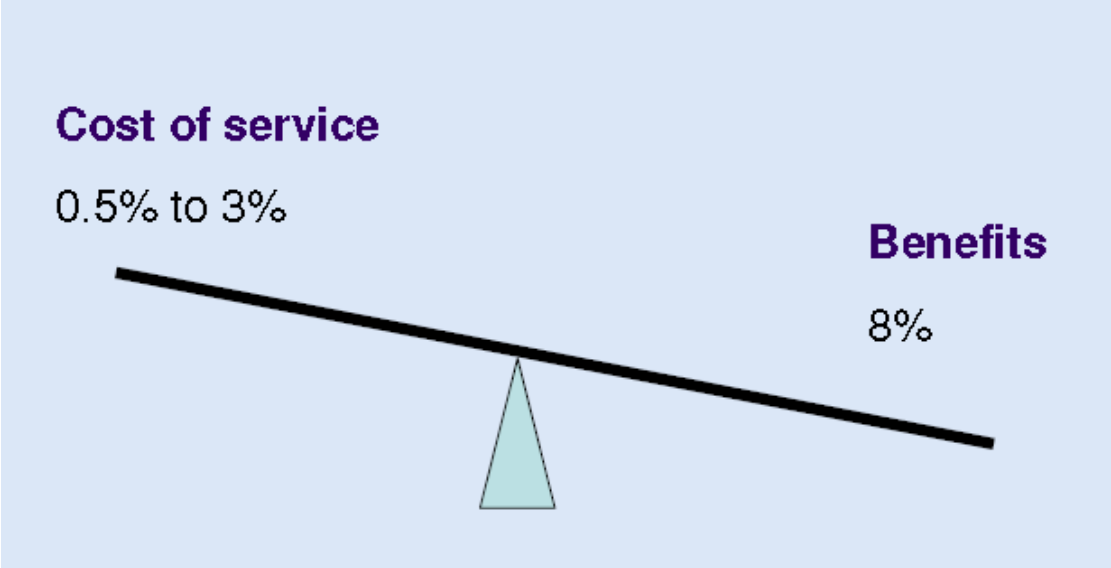

Figure 5.1 LCCC measured economic benefits

According to this figure 5.1 saved resource is 8% - 3% = 5% of total construction cost. But when it comes to using a consolidation center all interviewees have consensus regarding extra costs which are relate to using a CC. The costs which are generated by a consolidation center at its basic level are costs for energy consumption, more material handling, material supervision, salary of personnel, rent of storage, and cost of maintains. At the beginning they see only extra cost, and difficult to calculate benefits at this level. And it is the main challenge to using CC. nobody want to take risk and start to use CC.

5.7 Barriers affecting CCC

- Construction managers with no experience using CCC or few understanding
- Ineffective leaderships
- Industry´s hesitation to change
- Lack of effective ICT infrastructure
- Perceived Cost

6 Discussions

Construction is a very old profession and a very much based on human activity. Therefore, construction is more a traditional industry.

In many construction processes, such non-value added activity can comprise more than 50 percent of total activity. Accordingly the purpose of this study is to identify the scope of current method of construction logistics being used, both traditional and alternative, and the role they can play in reducing this waste.

Construction materials count for 50 percent of the building costs, and the total cost of transportation may be more than 10 percent of the net building costs (Andersson 1983, cited by Bertelsen, & Nielsen, (1997). Better managing this variability is great successes for construction logistics management. In construction sector the implications of incorrect delivery from the CC may be cost more money than in the retail sector. In retail, such problems can result in lost sales, but on a construction site it can lead to reschedule work or even stop work and which lead to cost overruns. Accordingly the operational benefits of consolidation centre, the business culture in the construction sector is not easy to adopt this logistics innovation than in the retail sector (Stanhope and Wilson James 2008).

Poor logistics in construction industry manifest as wastes, according to lean philosophy, like excessive material handling, damaged inventory, environmental pollution and etc. these wastes cause monetary lost for the construction company and could be quantified. One suggestive alternative to reduction of costs of wastes is using CC. the pitfall with using CC is that the aforesaid wastes could be generated in CC even in larger scale if enough considerations regarding its related issues Consolidation centre is a new innovation. The main aim of this innovation is to push the construction site to be lean.. According to the literature review which is done during this thesis work there is a huge amount of waste in construction process and the potential remedy for this illness is CC. Every entity who deals with construction logistics uses CC or denies it according to its knowledge and context of project. New with this research is that it gathered experts' points of view from all over the supply chain. It includes supplier, logistics service provider and construction contractor. For supplementing the research as much as possible even the authorities' perspective and entities who just build CC are taken into account. Accordingly, the effect of limited knowledge, specific context and its consequent bias is avoided and a comprehensive view is provided.

The authors believe the result of this study would help construction companies not only in the Swedish construction market but also worldwide to do a wise decision making regarding using or denying a CC. Moreover, the authors and one of the logistics experts who is interviewed, believe in this study could be useful, to improve our environment by reducing waste and carbon emission, developing sustainable products and using resources in an efficient way.

7 Conclusion

The purpose of this study is to identify the scope of current method of construction logistics being used, both traditional and alternative, and the role they can play in reducing waste, and to develop an efficient logistics management within and outside a construction site. And also to indicate other important points about the use of consolidation centers in the construction logistics. The study has describes the problem in the industry and suggests consolidation center as a solution. Consolidation centre has an important role to play in improving productivity and efficiency by eliminating waste from construction site. But CC alone is not enough, therefore several logistics techniques could be used, such as logistics planning across the supply chain, JIT deliveries, and using logistics specialists on the construction site, etc discussed. CC could also, due to short delivery times, play an important role to reach shorter lead time of materials, deliveries, which is a foundation for Lean philosophy eliminating waste. According to literature review logistics is immature in construction industry and it takes time to implement this golden opportunity to improve performance, add value, reduce waste, and reduce environmental impact. The interviewees identified some benefits from using CC. In general from literature and empirical finding pointed out at most construction managers have fewer understanding of what effective supply chain management and logistics is all about? Therefore, it takes some years to realize business benefits of using CC in construction logistics. Currently there are limited examples of CCCs in operation in Sweden and even UK as well as, surprisingly, despite the benefits it is considered to have. It is normally up to the main contractor to take the decision to use a CCC and to carry the cost. Subcontractors, suppliers, and haulers all who benefits from using CCC, and ways needs to be found to spread the cost among the other participants in line with the saving they make. It is the main challenge to using CCC relationships that do not encourage shared risk, open book,

8 Recommendations

Nine factors which influence CC work is determined in the results section authors already categorized these factors into two different groups: primarily group and functional group. The primarily group are the factors which make the implementation of CC possible. The second group is functional issues which encompass: being environmental friendly, ordering and delivery and cost. It could be said that after assessing the feasibility of a CC by primarily issues the functional issues have to be taken into account. The balance in functional issues is took place when monetary cost saving of being environmental friendly and efficiency resulting from superior ordering and delivery are equal with its cost. As the cost saving weights more in compare with cost, the amount of profitably is more and CC is a more wise solution.

Firstly companies have to consider primary issues to evaluate the possibly of using a CC. Afterward, functional issues have to be considered. This is the functional issues which determine how the investment in CC will be paid off in construction site. Moreover, companies have to be conscious about the fact that primary factor sometime affect functional factors. For example proximity to other construction projects is a primary issue and being environmental friendly is a functional issue.

9 Future studies

This study is mainly deals factors influencing CC in a qualitative aspect. Future studies can be ideally concentrated on providing a model which compares the cost consumptions of maintenance and operation of CC and cost savings of CC and its effects on efficiency on the construction site. Studies can be focused on quantifying the extra costs which are produced in the CC. same studies could be made for quantifying the costs savings in construction site which is caused by increased efficiency.

Further research to build the business case:

a) Environment – transport assessment before and after using CC
b) Productivity – value stream analysis before and after using CC
c) Material waste – survey of before and after using CC

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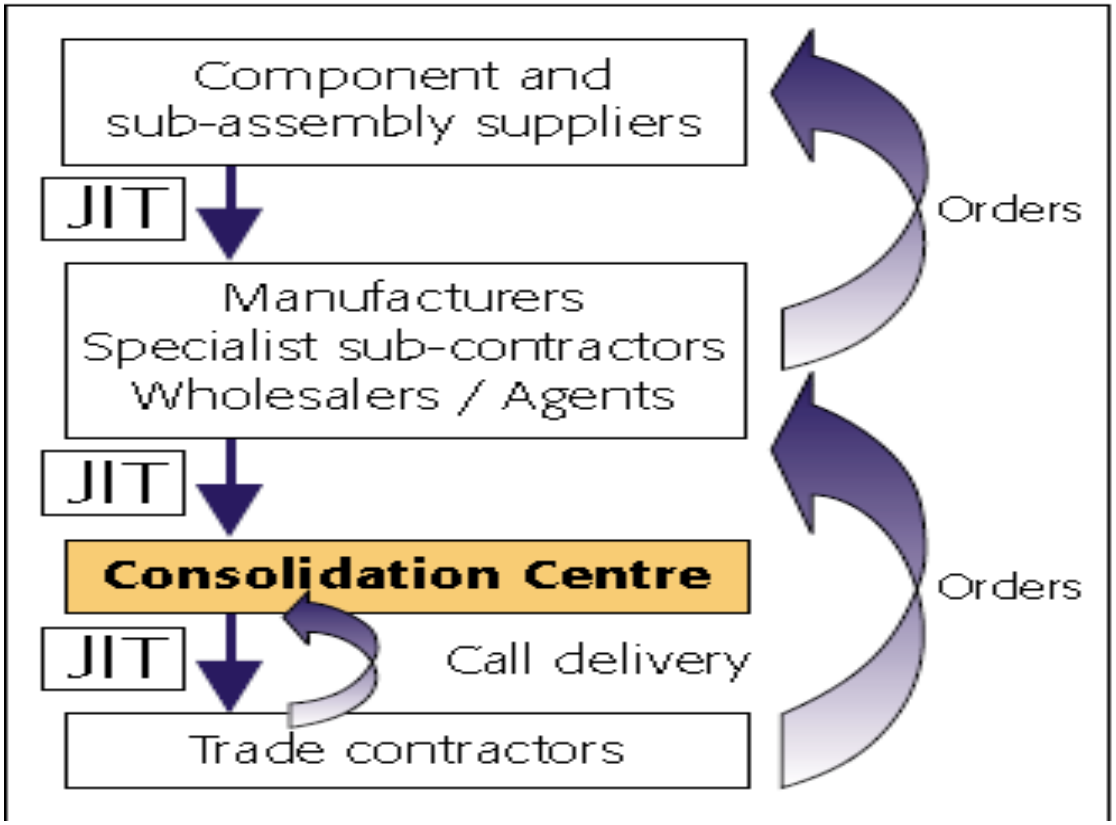
11 Appendix

Appendix 1 orders and delivery via consolidation centre



Orders and delivery via consolidation centre, (Adrian Young 2004),

Appendix 2 Overview of the best practice in using consolidation centre

Warehouse with racking at Sainsbury's consolidation centre (Greger Lundesjo, 2011),

Greger L, (2011) and Patrik J. (2008), explain that the consolidation centre has been used in other sectors for many years such as distribution centers or logistic centers, within construction industry, it is a new concept. In 2001 the Heathrow Construction Consolidation Centre (HCCC) was set up to serve the ongoing construction work at Heathrow`s terminals 1-4. At the same time a well publicized construction consolidation centre was in operation in Stockholm to support a project called Stockholm Hammarby Consolidation Centre (SHCC). A few years later in 2005 the London Construction Consolidation Centre (LCCC) began operation in London (Greger Lundesjo, 2011). Table below shows the basic characteristics of the six centres that are considered in detail.

Key characteristics of consolidation centre (Scott Wilson 2010)

No	Centre	Location	Sector	Status	Terms of use
1	Bristol	UK	Retail	Active	Optional
2	Sheffield	UK	Retail	Active	Optional
3	London	UK	Construction	Closed	Optional
4	Heathrow Airport	UK	Retail	Active	Optional
5	Monaco	Monaco	All	Active	Compulsory
6	Hammarby	Sweden	Construction	Closed	Compulsory

A) Heathrow Consolidation centre

The sustained growth of retail activities at airports presents a new challenge for their management sustainability. According to Greger Lundesjo, (2011), the Heathrow consolidation was set up to provide an alternative method of delivering materials to site. Its purpose was to promote the efficient flow of construction materials, plant and equipment from the supplier to the point of use on a project site. In total, 45,000 deliveries are made per annum and 190 stores are serviced. The benefits that have been gained from using the consolidation centre are as follows:

. There is a 99% delivery success rate

. Overall project plan reliability has increased by 4%

. Total transport and logistics cost have been reduced

. a decrease in supplier handling and a reduction in on-site storage.

B) Stockholm (Hammarby) Consolidation Centre (SHCC)

The Hammarby consolidation centre was active from 2001 to 2004 for the duration of redevelopment in the former docklands and industrial area of Stockholm. When the redevelopment complete there will be 8000 new apartments as well as schools, and commercial facilities; and an estimated 30 000 people will be live and work in the redeveloped area. It offered 3500 sq. m. of storage indoors and a further 4000 sq. m outside. If flows had not been coordinated, 700 tones of materials would have been delivered into the project site by 400 vehicles during peak period each day. The Hammarby consolidation centre, flows of materials was consolidated for 22 different delivery areas within the site. In this centre 10 employees were employed and five goods vehicles and three forklift tracks were used (Scott Wilson 2010).

The objectives for the Hammarby Sjöstad consolidation project in Stockholm were:

. Decreasing the number of small direct deliveries

. Less traffic congestion on the construction site

. Improved living condition at for new teams

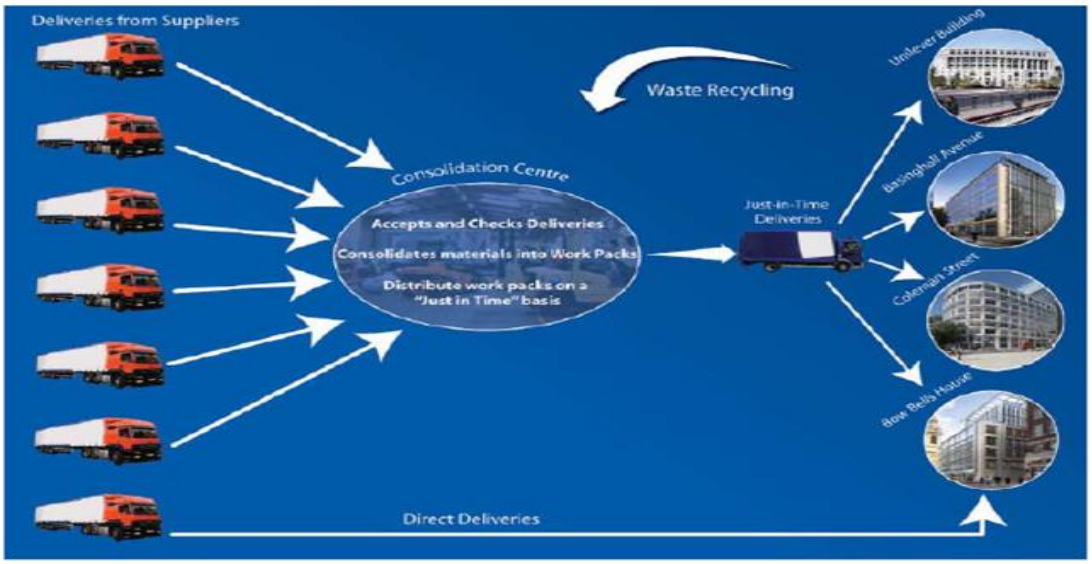
. Improved working environment

. Reduced energy use, emission of CO2, and nitrogen oxide

On all these counts the projects was deemed a success follow the evaluation by the city of Stockholm (Greger Lundesjo, 2011),

C) **London Construction Consolidation Centre (LCCC)**

The London Consolidation centre was operated from 2005 to 2007. It was a two year pilot study involving the LCCC to serve four large construction sites. Except steel, cement, concrete, sand and aggregates, the principal contractor expected all materials to be delivered to LCCC for JIT delivery to each site. The two year trial was judged to have been a success as overall. As a result the operator of the trial LCCC Wilson James was replacing the centre. Currently Wilson James has a 7500 sq. m facility and it had a capacity of more than 200 000 pallets per annum. The direct benefits of using CCCs relate to the reduction in construction traffic – and this is the main reason that CCCs have been promoted by authorities as in the case of Transport for London and City of Stockholm. The LCCC`s mission statement is: ``to deliver in the safest and most efficient manner possible the right materials to the right site at the required time in active partnership with trade contractors and project managers`` (Stanhope and Wilson James (2008). In Figure below overviewed the LCCC operation to the four construction sites



Overview of the LCCC operation to the four construction sites (Stanhope and Wilson James 2008),

The LCCC served four large construction sites in the City of London (images are shown below)

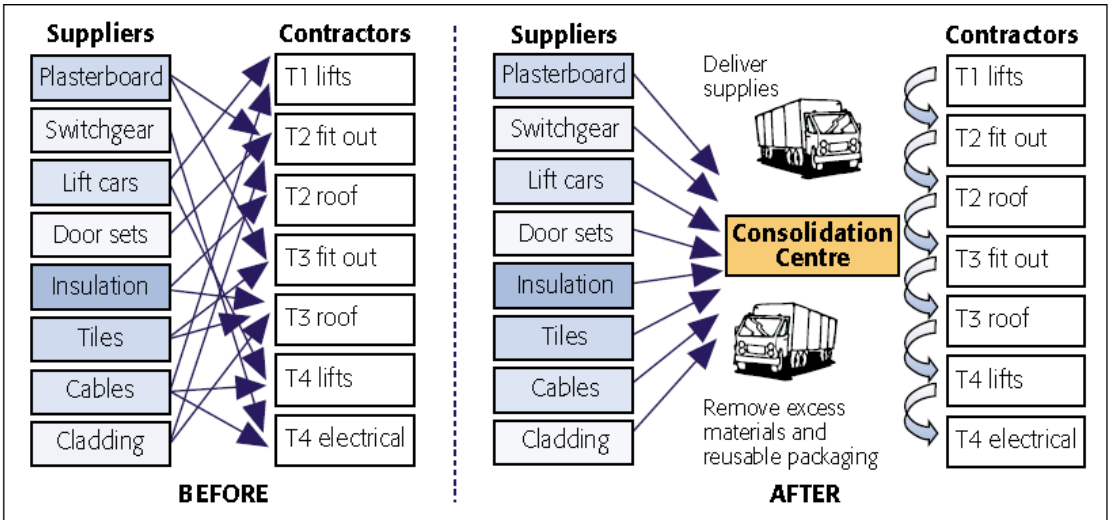
Unilever House is the head office of Unilever Plc and will provide 250,000 sq ft of office space

Coleman Street will be the global headquarters of Legal & General, with 10 storeys and 180,000 sq ft of office space

Basinghall Street is being developed into the global headquarters for Standard Chartered Bank, providing 200,000 sq ft.

Bow Bells House is likely to be of mixed use with 140,000 sq ft of offices and 14,500 sq ft of retail space

Appendix 3



How consolidation simplifies distribution at Heathrow Terminals 1 – 4 (Adrian Young 2004)

Appendix A – Interview questions

In between a logistics company can perform the transportation task. As a whole it could be said that three entities collaborate with each other for undertaking a construction logistics task..

Each of these parties has their own concerns, methods and purposes. They work independently and since all of these parties could influence the logistics of a project, it is tried to arrange at least one interview with each. Moreover, attentions are paid to interview different positions in companies with different ages. Because, authors think depending upon the position people can have holistic or detailed perspective.

Two interviews are done with a manufacturing company which is between the biggest in the world.

Although, there are differences between manufacturing and construction industry there are also similarities which result in flow of knowledge and innovation from manufacturing to construction. Construction learnt both lean and consolidation centres from manufacturing. Manufacturing often stands forward in compare with construction with regard to learning. That is why these two interviews could contribute to this study when it comes to recommendations for bridging the gaps. Furthermore, logistics which is the core part of this study is much bigger in manufacturing in compare with construction with regard to scope, size, range of materials and costs. This matter could be an appropriate justification for finding some suitable data which can help improving construction logistics

Appendix A .1 Sample interview questions

Opening questions

The term Consolidation Centers, CC, is you familiar with that function in the supply chain?

If yes, how and when did you learn about this function?

Do you use CC in construction projects?

What do you see as their main function?

If not, why do you not consider it to be appropriate?

If yes, how did you get_started to work with CC

Could you give us a picture of projects where you used CC and the reason for that?

What is the basis for a decision to use a CC for material in a specific project respectively for materials that are used for all projects?

How you are arguing pro's/con's of using CC when you decide to use that for a specific project

What are your criteria to choose/not choose a CC for a project?

In the projects you mentioned, regarding your choice of using/not using CC

What were the key business issues in that decision?

What were the key **practical issues** in that decision?

Key questions

Lean

Regarding Lean processes in construction

Are you familiar with the concept?

Do you use such methods?

How do you understand lean in your work/projects?

How does lean thinking play a role in your decision making?

How do you consider lean in your logistics processes

Do you consider how much other parties precisely understand the concept of the lean

In decision making of using precisely CC how you consider lean

What are the challenges in lean thinking in construction logistics?

Are there any specific or general **requirements** for implementing lean in a logistics task?

How you are explain efficient construction logistics

How you are describing DC or LC & CC

How do you think other parties like contractors and suppliers understand LC or CC?

What are the effects of delivery from CC or directly from supplier? What are the advantages and disadvantages?

JIT

Supplier disturbances

Transportation disturbances

As a whole, which delivery system do you prefer, delivery from CC or direct delivery from supplier

Please explain reasons

How you are determining where is the most appropriate place for locating a storage which is efficient for every party in the project (by supplier, by contractor, or in CC)

What criteria do you consider?

Is it differing from one project to another?

Where is the appropriate place which benefit contractor more

Where is the appropriate place which benefit Logistics Company more

Appendix B – Interviews

Appendix B.1 Case company A

Interview date: 2014-03-10

Company's function: logistic service provider

Interviewed person position: manager

Purpose of interview: introductory to the construction logistics in practice.

Company background:

Company A works as a 3rd party logistics service provider and is specialized to provide logistics service at the construction site. Their tasks are include but not limited to site planning, placing the crane in relation with location of material, bringing material from gate to exact workplace and etc.

Geographically the company is located in five different major cities in Sweden: Malmö, Goteborg, Borås, Stockholm and Linköping. Normally working day starts at 7 and ends at 4 o'clock. Since the company tries to extend the working day there is a new part which provide construction sites with materials in the evenings. Some years ago company A was selling material within kind of consolidation center. That part is sold to other company and now it cooperates with that company instead of having CC itself. Also, company A has collaboration with other companies in the supply chain like factories and material sellers.

Now they just transport material from gate to the workplace. They say maybe it is a short way but it is where the cost is and our mission is to improve site logistics.

Interviewee background: He is 30 years old. His educational background is M.Sc. in Design and Construction project Management and B.Sc. in business administration. He has worked in the company more than 4 years. At the moment he works as a manager. He supervises 30 people in the company. Before current position he was worked as a consultant manager.

Logistics

Interviewee's knowledge: he considers logistics as moving material from point A to point B in an efficient way without waiting in the middle in a way which is efficient and fast.

Lean consideration: it depends on if other party is construction contractor or material supplier. Contractors do not consider lean in their logistics task otherwise if a logistics expert from inside or outside of the company is involved in the task. There is a difference between depending on if supplier is selling or manufacturing company. Selling company because they have a huge turnover and earning money by storing material in sites lean is not very important for them. Factories use big volume and few repetitions so they try to be leaner.

Many companies claim that we work by lean thinking but in the reality it is not true. The main point is that it is hard for Construction industry to change. Involved people in this industry get used to current situation and consider it as profitable enough.

Requirements and challenges: usually younger people are more suitable for implementing new methods. They have academic backgrounds which give them information about new innovations. Also, they did not get used to current practice and changing easier.

Experience of CC

He is familiar with the concept of CC. His company was worked with CC. It was comprised of office for administration work and storage for inventory. Although, that was before his time, he claim about having enough knowledge regarding why the company started and stopped its involvement with CC

At first the company thought using CC is the right way to work with and companies should have CC to be profitable. However, afterward they understood material shouldn't be stored anywhere they should be used immediately. That is why right now they store material in the factory instead.

Functional issues

Materials: There are materials that CC can be used for them. Materials with small volumes which are delivered to the construction site continually are good to be stored in CC like screws. Yet, main materials which are mainly big and large items like gypsum board and prefabricated concrete and walls should be delivered directly from factory to the site.

Space limitation in construction site: Using CC can make sense when construction site is very small and there is no place for storing material inside of the site. Construction site demands specific kinds of material on specific days which can satisfy its short term needs. In this case Logistics Company can provide the construction site with CC to meet its need; however, it would be considerably more expensive

Environment: Delivering material from CC is always considered as high level of environmental friendly. Because, in this case a full truck is consolidated by different kinds of materials; However, if Logistics Company plans the transportation task most of trucks can be full in direct delivery as well and delivery can be environmental friendly. Because a truck will be allocated to serve couple of construction sites not only one site.

The issue is that the suppliers usually don't own their trucks. They have external contracts with transportation companies. It is what often happens with factories. However, material seller sometime has their own trucks. This could trigger the assumption of presence of half empty trucks. As a whole, both kinds of delivery can hold more or less same level of being environmental friendliness if a third party perform delivery for the supplier.

Advantages

Storage situation: CC is better for saving material safer

Disadvantages

High costs: the company use to have CC which was belonging to it and it was just profitable for the logistics company but not for contractor. Because contractor was paying to logistics service provider for storage place and administration costs which was not necessary. Also, costs are never compensated by benefits which were provided. So, CC is much more expensive in compare with direct delivery. It was about to result in losing part of the market for the logistics company. A simple example is gypsum boards. If you bring them via CC contractor have to pay more for the same amount by direct delivery.

High lead-time: it is faster to deliver directly from the supplier. With CC lead-time is expanded.

Tied up capital: The best place for storing material is by the supplier because value will be added to material when it comes further in the supply chain; because, some costs is added to the material cost like transportation cost and costs for dealer parties. Obviously, value is lowest in the beginning of the supply chain and highest in the construction site, since CC is located in the middle of the way the value of material is in average Extra information

Perspective people in high positions: the question of if CC is beneficial solution or not differs from one project to other one and more from one site manager to other site manager, since it is the site manager who decides regarding logistics plan. Maybe just because a site manager is not familiar with CC do not use it even though the project needs it.

Just projects with bad planning need CC. and you can plan every kinds of the site and it's not related to small or big sites or anything else. If you plan right there is no demand for CC

Appendix B .2 Case company B

Interview date: 2014-03- 18

Company function: construction

Purpose of interview: was to get the construction industry practitioners´ understanding of logistics management and CC

Interviewed person position: logistics coordinator

Interviewee's Background: She had studied her B.Sc. degree in civil engineering in Chalmers University. She has one year of experience in construction industry as a logistics coordinator in the company.

Responsibilities: the logistics task in the project is managed by a group of three people. Interviewee herself and a colleague do the office and administrative tasks. The other co worker coordinates with them on site. Interviewee is in charge of site logistics, like material unloading, handling and buffering. She also managing supply relations, booking transportation, planning material and machinery delivery. As a whole, she is responsible to prepare involved parties in project with their needed material JIT. The needed information to satisfy this task is gathered by direct questions from entrepreneurs and involved parties about time and kind of needed material and machinery.

Lean knowledge

Interviewee: Interviewee claiming about having knowledge about lean and some theories and concepts about it. She implement lean in her logistics task by delivering as much fewer as possible amount of material in a JIT manner which are placed in a proper place inside the construction site. The proper place is where materials will be used in future and do not make obstacles on the ways of other professionals.

Other parties' lean knowledge: Other parties know about lean but entrepreneurs don't consider lean and just ordering material as much as it is possible. Because they do not have a precise plan and do not know what will be needed tomorrow. So it's nice to them to have material in site so it's available if it is needed.

Lean implementation: it is not for every decision making like if it is a waste or not or if my boss tells me think lean. We just know the concept of JIT and we are concentrated on it. We don't take into account other aspects of the lean like storage and transport.

Challenges and requirements: bringing one line of thinking through the all hierarchy of organization, from CEO and economics to workers, is the challenge. Even if some people with high positions in company want to prosper a method every involved person have to be convinced regarding the subject. The convincing process demands its own perquisites, like giving information as courses and putting motivations.

Consolidation center

CC experience: the interviewee had negotiations with a logistics service provider company regarding renting a CC. The function of the CC would be receiving all materials from all suppliers and co-pack them. The co-packed material would be delivered to the construction site ideally as a one truck delivery each day at a specific time. The negotiations stopped because of some issues which come in functional issue section.

Functional issues

Size of project: the project was too small to justify a CC costs by increased efficiency of the site. According to interviewee the project should be much bigger to compensate cost of operating a CC.

Small entrepreneurs: Small entrepreneurs do not have a precise plan of their future work. As a result they tend to deliver material as much as they can. This way everything will be available for the decision which is made at the moment. Also, small entrepreneurs deliver some machinery and material by their own car or public transportation in the case they need. If they suppose to deliver everything from CC they should to have a strict plan. Because material have to be ordered to CC at least one day before otherwise entrepreneurs' task will be stopped.

Unloading space and proximity to other projects: There are two types of delivery in this project a full truck delivery and portion of truck delivery. For full truck delivery since all the material which are carried by the truck will be unloaded in the construction site it does not make sense to do extra unloading, reloading and storing in CC. portion of truck deliveries could be up to 10 or 15 deliveries each day. Because there are enough spaces in the construction site to place a truck inside and do the unloading task the contractor should not pay compensation for otherwise stopping traffic for unloading. When delivery is from portion of truck kind, some amount of material belongs to this site and the rest belong to other construction site. So, the contractor should not pay for extra transportation. That is why extra cost for renting a CC is unjustifiable.

Proximity to other sites: If the place of the project is located where that there are not other construction projects to sharing a truck for small deliveries. In the case of this project couple of construction sites share same truck for small deliveries. So a cost of transportation is divided between them and will not be a crucial amount. Considering an isolated construction site, it is not far from the mind to have deliveries which just for example 20 per cent of truck is full but contractor have to pay for the whole truck. In such a land locations depending on number of half empty deliveries and material monetary value CC could be used

Stages on project: when the decision regarding using a CC is made the project was close to be finished. A significant amount of materials were already installed and the rest of materials did not make a balance to costs and benefits of using a CC. The bigger problem was associated with changing the routines of entrepreneurs. Entrepreneurs from the starting points of the project delivered material directly from supplier. Convincing them to substitute their routines which they get used to it demands a big effort.

Type of materials: the components of building, façade, roof, walls, in this project are mainly prefabricated and big sized. At the time of purchasing usually a full truck is ordered. These prefabricated materials are mainly big sized and not suitable for storing in CC.

Increasing supplier storage capacity: in the case you need a huge amount of a specific kind of material which is more than the factories storage capacity CC centers can be used. However, in such a situation they mostly function as logistic center not CC. because they just used to store the extra material.

Advantages of CC

Predetermined delivery: Getting fewer deliveries to site and taking deliveries at a specific time, so preparations could make for unloading and material handling and less time will be wasted as waiting.

Prevention of too small deliveries: When small amount of small sized material deliver to the site continuously because of the nature of the project. Such a situation will result in spending significant amount of time and concentration to delivery handling. Because, each time preparations have to made, some amount of time should be wasted as waiting time and etc. If these small deliveries consolidated in one delivery less effort will be spent for delivery handling.

Extra information

The company just receives material and do not send anything back with the truck. The only thing which is transferred from site is waste.

Not only CC but also logistics are new concepts in construction industry and people do not get used to think of that. In this project there are a lot of small subcontractors like electricians and plumbers and the construction contractor has the main responsibility of construction. Although, people in Construction Company are aware of logistics benefits, it is a hard task to convince small subcontractors regarding importance of logistics. That is why sometimes involved entrepreneurs resist sharing information with logistics specialists

Appendix B .3 Case company C

Interview date: 2014-03- 27

Company function: production

Purpose of interview: was to get the manufacturing industry practitioners experience of logistics management and using CC

Interviewed person position: logistics manager

Company background:

The company produces gypsum boards. The products are in different sizes and types. For say, they could be normal, noise or water resistant. The company's clients are retailers (60%), prefabricated companies (30%) and also construction contractors and other customers about (10%). The company has contracts with external companies who perform transportation task. The company has two storages. One of them is close to the factory the other one is in the north of the Sweden. Since there are lot customers near the factory's place and their products are sensitive and can be damaged because of more transportation it makes sense to have one store in the factory.

Interviewee background: She has experience about 15 years in logistics. Her work with logistics started with purchasing and ordering department. She also has experience in production systems and transportation planning. Right now she is a logistics manager.

Lean

Interviewee's knowledge: Interviewee claiming about having enough understanding and knowledge about lean. She learned about lean in courses which she took during her working period. She thinks lean can be analysis for improvement.

Other parties' knowledge: Most of big transportation companies are following lean routines; yet, it is difficult for small companies to follow lean norms mainly because of monetary reasons. Most of companies' vendors are doing according to lean.

Challenges and requirements: The Company started to implement lean from production stage. Now it is expanded to logistics.

1. It is more difficult to do lean in logistics since it is dealing with processes. In other words, it deals with how people work. For example: optimizing processes, reducing truck usage and loading truck in an efficient way.
2. The other reason is difficulties to change people's opinion and behavior.
3. For implementing lean company needs a sophisticated and applicable plan. Such a plan demands a significant amount of monetary investment and the company should afford it. As an example in this company people is get prepared by participation in related courses regarding lean. Also, there are prices to the top learners as motivation.

Consolidation center

CC experience: in 2013 the company started to collaborate with 2 other companies for sharing a warehouse in the north of the Sweden which functions as CC. CC storage is rented from a logistics company also the logistics company is in charge of part of material handling in CC. There are IT systems for three suppliers and Logistics Company but they are not fully shared.

Right now there is no monetary profit from functioning CC. It mostly acts as an extra service to be closer to customers. Because, customers like to have access to a lot of material at the same time As a result, company can conquer competitors and benefit from flow of the customers. Afterward, it is possible to increase efficiency in CC. Because, both people who work in CC and who work in headquarter will learn about how to be more efficient. This could compromise: optimizing a truck load and

freights, reduce inventory level in CC and develop IT to closer collaboration with customer.

Functional issues

Delivery service: choosing between direct delivery and CC could be under the influence by the customers' preference about the level of service associated with material delivery. For example, in factory there are equipment for labeling and marking and knowledge about different methods of loading a truck. Yet, such equipment and techniques are not available in CC. preparing such facilities in CC demand significant amount of investment which makes operation of CC too expensive. So, if customer needs a special service with cargo delivery there is not any other option except direct delivery.

Advantages

Less administration for contractor: the positive point with CC is that customer can call one place and order for 3 kinds of material instead of calling for 3 different places. It is attractive for customers because they can receive combined deliveries. Furthermore, it is reducing administration work for customers and is cost and time efficient for them.

JIT: CC should are more JIT in compare with direct delivery and this company considers JIT as lean thinking.

Environment concerns: Delivering from CC is more environmental friendly

Disadvantages

Extra costs: extra costs are generated by extra administration, business system, planning and IT system. Other costs could include cost of extra staff and machinery for providing technical details. These technical details could be labeling cargos and material or techniques which are required for load and unload a truck in an efficient way.

Appendix B. 4 Case of company D

Interview date: 2014-04-09

Company function: construction

Purpose of interview: was to get the construction industry practitioners understanding of logistics management and using CC

Interviewed person position: logistics manager

Company background: company D is a construction company which is between biggest in Sweden. Company has a supply chain which involves all materials in a construction project. The company itself has access to limited number of transportation vehicles and they are rarely used. The transportation task often is the burden of the supplier. There is a tendency in the company which tries to keep material by the supplier and deliver to construction site as less as possible.

Interviewee background: The interviewee is a logistics manager who is involved with construction projects in all regions of the Sweden. The projects she works with are in a broad range from residential buildings to tunnels.

Lean

Interviewee knowledge: The interviewee claim about being up to date regarding lean. She got familiar with lean during her studies in Lund University. She supplemented her knowledge with participation in related courses in Chalmers University. The concept of lean is implemented in the company's logistics as reducing human resources, level of transportation and other wastes.

Other party's lean knowledge: Lean is a new concept that is why a considerable number of people in this industry are not aware of it. Even in this company which is among biggest in Sweden there are a lot who has not appropriate understanding of lean. The company logistics and the company itself are not lean right now, but the effort is to make it lean couple of years. Other parties in the construction supply chain are not lean. They have also problems of understanding and innovation. Consequently the first step in lean implementation would be to introduce people the concept of it.

Consolidation Centers

CC experience: interviews experience about using logistics centers in the company comes back to 2005, when she recruited in the company. But her experience about using CC started in 2009.

Functional issues

Site location: The best place for using a CC is crowded areas in the middle of big cities which makes the truck delivery difficult.

Space limitation: CC is a good alternative in projects with space limitation. There are projects which are under a strong space pressure. In such cases there no choice except using an external storage.

Proximity to other projects: It is an economical alternative to use CC when there are some construction sites close to each other and they can share one CC

Advantages

Few deliveries: it will be fewer deliveries to the site. More kinds of materials would be unloaded from one truck and more entrepreneurs need to be satisfied by one delivery.

Extra information:

Being environmental friendly at least in transportation aspect is role of Transportation Company, because other parties do not have information and power to influence it.

Appendix B .5 Case company E

Interview date: 2014-04-17

Company function: manufacturing

Purpose of interview: was to get the manufacturing industry practitioners experience of logistics management and using CC

Interviewed person position: Logistics Management Sourcing

Background information

Interviewee background: his education is B.Sc. in Shipping and Logistics and B.A. in Logistics and Supply Chain Management. Right now he holds the position

Logistics Management Sourcing. He has 8 years professional experience within logistics and purchasing.

Company's background: the company is a huge automotive manufacturing and deals with typical automotive material. It could be anything from nuts and bolts to parts that weight a few hundred kilos. Also there is vast variation in material cost and the most expensive one is the engine with a cost of more than50 000 SEK. The company has several hundred suppliers both local and global most of them are typical for the entire automotive sector

Material transportation task is managed internally. In determining route of delivery factors like location and infrastructure will be taken into account. The route of delivery is defined by Volvo together with the supplier where Volvo leads the discussion. There are two different kinds of material delivery in this company. Direct delivery which is for local suppliers and delivery by logistics center for long distance suppliers. The reason for using CC for long distance deliveries indicated as robustness in the supply chain. It means there is still enough inventories if any disturbances happen in the supply chain.

Lean

Interview's knowledge: interviewee claim about having professional understanding about lean. He learnt primarily accept of lean in high school and define it as Removing none value adding activities for the end-customer through the supply chain and identify areas through VSM etc.

Other parties' knowledge: Company's supplier and logistic service provider precisely understand the concept, because within automotive it's a common concept.

Challenges and requirements: the most common problem is to convince people around the organization regarding new working method. The other typical challenge is to educate the whole organization, because education demand its own resources

Consolidation Centers

CC experience: The interviewee has academic knowledge of CC through school. His professional experience regarding CC is more from a strategic perspective but not hands-on operational experience.

Advantage

Backup: the most important function of a CC is to store materials which come across the continents and keep them safe prior to distribution. The CC are used in this company as long as the company was in charge of transportation

Appendix B. 6 Case company F

Interview date: 2014-03-24

Company function: supplier

Purpose of interview: was to get the supplier's practitioner's experience of logistics management and using CC

Interview person position: logistics manager

Interviewee's background: She started to do her practice in the company in 2008. She started to work for the company in 2010. Her educational background is purchasing and supply chain management. Her position is logistics manager. She is in a department in her company which works only with projects which are bigger that two hundred million Swedish crowns.

Lean

Interviewee's knowledge: interviewee claims to have enough knowledge about lean and describes it as: involving everyone on the work, making it visible and trying to work in a learning environment. She learnt about lean in courses which took place in Chalmers University. The lean should implement in the logistics task by involving parties who will work on site in the early face planning. She considers that it is not very common in construction, but it is going to develop.

Challenges and requirements: It is not difficult to implement lean in logistics but it has its own requirements. The most important requirement is that someone who has enough knowledge about the subject and power to influence decide to implement. Needed information for implementing the subject should be shared between people so everyone see the same goal. A lot of routines and methods have to change

Consolidation centers:

CC Experience: CC is used but the effort is to avoid them as much as possible. CC is used as backup just in case something is going wrong with supply chain. Otherwise materials are delivered directly from suppler in the just in time manner. Because it is tried to keep materials with suppliers to decrease tied up capital. Also, avoid extra costs like re-packing and re-loading.

Ownership of supply chain: The supply chain is different depending on some specific factors. These factors could be monetary or nature of the task or other reasons. In this special department sub-contractors are often hired to do the construction task, like carpenter and concrete workers. The hired sub-contractors buy their own needed materials and they have their own supply chain. In minor cases company buy and support sub-contractor with the materials, like doors and plasters. The simple reason is company has better price than sub-contractor. It rarely happens that company uses its own workers to do the task.

Assembly in CC: the department of interviewee does not work with residential buildings. She argues CC can be more efficiently used for residential buildings if construction contractor own the supply chain. In residential buildings customer customize the design of the property according to his or her personal preference. It causes different materials consumption for every different room. It is a hard task to search and find the customer choice material between a large numbers of inventories for every specific room. If needed material for the special part of the building can be packed, like for kitchen or for bedroom, in CC this will increase efficiency in site. Because, the materials will be located in usage place as a ready kit and will not move. They are not in way of other worker and just will be installed in their place.

Space limitation: there are two kinds of storage depend on the project space limitation: in-site and out-site storage. If there are enough spaces on site the site will be used as storage. If there is not enough space in the site there are two alternatives. Either CC could be used or a normal storage place could be rent like a garage. These

alternatives would be used if something is crucial for the production and unavailability of material results in a lot of lost. For example, the company used to has storage for prefabricated bathrooms which had an international supply chain. Thereby, in the case of disturbances in supply chain, like delay of train, it was still possible to continue production. Because there was enough material as inventory in CC. the other case for using CC is when the company belong to a storage which is more suitable than the one which belongs to suppliers.

Scope of supply chain: CC centers will be more common if the supply chain would be more international. Because in an international supply chain CC are guarantees for JIT deliveries

Environmental issues: it depends on type of delivery. If the truck is full and all of it will be unloaded it is better to go directly to the site. Because it does not make sense to unload and reload it and also spending resources in CC for heating, administration work and etc. But if it is not full it is better to go to the CC

Being environmental friendly for the construction contractor depends on the customer. The company has a lot of environmental certificates and if the customer puts the demand the contractor will adopt as the manner as customer wants

Size of project: Since projects under supervision of interviewee are very big a lot of workers work on the site. That is why the materials which are delivered as one full truck would be mounted in couple of days. It does not make sense to consolidate a truck's cargo and deliver less material because materials are used so fast. So, in such a work atmosphere it is rational to deliver directly from supplier.

JIT: both direct delivery and delivery from CC can be JIT. Delivery from CC is well-known to be JIT and expensive by its nature. Direct delivery can be JIT as well. When supplier delivers materials JIT in time it charge the construction contractor extra fee. When materials come JIT contractor is sure about availability of person has to unload it, unloading resources and material handling personnel. All of these increase efficiency on the construction site because no one waited and no waste is produced. This way, the extra fee which is paid to supplier for JIT delivery is compensated by more efficiency.

If there is an agreement between supplier and Construction Company for JIT delivery, it is always wise to have small buffers on the site. By the reason that interruptions can always happen in supply chain and it is too expensive to pause the production for lack of material. Direct delivery is always a risk since you do not have buffer anywhere so if something wrong happens with material transportation work will be stopped.

Advantages:

Fast call-off: it is easier to call-off because it goes directly to the site. It takes less time to delivery. If the plan is changed suddenly, needed material could be delivered to site fast. So, it makes decision making more flexible.

Material watchfulness: In the cases that you cannot store material in site because maybe in the site material will be getting damaged, missed or broken down CC could be used.

Disadvantage:

Extra handling: There are 4 extra activities associated with using a CC. unloading, handling and loading in CC and unloading in construction site. There are other extra costs regarding operation and maintains of a CC. extra handling could result in damage, extra cost. Using CC is rationalized when efficiency which is produced by CC can exceed aforesaid costs. This exceeding issue mainly depends on the project.

Extra information

Transportation: Supplier burdens the transportation task. But the company F put a lot of demand on the transport company. For example size of a truck is important when delivery have to done to a site with limited space; it cannot be larger than 24 meters.

Environmental issues: The Company has environment policy.

Temporary or permanent: The Company uses temporary CC. because it usually used as a backup for a specific project and the costs of CC goes under project costs. As soon as project finished there is no need for CC.