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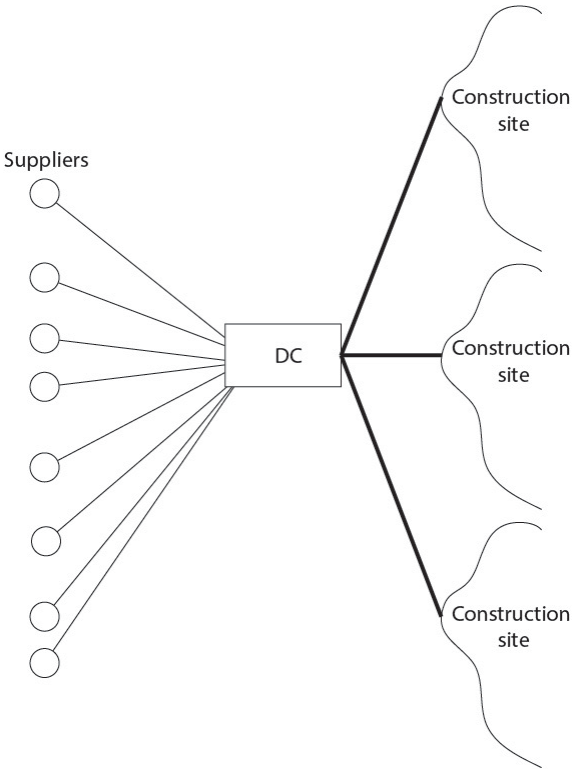

Distribution centres in construction logistics

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

ERIK SALVÉN

Department of Civil and Environmental Engineering
Division of Construction Management
CHALMERS UNIVERSITY OF TECHNOLOGY
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Master's Thesis 2013:09

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Cover:
A distribution center serving multiple construction sites.

Chalmers Reproservice / Department of Civil and Environmental Engineering
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ABSTRACT

This thesis covers the idea of implementing a distribution center in the logistics process in the construction industry. The idea is that all deliveries should go through the distribution center and there be combined with other shipments and delivered to the construction sites Just-In-Time. The thesis identifies a number of problems when it comes to the supply chain in construction such as excessive material handling on construction site, late changes to the projects causing disruptions etc. The aim of the thesis is to find out to what extent these problems can be solved with a distribution center in the logistics process and how such a solution would work. The study is based on interviews with actors in the construction industry. The thesis presents four different solutions and evaluates the same. The conclusion from the study is that the problems identified concerns more than just logistics and that any solution should do so as well. Benefits are shown from using distribution centers such as mixed shipping where material from multiple suppliers are combined into smaller batches and delivered Just-In-Time.

Key words: *Logistics, Distribution center, construction, productivity, waste, JIT*

Contents

1 Introduction

How can construction companies minimize the on-site material handling and cope with disruptions in the supply chain? The idea that is tested in this thesis is about using a distribution center, which is a distribution center connected to one or several ongoing construction projects. Material should be delivered to the distribution center where it is stored, re-packed and delivered to the construction site just before it's needed. The assumption is that this could make construction logistics more Just-In-Time and thereby lowering the amount of material being stored on site risking damages and causing confusion and additional handling when moving it around.

The study is made in cooperation with a major Swedish construction company, further on referred to as "the company". The company have found that there workers spend too much of their time on handling material on site. The material handling can be divided up in three main activities; Handling the deliveries and moving the material to a storage area on the construction site, moving the material around on the construction site due to that it's in the way of other workers and transporting the material from the storage area to the assembly area. The company have identified inadequate planning and late changes to the project as main reasons for this problem. The company have taken a few initiatives to minimize this problem on a few projects by trying to work more Just-In-Time and outsourcing some of the material handling. The company now seeks a more lasting solution and wants to investigate how distribution centers can be a part of this solution.

The purpose of this thesis is to design and evaluate solutions for a distribution center in construction logistics. The design and evaluations is based on interviews and focus on how the solutions can help the company to be more efficient rather than be based on financial assumptions.

2 Theoretical framework

2.1 Waste in construction

One term that's often used in the ongoing debate about the construction industry is the concept of "waste". Within the industry the term waste is often confused with debris generated and disposed of due to the fact that it is easy to see and quantify (Formoso, et al., 2002).

Waste as a business term originates from the Japanese automotive industry and the philosophies of Lean production. In Lean production, waste regards the activities that don't add any value to the final customer and pay minor attention to the direct waste of material. Since waste is important in the construction industry Formoso et al. (2002) defines waste as:

> "*The loss of any kind of resources, materials, time (labour and equipment), and capital produced by activities that generate direct or indirect cost but do not add any value to the final product from the point of view of the client.*"
> (Formoso, et al., 2002)

To measure the total waste in construction though is a difficult task but studies from different countries confirms that the level of waste constitute an extensive part of the total construction cost (Formoso, et al., 2002). Josephson and Saukkoriipi (2007), for instance, shows that waste represents around 30-35% of the production costs in construction.

Within the concept of lean production 7+1 types of waste is identified. The first seven is the original ones identified by Toyota. The eighth one was added by Jeffery K. Liker (Liker, 2004). The types of wastes are:

1. **Overproduction** – production of items not needed.
2. **Waiting** – workers waiting for tools, information, material etc.
3. **Unnecessary transport or conveyance** – transporting material and finished products.
4. **Overprocessing or incorrect processing** – inefficient or unneeded activities due to poor tools or methods. Incorrect processing can also lead to defects.
5. **Excessive inventory** – excessive storage of material causing extra costs for transport and storage. Excessive inventories also risks damaging material when handling it and hides other problems such as production imbalances or uncontrolled deliveries.
6. **Unnecessary movement** – looking for material or tools, walking around, fetching material etc.
7. **Defects** – damages on material or products causing rework, repairs, replacements, inspections etc.

8. **Unused employee creativity** – missing good ideas, skills, improvements due to not engaging or listening the employees.

2.2 Logistics in construction

One of the core methods to eliminate waste within Lean Production is the concept of Just-In-Time (JIT) (Vrijhoef & Koskela, 2000). JIT means that the right amount of material is delivered at the right place and in the right time and thereby reduces inventory levels (Low & Choong, 2001). This is crucial for a construction project and can lead to both increased productivity and lower production costs (Agapiou, et al., 1998).

Construction projects are carried out within an unpredictable environment with a lot of variables making the forecasting of material hard and shortage in material can lead to a stand-still in a project with resources being idle. Therefore JIT is less popular in the construction industry than in manufacturing (Thomas, et al., 2009) (Agapiou, et al., 1998).

There are opinions in the industry arguing that substantial financial gains can be drawn by focusing more on material handling on an early stage in the project. But due to the climate in the industry changes like that is difficult to implement (Lindén & Josephson, 2013). Josephson and Saukkoriipi (2007) shows that workers spend as much as 14% of their work-time on transporting material to their work place and thereby providing a great opportunity for reducing waste and cutting costs. Beyond workers having to spend a great deal of time handling material on site, inadequate material management can lead to; material stored on site under improper conditions causing damages on the material, deliveries not coordinated with production causing shortage of material and crew slowdown to prevent material from running out etc. (Thomas, et al., 1989).

Most of the waste in material handling has its roots in a previous stage of the supply chain than where it occurs (Vrijhoef & Koskela, 2000). Purchasing material at the lowest price in big batches is often prioritized higher than the extra costs for material handling on the construction site (Lindén & Josephson, 2013). This ad hoc purchasing behaviour can lead to a range of problems. Firstly, material could be purchased in the last moment resulting in delays and stand stills for the workers and equipment causing a delay of the project. Secondly, materials bought in big batches without consideration of the current need could lead to damages and waste in storing, handling and transporting material (Agapiou, et al., 1998).

Storage of building material often requires a large amount of space, which is rarely available on a construction site. In the case where space is available, it is usually temporary which requires the material to be moved around. This is a waste of time that could be spent on value-adding activities. The conditions of the storage areas often are so that material gets damaged from weather or accidents (Agapiou, et al.,

1998). The European Construction Institute Total Productivity management Report (The European Construction Institute, 1994) states that:

> *"materials delivery to site is a critical productivity-related aspect which demands the introduction of a carefully developed system of monitoring and control as early as possible"*.

In a lot of ways the supply chain in construction differs from the one in manufacturing. Firstly, the construction site is unique for each product with its own conditions and prerequisites where in manufacturing a lot of different products pass through the same factory. Secondly, the organization is temporary with new sets of actors (client, contractor, subcontractors, suppliers etc.) in each project (Vrijhoef & Koskela, 2000). Even if the product and organization is different in each project, information and material delivery processes are pretty much the same (Wegelius-Lehtonen & Samuli, 1998).

Vrijhoef & Koskela (2000) discuss the roles of Supply Chain Management (SCM) in construction and different approaches on how to focus management efforts to improve the supply chain in construction. One way discussed is by focusing solely on improving the supply chain and thereby, amongst other, cut lead-times and minimize inventory. Unforeseen events are more a rule than an exception in the industry. It's therefore important to plan the logistics carefully to avoid that each delivery as well becomes an unforeseen event contributing to the disorder on site (Bertelsen & Nielsen, 1997).

Bertelsen & Nielsen (1997) studied a logistics initiative on a housing project in Denmark. The initiative was based on JIT with all material arriving at the right time and with detailed packing instructions and mark up so that the material could be delivered to the right place. They argue that this sort of logistics operations can help cut the total production cost with 5-10%.

Josephson & Saukkoriipi (2007) states that:

> *"Reducing waste is one of the greatest challenges, and should be one of the highest priorities for both individual companies and the building sector as a whole"*.

Measuring waste is an effective way to estimate the performance of an organization since it could identify main causes of inefficiency and possible areas of improvement (Formoso, et al., 2002). Waste is usually caused by traditional management and that new tools and methods a great potential to improve the supply chain in construction (Vrijhoef & Koskela, 2000).

2.3 Distribution centres in supply chains

The competitive nature in today's business-environment forces companies to continuously try to lower their operation costs, create new services to raise customer satisfaction through designing efficient and reliable supply chains (Bellamy & Basole, 2012). Distribution centers and Warehouses can play an important role and perform important tasks in supply chains (Higginson & Bookbinder, 2005). The distinction between a distribution centers and a warehouse is hard to make. Frazelle (2001) defines distribution centers as facilities that

> *"accumulate and consolidate products from various points of manufacture within a single firm, or from several firms, for combined shipment to common customers."*

Many supply chain actions has been taken in order to reduce the inventory levels. Ackerman and Bewer (2001), for example, showed that the largest cost-saving from the 70's in logistics has been due to reduced inventory levels. This leads to a more centralized inventory where warehouses change their scope from storing material to a flow of material and thereby becoming distribution centers.

Higginson and Bookbinder (2005) discusses the different possible roles for a distribution center in the supply chain. One of those is a "brake-bulk consolidation center" where larger shipments arrive from to distribution center. The shipment then get split up and mixed to smaller outgoing shipments. One commons use for this type of distribution center can be found in the automotive industry where the distribution centers located near the factory and used to receive larger shipments, brake them up, removing the suppliers wrapping and deliver in smaller quantities to the factory (Boudin, 2001). In this way the distribution center act as a supplier to the factory with frequent and smaller deliveries reliving the factory the stress from irregular and inappropriately packed shipments.

3 Case study – Distribution centres (DC) in construction logistics

3.1 Method

The study is performed in cooperation with a major Swedish construction company and more precise their region for Special projects in Gothenburg. The thesis aims to identify possible solutions for how distribution centers in construction could be designed. The solutions presented are then evaluated and a recommendation on how the company shall continue to work with this issue is presented. The study is therefore split up in two parts; firstly, designing different solutions and secondly evaluating them from relevant criteria. Both parts of the study are based on interviews with employees from the company. All interviews were semi-structured and recorded. After the interviews were carried out the recordings was analysed. In total ten interviews were carried out and they lasted 30 to 60 minutes each.

A side from these two parts a study visit was made to a logistics company providing this kind of service to construction projects in the Stockholm area. The purpose of this visit was to get inspiration on how this could work plus getting some input on how a distribution center could help the logistics in a construction project. From the visit I got input on what the logistics company saw as upsides and downsides with using distribution centers and what problems they had encountered. This helped me with both designing the different solutions and forming the evaluation.

3.1.1 Part 1 – designing solutions

For the first part of the study six interviews were performed. The interviewees were: three production managers, one logistics manager and two project managers. Three of the interviewees have prior experience from projects where logistical issues were in focus and additional efforts has been made to handle the logistics, such as Just-In-Time deliveries (one production manager, the logistics manager and one project manager). The interviews concerned their view on construction logistics plus if and how they could use a distribution center as an extra resource. The reason for why I chose to put emphasis on their view on construction logistics was to understand their view on the importance on focusing on logistics and investing resources in logistics. Their opinions on logistics and how they would like to use a distribution center resulted in four different solutions.

The interviewees were chosen in cooperation with the company based on their position, age, academic background and experience from construction logistics. The aim was to have a group of relatively young interviewees since they hopefully would be more open to new thinking. I also tried to create a group of interviewees with varying experience from construction logistics, positions and academic background,

this to get different perspectives and views from the industry. The group of interviewees was put together to get a variety of different people with different background that could provide different ideas on logistics and on how distribution centers could help them in their daily work.

3.1.2 Part 2 – evaluating the solutions

For the second part four interviews were performed. The interviewees were the overall logistics manager for the department I performed the study with, the purchasing and logistics manager for the Western division and a person working with logistic strategies for the Western division and the logistics manager for the company. These interviews consisted of one part where the general idea of distribution centers were discussed and how and if they could be useful and of one part where the identified solutions were presented to the interviewees and they then gave their opinion on each solution. The interviewees were asked what kind of characteristics they believed to be important in order for a solution like this to be successful. Based on these interviews and the important characteristics named in the interviews four evaluation criteria were found. Each solution was evaluated based on these criteria.

These interviewees were also chosen in cooperation with the company. They are all working with logistics on different levels of the company. They were chosen based on their competence in the area so that they could be able to review the identified solutions and see in which ways they could be successful.

3.2 Designing four solutions

This part of the study aims to identify different solutions of how a distribution center should operate and how the interactions between the distribution center and the construction site should be done. A few things all solutions that has been identified and designed have in common that characterize the idea of a distribution center is that all shipments of material should pass through the distribution center. An order is made with the supplier, but instead of delivering the material directly to the site they deliver it to the distribution center. The material is then stored until it is needed on site. At that time it is delivered to the site.

The view on logistics and the need for logistics varied a lot between the interviewees. The ones who had worked on project where logistics were in focus saw the needs and benefits from it to a greater extent than the ones that had less experience on the subject.

The interviewees with less experience from logistics were all unanimous that they did not see a need for a greater focus on logistics in their projects. They were all worried about the extra costs and saw little or no possibility to gain profit from focusing more on logistics in the current state of their projects. They said that they would solve any logistic problems such as scheduling and material handling as they occur and if they

needed an extra person working with logistics later on they would employ one. The logistics manager on the other hand stressed the need and benefits from being involved in the project from an early stage. She argued that by focusing on logistics in an early stage you could avoid a lot of the problems that otherwise would occur. On an early stage the logistics manager can be involved more in the planning of the construction site and the construction works in order to optimize material handling on site. The logistics manager also said that she thought that it would be harder to implement new working methods such as scheduled deliveries later on in the project than if it would have been done from the start.

All interviewees on the other hand saw potential benefits when it comes to efficiency from using a distribution center as an extra resource, but still showed concerns about if the costs would be covered by the benefits. The main benefit they identified were less material stored on site and therefore less risk for damage on the material and the building as well as less time spent on handling and moving around the material on site.

Another benefit identified were the possibility to take bigger shipments of “unique”, fragile and expensive material such as windows, doors etc. where they usually either split up the shipments in small shipments causing friction with the deliverer or bringing bigger shipments to the site increasing the risk that the material gets damaged. They also saw the distribution center as a security where they could have a buffer to eliminate the fear of material not arriving in tome or running out. From the interviews four solutions for distribution center s were identified:

3.2.1 A - A temporary distribution center for one single project

The center in this case is a temporary solution that only caters to one construction project, see Figure 1. The DC should then be located close to the construction site with easy access for deliveries to arrive to the distribution center. Managers from the construction site take care of ordering all material to the distribution center and also from the DC to the site. The DC shall mainly work as a through-put distribution center where material arrives, gets repacked to fit the daily need for the project. All shipments from the DC get marked up for smoother handling on site. A normal shipment to the DC stays in the distribution center for no longer than a couple of weeks. Smaller batches are then delivered to the construction site. Some material such as doors and windows could be stored for longer periods of time. External truck drivers are used to ship the material from the DC to the site.

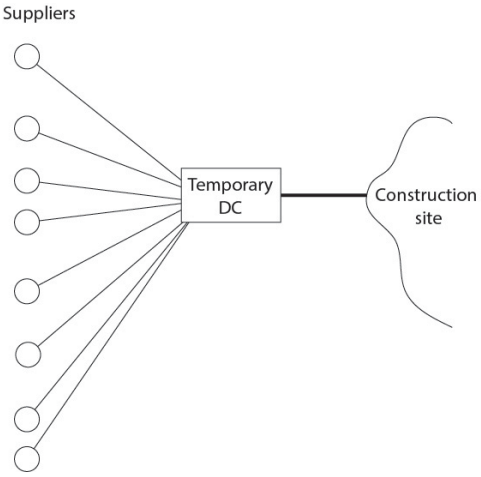

Figure 1 - A logistics sysem were a temporary distribution center is used to serve a construction project (solution A)

3.2.2 B - A temporary distribution center for multiple projects

Just as in solution (a) the distribution center is temporary, but it caters to more than one project, see Figure 2. In this solution, the cost for the distribution center is spread out on multiple projects. A solution like this would require a bigger organization in order to separate the different projects. With managing personnel stationary on the distribution center the level of service the distribution center can deliver raises. The distribution center then maintain a sufficient stock level of more common material such as gypsum boards, insulation, nails etc. while managers from each construction project takes care of ordering material that's not in stock at the distribution center . This opens up the possibility of coordinating material purchasing between different projects to keep the prices down. This requires a high level of communication between the construction projects and the distribution center in order for the distribution center to have the right material in the right amount in stock. When a construction project ends the left-over material can be transferred to another project easily through the distribution center.

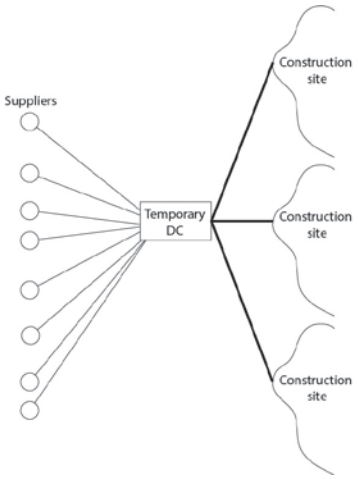

Figure 2 - A logistics sysem were one temporary distribution center is used to serve multiple construction projects (solution B)

3.2.3 C - Permanent distribution center in Gothenburg

This solution provides a permanent distribution center that construction projects in or around Gothenburg can use, see Figure 3. A project can use the distribution center for either the entire project or for specific shipments such as windows, doors or other fragile material. The distribution center should be located together with other company-facilities in the region such as equipment rental subsidiary. This opens up for cooperation when it comes to administrative functions. Since the subsidiary already has an organization to deliver machinery to the construction sites they could cooperate with the distribution center to coordinate shipments and keep the costs down. In this solution the staff becomes permanent and can be more specialized in this line of work and therefore provide a higher level of service. Material purchasing is done in the same way as in solution (B) with the possibility to keep even more types of material in stock at the DC.

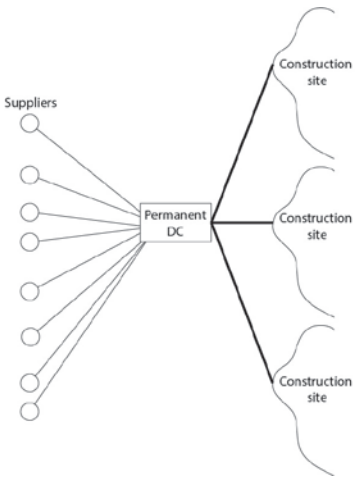

Figure 3 - A logistics sysem were a permanent distribution center is used to serve a multiple construction projects (solution C)

3.2.4 D - Using an already existing logistics company

With this solution a project cooperates with an existing logistics company such as DB Schenker, DHL etc., see Figure 4. The material is being stored in their terminals and delivered with their regular trucks. This solution is more flexible since a project just pays for the amount of resources they use in terms of storage areas and transportation, but is less flexible in terms of repacking material to fit the daily need on the construction site. These companies already have existing organizations to handle the material in their warehouse and to transport it. Ordering of material both to the distribution center and from the distribution center to the construction site are carried out by the managers on the construction site.

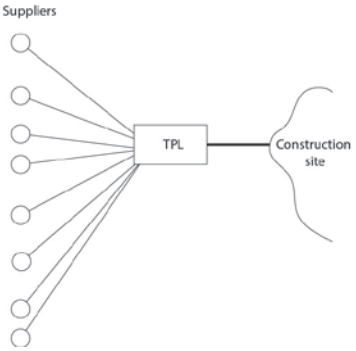

Figure 4 - A logistics sysem were a Third Party Logistics company is used to serve as a distribution center to serve a construction project (solution D)

3.3 Evaluating distribution center solutions

3.3.1 Criteria for evaluation

The second part of the study was to evaluate the identified solutions. In order to do this a second round of interviews were carried out with people working with logistics within the company. The general idea of distribution center s was discussed during the interviews. The interviewees was asked to give their opinion on the idea and what they believed to be important factors in order for a distribution center to be successful. From the interviews a number of criteria for evaluation was identified.

Flexibility. How flexible is the solution? Can it be scaled or adjusted to fit the needs for the project? The interviewees pointed out that the flow of material varies throughout the project and so do the need for using a distribution center. They raise the problem that in times when the material flow in the project is low, the project has to pay for a big empty storage-facility. This criteria test how well each solution can adjust to the varying need from the project.

Stability. Is the solution reliable? One of the main reasons to use a distribution center is to move disruptions in the supply chain away from the construction site and handle them in the distribution center. By setting up new distribution center s and new organizations for each project, the interviewees pointed out that there will probably be a learning-period for the distribution center. During the period when the new distribution center is built up, there is a risk that the distribution center won't be able to deliver a stable service. Following this, it will lead to increased stress on the construction site instead of relieving it. This criterion is a way to measure how well the distribution center can be stable and handle the disruption on site throughout the entire project.

Capacity. This criterion tests the capacity of the distribution center. The interviewees pointed out that the size of their projects vary a lot and that this sort of solution, i.e. using distribution center s, need to be able to handle their largest projects. They also reasoned about the predictability or lack of predictability on how big a distribution center would have to be. It would be difficult to forecast the flow of material and thereby how big a distribution center would need to be. If a construction project build their supply chain around a distribution center it's crucial that the distribution center has the capacity to handle the flow of material.

Service. Aside from the first three criteria that checks if the distribution center actually works, the interviewees were interested in how it would work. This criterion tests how the level of service the distribution center provides to the construction site and how this can help smoothen the material flow.

3.3.2 Evaluation

When it comes to the general idea of using distribution center s as a part of the supply chain in logistics the interviewees showed uncertainty. The fact that the construction industry has a lot to improve from working with logistics was stated by all interviewees. They all saw problems with workers spending too much time handling material on site and also that late changes made to the project causes stress in the supply chain. They all saw a problem with uncertainty in the supply chain where people working on site are unsure about what will be delivered and when. They also saw a potential for a DC to solve some of these problems. However, they were clear in stating that a lot of these problems are caused by the lack of capability in the site organization to organize their work. They were afraid that a distribution center might take care of symptoms of problems rather than solving the real problems.

Going back to the 7+1 wastes described earlier we can examine the possible effects a distribution center can have on the different types of waste. A distribution center would mainly reduce the waste due to *unnecessary transport and conveyance.* This due to reducing the amount of material stored on site and thereby also reducing the amount of time spent on handling the material on site. There is a risk though that waste due to excessive inventory increases if excessive amounts of material is stored

in the distribution center. In table 1 the potential influence a distribution center can have on each type of waste is presented.

Waste type	**Influence**
Overproduction	No obvious influence.
Waiting	With increased control of the supply chain, the amount of time spent on waiting for material will be reduced.
Unnecessary transport or conveyance	By reducing the amount of material stored on site, the amount of time spent on handling the material on site will be reduced.
Overprocessing or incorrect processing	No obvious influence.
Excess inventory	The inventory on site will be reduced, but there is a risk for excessive amounts of material stored in the distribution center.
Unnecessary movement	By splitting up and combining the material into smaller kits and deliver it directly to the assembly area, the amount of time spent on looking for and fetching material will be reduced.
Defects	By reducing the material handling on site, the risk for defects on the material or the building will be reduced.
Unused creativity	No obvious influence.

Table 1- Potential influence by a distribution center on the 7+1 types of waste in Lean Production

The interviewees stressed that they saw no ultimate solution, that the distribution center and processes around it must be suited to fit the needs for the specific project. The idea that the distribution center would keep the most common materials in stock was met with split feelings. The logistics strategist saw the idea as tempting in theory but was afraid that it would result in overstocking and moving the suppliers' warehouse to the distribution center. He saw that if it would work, costs could be cut by increased orders that could be split up on multiple projects.

The interviewees saw few differences between solution A and B and the strategist pointed out that solution B (temporary distribution center for multiple projects) at some point probably will cater only to one project and thereby acting as solution A (temporary distribution center for one project) leaving the two main options; a

temporary distribution center or a permanent one. Here he argued around the flexibility with a temporary solution and lower costs in a permanent:

> *"a permanent solution might cost less to run than a temporary, but it will cost money every day even when it's not used while a temporary solution only cost money as long as you need it"*.

The one problem that the interviewees were most concerned about was how well the distribution center could handle the need from the construction project and how flexible the solution is. They predicted that the need from the projects would vary over time and at some point reach a maximum level. A distribution center designed for just one single project would then have to be designed to fit this maximum level and thereby being oversized the rest of the time. The interviewees also saw difficulty in predicting the need from the distribution center. If these predictions are inaccurate there is a risk that the distribution center at some point won't be able to handle the need from the projects. The full evaluation for all solutions based on the criteria is presented in table 2.

The interviewees all saw a temporary solution as a starting point with the possibility to result in a permanent one. They also said that neither one rules out the other. If investing in a permanent solution there might still be need for a temporary one. A permanent solution would have to be designed to fit an estimated demand from construction projects in the region. When large construction projects, that would put an extra demand on the distribution center, are carried out the distribution center might not be able the serve those project so a temporary distribution center for this projects would have to be used.

When it comes to using a third party logistics company (TPL) the interviewees were concerned with the low level of extra service provided. The main reasons that they saw for using a distribution center was the possibility for splitting up and combining shipments. In this solution the distribution center would only function as a warehouse where material is stored before shipping to the construction site. The interviews showed that a distribution center should be able to carry out more duties than just storing the material such as splitting, combining and kitting the shipments in order to minimize the handling on site. The interviewees, based on this, said that they weren't interested in a solution like this since they only saw it as moving material from the suppliers' warehouse to another and thereby only benefitting the supplier.

	A – Temporary distribution center for one project	B - Temporary distribution center for multiple projects	C – A permanent distribution center	D – Using a third party logistics company
Flexibility	+ Can be designed to fit a specific project + Can be terminated when the project is over - Must be designed to fit the maximum amount of material the project might need to store	+ Can be designed to fit specific projects + Can be terminated when the projects are over - At some point it might only serve one project and then be oversized and expensive.	+ Projects only pay for the resources they use/need + Can be used for entire projects or for specific shipments - The location of the DC is fixed. For some projects the Dc then might be difficult to reach.	+ Projects only pays for the resources they use - The location of the DC is fixed. For some projects the Dc then might be difficult to reach.
Stability	+ The distribution center only needs to focus on one project - A temporary organization with a learning curve. There is a risk that the DC at first causes more problems than it solves.	- A temporary and new organization with a learning curve	+ A permanent solution with a more consistent organization	+ Established methods to handle logistics
Capacity	+ Can be designed to fit the needs of the projects	+ Can be designed to fit the needs of the projects	- Can't be designed to fit an actual need. Risk for that the distribution center can't serve some projects that needs it	
Service	+ Combined and fewer shipments + Smaller batches - This distribution center doesn't deliver any extra service that the other alternatives do	+ Combined and fewer shipments + Smaller batches + Some material can be ordered directly from the distribution center + Transportation can be coordinated with the other projects	+ Combined and fewer shipments + Smaller batches + Some material can be ordered directly from the distribution center + Transportation can be coordinated with the other projects	+ Combined and fewer shipments - Low level of service. The DC only store the material before shipping to the construction site.

Table 2 - *Evaluation of distribution center solutions*

4 Discussion

The key question raised by most of the interviewees is why use a DC as a warehouse when the supplier already has one? The argument is that a DC could provide extra service such as combined shipping in smaller batches. This could then lead to less material handling on the construction site and thereby to raise productivity by reducing the amount of disruptions on site.

One of the benefits from using distribution centers is fewer deliveries to the construction site. This is achieved by combining deliveries from multiple suppliers. Instead of each supplier sending one truck to the construction site the trucks arriving to the construction site contains of material from multiple suppliers. The logistics manager saw that this could be beneficial for projects were the construction site is hard to reach for trucks. Such sites could be, for example, one located in a city center with much traffic and many pedestrians or construction sites in remote locations where each truck would have to travel a long way to reach the site.

The evaluation shows that a distribution center potentially can reduce several of the 7+1 types of waste presented in the lean philosophy. With material delivered to fit the daily need, the amount of material stored on site can be lowered. This could lead to less damages on the material and on the building. This could also lead to less time spent by the workers on material handling. According to Josephson and Saukkoriipi (2007) 14% of the workers time is spent on handling material on site, so it seems to be a potential improvement by reducing that time.

The issue brought up by the interviewees as the deal-breaker is the costs for building up and running distribution centers. The interviewees are unanimous in the opinion that they like the idea and believe that it would improve the construction processes but they are afraid that the financial benefits won't cover the extra costs. The main costs for a DC is the costs for running the warehouse, costs for labour, extra delivery costs and administrative costs. The main benefits come from a more efficient production process with lower production costs. In my study I've choose not to analyse the financial aspects of the different solutions. However, an employee in a logistics company, that provides services similar as distribution center s do, experienced that the costs for this kind of solutions represents approximately 2-2.5% of the production costs. Bertelsen & Nielsen (1997) argues for potential savings of 5-10% of the production costs by focusing on logistics and JIT. This indicates the potential for logistic distribution center s in construction.

The logistics strategist described the problems and obstacles in construction logistics. He said that PEAB in Gothenburg works quite well with the logistics in large construction projects, but that there are no real efforts or procedures to improve the logistics in small construction projects, since small projects has less resources. In these smaller projects the problems with logistics is less critical than in larger

projects, but there is still a risk for stressful situations on the site. He therefore argued that their primary focus would be to find a solution that would help all their projects and especially the medium-sized projects since most of their profits come from these. Based on this, he found alternative C as the best solution, since it has a potential to work for smaller projects.

The purchasing and logistics manager for their western division agreed with the problems presented concerning the logistics in construction. He though said that those problems more likely are symptoms from other, underlying, problems with the construction industry. He saw those problems as the production organizations disability to plan and organize their work and that they tried to fix this with logistics solution. These opinions were supported by the other interviewees with experience from the logistic processes. They said that logistics couldn't solve the issues with production, just minimize the symptoms and that efforts should be put on getting the production to solve their own problems.

5 Conclusion

This aim of this study was to design and evaluate different solutions for a distribution center to be used in the construction industry. In order to do this ten interviews plus one study visit was performed. The study has shown that there are problems in the construction industry with excessive material handling on site and uncertain deliveries were the site organization doesn't know what will be delivered or when. The study also concludes that these problems more likely are symptoms of a greater problem with poor planning and coordination of the ongoing work. A distribution center then would then only work as a Band-Aid and reducing the symptoms and not solve the underlying problems.

The interviewees identified a few benefits from using a distribution center where the main one is coordination, that the sites can get material from multiple suppliers in the same delivery on a daily basis. As argued by Higginson and Bookbinder (2005) a distribution center could be used as a "brake-bulk consolidation center" where larger shipments gets split up and mixed with other shipments before it's delivered to the construction site. In a distribution center you then could get the material packed in kits for for-instance an apartment or a room so the material is delivered directly to the assembly area and not spread out over the building. This would relieve the construction site the stress from irregular and inappropriately packed shipments (Boudin, 2001). By this you also could reduce the number of deliveries to the construction site. As presented by Bertelsen and Nielsen (1997) plan the logistics carefully so deliveries don't contribute to the general disorder on a construction site. If the material also can be shipped in kits for each room and delivered to that room just in time for when the material is to be used you could minimize material handling on site and reduce waste caused by material handling.

The logistics strategist said in the interview that their main profits comes from projects in the size range of 30-50 MSEK and that any major logistics initiative must be taken in order to increase profitability on these projects. All the interviewees agreed on that a distribution center perhaps could be beneficial in bigger construction projects but that these are rare. My recommendation therefore is that the company does not further explore or invest in a distribution center.

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